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ORIGINAL ARTICLE

Feasibility of the Glissonian approach during right hepatectomy

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Abstract

Objective: The Glissonian approach during hepatectomy is a selective vascular clamping procedure associated with low rates of technical failure and complications. The aim of the present study was to assess the feasibility of a right Glissonian approach in relation to portal vein anatomy.

Methods: This was a prospective study conducted over a 12-month period, which included 32 patients for whom preoperative three-dimensional reconstruction using contrast-enhanced computed tomography in the portal venous phase and portography for right portal vein embolization were available, and in whom a right Glissonian approach was applied during right hepatectomy. Preoperative imaging data were correlated with intraoperative Doppler ultrasound findings (considered as the reference dataset). Causes of failures and complications specifically related to the Glissonian approach were identified.

Results: Right hepatectomy was performed for colorectal liver metastases (n = 25), hepatocellular carcinoma on cirrhosis (n = 6) and intrahepatic cholangiocarcinoma (n = 1). The Glissonian approach was effective in 24 (75%) patients. In the remaining eight (25%) patients, failure was caused by incomplete clamping (n = 2) or clamping of the left portal pedicle (n = 6). The portal anatomy was aberrant in six patients with failure, showing portal trifurcation (n = 1), right portal trifurcation (n = 1) and a common trunk between the right anterior and left portal branch (n = 4). An angle of less than 50 ° between the portal vein and left portal branch was reported in association with extended clamping to the left portal branch (selectivity = 72%, specificity = 71%). Intraoperative bleeding and biliary fistula occurred in two patients with non-normal portal anatomy.

Conclusions: The right Glissonian approach was effective in 75% of patients. Failure of the procedure (including the extension of clamping to the left pedicle) mostly occurred in patients with portal vein variations, which can be accurately assessed using a combination of preoperative imaging and intraoperative Doppler ultrasound.

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Introduction

Intraoperative bleeding is a major concern during liver resection; postoperative mortality and morbidity are correlated with the amount of blood loss,[1,2] which can be reduced by vascular clamping.[3] Although liver parenchyma is more tolerant of intermittent pedicle clamping than it is of continuous pedicle clamping,[4] selective clamping techniques have been developed in order to avoid ischaemic injury of the liver remnant. Three different techniques allow the control of Glisson's pedicles (Fig. 1): (i) the extrahepatic approach, first described by Lortat-Jacob *et al.* in 1952;[5] (ii) the transhepatic approach, described by Ton-That-Tung and Nguyen-Duong-Quang in 1965,[6] and (iii) the Glissonian approach.[2] In the extrahepatic approach, misidentification and ligation of the wrong vessels can occur and may devascularize an area of liver that is not scheduled for resection, and variable biliary anatomy may increase the risk for surgical injury of the contralateral biliary

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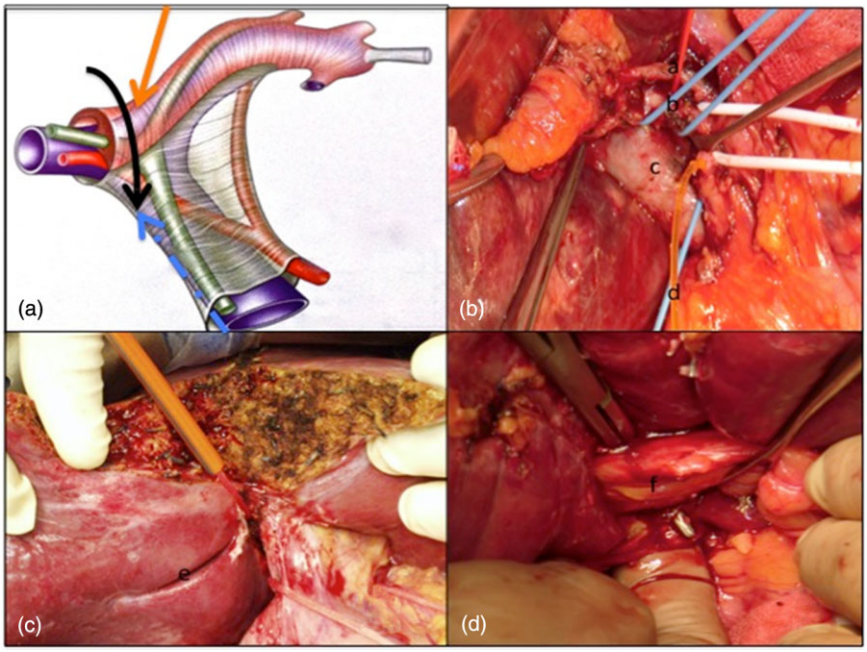

