Original Article

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Value of multidisciplinary team (MDT) in minimally invasive treatment of complex intrahepatic bile duct stones

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SUMMARY This study aimed to investigate the value of multidisciplinary team (MDT) management in minimally invasive treatment of complex intrahepatic bile duct stones (IHDs) by laparoscopy, choledochoscopy and percutaneous choledochoscopy. The characteristics, perioperative index, complication rate and minimally invasive rate of patients in MDT group (n = 75) and non-MDT group (n = 70) were compared. The members of MDT include doctors in ultrasound, imaging, hepatobiliary and pancreatic surgery, anaesthesia and intensive care medicine. The results showed that minimally invasive surgery reduced the incidence of postoperative residual stones, OR (95% CI) = 0.365 (0.141-0.940) (p = 0.037). MDT reduced the operation time, OR (95% CI) = 0.406 (0.207-0.796) (p = 0.009). Minimally invasive surgery significantly reduced intraoperative bleeding, OR (95% CI) = 0.267 (0.133-0.534) (p < 0.001). Minimally invasive surgery also reduced hospitalization time, OR (95% CI) = 0.295 (0.142-0.611) (p = 0.001). The stone clearance rates of MDT group and non-MDT group were 81.33% and 81.43% respectively. In the MDT group, the operative time was less than that in the non-MDT group (p = 0.010); the intraoperative bleeding volume was significantly less than that in the non-MDT group (p < 0.001); the hospitalization time was less than that in the non-MDT group (p = 0.001). Minimally invasive operation rate:48 cases (64.00%) in MDT group were significantly higher than 17 cases (24.29%) in non-MDT group (p < 0.001). In conclusion, minimally invasive procedures can be selected more through MDT. MDT can shorten the operation time, and minimally invasive surgery can reduce the incidence of residual stones, reduce intraoperative bleeding, and may shorten hospital stay. Therefore, MDT management model can provide personalized and minimally invasive surgical protocol for patients with complex IHD, which has high application value.

Keywords multidisciplinary team, minimally invasive surgery, laparoscopy, choledochoscope, percutaneous choledochoscope

1. Introduction

Complex intrahepatic bile duct stones (IHDs) usually refer to multiple intrahepatic stones, sometimes combined with extrahepatic bile duct stones. It is a difficult disease to treat because of its complicated etiology, large number of stones and wide distribution, high residual rate and recurrence rate. For patients with IHDs, open hepatectomy (OH) combined with intraoperative choledochoscopy is usually chosen for the convenience of operation and stone eradication (*1*). With the development of laparoscopy and choledochoscopy, the choice of surgical methods for complex IHDs tends to be diversified. However, there is still no standard on how to select minimally invasive procedures for patients. Multidisciplinary team (MDT) is a kind of structural mode to optimize patient management, including holding group meetings regularly and setting up multidisciplinary forums. MDT is usually emphasized in the clinical management of complicated diseases. The aim is to provide more complete and accurate diagnosis and more favorable treatment methods (*2,3*). On the basis of MDT, combined with the techniques of laparoscopy, choledochoscopy and percutaneous choledochoscopy, this study made decisions on treatment methods for patients to evaluate the value of MDT in minimally invasive treatment of complex IHDs.

2. Patients and Methods

2.1. Patients

Patients included in this study received surgical treatment at our hospital from July 2017 to November 2020. The data of patients with IHDs are usually discussed by MDT in the second department of hepatobiliary and pancreatic surgery in our hospital. We divided 145 patients who met the inclusion criteria into two groups. The patients in MDT group (*n* = 75) were from the second department of hepatobiliary and pancreatic surgery, while those in non-MDT group (*n* = 70) were from the first department of hepatobiliary and pancreatic surgery. In the MDT group, 27 cases were treated with OH combined with choledochoscopy, 33 cases were treated with laparoscopic hepatectomy (LH) combined with choledochoscopy, and 15 cases were treated with percutaneous transhepatic cholangioscopic lithotripsy (PTCSL). In the non-MDT group, 53 cases were treated with OH combined with choledochoscopy, 16 cases were treated with LH combined with choledochoscopy, and 1 case was treated with PTCSL. The inclusion criteria for this study were as follows: (*i*) diagnosis of IHDs with (or without) extrahepatic bile duct stones; and (*ii*) patients undergoing at least one procedure. The exclusion criteria for this study were as follows: (*i*) high suspicion or diagnosis of cholangiocarcinoma; (*ii*) poor general condition, intolerance to surgery; and (*iii*) patient rejection. Patients in the MDT group were informed that their case data were discussed with MDT. All patients finally agreed to the operation.

