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Segmental Bile Duct-Targeted Liver Resection for Right-Sided Intrahepatic Stones

Shao-Qiang Li, MD, PhD, Yun-Peng Hua, MD, PhD, Shun-Li Shen, MD, PhD, Wen-Jie Hu, MD, PhD, Bao-Gang Peng, MD, PhD, and Li-Jian Liang, MD

Abstract: Hepatectomy is a safe and effective treatment for intrahepatic stones (IHSs). However, the resection plane for right-sided stones distributed within 2 segments is obstacle because of atrophy-hypertrophy complex formation of the liver and difficult dissection of segmental pedicle within the Glissonean plate by conventional approach. Thus, we devised segmental bile duct-targeted liver resection (SBDLR) for IHS, which aimed at completely resection of diseased bile ducts. This study aimed to evaluate the outcomes of SBDLR for right-sided IHSs.

From January 2009 to December 2013, 107 patients with IHS treated by SBDLR in our center were reviewed in a prospective database. Patients' intermediate and long-term outcomes after SBDLR were analyzed.

A total of 40 (37.4%) patients with localized right-sided stone and 67 (62.7%) patients with bilateral stones underwent SBDLR alone and SBDLR combined with left-sided hepatectomy, respectively. There was no hospital mortality of this cohort of patients. The postoperative morbidity was 35.5%. The mean intraoperative blood loss was 414 mL (range: 100–2500). Twenty-one (19.6%) patients needed red blood cells transfusion. The intermediate stone clearance rate was 94.4%; the final clearance rate reached 100% after subsequent postoperative cholangioscopic lithotomy. Only 2.8% patients developed stone recurrence in a median follow-up period of 38.3 months.

SBDLR is a safe and effective treatment for right-sided IHS distributed within 2 segments. It is especially suitable for a subgroup of patients with bilateral stones whose right-sided stones are within 2 segments and bilateral liver resection is needed.

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Abbreviations: CBD = common bile duct, CPC = chronic proliferative cholangitis, CT = computed tomography, ERCP = endoscopic retrograde cholangiopancreaticography, HIS = intrahepatic stone, IVC = inferior vena cava, LH = left hepatectomy, LLS = left lateral sectionectomy, SBDLR = segmental bile duct-targeted liver resection, Sg = segment.

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From the Department of Hepatic Surgery, The First Affiliated Hospital, Sun Yat-sen University, Guangzhou, China.
Correspondence: Shao-Qiang Li, Department of Hepatic Surgery, The First Affiliated Hospital, Sun Yat-sen University, No. 58 Zhongshan Er Road, Guangzhou 510080, China (e-mail: lisq@medmail.com.cn).
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INTRODUCTION

Intrahepatic stone (IHS) is a common disease in South East Asia.[1,2] And it is an increasing tendency in Western countries.[2,3] IHS causes biliary stricture and affected segmental parenchyma atrophy because of repeated episodes of acute cholangitis. The principle of treatment has been well established in past decades. Hepatectomy that can clear stones and remove biliary stricture and atrophic liver tissue provides the optimal treatment for IHS in selected patients.[3–9]

The IHS distributes strictly within segments. The left lateral section of liver is the most favor side for IHS formation, and the right posterior section runs the second owing to the intrahepatic bile duct anatomy. For left-sided IHS, left lateral sectionectomy (LLS) or left hepatectomy (LH) is the most common performed procedure. The landmark of the left lateral section (the Falciform ligament) or the left hemi-liver (the Cantlie line) is clear, which makes the procedures of LLS and LH to be performed easily and precisely. However, for the localized right-sided IHS defined as stone-affected segment was ≤2 segments, the resection planes of stone-affected segment or section are sometimes difficult to make because of no obvious landmarks between segments or sections on liver surface. Conventional anatomic segmentectomy or sectionectomy guided by Glisonean pedicle blood inflow control approach[10,11] is difficult to be performed in IHS patients because the periductal dense inflammatory adhesion generated by repeated cholangitis makes the dissection of segmental Glissonean plate which is untoward and at risk of massive bleeding, especially for those with liver rotation resulting from stone-affected segments atrophy and the unaffected segments hypertrophy, that is atrophy-hypertrophy complex.[12]

Therefore, aiming at circumventing the aforementioned constraint and considering that resection of the stone-bearing or strictured bile duct is the fundamental issue of treatment for IHS, we modified the conventional liver resection to be the procedure called segmental bile duct-targeted liver resection (SBDLR) for localized right-sided IHSs in 2009. SBDLR refers to the extent of liver resection which is guided by the segmental stone-bearing or strictured bile ducts, but not the borderline of anatomic segmental parenchyma. The key purpose of SBDLR is to completely remove localized stone-bearing or strictured bile duct and maximally preserve the unaffected ones. This article was to summarize our initial experience of SBDLR performed for right-sided IHS in our center.

