Original article

Caudate lobe-sparing subtotal hepatectomy for primary hepatolithiasis

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Background: Patients with frequent and life-threatening attacks of cholangitis due to bilateral primary hepatolithiasis with atrophy of the main liver and giant hypertrophy of the caudate lobe were assessed for caudate lobe-sparing subtotal hepatectomy.

Methods: This was a retrospective study of prospectively collected data from patients who underwent subtotal hepatectomy with sparing of the caudate lobe (resection of 7 liver segments, leaving only the caudate lobe) between March 2003 and December 2009. All patients had concomitant bile duct exploration and choledochoscopy. Perioperative and long-term outcomes were analysed.

Results: Immediate stone clearance was obtained in all 12 patients enrolled in the study. Two patients had strictureplasty of the strictured caudate bile duct. There was no hospital mortality and six complications developed in three patients. At a mean follow-up of 51 months, one patient had developed recurrent stones in the caudate lobe bile ducts at 8 months and died from acute purulent cholangitis, 17 months after surgery. The remaining 11 patients were symptom-free with no further attacks of acute cholangitis.

Conclusion: In selected patients with bilateral primary hepatolithiasis, caudate lobe-sparing subtotal hepatectomy is a safe and effective treatment.

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Introduction

Primary hepatolithiasis is a disease characterized by *de novo* formation of stones in the intrahepatic bile ducts[1]. The disease was first reported by Digby from Hong Kong in 1930[2]. As it presents clinically with repeated attacks of acute bacterial cholangitis, Cook and associates[3] used the term recurrent pyogenic cholangitis in 1954 to describe the condition, but other synonyms have also been used[4].

Infections or stones in the intrahepatic biliary system initiate a vicious cycle of stone, leading to obstruction, infection and further stone formation. If left untreated, the liver segments proximal to the biliary obstruction are gradually destroyed and become atrophic. Compensatory hypertrophy occurs in unobstructed parts of liver (atrophy–hypertrophy complex)[5]. The left liver is preferentially affected by stones, cholangitis and atrophy, although part or the whole of the right liver can be similarly affected at the same time. In extreme cases with longstanding and severe disease, biliary cirrhosis or complete hepatic atrophy occurs. Death from bleeding oesophageal varices as a consequence of portal hypertension or liver failure follows, unless liver transplantation is performed[4].

In treating patients with primary hepatolithiasis, severe atrophy of the main liver (Couinaud segments II–VIII) with giant compensatory hypertrophy of the caudate lobe may be encountered. Caudate lobe-sparing subtotal hepatectomy (resection of 7 liver segments, leaving only the caudate lobe) may be used to treat these patients. This retrospective study of prospectively collected data aimed to review the experience with this operation in the authors' institution.

Methods

Study design

The records of all patients with complicated primary hepatolithiasis who underwent liver resection at the Department of Hepatobiliary Surgery, Chinese PLA General Hospital, Beijing, China, between March 2003 and December 2009, were studied retrospectively. Included in this study were

patients who underwent caudate lobe-sparing subtotal hepatectomy for bilateral primary hepatolithiasis with severe atrophy of the main liver (Couinaud segments II–VIII) and giant hypertrophy of the caudate lobe. Patients with a pathological diagnosis of cholangiocarcinoma associated with intrahepatic stones were excluded from the analysis. Informed consent for the surgical procedure was obtained from all patients. Demographic, operative and follow-up data were collected prospectively and analysed retrospectively. Perioperative/short-term outcomes included stone clearance rate, operative morbidity and mortality. The long-term outcomes included stone recurrence rate and survival. The study was approved by the ethics committee of the Chinese PLA General Hospital.

Management of primary hepatolithiasis

Management of primary hepatolithiasis was based on control of infection during attacks of cholangitis by antibiotics, and if necessary by endoscopic/percutaneous biliary drainage, followed by elective definitive surgery when the disease was quiescent[1,4]. The aims of definitive surgery were to remove all biliary stones, to establish adequate drainage of the biliary system, and to resect atrophic and non-functioning liver segments, which harbour bacteria and serve as foci of infection[4]. These aims were achieved endoscopically, percutaneously or by means of laparoscopic/open surgery.

