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Contents

Monthly Volume 16 Number 10 October 27, 2024

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Contents

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World Journal of Gastrointestinal Surgery
Monthly Volume 16 Number 10 October 27, 2024

Contents

World Journal of Gastrointestinal Surgery

Monthly Volume 16 Number 10 October 27, 2024

Contents

LETTER TO THE EDITOR

ABOUT COVER

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WJGS mainly publishes articles reporting research results and findings obtained in the field of gastrointestinal surgery and covering a wide range of topics including biliary tract surgical procedures, biliopancreatic diversion, colectomy, esophagectomy, esophagostomy, pancreas transplantation, and pancreatectomy, *etc*.

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ORIGINAL ARTICLE

Retrospective Cohort Study

Development of a novel difficulty scoring system for laparoscopic liver resection procedure in patients with intrahepatic duct stones

Bo Luo, Si-Kai Wu, Ke Zhang, Pei-Hong Wang, Wei-Wei Chen, Ning Fu, Zhi-Ming Yang, Jing-Cheng Hao

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Abstract

BACKGROUND
For intrahepatic duct (IHD) stones, laparoscopic liver resection (LLR) is currently a reliable treatment. However, the current LLR difficulty scoring system (DSS) is only available for patients with hepatocellular carcinoma.

AIM
To explore the development of a DSS for IHD stone patients with LLR and the validation of its reliability.

METHODS
We used clinical data from 80 patients who received LLR for IHD stones. Forty-six of these patients were used in multiple linear regression to construct a scoring system. Another 34 patients from different centers were used as external validation. The completeness of our DSS was then evaluated in patients with varying degrees of surgical difficulty based on documented surgical outcomes in the study group of patients.

RESULTS
The following five predictors were ultimately included and scored by calculating

the weighted contribution of each factor to the prediction of operative time in the training cohort: Location of stones, number of stones ≥ 3, stones located in the bile ducts of several grades, previous biliary surgery less than twice, distal bile duct atrophy. Subsequently, the data set was validated using a DSS developed from the variables. The following variables were identified as statistically significant in external validation: Operative time, blood loss, intraoperative transfusion, postoperative alanine aminotransferase, and Clavien-Dindo grading ≥ 3. These variables demonstrated statistically significant differences in patients with three or more grades.

CONCLUSION

Patients with IHD stones have varying degrees of surgical difficulty, and the newly developed DSS can be validated with external data to effectively predict risks and complications after LLR surgery.

Key Words: Intrahepatic duct stones; Laparoscopic liver resection; Difficulty scoring system; Outcome; Complication

Core Tip: This is a retrospective observational study that employs a training group to develop a difficulty scoring system for evaluating patients with intrahepatic duct stones who are undergoing laparoscopic liver resection. By employing multiple linear regression modeling, five correlates of surgical difficulty were identified (location of stones, number of stones ≥ 3, stones located in the bile ducts of several grades, previous biliary surgery less than twice, distal bile duct atrophy). Validation with an external dataset demonstrated that the model exhibits favorable predictive performance to surgical difficulty and surgical complications.

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INTRODUCTION

Intrahepatic duct (IHD) stones are a common disease in the Asia-pacific region, and the incidence of IHD stones is now gradually increasing in the West[1]. IHD stones are usually treated with endoscopic[2], percutaneous (percutaneous transhepatic cholangioscopic lithotomy and percutaneous transhepatic biliary laser lithotripsy)[1] and surgical therapy [3]. The most commonly used surgical procedures are hepatectomy with (or without) hepaticojejunoanastomosis, hepatectomy with common bile duct exploration, and T-tube drainage[4]. The advantages of hepatectomy over other modalities for the treatment of IHD stones include the ability to remove clean stones, relieve bile duct stenosis, and remove atrophied liver parenchyma[5]. Indications for hepatectomy in patients with IHD stones are suspected bile duct cancer, biliary stricture or dilatation, failure of other interventions, single lobe hepatobiliary stones, and hepatic segmental atrophy[6]. Hepatectomy is currently considered to be one of the methods for complete stone removal[6]. Following the rapid development of laparoscopic techniques, laparoscopic liver resection (LLR) is increasingly being used proficiently in major centers. In Asia, IHD stones are one of the most common reasons for patients undergoing LLR[7]. Compared to open liver resection (OLR), LLR is safer and more beneficial in terms of intraoperative blood loss, length of hospital stay, and postoperative complications[8,9]. Therefore the LLR is often preferred by surgeons. However, preoperative evaluation of the surgical difficulties is the key to successfully carrying out LLR.