2.2. Preoperative evaluation

All patients underwent liver function tests, ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), and magnetic resonance cholangiopancreatography (MRCP), which provided important information about the location and size of the stone, and anatomy of the biliary tract. Preoperative selective percutaneous transhepatic biliary drainage (PTCD) was performed in patients with severe jaundice and intrahepatic bile duct (IHD) dilation to improve liver function. When stones cause serious infection, the patient is treated with anti-infective treatment to improve the basic condition of the patient. After the completion of the auxiliary examination, the data of patients in MDT group were discussed with the doctors of ultrasound, imaging, hepatobiliary and pancreatic surgery, anaesthesia and intensive care medicine, and the minimally invasive treatment scheme was finally determined. In addition, patients undergoing hepatectomy were subjected to an indocyanine green 15 minute retention rate test (ICG-R15) to estimate the volume of residual liver and determine the specific segment of the liver to be resected.

2.3. Surgical procedure

OH combined with choledochoscopy: A right subcostal inverted L-shaped or arc-shaped incision was used, the midline extended to xiphoid process, and the length was about 25-45 cm. During the procedure, the exact location of IHDs was determined again by the operator's palpation. The liver parenchyma was resected using ultrasonic knife clamping. The portal vein and hepatic artery were blocked according to the results of preoperative MDT and intraoperative conditions (Figure 1B). We opened the IHD or common bile duct (CBD) and performed choledochoscopy, we repeatedly flushed the bile duct or removed the stone with a basket. After choledochoscopy confirmed that the bile duct was free of stone and severe stenosis, the abdominal drainage tube and T tube were placed. Roux-en-Y cholangiojejunostomy was performed to drain bile if necessary.

LH combined with choledochoscopy: Five-hole method was used. Laparoscopy was used to detect abdominal adhesions and liver atrophy. Intraoperative ultrasound was used to further determine the location of stones, the condition of intrahepatic vessels and bile ducts (Figure 2A). Severe stenosis of IHD and severe atrophy of liver parenchyma were removed. Liver parenchymal resection was performed with ultrasonic knife clamping, and the left or right portal vein and hepatic artery were blocked if necessary to reduce intraoperative bleeding (Figure 2B). IHD or CBD was explored during the operation, and stones were removed with a choledochoscope and basket (Figure 2C). Repeated exploration and flushing of the bile duct was conducted, if necessary, and reuse of intraoperative ultrasound to determine whether the stone was removed. We used 4-0 absorbable sutures to close IHD or CBD. Drainage tubes were placed at the liver section, winslow hole and pelvic cavity, and T tubes were placed in patients with CBD exploration.

PTCSL: The procedure was performed under general anesthesia. To facilitate stone extraction, the stone extraction channel should be parallel to the target bile duct as much as possible. Therefore, surgery is performed in the left or right lying position depending on the stone location. The relationship between hepatic vascular system and target bile duct was studied by intraoperative ultrasound, preoperative MRI and MRCP (Figure 3A). An ultrasound-guided puncture needle was inserted into the target bile duct and a passage was established with a 16 F fascia dilator and 14 F outer sheath. Choledochoscopy was used to explore the bile duct, holmium laser shattered the stones and were removed with basket (Figure 3B). Patients with bilateral IHDs underwent similar procedures on the other side. After confirming that there was no stone in the bile duct within the visual range of choledochoscopy, we placed the biliary drainage tube (Figure 3C). We chose whether to place biliary stent to dilate the narrow bile duct according to the situation.

2.4. Statistics

The normality of metrological data was expressed

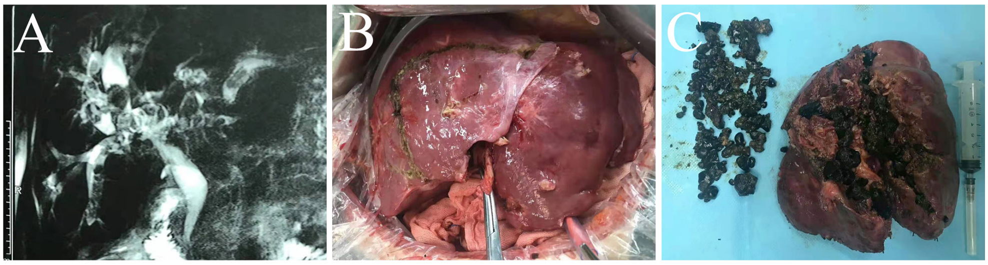

Figure 1. OH procedure. (A) MRCP of patient before OH. **(B)** Block the left hepatic artery and left branch of portal vein to determine the extent of hepatectomy. (C) The liver specimens were dissected and a large number of IHDs were found.