PATIENTS AND METHODS

Patients

From January 2009 to December 2013, there were totally 413 patients who underwent elective hepatectomy for IHS in our center. Among them, 107 patients who underwent SBDLR for localized right-sided IHS alone or SBDLR combined with left-sided hepatectomy for those with bilateral stones were enrolled in this study from a prospective database. This study was approved by the ethical committee of the hospital and written informed consents were obtained from patients.

Preoperative Work-Up and Procedure of SBDLR

The preoperative work-up and surgical indications of patients with IHS in our center have been well established and mentioned in detail in our previous report.[9] In addition to biliary stricture and segmental atrophy, the indications of SBDLR included IHS-affected $\leq$2 segments at right side of the liver, or bilateral stones which right-sided stones distributed $\leq$2 segments and bilateral liver resection was needed.

Bilateral subcostal incision was done under general anesthesia. The hepatic hilar structures were clearly identified. Cholecystectomy was routinely done for patients even though it was no gallstone. Right-sided liver was fully mobilized. In some cases with Sg7 or Sg 6,7 stones, there was dense inflammatory adhesion between the right side of inferior vena cava (IVC) and the atrophic liver parenchyma because of repeated attack of cholangitis, isolation of Sg 7 should be careful so as to avoid iatrogenic injury of IVC. After that, choledochotomy and extra- or intrahepatic bile ducts exploration by lithotomy forceps and cholangioscopy (5 mm in diameter; Olympus, Japan) were performed to further verify the distribution of stones and biliary stricture intraoperatively.

For Sg6 or 7 bile ducts stones with highly atrophic segmental parenchyma, the stone-bearing bile ducts are always thickening and dilating and sometimes could be visualized on the surface of atrophic segment after fully mobilization of right-sided of the liver. On the contrary, the location of peripheral bile duct stones could be palpated by surgeon's fingers on the involved segment. For Sg5 or 8 stones, and other circumstance that palpation was ill defined, intraoperative lithotomic forceps and cholangioscopy were applied. We first used lithotomic forceps to explore the stone-bearing bile duct. The direction and, most importantly, the position of end-tip of this bile duct that forceps could reach as far as possible could be palpated by surgeon's left hand fingers. Then, the nearest point on the liver surface to the position of top-tip of forceps was labeled on liver surface under the guidance of lithotomic forceps. And subsequently, these findings were verified by cholangioscopy.

Then, the resection line around the targeted bile duct could be delineated on the surface of the liver. Liver parenchyma transection from the surface to the segmental hilum along the stone-bearing bile ducts or strictured bile duct was performed (Figure 1C). Liver parenchyma transection was done by Harmonic Ultrasonic Devices (Ethicon Inc, NJ) or Clamp crashing. Finally, the diseased bile duct was transected at the segmental hilar bifurcation (Figure 3C). The biliary stump was sutured by 4-0 or 5-0 absorbable monolayer material (Vicryl; Ethicon Inc, Cornelia, GA). The segregated branched bile ducts on the raw surface were ligated or sutured by 5-0 Vicryl. Intermittent Pringle maneuver was used to reduce bleeding during parenchyma transection if necessary.

T tube was routinely inserted into the common bile duct (CBD). In the patients with hepaticojejunostomy, a rubber tube measuring 5 mm in diameter was inserted through the biliary-enteric anastomosis for postoperative cholangiography or cholangioscopic manipulation if necessary.[9] Bile leak test was done by injection of 50 mL of normal saline through the T tube or the transanastomotic tube to identify bile leakage from the raw surface or the sutured site of CBD and anastomosis. Bile leak hole was repaired by 5-0 Vicryl immediately.