The importance of assessing surgical difficulty began to be emphasized at conferences as recently as 2014[10]. In the same period, a consensus also concluded that a detailed preoperative evaluation of patients should be performed using a difficulty scoring system (DSS) that combines all patient-related factors (basic patient information, imaging features, laboratory indicators, *etc.*)[11]. The DSS can also help surgeons predict the risk of surgery for presenting patients[12]. In LLR patients, Ban *et al*[13] pioneered the preoperative evaluation of patients by proposing the use of DSS. Later, Halls *et al* [14], Hasegawa *et al*[15], and Kawaguchi *et al*[16] also proposed new DSS. These DSSs are mainly applied to hepato-cellular carcinoma (HCC), and patients are evaluated before LLR by factors such as proximity to major blood vessels, the location of the tumor, the extent of liver resection, and the size of the tumor as indicators[3]. However, there may be differences in the choice of surgical strategy between IHD stones and HCC, and the assessment of surgical difficulty cannot be generalized as patients with IHD stones may have had multiple previous stone retrievals.

In the past, no DSS was developed for LLR based on IHD stones, and existing DSSs were only available for patients with HCC, in the patients with IHD stones, these DSSs are not suitable for pre-operative evaluation. Accordingly, the objective of our study is to develop a new DSS for the assessment of the difficulty and risk of LLR in patients with IHD stones.

MATERIALS AND METHODS

Research design

The institutional review board of the First Affiliated Hospital of Chengdu Medical College approved our study. We reviewed clinical data from 56 patients treated with LLR for IHD stones at The First Affiliated Hospital of Chengdu Medical College between May 2018 and November 2022, as a training group for the DSS model. In addition, data from 40 patients who received LLR for IHD stones at the Western Theater Command General Hospital between December 2022 and January 2018 were collected as a validation group. We followed the following inclusion criteria: (1) Presence of IHD stones confirmed by preoperative imaging data; (2) Age 18 years or older; (3) American Society of Anesthesiologists (ASA) classification below grade IV; (4) Patients without other serious complications; and (5) Women during pregnancy. We followed the exclusion criteria: (1) Patients with missing data on patient characteristics and surgical records; (2) Conversion of surgery to open surgery for various reasons; and (3) Patients who required hepaticojejunoanastomosis or biliary ductoplasty for the surgery. In the end, eventually, 80 patients were recruited into our study, of which 46 patients were in the training group and 34 patients from another center was in the external validation group.

Surgical procedures

In our study, LLR was performed by five senior surgeons, all of whom had at least ten years of specialty experience. Our basic procedure was as follows: At the start of the operation, the surgery was performed by a surgeon and two assistants. After the surgeon has empirically placed four to five trocars, the pneumoperitoneum is maintained with a carbon dioxide pneumoperitoneum pressure of 8-12 mmHg. The abdominal adhesions are first divided to expose the surgical field (if present). The liver parenchyma is transected by forceps extrusion or ultrasonic stripping. The abdominal adhesions are first separated and the area to be operated on is exposed. The clamp method or ultrasonic stripper is usually used to transect the liver parenchyma. Intermittent pringle maneuvers and hemostatic forceps were routinely used to reduce bleeding from the liver parenchyma, and vascular clamps were used for larger vessels. Intraoperative ultrasound was used to localize the IHDS. Cholangioscopy is routinely used to explore residual IHDS. The T-tube was routinely placed into the common bile duct after the exploration was completed. Subsequently, intra-abdominal fluid was drained, and a drain was placed at the site of the liver incision.

Definitions

According to the location of the IHD stones, we classified the patients into two different types. Type left (TL) is defined as stones in the left lateral or/and left medial sections. Type right (TR) is defined as stones in the right anterior or/and right posterior section, and TR also includes the stones in both the right and left sides of the caudate lobe. History of biliary surgery includes bile duct exploration with stone extraction, partial hepatectomy, and biliary ductoplasty[3]. Distal bile duct atrophy is primarily a reduction in the diameter of the bile duct relative to the site where the adjacent stone is located. This was determined primarily by preoperative imaging features[17]. We further classify intrahepatic bile ducts into three levels: Left and right hepatic ducts (primary bile ducts), left lateral section, left medial section, right medial section, and right lateral section (secondary bile ducts), and the bile duct of every liver segment (tertiary bile ducts)[18]. Our study was categorized according to Clavien-Dindo postoperative complications[19].