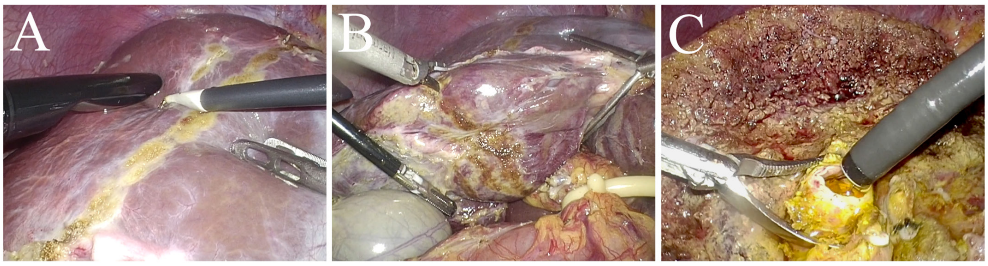

Figure 2. LH procedure. (A) Intraoperative ultrasound was used to determine the location of stone and middle hepatic vein. **(B)** The liver parenchyma was resected with ultrasonic knife clamping after setting the blocking band. **(C)** Intraoperative choledochoscope was used to explore the right hepatic duct and remove the stone with basket.

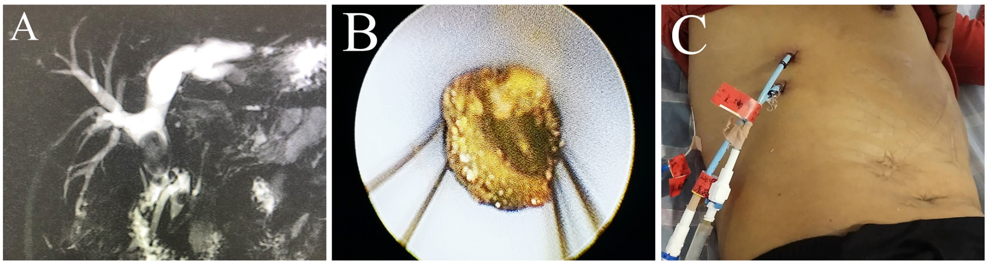

Figure 3. PTCSL procedure. (A) MRCP of patient before PTCSL. **(B)** Basket for stone removal during PTCSL. **(C)** A biliary drainage tube was placed to preserve the tract for stone removal. Abdominal surgical scars caused by multiple biliary operations.

by Shapiro-Wilk test, if the normal distribution was satisfied, it was expressed by $\overline{x} \pm s$, and if the variance homogeneity was satisfied, the independent sample *t* test was used for group comparison. If the metrological data did not satisfy the normal distribution, it was expressed by inter-quartile range [M (P_{25}, P_{75})], and the Mann-Whitney *U* test was used for group comparison. The counting data were expressed as the rate, and the Pearson Chi-Square test and Fisher's exact test were used in the group comparison. Some studies suggest that intrahepatic bile duct stones can be classified into simple and complex types based on the presence or absence of biliary stricture, infection, sepsis and liver abscess (*1,4*). These indicators were closely followed in this study. When a patient has the characteristics of both presentations and concomitant conditions, it is considered as a severe stone. Transforming the history of biliary surgery and minimally invasive surgery into dichotomous variables. The operation time, intraoperative bleeding, and hospital stay data were converted into dichotomous variables based on the mean or median values in 145 patients. The dependent variables were residual stone, operation time, intraoperative bleeding and hospitalization time, and other related indexes were independent variables for logistic regression analysis. $p < 0.05$ was allowed for statistical significance. SPSS 26.0 was used for statistical analysis.

3. Results

3.1. Characteristics of patients

The data results are shown in Table 1. The main clinical symptoms of both groups were abdominal pain, fever and jaundice. There were 29 males and 46 females in MDT group, aged 58.00 (50.00, 65.00) years (range: 18-85 years), 26 males and 44 females in non-MDT group, aged 56.00 (49.00, 65.00) years (range: 20-79 years). Forty-three patients (57.33%) in MDT group (range 0-5 times) and 35 patients (50%) in non-MDT group had history of biliary operation (range 0-6 times). There was no significant difference in history of biliary operation between groups (p = 0.376). Patients with cirrhosis and extrahepatic bile duct stones in the MDT group were fewer than those in the non-MDT group (p = 0.024 and p = 0.021).