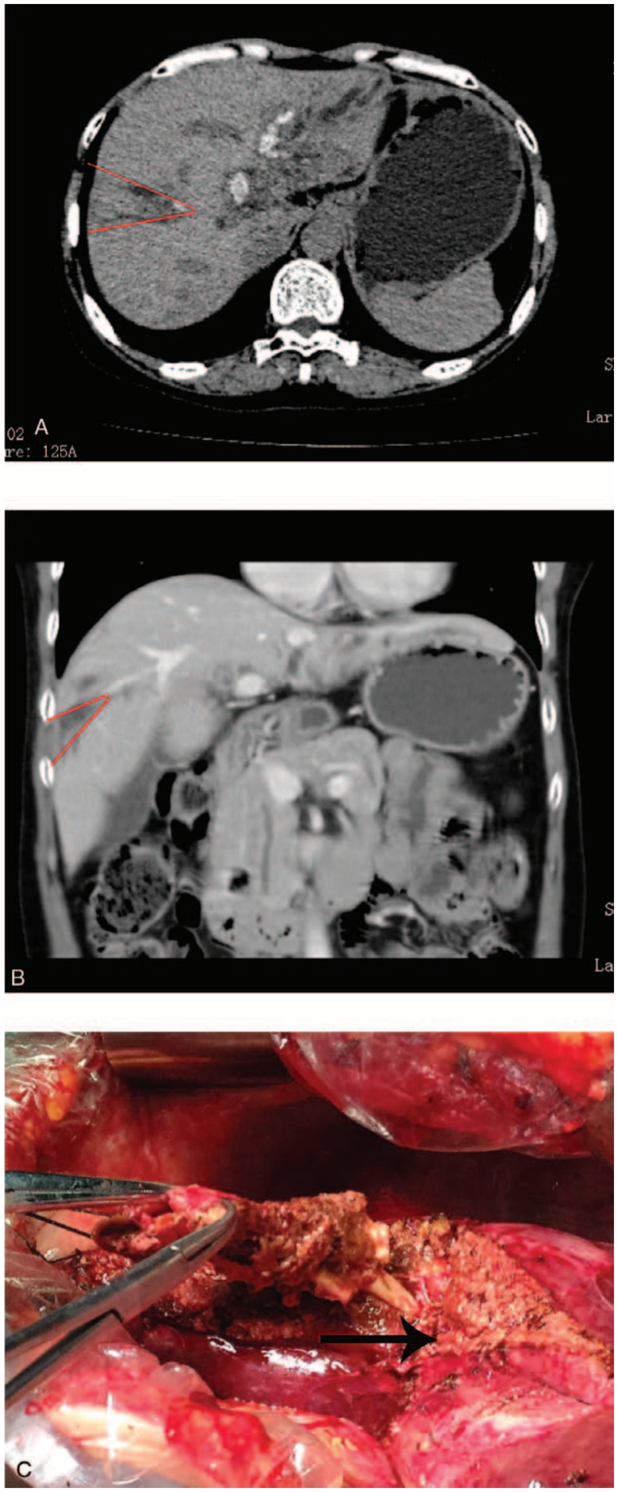

FIGURE 1. A 55-year-old female patient with bilateral stones underwent LH and SBDLR of Sg8. Panels A and B showed stones distributed in Sg 8 and left side of the liver in coronal and sagittal planes. Red lines indicated the planned resection line of SBDLR of Sg8. Panel C, an intra-operative photo, illustrated the procedure of SBDLR. Black arrow indicated Sg8 stone-bearing bile duct. LH = left hepatectomy, Sg = segment, SBDLR = segmental bile duct-targeted liver resection.