New DSS

We constructed the new DSS by analyzing the factors that had predictive value for the duration of surgery through multiple linear regression using data from patients in the training group and scoring these valuable factors. The following patient data were included: Age, sex, body mass index (BMI), ASA ≥ 3, previous biliary surgery less than twice, location of the stone in the bile duct distal bile duct atrophy, number of stones ≥ 3, the stone is less than 1 cm from a large blood vessel, diameter of common bile duct, maximum diameter of IHD, maximum stone size, preoperative platelet, preoperative white blood cell count, preoperative total bilirubin, preoperative alanine aminotransferase, preoperative aspartate aminotransferase. We referred to the methods used in previous studies of DSSs development[13,15]. The relevant factors affecting the operation time were screened by multiple linear regression, and the scores were finally obtained by rounding off the coefficients of these factors after dividing them by 100. The total of these scores will be used to score the patients in the external validation group and categorized into "low", "medium" and "high" groups, comparing their outcomes after surgery (Figure 1).

Statistical analysis

If the data in the study conformed to the normal distribution of a continuous variable, the mean and standard deviation were used; if the data did not conform to the normal distribution of a continuous variable, the median and range were used. The χ^2 test was used when the data were categorical variables. Multivariate linear regression modeling was also performed using statistical product and service solutions (SPSS) version 26.0 to predict the difficulty index. In this study, all statistical significance was defined as $P < 0.05$. SPSS 26.0 software (International Business Machines Corporation, Armonk, NY, United States) was used for all analyses in our study.

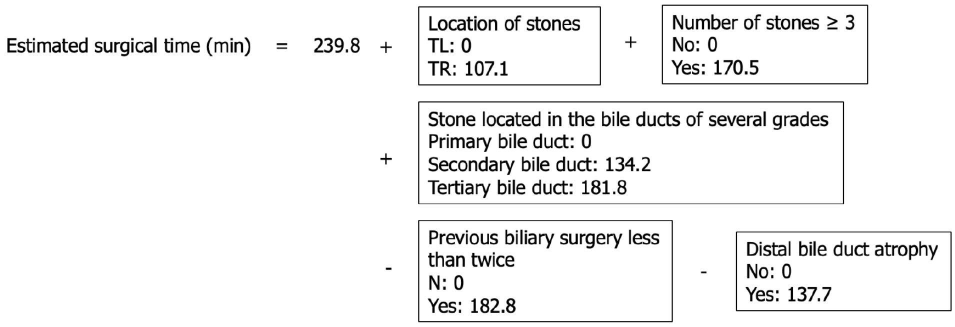

Figure 1 Laparoscopic liver resection operative time prediction formula. We used multivariate linear analyses to derive relevant variables affecting operative time and used these constants for these relevant variables to predict the operative time for laparoscopic liver resection. TL: Type left; TR: Type right.

RESULTS

Characteristics of patients

In our study, there were 46 and 34 patients with IHD stones trained and validated respectively. The overall age of the training group was older than that of the validation group. (61 years *vs* 52 years), but there was no statistical difference in gender. There was also no statistical difference in the history of biliary surgery (P = 0.355). The number of patients with ASA scores ≥ 3 was close in both groups (34.8% *vs* 35.3%). In terms of previous medical history, there was no difference between these groups. There were more patients with TL in the validation group (P = 0.001), and the number of stones ≥ 3 was comparable in the two groups (P = 0.221). The larger number of patients with atrophy of the distal bile duct in the validation arm of the study (P = 0.013), the common bile duct diameter was longer in the training group (P = 0.001) and the maximum diameter of the IHD was longer in the validation group (P = 0.028). There was no difference in maximum stone size. Preoperative platelet count (P = 0.015) and preoperative white blood cell count (P = 0.008) differed between both groups (Table 1).