Figure 1 Selective pedicle clamping (extrahepatic, transhepatic and Glissonian). (a) Selective pedicle clamping. (b) Extrahepatic clamping. (c) Transhepatic clamping. (d) The Glissonian approach. a, hepatic artery; b, biliary duct; c, portal vein; d, transcystic drain; e, Rouviere's sulcus; f, right portal branch

duct. The Glissonian approach, which uses the Glissonian sheaths, was established by Takasaki *et al.*[7] and Launois *et al.*[8] and subsequently popularized by Machado *et al.*[9] The technique has been evaluated by Figueras *et al.* and Giordano *et al.*[2,10,11] Incisions of the liver capsule around the hepatic pedicle enable limited intrahepatic dissection. Dissection along the sheaths around the portal triads provides access to the main trunk sheaths supplying an entire hemiliver and then to sectorial divisions and segmental divisions. This method uses the extrahepatic landmarks described by Machado *et al.*[12] to facilitate selective clamping around the right or left Glissonian pedicle in the suprahilar area. The extrahepatic landmarks in a normal portal anatomy are well known, but may be modified by variations in the portal anatomy; in such contexts, clamping may increase bleeding and biliary injury.[13] To date, prospective studies have emphasized the feasibility and safety of the Glissonian approach. In a study of 89 patients, Giordano *et al.* reported successful clamping in 69% of patients undergoing major hepatectomy and 26% of patients undergoing minor hepatectomy, with no intraoperative complications.[11] However, the authors did not provide information on the reasons for technical failure or on specific complications (i.e. biliary fistula, haemorrhage).

To the best of the present authors' knowledge, the right Glissonian approach has not yet been examined in a context of standard right hepatectomy with variations in the right portal anatomy. This study was conducted to assess the feasibility of the Glissonian approach and identify risk factors for the failure of this approach by focusing on portal vein anatomy.

Materials and methods

Patient selection

From 2002 to 2011, 310 hepatectomies were performed at Amiens University Medical Centre for benign or malignant tumours; these included 192 (62%) major resections (of more than three hepatic segments). A total of 130 right hepatectomies were performed, including 70 (23%) after portal embolization. From January 2010 to December 2011, a total of 48 right hepatectomies were performed. Among them, portal vein embolization (PVE) was undertaken in 32 patients, including six patients with hepatocellular carcinoma (HCC) on a background of liver cirrhosis, one patient with right-sided intrahepatic cholangiocarcinoma and 25 patients with colorectal liver metastases (CLM). Among patients with CLM, 18 had bilateral lesions requiring two-step hepatectomy and seven had been given more than six cycles of chemotherapy. Patients with previous cholecystectomy or hepatectomy, patients not requiring PVE and patients for whom imaging data were not available were excluded. The Glissonian approach was contraindicated in patients in whom the tumour was too close to pedicular structures to allow safe dissection (e.g. patients with hilar cholangiocarcinoma).