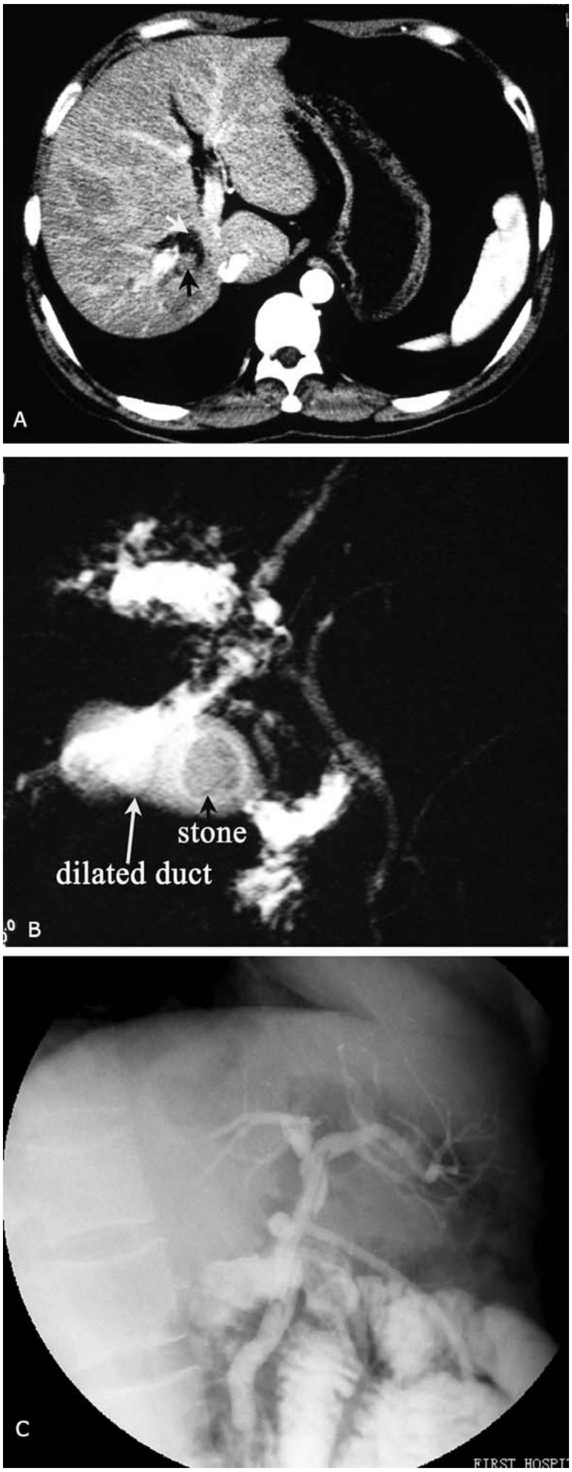

FIGURE 2. A 37-year-old male patient underwent SBDLR of Sg7 for Sg7 stone. Panel A: contrast-enhanced CT showed stone (black arrow) located within Sg 7 cystic dilating bile duct (white arrow). Panel B: magnetic resonance cholangiopancreaticography indicated cystic dilating bile duct of Sg7 and a stone formation. Panel C: postoperative T tube cholangiogram showed the diseased Sg 7 bile duct had been completely resected. CT = computed tomography, Sg = segment, SBDLR = segmental bile duct-targeted liver resection.