Indications for partial hepatectomy were intrahepatic biliary strictures that failed other forms of treatment, atrophy of liver segment(s) or a hemiliver, suspected cholangiocarcinoma, and segmental bile ducts with stones inaccessible to treatment by other approaches (*Fig. 1*). The severity of symptoms, status of the remaining biliary tract, hepatic parenchymal reserve, the patient's general condition and alternative procedures were considered before deciding on partial hepatectomy. Partial hepatectomy was performed only in patients with recurrent, troublesome and severe disease[1].

The indications for caudate lobe-sparing subtotal hepatectomy were more stringent. In addition to the criteria and considerations used for partial hepatectomy, only patients with a long history of repeated and frequent attacks of life-threatening cholangitis were investigated further for subtotal hepatectomy sparing the caudate lobe. Before surgery, computed tomography (CT) was employed to estimate caudate lobe volume and total liver volume (TLV), using the formula[6] TLV (ml) = 706·2 × body surface area (m^2) + 2·4, and Child–Pugh classification[7] and indocyanine green retention rate at 15 min ($ICGR_{15}$)[8] were obtained routinely. Inclusion criteria for caudate lobe-sparing subtotal hepatectomy, in addition to good general condition, were: caudate lobe volume greater than 500 ml, proportion of caudate lobe volume to TLV above 40 per cent, Child–Pugh grade A, and $ICGR_{15}$ below 14 per cent in patients without obstructive jaundice.

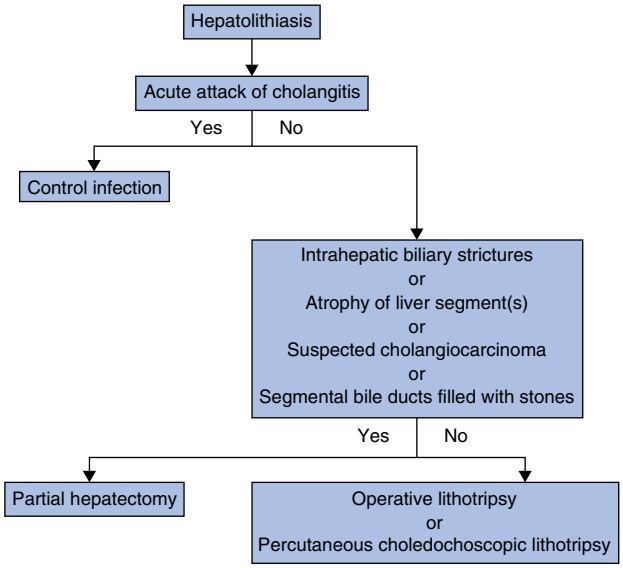


Fig. 1 Algorithm for management of primary hepatolithiasis

Preoperative investigations

All patients had chest X-ray, electrocardiography, lung function tests, ultrasonography, and contrast-enhanced CT or magnetic resonance imaging (MRI) of the abdomen. Magnetic resonance cholangiopancreatography (MRCP) or percutaneous transhepatic cholangiography/endoscopic retrograde cholangiopancreatography (ERCP) was performed to determine the location of stones, the presence and site of biliary stricture, the presence or absence of atrophic liver segments, and malignant changes in the biliary system. CT volumetry was carried out on the main liver and caudate lobe. Laboratory tests including hepatitis B surface antigen, antibodies to hepatitis C, serum α-fetoprotein, carcinoembryonic antigen, carbohydrate antigen 19-9, serum albumin, serum total bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT) and prothrombin time were obtained.

Surgical procedure

Surgery was performed via a right subcostal incision with a J extension. Peritoneal adhesions were freed, separating the liver from the diaphragm and exposing the hepatoduodenal ligament. The common bile duct was

identified and opened, and flexible choledochoscopy, with or without intraoperative cholangiography, was performed. The caudate lobe bile ducts were identified and stones in the ducts removed. Any associated strictures were identified.

The right and left hepatic pedicles were dissected to identify the right and left hepatic ducts, arteries and portal veins. The portal triads supplying the caudate lobe were carefully identified and preserved. Identification of the caudate lobe portal triad was facilitated by choledochoscopy. The left hepatic duct was divided proximal to the caudate lobe bile duct, and the stump was sutured with 3/0 polyglactin (Vicryl®; Ethicon, Johnson & Johnson, San Angelo, Texas, USA). The right hepatic duct was similarly divided and sutured. Division of the left and right hepatic arteries, and portal veins was then carried out distal to the portal triads supplying the caudate lobe. Special care was taken not to injure the blood supply or bile ducts to the caudate lobe.