Portal anatomy

Normal portal anatomy was defined as division of the portal vein into right and left branches immediately before reaching the liver, with further division of the right portal branch into anterior and

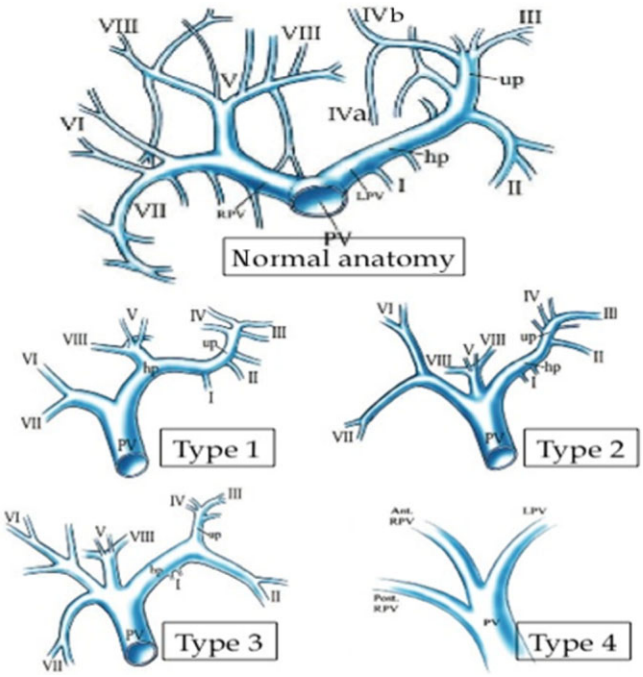

Figure 2 Portal anatomy (according to the classification of Madoff *et al*.[15]), showing normal anatomy of the portal vein (PV), type 1 anatomy (a common trunk between the anterior right portal branch and the left branch), type 2 anatomy (portal trifurcation) and type 3 anatomy (quadrifurcation)

posterior sectorial branches.[14] Three anatomic variations of the right portal vein were identified according to the classification described by Madoff *et al*.[15] These include: (i) a common trunk between the anterior right portal branch and the left portal branch (type 1); (ii) a portal trifurcation in which the left portal branch and both right sectorial portal branches share the same origin (type 2), and (iii) a right portal trifurcation in which the segment VI branch, the segment VII branch and the anterior sectorial branch share a common origin (type 3). These anatomic variations of the right portal vein are illustrated in detail in Fig. 2. The angle between the left portal branch and the main portal vein was also recorded in order to evaluate the risk for accidental clamping of left pedicles. This angle was routinely evaluated in a three-dimensional reconstruction of enhanced computed tomography (CT) scans using three radiologic landmarks in the middle part of the portal vein, the portal bifurcation and the left portal vein, respectively.

Study protocol

Preoperative evaluation of portal anatomy

Before surgery, a portal-phase, contrast-enhanced CT scan and portography after portal embolization were performed. Portal anatomy was systematically analysed by two experienced radiologists. A dual-phase, abdominal CT scan was performed with a 16-row multidetector system (LightSpeed 16; GE Medical Systems, Milwaukee, WI, USA). Images were acquired in the absence and then presence of contrast, starting 80 s after the i.v. bolus injection of contrast material (2 ml/kg, 3 ml/s). The CT parameters were as follows: slice thickness, 1.25 mm; collimation, 1.25 × 16; pitch, 1; tube voltage, 100–120 kVp, and tube current, 240 mAs. Multiplanar reformation with 3-D reconstruction and ray casting models was used to enable a more detailed analysis of the right portal branch anatomy.

Portal vein embolization was performed using the contralateral transhepatic approach. A collateral vein of the left branch of the portal vein was punctured under local anaesthesia and sedation and ultrasound (US) guidance. Following control venous portography, the right anterior and posterior portal branches were embolized with a mixture of cyanoacrylate and lipiodol as distally as possible. Surgery was performed 4–8 weeks after embolization.

Surgical procedures

As described previously,[9,13] a right subcostal incision was made and the liver was mobilized. During hepatectomy, the portal anatomy was analysed using Doppler US (Ultrasound Scanner Class I type B; B-K Medical ApS, Peabody, MA, USA) before and after taking the right Glissonian approach. After cholecystectomy, the cystic duct is usually ligated and divided prior to isolation of the right hepatic pedicle. Then, control of the right pedicle was facilitated through two 3-mm parenchymal incisions: the anterior incision was made in the middle part of the hilar plate (between the round ligament and gallbladder) and the posterior incision was made on the right-hand side of segment I (at a distance from segment VI to avoid a constant segment VI portal branch) (Fig. 3). A large, curved Mixter clamp was inserted through the two incisions. The right pedicle was encircled with rubber tape and checked with Doppler US (Fig. 4).