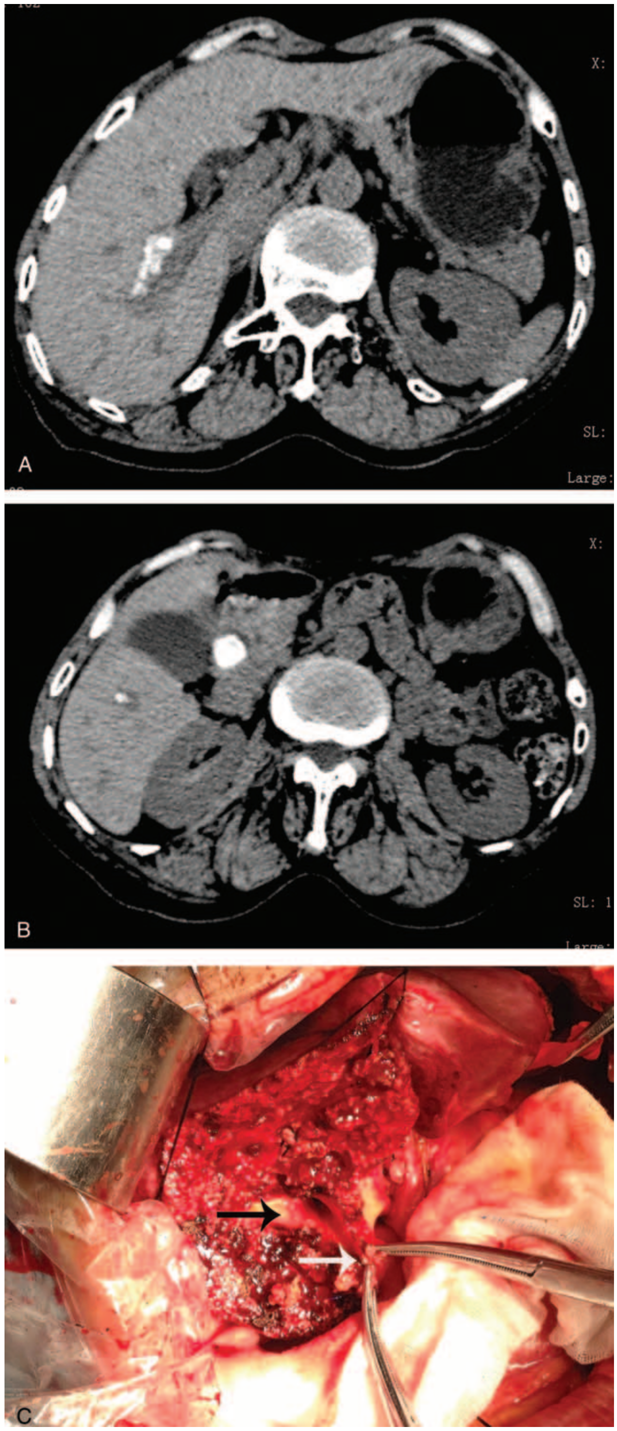

FIGURE 3. A 56-year-old female patient with Sg6,7 and common bile duct stones. She underwent SBDLR of Sg 6,7. Panels A and B showed the location of stones in CT scans. Panel C indicated the orifice of Sg6 bile duct (write arrow) and Sg7 bile duct (black arrow). The Sg 6 and 7 bile ducts had been completely resected. Sg = segment, SBDLR = segmental bile duct-targeted liver resection.

Drains were placed in the subphrenic space for draining peritoneal fluid in all patients. Drains were removed when drainage became serous in nature and no bile stained or blood