The main liver was mobilized by division of the falciform, left triangular, coronary and right triangular ligaments. The fossa between the right hepatic vein and the trunk of the middle/left hepatic veins was dissected. The fissure that harbours the ligamentum venosum was identified. Liver parenchymal transection started on the left side along this fissure, separating the atrophic main liver from the hypertrophied caudate lobe. As liver transection proceeded gradually from left to right through the superior liver segments IV, VIII and VII, the left, middle and right hepatic veins were identified. These veins were transected individually and sutured with 5/0 polypropylene. After haemostasis of the raw liver surface, attention was turned back to the biliary system. Choledochoscopy was repeated and any stones in the extrahepatic and caudate lobe bile ducts were removed. Strictures in the caudate lobe bile duct were dealt with by either dilatation or strictureplasty. The choledochoscope was then passed distally into the duodenum. Any evidence of dysfunction of the sphincter of Oddi or strictures in the extrahepatic bile ducts was dealt with by an end-to-side hepaticojejunostomy, anastomosing the common hepatic duct to a Roux-en-Y loop of jejunum. After complete haemostasis was assured, a T tube was put into the extrahepatic duct, as the bile was usually muddy and contained debris and small stone fragments. The abdominal cavity was closed with a drain to the liver bed. A T tube cholangiogram was performed approximately 10 days after surgery. If no residual stones were detected, the T tube was removed.

Postoperative management

All patients received the same postoperative management. Patients were monitored in the intensive care unit (ICU) during the early postoperative period. Subsequent need for stay in the ICU was determined by the patient's condition.

Follow-up

All patients had regular postoperative follow-up, once every 2 months. CT volumetry was carried out routinely, 2 months after surgery. Ultrasonography, MRCP and liver function tests were conducted every 6 months. MRCP, ERCP or percutaneous transhepatic cholangiography was performed if the patient presented with symptoms suggestive of cholangitis. CT or MRI was done subsequently, when clinically indicated. Patients with recurrent stones were treated conservatively.

Statistical analysis

Continuous data are expressed as mean(s.d.), unless indicated otherwise. Stone recurrence-free survival was measured from the date of surgery to the date on which recurrence was diagnosed. Overall survival was determined from the date of surgery to the time of death. The statistical package SPSS® version 11·5 (SPSS, Chicago, Illinois, USA) was used for all analyses.

Results

During the study period 862 patients with primary hepatolithiasis were operated on in the Department of Hepatobiliary Surgery, Chinese PLA General Hospital, Beijing. Primary hepatolithiasis in both right and left livers occurred in 252 patients. In 12 patients, there was atrophy of the main liver with giant hypertrophy of the caudate lobe (*Fig. 2*), and caudate lobe-sparing subtotal hepatectomy was carried out. Eight patients underwent common bile duct exploration with or without cholecystectomy for stones. Obstructive jaundice was still present in three patients and the Child–Pugh classification and $ICGR_{15}$ did not accurately reflect the liver function in these patients. Blood tests showed raised AST levels (above 40 units/l) in five patients, and increased levels of ALT (above 40 units/l), alkaline phosphatase (above 130 units/l) and γ-glutamyltransferase (above 50 units/l) in four patients each. The mean preoperative volume of the caudate lobe was 723(65) ml, mean TLV was 1138(82) ml, and mean caudate lobe volume was 64·4 per cent of TLV (*Table 1*).