A TA-30 vascular stapler was used to clamp the right pedicle. The procedure was facilitated by firm countertraction of the rubber tape. After clamping, Doppler US was used to ascertain the complete lack of flow in the right liver and the maintenance of left portal flow. Next, a US air test was used to check the patency of the left biliary duct.[16] The liver was transected along the discoloured zone, with selective hepatic inflow occlusion of the right pedicle. Haemostasis was achieved using monopolar irrigated electrocautery. Major vascular structures were ligated or secured with interrupted sutures. Biliostasis was achieved with the aid of dye injection in the biliary tree through the cystic duct catheter. The amount of blood lost was estimated according to the volume of blood collected in the container of the aspirator and the ultrasonic dissector.[10]

Study criteria and study design

Successful clamping was defined as discoloration of the right liver, with no flow in the proximal part of the right portal branch on Doppler US and the persistence of flow into the left portal branch. Failure was defined as incomplete right clamping or clamping extending to the left portal branch. Perioperative complications

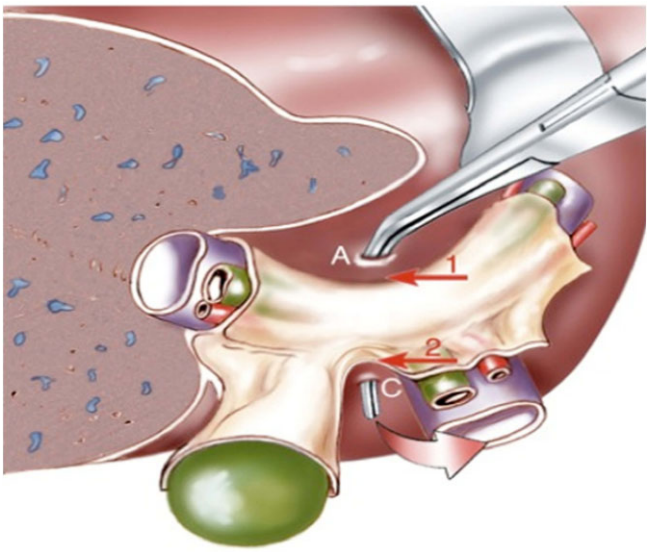

Figure 3 Anterior right landmarks for the right Glissonian approach. A, anterior incision in the middle part of the hilar plate; C, posterior incision in the right side of segment I; 1, first incision; 2, second incision. (This figure has been published in Regimbeau JM, Mauvais F; L'abord glissonien pour les résections hépatiques.[13]. All rights reserved)

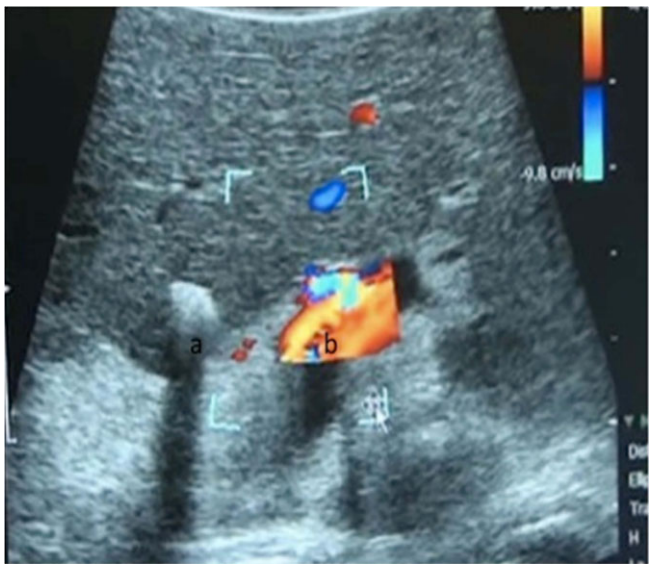

Figure 4 Doppler ultrasound monitoring of left portal flow after right portal vein control clamping. a, rubber tape on the right portal vein; b, left portal flow