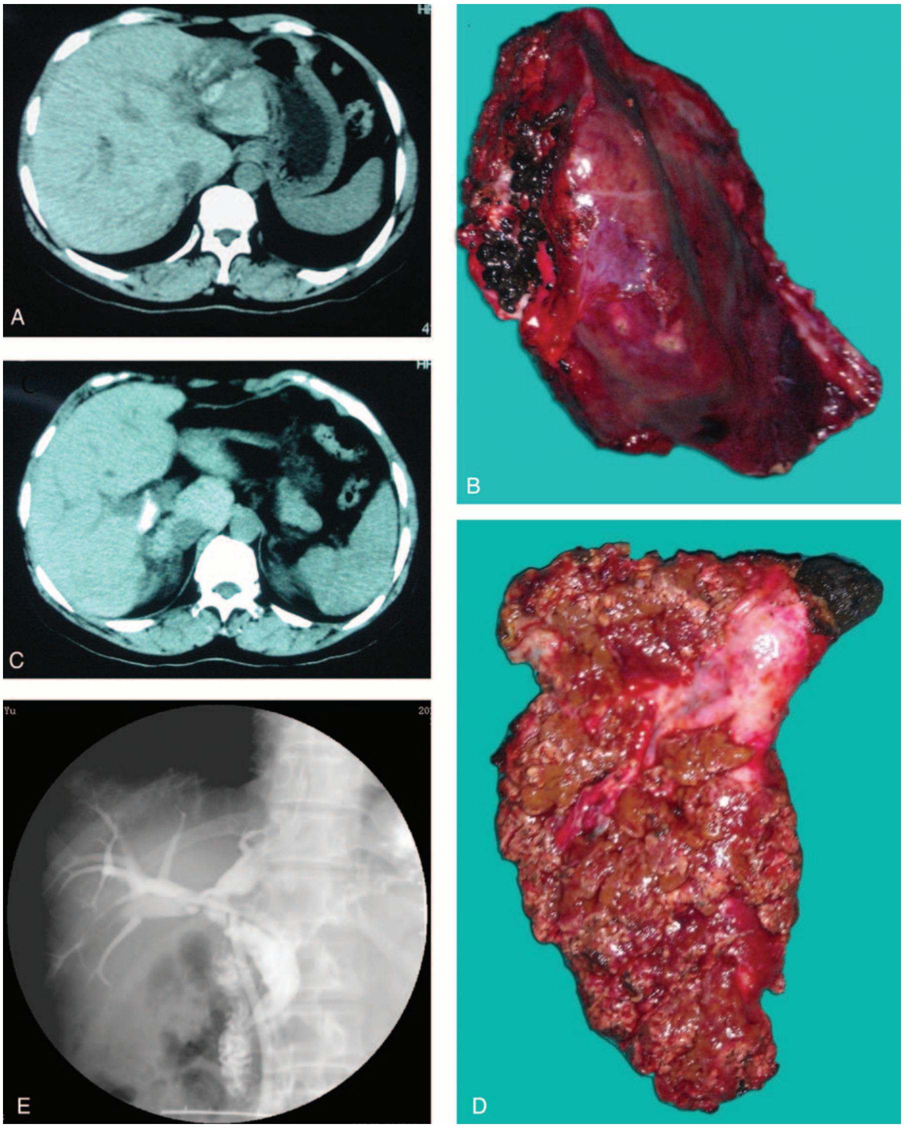

FIGURE 4. A 55-year-old female patient with bilateral stones underwent LLS and SBDLR of Sg6. Panels A and C: CT scans showed left lateral section and Sg 6 stones. Panel B: left lateral section specimen showed pigment stones and scar liver tissue. Panel D: Sg 6 specimen indicated a staghorn stone in Sg 6 bile duct and highly atrophic liver tissue. Panel E: postoperative T tube cholangiogram revealed no residual stone was found within the biliary tree. CT = computed tomography, LLS = left lateral sectionectomy, Sg = segment, SBDLR = segmental bile duct-targeted liver resection.

stained at postoperative days 3 to 5. T tube or transanastomotic tube was removed when no residual stone or bile leakage was documented within the biliary tree by postoperative cholangiography or ultrasound at postoperative day 14.[9]

Patient Follow-Up

The postoperative follow-up protocol for IHS had been well established in our center.[9] Briefly, the patients were followed up every 3 months for the first year, and twice a year thereafter. Liver function tests, blood routine profile, and ultrasound were performed in outpatient clinics. Computed tomography (CT) was done on patient with symptoms of stone recurrence. Data were collected from the prospective database and patients' interviews at the end of June 2014. The median follow-up period was 38.3 months (range: 6–66 months). Stone recurrence was defined as new stone formation within the biliary tree after complete initial clearance.[9]

Statistics

Patients' continuous data were expressed as mean ± standard deviation or median value. Discrete data were expressed in percentage.

RESULTS

Patients' Demographic Data

There were totally 107 patients enrolled in this study. The median age was 51.0 years (range: 22–76). Patients' demographic data were shown in Table 1. There were 64 (59.8%) female patients. A total of 49.0% of patients had previous history of biliary surgery, 62.7% of patients had bilateral stones, and 105 (98.1%) patients whose stone-affected segments were atrophic.

Patients' Operative Data

All patients underwent elective liver resection. The operative procedures were listed in Table 2. Forty patients with localized right-sided stone underwent SBDLR, and 67 patients with bilateral stones underwent SBDLR combined with left-sided hepatectomy. The mean operative time of this group of patients was 238.5 ± 72.8 minutes, mean blood loss was 414 mL (range: 100–2500). Twenty-one (19.6%) patients needed red blood cells transfusion.

Surgical Mortality and Morbidity

There was no hospital mortality occurred in this group of patients. Thirty-eight (35.5%) patients developed at least one kind of surgical complications. The postoperative complications were shown in Table 3. The most common surgical complications were septic complications, such as wound infection, subphrenic infection, and bile leak. These complications were cured by conservative treatment. There was no postoperative hepatic failure occurred in this group of patients. The mean hospital stay of this group of patients was 26.4 ± 10.6 days.

TABLE 1. Patients' Preoperative Data

Variables	n (%)
Sex, male/female	43 (40.2)/64 (59.8)
Symptom: Charcot's triple*	56 (52.3)
Previous biliary surgery	47 (43.9)
CTx	14
CTx+choledochotomy	20
LLS	6
Hepaticojejunostomy	4
CBD duodenal anastomosis	2
Stone extraction via ERCP	1
Stone location	
Localized right-sided stone	40 (37.3)
Sg5	2 (1.9)
Sg6	7 (6.5)
Sg 7	4 (3.7)
Sg8	1 (0.9)
Sg 6,7	23 (21.5)
Sg5,6	3 (2.8)
Bilateral stone	67 (62.7)
Combined with extrahepatic stone	75 (67.3)
Stone-affected segment atrophy	105 (98.1)
Alanine transaminase, U/L	42.3 ± 8.7
Total bililubin, μmol/L	21.6 ± 10.2
Albumin, g/L	42.1 ± 6.8
Prothrombin time, s	12.2 ± 3.0
White blood cell count, $\times 10^9$/L	6.4 ± 2.3
Platelet count, $\times 10^9$/L	135 ± 18.3
Hemoglobin, g/L	122.8 ± 11.5

CBD = common bile duct, CTx = cholecystectomy, ERCP = endo-endoscopic retrograde cholangiopancreaticography, LLS = left lateral sectionectomy, Sg = segment.
* These patients experienced at least one episode of acute cholangitis in the course of disease. But the symptoms subsided at least 1 month before operation. Other patients were symptomatic and presented with repeated right upper quadrant pain or fever.