Independent variables

By multivariate linear retrospective analysis, we found that the location of stones (P = 0.002), The number of stones ≥ 3 (P = 0.037), the stone located in the secondary bile duct (P = 0.022), the stone located in the tertiary bile duct (P = 0.004), Previous biliary surgery less than twice (P < 0.001), and distal bile duct atrophy (P < 0.001) were significant factors (Table 2). These factors were ultimately used as the scoring criteria.

The coefficients of these factors were divided by 100 and rounded to the nearest whole number to obtain a score: Location of stones (TL: 0; TR: 1), number of stones ≥ 3 (No: 0; Yes: 2), stones located in the bile ducts of several grades (Primary bile duct: 0; Secondary bile duct: 1; Tertiary bile duct: 2), previous biliary surgery less than twice (No: 0; Yes: 2), distal bile duct atrophy (No: 0; Yes: 1) (Table 3 and Table 4).

Difficulty grading

The validation group was categorized into three levels based on the final score of the external validation. The DSS was segmented into three groups: Low difficulty (≤ 3 scores), medium difficulty (4-5 scores), and high difficulty (≥ 6 scores) according to the scores of each relevant factor. After classifying the 34 patients with IHD stones, we categorized 24 of these patients in the low difficulty level, with seven and three in the medium and high difficulty levels below them, respectively. Statistical significance was confirmed between these three groups in terms of operative time (P = 0.034), with the high difficulty group having a longer median operative time than the other two groups (401 *vs* 355 *vs* 292). Clavien-Dindo classification ≥ 3 (P = 0.007), intraoperative blood transfusion (P = 0.007), blood loss (P = 0.002), and postoperative alanine aminotransferase (P = 0.002) differed significantly between these groups. However, the length of hospital stays, and hospital costs were not statistically different between the three groups. (8 *vs* 9 *vs* 9, P = 0.269) (P = 0.336) (Table 5).

DISCUSSION

Our study used a multiple linear regression model to develop a new DSS specifically tailored for patients with IHD stones who require LLR, and we externally validated that our DSS has certain predictive value in postoperative recovery after LLR. LLR, as compared to OLR, is a common modality in hepatobiliary surgery and has rapidly evolved in recent years[20,21]. From an educational and evaluative perspective, it's important to determine a classification system for difficulty levels[16]. Of course, LLR difficulty ratings are very subjective and vary from person to person, however, proper preoperative assessment is still required.

As early as 2014, Ban *et al*[13] pioneered the development of DSS for patients with HCC, primarily based on tumor size, proximity to major blood vessels, tumor location, extent of liver resection, and liver function. Halls *et al*[14] later developed a combined DSS based on tumor size, neoadjuvant chemotherapy, lesion type, classification of resection, and surgical history of previous OLRs. Hasegawa *et al*'s DSS, which was evaluated by the extent of resection, platelet count,

Table 1 Characteristics of 46 patients with intrahepatic duct stones

Variables	Training group (*n* = 46)	Validation group (*n* = 34)	*P* value
Age, years	61 (49-73)	52 (40-64)	0.690
Sex (male/female)	11/35	25/9	0.795
BMI, kg/m^2 (IQR)	21.9 (20-24.4)	22.8 (20.4-24.2)	0.514
Previous biliary surgery, *n* (%)	21 (45.7)	12 (35.3)	0.355
ASA score ≥ 3, *n* (%)	16 (34.8)	12 (35.3)	0.491
History of hypertension, *n* (%)	8 (17.4)	4 (11.8)	0.489
History of diabetes, *n* (%)	2 (4.3)	1 (2.9)	0.745
History of coronary artery heart disease, *n* (%)	0 (0)	2 (5.9)	0.098
History of lung diseases, *n* (%)	5 (10.9)	1 (2.9)	0.186
Location of stones (TL/TR)	22/24	29/5	0.001
Number of stones ≥ 3, *n* (%)	44 (95.7)	34 (100)	0.221
Distal bile duct atrophy, *n* (%)	24 (52.2)	27 (79)	0.013
Diameter of common bile duct, cm (IQR)	1.5 (1.2-1.8)	1.1 (0.8-1.4)	0.001
Maximum diameter of intrahepatic duct, cm (IQR)	1.4 (1-1.6)	1.5 (1.2-1.8)	0.028
Maximum stone size, cm (IQR)	1 (0.6-1.5)	0.9 (0.6-1.2)	0.225
Platelet count, 10^9/L (IQR)	156 (79-233)	190 (119-261)	0.015
White blood cell count, 10^9/L (IQR)	7.7 (4.6-10.8)	6.1 (3.9-8.3)	0.008
Red blood cell count, 10^9/L (IQR)	4.2 (3.6-4.8)	4.4 (3.8-5)	0.654
Alanine aminotransferase, U/L (IQR)	59 (25-189)	33 (21-90)	0.066
Aspartate aminotransferase, U/L (IQR)	43 (27-136)	49 (20-117)	0.446
Total bilirubin, μmol/L (IQR)	22.4 (14.9-44.9)	18.7 (13-31.6)	0.149
Prothrombin time, s (IQR)	11.4 (10.5-12.3)	10.9 (10.1-11.7)	0.311