specifically related to the use of the Glissonian approach were defined as haemorrhage and biliary injury. The International Study Group of Liver Surgery definition of biliary leakage[17] was applied. Postoperative complications included persistent biliary fistula and biliary duct stenosis. This study first assessed the feasibility of using the right Glissonian approach during right hepatectomy after portal embolization. A retrospective analysis of the relationship between the outcome of the right Glissonian approach and portal anatomy was then performed.

Statistical analysis

Patients were stratified into two groups consisting of those in whom the Glissonian approach had been successful (the Success group) and those in whom it had failed (the Failure group). The chi-squared test was used to analyse the distribution of nominal variables (such as underlying liver disease, nature of the tumour). The Wilcoxon rank sum test was used to analyse ordered categorical variables (such as tumour size). *P*-values of <0.05 were considered to indicate statistically significant effects. All statistical analyses were performed using SPSS Version 18.0 (SPSS, Inc., Chicago, IL, USA).

Results

Demographics, portal anatomy and surgical procedures

The study population included 18 men and 14 women. The patients' median age was 71 years (range: 54–83 years). Right hepatectomy was performed for CLM in 25 patients, HCC in six patients and intrahepatic cholangiocarcinoma in one patient. The median tumour size was 6 cm (range: 2–12 cm). The underlying liver parenchyma included post-chemotherapy steatosis in seven patients, cirrhosis in five patients and cholestasis in one patient. On preoperative imaging, 25 (78%) patients had normal portal anatomy, five (16%) patients had type 1 portal anatomy, one (3%) patient had type 2 and one (3%) patient had type 3 anatomy (Table 1 and Fig. 5). The median operative time was 290 min (range: 180–520 min). The median blood loss was 350 ml and four patients required intraoperative transfusions. The median length of stay was 7.3 days (range: 4.6–15.7 days).

Feasibility of the Glissonian approach

The Glissonian approach was successful in 24 (75%) patients. There was no difference in outcome as a function of the underlying liver disease ($P = 0.96$), the nature of the tumour ($P = 0.47$) or tumour size ($P = 0.38$). The scheduled clamping failed in eight patients: in two (6%) patients, clamping was incomplete and in six (19%) patients clamping extended to the left portal pedicle.

Failure of the Glissonian approach

Six of the eight patients in the Failure group had aberrant portal anatomy; these included four patients with type 1, one patient with type 2 and one with type 3 portal anatomy (Table 1). Extended left portal clamping (extended clamping to the left portal branch) was observed in four patients with type 1 portal anatomy. In patients with types 2 and 3 portal anatomy, clamping was incomplete, with the right posterior branch outside the clamping area.

The median angle between the left portal branch and the main portal vein was 56.5 °. In the six patients in whom clamping was

Table 1 Anatomic variations and the Glissonian approach

	Normal anatomy *n* (%)	Type 1 *n* (%)	Type 2 *n* (%)	Type 3 *n* (%)
Right Glissonian approach	25 (78%)	5 (16%)	1 (3%)	1 (3%)
Clamping failure	2 (8%)	4 (80%)	1 (100%)	1 (100%)

Figure 5 Imaging of portal anatomy. (a) Portography of normal portal anatomy. (b) Axial enhanced computed tomography (CT) scan at portal phase of normal portal anatomy. (c) Ultrasound (US) of normal portal anatomy. (d) Portography of type 1 portal anatomy. (e) Axial enhanced CT scan at portal phase of type 1 portal anatomy. (f) Axial 3-D reconstruction of type 1 portal anatomy. (g) Axial enhanced CT scan of type 2 portal anatomy. (h) Axial 3-D reconstruction of type 2 portal anatomy. (i) Portography, axial 3-D reconstruction of type 3 portal anatomy. (j) Axial 3-D reconstruction of type 3 portal anatomy

extended to the left portal branch, the median angle between the left portal branch and the main portal vein was always <50° (range: 35–47°).