TABLE 2. Operative Procedures

Procedures	n (%)
SBDLR	
Sg5	2 (1.9)
Sg6	4 (3.7)
Sg7*	2 (1.9)
Sg8	1 (0.9)
Sg6,7†	23 (21.5)
Sg5,6	3 (2.8)
SBDLR + left-sided hepatectomy	
SBDLR (single segment) + LLS‡	20 (18.7)
SBDLR (2 segments) + LLS	30 (28.0)
SBDLR (single segment) + LH§	14 (13.1)
SBDLR (2 segments) + LH	3 (2.8)
Concomitant procedure	
Hepaticojejunostomy	20 (18.7)‖
T tube drainage	87 (81.3)

LH = left hepatectomy, LLS = left lateral sectionectomy, SBDLR = segmental bile duct-targeted liver resection.
*,†,‡,§Represented case's figures were shown in Figure 2, Figure 3, Figure 4, and Figure 1, respectively.
‖These included 4 patients with previous hepaticojejunostomy. Biliary-enteric anastomosis had been revised because of stricture of the previous anastomostic mouth in 3 patients. Two patients with previous CBD duodenal side-to-side anastomosis had been revised to natural CBD drainage.

Intermediate and Long-Term Outcomes

The surgical stone clearance rate was 94.4% (101/107). Six patients with bilateral stones had postoperative residual stones and subsequently underwent cholangioscopic lithotomy 6 weeks after operation through T tube or transanastomotic tube track. Their stones were completely removed after cholangioscopic lithotomy. In a median follow-up period of 38.3 months, 3 (2.8%) patients developed stone recurrence. One patient developed stone recurrence within the CBD 44 months after operation, she received endoscopic stone retraction. Two patients whose stone recurred in Sg4 after 26 and 35 months after initial hepatectomy, respectively, both of the two patients are symptom-free and under follow-up.

DISCUSSION

With the improvement of preoperative assessment, perioperative care, and meticulous intraoperative manipulations,

TABLE 3. Postoperative Complications

Complications	n (%)
Wound infection	19 (17.7)
Subphrenic infection	14 (13.1)
Pleural effusion needed tapping	13 (12.1)
Bile leak	8 (7.5)
Septicemia	4 (3.7)
Pneumonia	2 (1.9)
Acute right heart failure	1 (0.9)
Lower urinary tract infection	1 (0.9)

hepatectomy becomes a safe, definitive, and effective treatment for IHS.[3–9] The hospital mortality ranged from 0.4% to 2.0%, and stone clearance rate was >90% in recent large reports.[5,6,9] In our previous report, we had demonstrated that optimal results could be achieved when the extent of liver resection was consistent with the stone-affected segments in patients with sufficient future liver remnant, in which the 5-year cumulative recurrence rate was 3.0% for unilateral stone and 3.4% for bilateral stone.[9] However, the extent of liver resection for localized right-sided IHS is sometimes difficult to achieve precisely because of the pathologic changes of the local Glissonean plate and the liver morphology resulted from repeated cholangitis.

Considering that removal of the stone-bearing bile ducts or strictured bile ducts is the key issue in the treatment of IHS, we modified the conventional anatomic liver resection which segmental liver parenchyma en bloc resection is requested to be the procedure of SBDLR. It means that the extent of liver resection is guided by the segmental stone-bearing bile ducts. We emphasize completely or maximally resection of segmental stone-bearing bile duct rather than segmental parenchyma itself in SBDLR.

The results of this cohort of patients demonstrated that SBDLR is a safe and more effective procedure for IHS. The intermediate and long-term outcomes after SBDLR were satisfactory. There was no surgical mortality. The most common postoperative complications were septic complications such as wound infection, subphrenic infection, and bile leakage. The occurrence rates of these complications were comparable with our previous report.[9,13] The intermediate stone clearance rate was 94.4%. The final stone clearance rate reached 100% after subsequently cholangioscopic lithotomy. In a median follow-up period of 38.3 months, only 3 (2.8%) patients developed stone recurrence. One whose stone recurred within CBD received stone extraction through ERCP; the other 2 whose stones recurred at Sg4 without symptom is under follow-up.