3.2. Results of logistic regression analysis

Logistic regression analysis was performed with residual stones, operation time, intraoperative bleeding volume and hospitalization time as dependent variables (Table 2), with statistically significant results as follows. A history of biliary surgery increased the incidence of postoperative stone residue, OR (95% CI) = 2.702 (1.106-6.600) (p = 0.029). Minimally invasive surgery reduced the incidence of postoperative residual stones, OR (95% CI) = 0.365 (0.141-0.940) (p = 0.037). MDT reduced the operation time, OR (95% CI) = 0.406 (0.207-0.796) (p = 0.009). Minimally invasive surgery significantly reduced intraoperative bleeding, OR (95% CI) = 0.267 (0.133-0.534) (p < 0.001). Minimally invasive surgery also reduced hospitalization time, OR (95% CI) = 0.295 (0.142-0.611) (p = 0.001). An increase in intraoperative

Table 1. Patient characteristics

	MDT group	Non-MDT group	*P*
Age (years)	58.00 (50.00,65.00)	56.00 (49.00,65.00)	0.638
Gender			
Male	29 (38.67%)	26 (37.14%)	0.850
Female	46 (61.33%)	44 (62.86%)	
Presentation			
Acute cholangitis	32 (42.67%)	23 (32.86%)	0.224
Liver abscess	5 (6.67%)	2 (2.86%)	0.444
Jaundice	8 (10.67%)	5 (7.14%)	0.458
History of biliary operation	43 (57.33%)	35 (50%)	0.376
Cholecystectomy	30 (40%)	33 (47.14)	0.386
Exploration of bile duct	2 (2.67%)	1 (1.43%)	1.000
Bilioenteric anastomosis	8 (10.67%)	5 (7.14%)	0.458
Hepatectomy	8 (10.67%)	4 (5.71%)	0.279
PTCSL	0	1 (1.43%)	0.483
Concomitant condition			
Bile duct stricture	20 (26.67%)	15 (21.43%)	0.461
Liver atrophy	23 (30.67%)	13 (4.29%)	0.092
Cirrhosis	0	5 (7.14%)	0.024
Extrahepatic bile duct stone	35 (46.67%)	46 (65.71%)	0.021

Table 2. Logistic regression analysis of outcome indexes and related factors

		OR (95%CI)	*P*
Residual stone	Age	-	0.139
	MDT	-	0.278
	History of biliary operation ≥1 (time)	2.702 (1.106-6.600)	0.029
	Stone severity	-	0.413
	Minimally invasive surgery	0.365 (0.141-0.940)	0.037
Operation time > 325 (min)	Age	-	0.336
	MDT	0.406 (0.207-0.796)	0.009
	History of biliary operation ≥1 (time)	-	0.697
	Stone severity	-	0.425
	Minimally invasive surgery	-	0.375
Intraoperative bleeding ≥ 400 (mL)	Age	-	0.255
	MDT	-	0.121
	History of biliary operation ≥1 (time)	-	0.849
	Stone severity	-	0.427
	Minimally invasive surgery	0.267 (0.133-0.534)	< 0.001
Hospitalization time ≥ 20 (day)	Age	-	0.450
	MDT	-	0.115
	History of biliary operation ≥1 (time)	-	0.578
	Stone severity	-	0.265
	Minimally invasive surgery	0.295 (0.142-0.611)	0.001
	Operation time > 325 (min)	-	0.262
	Intraoperative bleeding ≥ 400 (mL)	2.281 (1.105-4.712)	0.026

Table 3. Perioperative data results

	MDT group	Non-MDT group	*Z* or *t* value	*P*
Operation time (min)	300.09 ± 125.41	352.81 ± 116.05	-2.614	0.010
Intraoperative bleeding volume (mL)	225.00 (137.50, 500.00)	500.00 (300.00, 900.00)	-3.848	< 0.001
Length of stay (days)	18.00 (15.00, 24.00)	22.00 (17.75, 29.25)	-3.181	0.001

Table 4. Postoperative complications and minimally invasive surgery

	MDT group (n = 75)	Non-MDT group (n = 70)	Value	*P*
Liver failure	0	0	-	-
Biliary fistula	0	4 (5.71%)	-	0.052
Residual stone	14 (18.67%)	13 (18.57%)	0.000	0.988
Minimally invasive surgery	48 (64%)	17 (24.29%)	23.090	< 0.001
Stone recurrence	6 (8%)	3 (4.29%)	-	0.496