BMI: Body mass index; TL: Type left; TR: Type right; ASA: American Society of Anesthesiologists; IQR: Interquartile range.

Table 2 Independent factors predicting surgical difficulty by multiple linear regression

Independent variables	*P* value
Location of stones	0.002
Number of stones ≥ 3	0.037
Stone located in the bile ducts of several grades	
Primary bile duct	0
Secondary bile duct	0.022
Tertiary bile duct	0.004
Previous biliary surgery less than twice	< 0.001
Distal bile duct atrophy	< 0.001

obesity, and location of the tumor, this DSS was validated in a large cohort and showed good results, particularly in terms of blood loss, surgery times, and postoperative complications[15]. Although these DSSs demonstrated good predictive power, these models contain variables regarding tumor characteristics that do not apply to patients with other diseases for preoperative evaluation. But the current DSS is not indicated for IHD, mainly because most intrahepatic bile duct stones are associated with recurrent pyogenic cholangitis, and there may be hepatic parenchymal atrophy, bile duct dilatation with or without proximal stricture, and multiple stone locations[22]. While patients with IHD usually have a history of multiple surgeries and may have stones in more than one location, patients with HCC rarely have bile duct atrophy or recurrent cholangitis. HCC invades the patient’s blood vessels, whereas IHD is a benign disease that does not

Table 3 The multiple linear regression model calculates the constants of the variables of the coefficient

Variables	Variables category	Coefficient
Location of stones	TL	0
	TR	1107.1
Number of stones ≥ 3	No	0
	Yes	170.5
Stone located in the bile ducts of several grades	Primary bile duct	0
	Secondary bile duct	134.2
	Tertiary bile duct	181.8
Previous biliary surgery less than twice	No	0
	Yes	182.8
Distal bile duct atrophy	No	0
	Yes	137.7

TL: Type left; TR: Type right.

Table 4 Difficulty factor score classification associated with laparoscopic liver resection

Variables	Variables category	Score
Location of stones	TL	0
	TR	1
Number of stones ≥ 3	No	0
	Yes	2
Stone located in the bile ducts of several grades	Primary bile duct	0
	Secondary bile duct	1
	Tertiary bile duct	2
Previous biliary surgery less than twice	No	0
	Yes	2
Distal bile duct atrophy	No	0
	Yes	1
Total score		
≤ 3: Low difficulty		
4-5: Medium difficulty		
≥ 6: High difficulty		

TL: Type left; TR: Type right.

invade the patient's blood vessels[15]. Not only are the preoperative patient data different, but Park *et al*[23] found that the mean operative time for IHD and malignancy was different (290.9 minutes *vs* 172.7 minutes). In addition, the mean hospital stay for patients with IHD was 12.0 days compared to 7.1 days for patients with malignancy. Therefore, we believe there is a need for a separate DSS designed for patients with IHD.

IHD stones can be treated in several ways, but the primary goal is to relieve the biliary obstruction and remove the biliary stricture. The advancement of LLR technology has led to its widespread use in the treatment of IHD stones, as it offers several advantages over traditional methods. These include less bleeding, smaller surgical incisions, fewer postoperative complications, and quicker postoperative recovery[24,25]. The safety and reliability of LLR in the treatment of IHD stones have been confirmed in previous studies[26-28]. Early surgical resection of narrowed bile ducts and stone removal can significantly reduce the risk of bile duct cancer. Especially for patients with residual stones after non-surgical treatment, aggressive surgical treatment is recommended[29].