Intraoperative identification of stone-bearing bile ducts is a critical step for SBDLR. Intraoperative ultrasound is an important and widely used tool to guide liver resection for liver tumors, which aims at obtaining enough resection margin and preserving healthy tissue or important tubular structures.[14] Ultrasound-guided liver resection had been used for IHS whose resection plan was unclear before 2009 in our center.[9] However, we found that the diagnosis of IHSs and biliary stricture by intraoperative ultrasound is less accurate when compared with that by intraoperative cholangioscopy. The air bubbles within the bile duct or preexisting pneumobilia may mimic stones by ultrasound. Furthermore, most of the portal veins supplied the stone-affected segments were stenosis or occlusion because of repeated periductal inflammation.[15,16] Liver resection under ultrasound-guided portal pedicle control approach is not feasible in this case. Therefore, we use intraoperative cholangioscopy rather than ultrasound to target stone-bearing bile duct at surgery after 2009. We believe that liver palpation combined with lithotomic forceps and intraoperative cholangioscopy is a convenient and accurate approach to target the diseased bile ducts. The Sg6 or 7 diseased bile duct can be identified by palpation in the visceral surface or the bare area surface of the liver after fully mobilization of right hemi-liver. The stone-bearing bile ducts are usually thickening or dilating, and the affected segment is atrophic. These pathologic changes facilitate the palpation of the diseased bile ducts. As to the Sg5 or 8 bile duct, and other condition that palpation is ill defined, lithotomic forceps combined with intraoperative cholangioscopy is available to define these bile ducts.

After identification of the targeted bile ducts, the resection plane that contains the diseased bile ducts can be marked on the surface of the liver. Then, liver parenchyma transection from the surface to the segmental hilum along the stone-bearing bile duct or strictured bile duct was performed (Figure 1C). The diseased bile duct was transected at the segmental hilar bifurcation (Figure 3C). The biliary stump was sutured by 4-0 or 5-0 absorbable monolayer material.

One of the typical features of stone-bearing bile duct is chronic proliferative cholangitis (CPC), which is caused by stone mechanical stimulation and repeated acute cholangitis. CPC may persist and progress even though stones had been retrieved.[17] It is a risk factor for stone recurrence. In this group of patients underwent SBDLR, the stone recurrence rate is very low. No stone recurred in the right-sided of the liver in the follow-up period. This largely contributes to the diseased bile ducts (stricture, CPC) being completely or maximally resected by SBDLR.

The advantages of SBDLR can be summarized as the follows. The diseased bile ducts can been potentially resected, thus reduces the possibility of stone recurrence. Simplify the conventional anatomic segmentectomy guided by pedicle vascular control approach. The segmental pedicle need not dissect before liver transection in SBDLR, which reduces intraoperative blood loss and the possibility of iatrogenic injury of the Glissonean tubular structures. We used intermittent Pringle's maneuver to control bleeding during SBDLR. The intraoperative mean blood loss was 414 mL, only 19.6% patients needed red blood cells transfusion in our series. The nonstone segments are maximally preserved. In this regard, it is especially suitable for patients with bilateral stones whose right-sided stones distribute within 2 segments and bilateral liver resection is indicated. In this case, the bilateral extents of liver resection should be accurately tailored not only to completely remove the foci but also to maximally preserve the nonaffected tissue for ensuring sufficient future liver remnant. In our group of patients, 62.7% of patients underwent bilateral liver resection. These patients would first undergo LLS or LH for left-sided stones, and then SBDLR for the right-sided stones. None of them developed postoperative liver failure.

The main disadvantage of SBDLR is possible remaining of the segregated branch of segmental bile ducts in the residual segmental parenchyma which might not be en bloc resection. Segregated bile duct is potential risk factor associated with postoperative bile leak.[16] Although the preventive role of intraoperative bile leak test for postoperative bile leakage is controversial,[18–21] we routinely performed bile leak test through T tube or transanastomotic tube to identify bile leakage from the transection surface intraoperatively. In our series, the overall occurrence rate of postoperative bile leak was 7.5%, which was not increased compared with our previous report.[9,12] We believe that refined ligation or suture of small bile ducts in the transection surface is important to prevent bile leak from the segregated bile ducts.

In conclusion, we devised a procedure called SBDLR from conventional anatomic liver resection for treatment of right-sided IHSs located within 2 segmental bile ducts. It may be a novel concept in the treatment of IHS. SBDLR is a safe, effective procedure for right-sided IHSs within 2 segments. In this selected group of patients, the stones are completely removed after SBDLR associated with postoperative cholangioscopic lithotomy, and the stone recurrence rate is very low. SBDLR is especially suitable for patients with bilateral IHSs whose right-sided stones are within 2 segments and bilateral liver resection is needed.

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