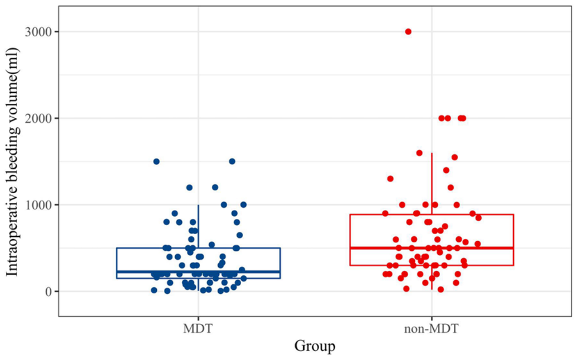

Figure 4. Intraoperative bleeding volume comparison.

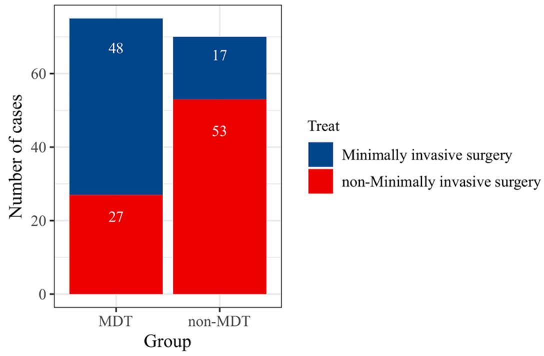

Figure 5. Comparison of minimally invasive surgery.

bleeding increased hospitalization time, OR (95% CI) = 2.281 (1.105-4.712) (p = 0.026).

3.3. Perioperative outcomes

The data results are shown in Table 3. The operation time was 300.09 ± 125.41 min in MDT group and 352.81 ± 116.05 min in non-MDT group. Intraoperative bleeding volume was 225.00 (137.50, 500.00) mL in MDT group and 500.00 (300.00, 900.00) mL in non-MDT group. The box diagram of intraoperative bleeding volume is shown in Figure 4. The hospital stay was 18.00 (15.00, 24.00) days in MDT group and 22.00 (17.75, 29.25) days in non-MDT group. In comparison, the operation time in MDT group was less than that in non-MDT group (p = 0.010), the intraoperative bleeding volume in MDT group was significantly less than that in non-MDT group (p < 0.001), and the hospitalization time in MDT group was less than that in non-MDT group (p = 0.001).

3.4. Postoperative complications

The data results are shown in Table 4. Postoperative liver failure did not occur in either group according to criteria presented in the International Study Group of Liver Surgery (ISGLS)2011 (*5*). Postoperative biliary fistula was identified by T-tube or biliary drainage tube angiography. There were 4 cases (5.71%) in non-MDT group and no biliary fistula in MDT group. There was no statistical difference between groups (p = 0.052). Postoperative CT, T-tube or biliary drainage angiography was used to confirm the presence of residual stones. Postoperative residual stones were found in 14 patients (18.67%) in MDT group and in 13 patients (18.57%) in non-MDT group. There was no statistical difference between the two groups (p = 0.988).

3.5. Stone clearance rate and minimally invasive surgery rate

The data results are shown in Table 4. The stone clearance rates of MDT group and non-MDT group were 72.00% and 81.43%. 48 Patients (64.00%) in the MDT group were successful in minimally invasive surgery (LH combined with choledochoscopy or PTCSL) and 17 patients (24.29%) in the non-MDT group were successful in minimally invasive surgery (Figure 5). The success rate of minimally invasive surgery in MDT group was significantly higher than that in non-

MDT group ($p < 0.001$). Patients with residual stones underwent PTCSL or T-tube sinus choledochoscope for removal of stones 8-10 weeks after surgery. Some patients with residual stones received conservative treatment. After the first PTCSL in the MDT group, 8 patients had residual stones (Table 5). All 8 patients underwent PTCSL again, but one patient still had residual stones. This patient ended up with conservative