Table 5 Postoperative outcomes of laparoscopic liver resection in three levels of difficulty, *n* (%) (mean ± SD)

Variables	Low (*n* = 24)	Medium (*n* = 7)	High (*n* = 3)	*P* value
Surgical times, min	292	355	401	0.034
Blood loss, mL	187	307	500	0.002
Postoperative hospital stays, day	8	9	9	0.269
Intraoperative blood transfusion	1 (4.2)	1 (14.3)	2 (66.7)	0.007
Hospital costs, CNY	47540	53956	52507	0.336
Clavien-Dindo classification ≥ 3	1 (4.2)	1 (14.3)	2 (66.7)	0.007
Postoperative alanine aminotransferase, U/L	169	352	320	0.002

CNY: China yuan.

In our study, we have developed a new DSS for LLR that is specifically designed for patients with IHD stones, because IHD stones differ from HCC. In patients with IHD stones, the primary focus is on removing the atrophied bile ducts, stone removal, and the resection of a portion of the atrophic liver if it is present. Kim *et al*[30] previously developed a DSS based on the location of stones, ductal stricture < 1 cm from the bifurcation, atrophy of liver parenchyma, combine cholangioscopy or not, and type of resection. This DSS, however, only demonstrated between-group differences in blood loss, surgery times, and hospital stay, and it lacked factors related to the biliary tract. In our study, we reclassified the location of the stones primarily into the left and right liver, as the left liver is generally less challenging to operate on compared to the right liver, a point also confirmed by Kim *et al*[30]. We also classified stones located in the three grades of bile ducts. When stones were in the tertiary bile duct, the score was notably higher. We consider that this is because the tertiary bile duct is more distally located, requiring more time to be located during surgery. In addition, this group of patients with IHD stones usually has a larger number of stones that are more extensive and require more time for exploration. It's worth noting that IHD stones often necessitate multiple surgical operations, and some patients still have the possibility of recurrence even after the first operation has completely removed the stone[31]. Our observation is that distal bile duct atrophy is associated with reduced surgical difficulty. We believe that in patients with bile duct atrophy, there may be a portion of the liver that is atrophied, making some parts of the procedure easier to navigate. And there may be a reduced risk of bleeding and complications. Although previous studies suggest a high BMI increases the risk associated with LLR surgery and postoperative complications, we did not observe this in our study[32].

In our study, the newly developed DSS exhibited favorable predictive efficacy with regard to surgical complexity in an external dataset validation, thereby substantiating the merits of our investigation. It is of paramount importance to conduct a preoperative surgical risk assessment of patients with IHD stones, particularly given the potential for variability in LLR techniques among surgeons. The prudent selection of patients for less experienced surgeons can help to mitigate the risk of postoperative complications. Surgeons can use the DSS to facilitate a smoother learning curve through a careful choice of cases. Our study has limitations, mainly because we did not include patients who required hepaticojejunoanastomosis or biliary ductoplasty, which are much more complex procedures that require larger sample sizes and joint multicenter studies. Indeed, we designed the DSS only for patients with IHD stones requiring LLR procedures. The surgical approach in our study did not include hepaticojejunostomy and biliary ductoplasty, as this could make the procedure longer and make the results biased. Despite these limitations, our DSS model has demonstrated satisfactory performance in external validation, and we believe that this new DSS could prove to be a valuable tool for assessing the risk of LLR surgery, particularly in patients with IHD stones. It can also provide some reference value for the prediction of postoperative outcomes in patients with IHD stones.

CONCLUSION

We developed a new DSS for IHDS patients requiring line LLR, and its performance was demonstrated to be satisfactory in external dataset validation. The DSS is capable of providing a degree of prediction regarding the difficulty of surgery and the potential for postoperative complications in patients with IHDS. This enables surgeons to tailor treatment plans to the individual patient.

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FOOTNOTES

Author contributions: Luo B and Wu SK contributed equally to this study; Luo B, Wu SK analyzed the data and wrote the manuscript; Hao JC and Zhang K collected the data; Wang PH, Cheng WW, Fu N, and Yang ZM performed the surgery and provided constructive discussion; All authors have read and approved the final manuscript.

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