Complications in the Glissonian approach

Complications associated with the Glissonian approach are detailed in Table 2. In terms of perioperative complications, bleeding during the Glissonian approach occurred in one patient with type 2 portal anatomy, but transfusion was not required. Intraoperative biliary fistula was observed and sutured in two patients, one (3%) of whom had type 1 portal anatomy and demonstrated a persistent biliary fistula, which was resolved by simple medical treatment. No biliary strictures were observed during the postoperative period.

Discussion

In the present series, overall operative time, intraoperative transfusion requirements, morbidity, mortality and length of stay were

Table 2 Anatomic variations and clamping failures and complications in patients in whom the Glissonian approach failed (n = 6)

	Anatomic variation	Clamping failure	Bleeding	Biliary fistula	Persistent biliary fistula
Patient 1	Type 1	Over-extensive left clamping	–	–	–
Patient 2	Type 1	Over-extensive left clamping	–	+	+
Patient 3	Type 1	Over-extensive left clamping	–	–	–
Patient 4	Type 1	Over-extensive left clamping	–	–	–
Patient 5	Type 2	Incomplete right clamping	–	–	–
Patient 6	Type 2	Incomplete right clamping	+	–	–

all similar to the rates given in the literature.[18] In the present study, portal vein variations were identified as a risk factor for failure. Nevertheless, the Glissonian approach was effective in 75% of patients. In the remaining 25% of patients, the scheduled clamping failed as a result of the incomplete clamping of the right branch or extended clamping of the left portal branch. Of the eight patients in whom the Glissonian approach failed, six (75%) had aberrant portal anatomy (four type 1, one type 2 and one type 3). Specific complications associated with the Glissonian approach included bleeding (3%), intraoperative biliary fistula (6%) and persistent biliary fistula (3%).

Although the three series described by Machado *et al.*[9,12,19] and the retrospective series described by Nakai *et al.*[20] showed a feasibility rate of 100%, the prospective series by Giordano *et al.* reported success in only 69% of patients undergoing major resection.[11] However, Giordano *et al.*[11] did not provide any information on the causes of failure. Findings in the present study confirmed that the Glissonian approach fails in nearly 30% of patients undergoing standardized right hepatectomy.

To the best of the present group's knowledge, this is the first series to have specifically assessed risk factors for the failure of the Glissonian approach. The present study found that most patients in whom clamping failed demonstrated aberrant portal anatomy (portal trifurcation, right portal trifurcation, a common trunk between the right anterior and left portal veins). Interestingly, outcomes of the Glissonian approach in relation to portal vein anatomy have not been previously reported in the literature. The present authors observed extended clamping to the left portal branch in six of 32 (19%) patients, four of whom had type 1 portal anatomy. The prospective study published by Figueras *et al.* reported extended right Glissonian pedicle clamping to the left portal branch in 20% of patients.[2] The authors attributed this failure to an unusually short, wide right portal pedicle. Fong and Blumgart[21] observed extended clamping to the left portal branch after vascular stapling and recommended countertraction before stapling. Interestingly, the present authors found that an angle between the portal vein and the left portal branch of <50° was associated with extended clamping to the left portal branch (sensitivity = 72%, specificity = 71%) in the two patients with normal portal anatomy. The countertraction suggested by Fong and Blumgart appears to decrease the risk for extended clamping to the left portal branch.[21] The present authors wish to highlight the fact that extended clamping to the left portal branch is a major issue during right hepatectomy. Because injury of the vascular supply to the future liver remnant is of greater consequence than incomplete right clamping, the role of systematic intraoperative Doppler US of the remnant liver after clamping should be emphasized. Although incomplete clamping has not been previously reported in the literature, the present study identified this problem in 6% of hepatectomies and found an aberrant portal anatomy in each case. Accordingly, this group now considers the Glissonian approach only in patients with normal portal vein anatomy.