Table 5. Stone location and operation method

Items	Cases	Segment of lobectomy or operation method	Number of patients with residual stones
MDT group			
OH combined with choledochoscopy	27		
LIHD	13	S2 and S3 (7)	3
		S2, S3 and S4 (5)	
		S4b (1)	
RIHD	4	S5 (1)	0
		S6 and S7 (1)	
		S5 and S8 (1)	
		S5, S6, S7 and S8 (1)	
BIHD	10	S2 and S3 (2)	6
		S2, S3 and S4 (2)	
		S2, S3, S4 and S6 (1)	
		S2, S3, S6 and S7 (1)	
		S2, S3, S4 and S8 (1)	
		S2, S3, S7 and S8 (1)	
		S2, S3, S7 and S8 (1)	
		S2, S3, S4, S6 and S7 (1)	
LH combined with choledochoscopy	33		
LIHD	26	S2 and S3 (16)	3
		S2, S3 and S4 (10)	
RIHD	3	S7 (1)	0
		S5 and S8 (1)	
		S5, S6, S7 and S8 (1)	
BIHD	4	S2, S3 and S4 (1)	1
		S2, S3 and S7 (1)	
		S2, S3, S6 and S7 (2)	
The first PTCSL	15		
LIHD	3	PTCSL	1
RIHD	5	PTCSL	3
BIHD	7	Double-channel PTCSL	4
The second PTCSL	8		
LIHD	1	PTCSL	0
RIHD	3	PTCSL	0
BIHD	4	PTCSL	1
Non-MDT group			
OH combined with choledochoscopy	53		
LIHD	22	S2, S3 (7)	0
		S2, S3 and S4 (15)	
RIHD	18	S6 (4)	4
		S7 (1)	
		S5 and S6 (2)	
		S6 and S7 (3)	
		S5, S6, S7 and S8 (8)	
BIHD	13	S2, S3 (5)	7
		S2, S3 and S4 (2)	
		S2, S3 and S6 (1)	
		S5, S6, S7 and S8 (3)	
		S2, S3, S6 and S7 (1)	
		S2, S3, S4, S6 and S7 (1)	
LH combined with choledochoscopy	16		
LIHD	13	S2 and S3 (2)	1
		S2, S3 and S4 (11)	
RIHD	2	S6 (2)	0
BIHD	1	S2, S3 and S4	0
PTCSL	1		
RIHD	1	PTCSL	1

Distinguishing liver segment by Couinaud method. LIHD: left intrahepatic bile duct; RIHD: right intrahepatic bile duct; BIHD: bilateral intrahepatic bile duct.

treatment for asymptomatic stones. The final stone clearance rate of 15 patients in MDT group was 93.33% after the second PTCSL. Due to the advantages and characteristics of the PTCSL, the stone clearance rate and stone residual rate were used as data after the second PTCSL. One patient in the non-MDT group had residual stones after a single PTCSL and was eventually treated conservatively.

3.6. Follow-up

The data results are shown in Table 4. After operation, the patients were followed up every 3 months for the first year, and once a year thereafter. The bile duct fistula was successfully closed after prolonging the drainage time of drainage tube, T tube or placing nasobiliary tube under endoscope. Abdominal ultrasound was done in outpatient clinic, and CT, MRI and MRCP were performed in patients with clinical symptoms. By February 2021, all patients completed at least one follow-up and collected stone recurrence data through retrospective medical data and telephone interviews. The mean follow-up period was 21.73 months (range: 3-43 months) in MDT group and 20.51 months (range: 3-38 months) in non-MDT group. Recurrence of stones is defined as the formation of new stones in the liver or outside the liver after surgical removal of stones. The overall stone recurrence rate was 6.21% in 145 patients. 6 patients (8%) in MDT group, and 3 patients (4.29%) in non-MDT group had stone recurrence. There was no significant difference between the two groups in the recurrence rate of stones (p = 0.496). The residual stone rate and stone recurrence rate of different operation modes in the two groups are shown in Figure 6. Specific treatment of patients with stone recurrence is as follows. In MDT group, 5 patients were treated with PTCSL again and 1 patient with asymptomatic calculus was treated conservatively. In the non-MDT group, 2 patients were treated with PTCSL again and 1 patient was treated conservatively.

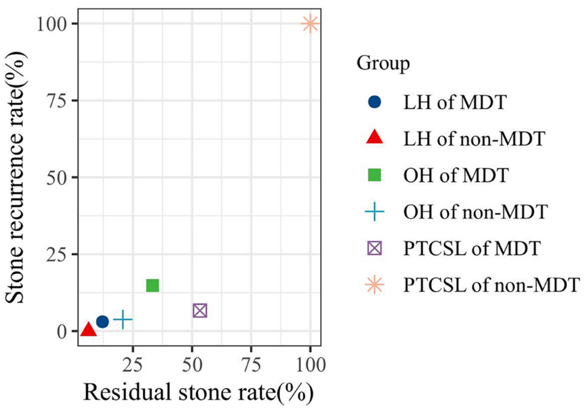

Figure 6. Comparison of residual stone rate and stone recurrence rate.