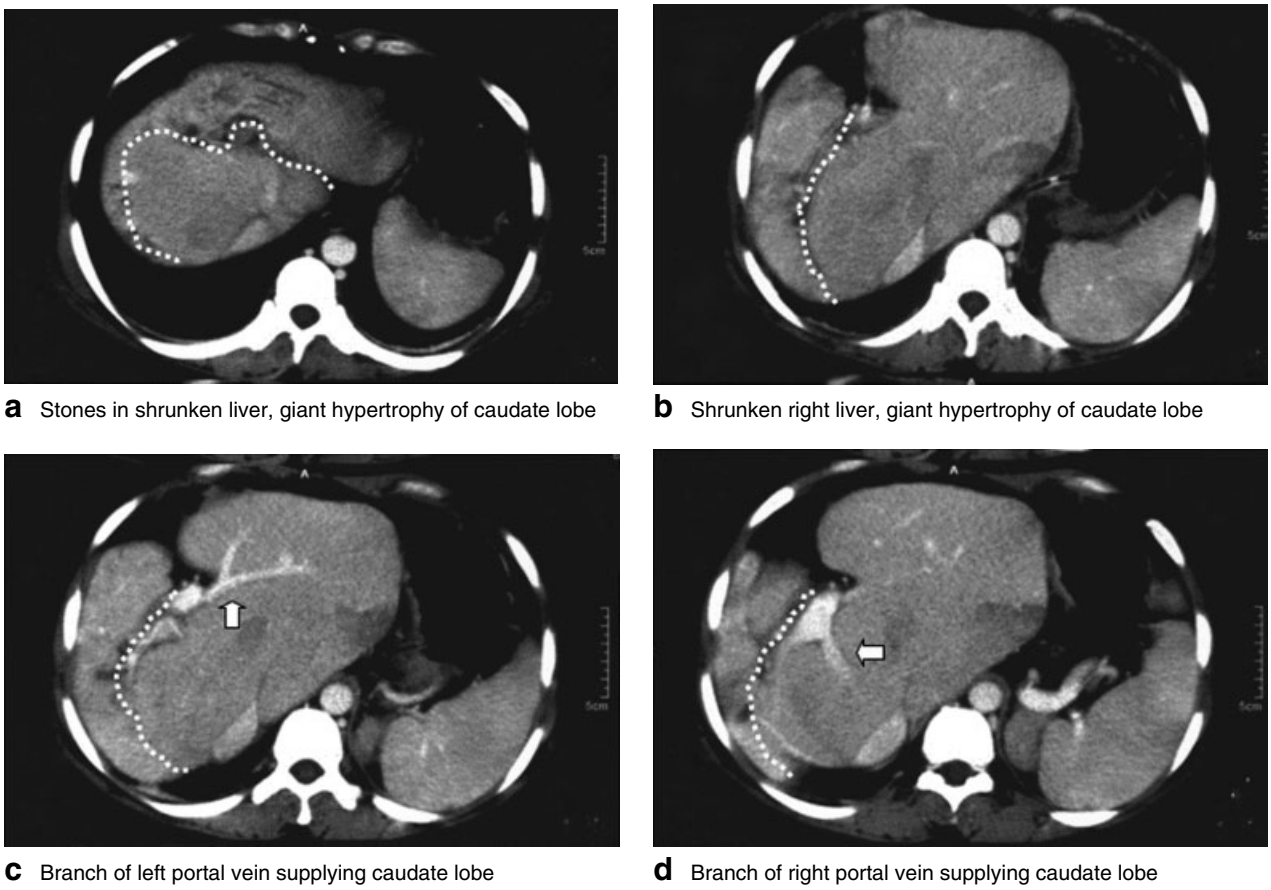


Fig. 2 Computed tomography (CT) before caudate lobe-sparing subtotal hepatectomy. **a** Shrunken right and left livers containing stones, and giant hypertrophy of the caudate lobe; **b** lower CT slice showing shrunken right liver and giant hypertrophy of the caudate lobe; **c** branch of left portal vein supplying the caudate lobe (arrow); **d** branch of right portal vein supplying the caudate lobe (arrow). The dotted white line indicates separation of right/left liver from the caudate lobe