Despite the high accuracy of preoperative CT and portography in the detection of portal vein anatomic variation, portal anatomy should be assessed by Doppler US before and after the Glissonian approach to avoid extended or incomplete clamping. During the procedure, a grasp placed on the right pedicle close to the biliary convergence helps to identify portal anatomy on US.

Biliary fistula occurred in two (6%) patients and included one case of persistent biliary fistula (3%) in a patient with aberrant (type 1) portal anatomy. In this patient, Glissonian pedicle clamping failed with extended clamping to the left portal branch. The prospective study by Figueras *et al.*[10] reported a biliary fistula in 10% of Glissonian pedicle clamping procedures. However, Figueras *et al.*[10] did not distinguish between right and left hepatectomies and gave no information on portal anatomy. Nakai *et al.* reported a biliary fistula rate of 14% during Glissonian pedicle clamping in right hepatectomy. Biliary fistula was more frequent in patients undergoing left lobectomy (46%) (P = 0.023). Nakai *et al.* speculated that biliary fistula might result from the presence of bile ducts in the caudate lobe and their frequent drainage into the left bile duct.[10] Indeed, an infraportal biliary branch to the caudate lobe may explain the occurrence of biliary fistula during right hepatectomy, especially in cases of portal anatomic variation.[22] The reported incidence of bile leakage after liver resection without biliary reconstruction ranges from 3.6% to 12%.[23–25] Inter-study disparities in the biliary fistula rate probably reflect the use of different definitions. The present authors used the ISGLS definition of biliary leakage.[17] As the present group does not routinely perform intraoperative cholangiography, it was difficult to distinguish biliary fistulas that were related to Glissonian pedicle clamping from those related to the use of staplers. Indeed, the present authors suggest that intraoperative cholangiography should be performed to assess biliary anatomy before and after the procedure.

In previous studies, intraoperative bleeding during a selective Glissonian approach was not reported as a technical complication or as a reason for clamping failure.[2,9–12] However, in the present series, intraoperative bleeding occurred in one (3%) patient with portal trifurcation and required pedicle clamping. In a retrospective study, a hilar dissection approach was associated with a greater risk for intraoperative blood loss ($P < 0.01$).[26]

Although branches to the right side of the liver had been occluded in the course of the preceding PVE, most patients in the present series demonstrated a flow into the proximal right portal branch before clamping. In the present study centre, PVE is routinely performed as distally as possible in the right anterior and posterior portal branches in order to avoid the migration of coils in the portal or contralateral veins. Thus, although the portal flow was absent distally, the Glissonian approach failed because of aberrant portal venous anatomy after PVE.

The techniques used to achieve the clamping of Glisson's pedicles differ among series; some authors have used hepatotomy and digital manoeuvres[11,27,28] and others have used separate ligation of the right and posterior sectors.[20] These differences may explain the lower rates of failure and complications found when the Glissonian approach is used during hepatectomy. In the present study, landmarks described by Machado *et al.*[12] were used, with en bloc ligation of the right Glisson's pedicle.

Hilar cholangiocarcinoma represented the main contraindication to the Glissonian approach because incisions near the Glissonian sheaths may violate the required safety margin. Adhering to the rules of the 'no-touch technique', the present authors did not consider this approach in patients in whom the tumour lay near to the portal bifurcation, as prescribed by Figueras *et al.*[10]

A major limitation of the present study concerns the small number of patients. Indeed, it is difficult to draw firm conclusions on significant outcomes of the Glissonian approach. However, this prospective study is the first to investigate the failure of clamping in relation to variations in portal anatomy. A prospective study with a larger patient sample is required to confirm the present conclusions.

Conclusions

In conclusion, the right Glissonian approach was effective in 75% of patients in the present series. The failure of the procedure, including the extension of clamping to the left pedicle, mostly reflected variations in portal vein anatomy. However, portal anatomy can be accurately assessed using preoperative CT and portography and intraoperative Doppler US.

Conflicts of interest

None declared.

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