4. Discussion

Biliary calculus is associated with women, age, pregnancy, BMI, alcohol consumption, eating habits, hyperlipidemia, and diabetes. As a result of these factors, IHDs are more common in Asia than in the West, but there is also a trend of increased incidence in the West (*6-9*). Because of stone obstruction and repeated infection, IHDs can cause bile duct stenosis and segmental liver atrophy, which can be transformed into cholestatic cirrhosis. And because of recurrent cholangitis and even pyogenic cholangitis, the possibility of cholangiocarcinoma is greatly increased (*10*). Treatment of IHDs is generally targeted at the removal of stones, drainage, eradication of narrow bile ducts and atrophic liver parenchyma, so hepatectomy for IHDs has been widely accepted (*1*). In recent years, more studies have shown that LH is a better choice for the treatment of IHDs than OH. LH has the advantages of less bleeding, less trauma, less complications and shorter hospital stay (*11-13*). In the past, LH was often limited to the treatment of IHDs in the left lateral lobe of the liver. However, with the progress of laparoscopy and choledochoscopy, laparoscopic major hepatectomy for large-scale IHDs (*14*) and LH combined with choledochoscopy for bilateral IHDs have also achieved good results (*1,4*). In this study, 15 patients in the MDT group and 12 patients in the non-MDT group underwent laparoscopic major hepatectomy (3 or more Couinaud segments). It is worth mentioning that, after MDT discussion, 3 patients in MDT group underwent laparoscopic resection of bilateral liver segments (Table 5). However, in the non-MDT group, there were no cases of laparoscopic bilateral hepatectomy. This suggests that MDT may benefit more patients with bilateral IHDs from LH. In addition, 33 patients in the MDT group and 16 patients in the non-MDT group underwent LH combined with choledochoscopy, and achieved good stone clearance outcomes (stone clearance rates were 87.88% and 93.75%).

Some patients with IHDs have biliary anatomic abnormalities, metabolic diseases and other factors, leading to recurrence of stones. Some of these patients had a history of recurrent infection and multiple biliary operations, which resulted in severe adhesions in the abdominal tissue and prevented reoperation (*15*). Multiple history of biliary surgery often indicates that patients with stones are prone to recurrence, and this type of patient is more likely to have these factors. Our study also showed that having a history of biliary surgery would increase the occurrence of postoperative residual stones (Table 2). In other patients, due to poor general conditions, hepatectomy was not tolerated and ERCP failed to clear large IHDs (*16*). In the above cases, PTCSL is considered as a good alternative because of less hepatic parenchyma injury, low complication rate, high removal rate of target stones and strong repeatability (*17-19*). Although PTCSL has a limited clearance rate for multiple IHDs, there have been studies in which single-step multi-channel PTCSL surgery is used to treat bilateral IHDs with increased stone clearance (*20*). In this study, 7 patients with bilateral IHDs were treated with single-step double-channel PTCSL, but the stone clearance rate was not significantly increased in a single operation (Table 5). Fifteen (20%) patients in the MDT group underwent one or two PTSSL (final stone clearance was 93.33%). One patient in the non-MDT group received PTCSL due to a history of 6 biliary operations. In this study, the rate of stone residue (56.25%) remained high in 16 patients after first PTCSL. In practice, however, after the first PTCSL, the major stones causing the symptoms were removed. After the first PTCSL, access to stones was retained by placing a drainage tube, and the patient with residual stones could usually have PTCSL again. And the second PTCSL was acceptable because of the minimally invasive features of PTCSL. Moreover, some studies have shown that, even if the rate of residual stones is high after a single PTCSL, the residual stones are almost completely removed by another PTCSL (*15*). In 16 patients in this study, the residual stone rate of the first PTCSL was up to 56.25%, but after the second PTCSL, the final stone residual rate was 87.5%. Therefore, for the patients with complex IHDs, after MDT discussion, the MDT group chose more PTCSL. PTCSL is often used in patients who are difficult for hepatectomy, but after discussion of MDT, PTCSL was still selected for the initial diagnosis of IHDs in 3 patients in the MDT group (2 left IHDs,1 right IHDs). This was mainly due to dilatation of the target bile duct and limited stone location. It should be noted that PTCSL does not address the problem of dilated IHD, which is still at risk of conversion to cholangiocarcinoma.