Operative findings

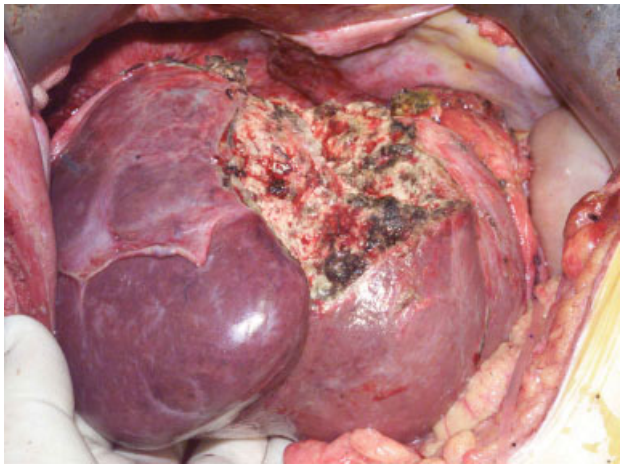
In all patients, the atrophic right and left livers sat on the anterosuperior aspect of the hypertrophied caudate lobe, like a hat. The giant hypertrophy of the caudate lobe pushed and stretched the hepatoduodenal ligament anteriorly. As the hypertrophy was limited by the hepatoduodenal ligament but not by the tissues on each side of the ligament, the hypertrophied caudate lobe was shaped like a dumbbell. The caudate lobe was attached to the atrophied right and left livers (*Fig. 3*).

The portal triads supplying the caudate lobe were identified easily because of the size of the vessels supplying the giant caudate lobe. Choledochoscopy helped to identify the internal openings of the bile ducts draining the caudate lobe, and thereby the portal triads. The bile duct to the Spigelian lobe drained into the confluence of the right/left hepatic ducts in one patient, but into the left hepatic duct in the other 11 patients. The bile ducts to the paracaval portion and caudate process of the caudate lobe drained into the right hepatic duct in all 12 patients. The mean size of the bile ducts supplying the caudate lobe

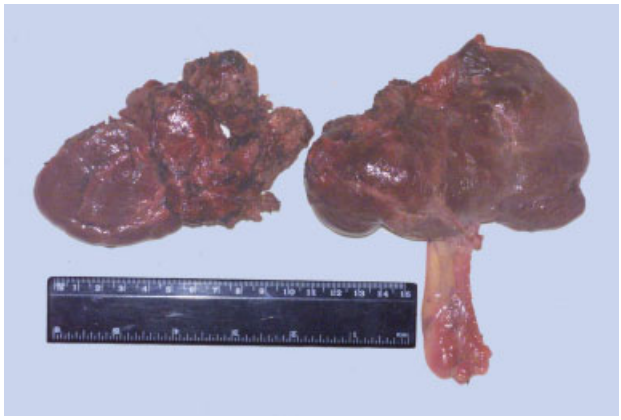
Table 1 Demographic data

	No. of patients*
Age (years)†	50(7)
Sex ratio (M : F)	2 : 10
TLV (ml)†	1138(82) (1034–1327)
Caudate lobe volume (ml)†	723(65) (652–902)
Caudate lobe volume/TLV (%)†	64·4 (55–73)
Previous CBD exploration (± cholecystectomy)	8
Obstructive jaundice	3
Child–Pugh grade A	9‡
$ICGR_{15}$ < 10%	10§

*Unless indicated otherwise; †values are mean(s.d.) (range). ‡Except three patients with obstructive jaundice; §except two patients with obstructive jaundice. TLV, total liver volume; CBD, common bile duct; $ICGR_{15}$, indocyanine green retention rate at 15 min.



a Raw surface of hypertrophied caudate lobe



b Resected right and left livers

Fig. 3 Operative photographs taken after caudate lobe-sparing subtotal hepatectomy: **a** raw surface of hypertrophied caudate lobe; **b** resected right and left livers

was 3·2(0·6) mm. The mean distance of the caudate lobe ductal opening to the confluence of the right/left ducts was 0·7(0·5) cm on the left side and 0·6(0·4) cm on the right.

A stricture of the caudate lobe bile duct was diagnosed in two patients. In one patient, strictureplasty followed by a Roux-en-Y hepaticojejunostomy was performed; in the other patient a strictureplasty was carried out. Stones were detected in the caudate lobe in two patients, and were removed with the help of choledochoscopy. In a further two patients, stones were found in the extrahepatic biliary system; these stones were removed by choledochoscopy and a Dormia basket.

Mean intraoperative blood loss was 1341 (range 300–7300) ml and mean duration of surgery was 513 (range 450–855) min. Mean postoperative hospital stay was 19 (range 10–48) days. There were no perioperative

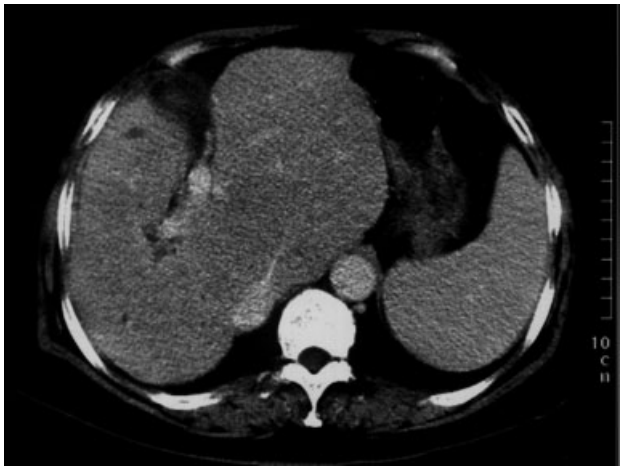


Fig. 4 Computed tomogram taken 2 months after caudate lobe-sparing subtotal hepatectomy showing further hypertrophy of the caudate lobe with no evidence of residual stones or dilated ducts

deaths and no patient developed liver insufficiency in the perioperative period. After surgery there were six complications in three patients: wound infection (2), pneumonia (2), bile leak resolving with conservative treatment (1) and right pleural effusion requiring drainage (1). Postoperative T tube cholangiography on around day 10 after operation showed no residual stones in any patient.

Routine CT volumetry at 2 months after operation showed further hypertrophy of the caudate lobe (*Fig. 4*). The caudate lobe had hypertrophied to almost the estimated TLV before operation (mean 96·4 (range 85·5–108·0) per cent of estimated TLV). The mean volume of caudate lobe at 2 months was 369·5 (range 296–482) ml, which was almost the estimated volume of liver resected (406·5 (296–515) ml).

At a mean follow-up of 51 (range 29–68) months, one patient had developed recurrent stones in the caudate lobe bile ducts (at 8 months) and died 17 months after surgery as a result of acute purulent cholangitis. There was no clinical or radiological evidence of stone recurrence in the remaining 11 patients. These patients were symptom-free with no further attacks of acute cholangitis.

Discussion

Hepatolithiasis is still common in many Asian countries. It may affect part or all of the liver and can induce secondary damage, ultimately leading to irreversible atrophy of part of the liver. Bacterial infection and certain parasites such as *Clonorchis sinensis* and *Ascaris lumbricoides* may induce or perpetuate the disease. For some reasons, the caudate lobe is not frequently affected.

The caudate lobe is anatomically and embryologically independent of the rest of the liver. It has a separate biliary system, arterial and portal venous inflow, and hepatic venous outflow. It consists of the Spigelian lobe, the paracaval portion and the caudate process. Each of these three parts of the caudate lobe has its own biliary and blood supply[9–11]. It is, therefore, not surprising that primary hepatolithiasis can affect the main liver (Couinaud segments II–VIII) without affecting the caudate lobe.

When part of the liver is damaged, the unaffected parts undergo compensatory hypertrophy via regeneration, attempting to maintain a normal liver volume and function[5]. Hypertrophy of the caudate lobe has been reported in a number of conditions, including cirrhosis[12], Budd–Chiari syndrome[13] and primary sclerosing cholangitis[14]. The amount of caudate lobe hypertrophy depends on the degree of damage of the rest of the liver and on whether the caudate lobe is affected by disease.

In a normal liver, the caudate lobe accounts for about 2–3 per cent of TLV[15]. This report has described the novel operation of caudate lobe-sparing subtotal hepatectomy in a highly selected group of patients with primary hepatolithiasis. All patients had repeated and frequent attacks of life-threatening acute cholangitis and bilateral primary hepatolithiasis, which had destroyed and shrunk the right and left livers. The caudate lobe had hypertrophied to become the major functioning part of the liver. In this small series, it proved to be possible and safe to remove all segments of the liver except the caudate lobe.

The low postoperative complication rate and absence of liver failure in this series of patients may have been the result of meticulous preoperative preparation, careful patient selection and a relatively small amount of liver resected (the shrunken liver segments II–VIII) compared with the hypertrophied caudate lobe that was left behind (about two-thirds of TLV).

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