MDT is a structure designed to optimize the clinical management of patients. Due to the serious harm of tumors and the variety of treatment methods, MDT has been developed rapidly in the field of tumors (*21,22*). Although IHD is a benign disease, there is a risk of conversion to cholangiocarcinoma. In addition, the surgical treatment of IHDs with (or without) extrahepatic bile duct stones is diversified. Therefore, it is necessary to explore the value of MDT in the treatment of complex IHDs.

In the specific decision-making process of MDT, all patients continued to need liver function tests, MRI, MRCP and CT after the initial diagnosis of IHDs by ultrasound. The doctors of ultrasound and imaging department have preliminarily understood the patient's condition during the preoperative examination. At the MDT meeting, the hepatobiliary surgeons summarized and reported the patient data in detail, and initially proposed an alternative procedure. Subsequently, the ultrasound and imaging doctors analyzed the specific location of the stones, dilatation or atrophy of the bile duct, and proposed treatment for the stones and liver segments. ICG-R15 was further accepted to assess the safety of hepatectomy when the MDT considered that the patient could undergo hepatectomy. According to the CT and MRI images, the target liver and bile duct were confirmed again, and whether the operation under laparoscopy was possible. The anesthesiologist evaluates the patient's ability to tolerate general anesthesia based on the patient's general condition, operation time, and other indicators. At the same time, anesthesiologists and hepatobiliary surgeons consider whether to block the portal vein and hepatic artery or reduce the central venous pressure during the operation to reduce bleeding. All patients were pre-discussed whether they would enter the ICU after surgery by the doctors of anesthesiology, intensive care medicine, and hepatobiliary surgery.

If the patient's condition is more suitable for PTCSL, then the ultrasound doctor suggests how to establish the stone extraction channel. The PTCSL is often faced with refractory bile duct stones, and the PTCSL is often limited to the removal of the target stones determined by preoperative discussion. Although intraoperative ultrasound can be very helpful, it is difficult to remove all bile duct stones at once (*17*). In addition, if the IHD is not dilated, the difficulty of establishing stone extraction channels is significantly increased and PTCSL is unable to eradicate the dilated bile duct. With the consent of all MDT members, the doctor obtains the operation consent based on full explanation of the above information to the patient, and actively prepares the equipment such as intraoperative ultrasound and choledochoscopy. The MDT discussion allows patients to be more prepared for surgery. For example, a better preoperative design, as well as more frequent intraoperative use of ultrasound, will make the procedure smooth, reducing the time of the procedure. Therefore, the surgical decision through MDT will be more beneficial to the patient. In addition, a comparison between the two groups showed that more patients underwent minimally invasive surgery after MDT. According to logistic regression analysis in this study, minimally invasive surgery can significantly reduce the occurrence of residual stones and the amount of intraoperative bleeding (Table 2). In fact, this is related to the use of ultrasound, and choledochoscope in minimally invasive surgery. Combined use of choledochoscope, transdermal choledochoscope and ultrasound avoids the disadvantage that traditional open surgery can only determine the location of stones by the touch of the hand. At the same time, ultrasound-guided liver resection and percutaneous choledochoscopy are safer. Moreover, intraoperative bleeding will prolong the hospital stay, and minimally invasive surgery indirectly reduces the hospital stay. More patients in the MDT group received minimally invasive surgery and intraoperative ultrasound-guided hepatectomy, with less intraoperative bleeding than in the non-MDT group (Figure 4). At the same time, the hospitalization time of MDT group was less than that of non-MDT group. So we believe that minimally invasive surgery is also beneficial for patients with intrahepatic bile duct stones.

Two patients in the non-MDT group had difficulty in the operation, which was transferred from LH to OH. One patient had more bleeding when the first hepatic portal was separated, and the other patient had severe adhesion between the target hepatic lobe and abdominal wall. In the MDT group, 75 patients were successfully operated on after the discussion of MDT, and more patients were successfully operated on with personalized and minimally invasive surgery.

In conclusion, it is necessary to establish the MDT model in the clinical management of complex IHDs. Minimally invasive procedures based on laparoscopy, choledochoscope and percutaneous choledochoscope can be selected more easily through MDT. MDT can shorten the operation time, and minimally invasive surgery can reduce the incidence of residual stones, reduce intraoperative bleeding, and may shorten hospital stay. Therefore, MDT management model can provide a personalized and minimally invasive surgical protocol for patients with complex IHD, which has high application value.

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