Original Article

The application of real-time indocyanine green fluorescence cholangiography in laparoscopic living donor left lateral sectionectomy

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Background: The judgment of the division point of the bile duct has always been one of the difficulties of laparoscopic left lateral sectionectomy (LLLS). The purpose of this study was to assess the effects of indocyanine green (ICG) fluorescence cholangiography during LLLS on the occurrence of biliary complications in both donors and recipients. The optimal dose and injection time of ICG were also investigated.

Methods: This is a retrospective cohort study. From October 2016 to December 2022, the clinical data of 103 donors who underwent LLLS and relevant recipients were retrospectively analyzed. According to whether ICG fluorescence cholangiography was used, they were divided into a non-ICG group (n=46) and an ICG group (n=57). Biliary complications were observed and the optimal dose and injection time of ICG were explored.

Results: Three donors in the non-ICG group suffered from bile leakage. Four grafts had multiple bile duct openings and biliary complications were observed in the relevant recipients who received these grafts in the non-ICG group. Two recipients had bile leakage, and the other two had biliary stenosis. There was no biliary complications both in donors and recipients in the ICG group. The fluorescence intensity of the liver was 108.1±17.6 at a dose of 0.004 mg/kg 90 minutes after injection, significantly weaker than that at 0.05 mg/kg 30 minutes (200.3±17.6, P=0.001) and 90 minutes after injection (140.2±15.4, P=0.001). The fluorescence intensity contrast value at a dose of 0.004 mg/kg was stronger than that at 0.05 mg/kg, both measured 90 minutes after injection (0.098±0.032 *vs.* 0.078±0.022, P=0.021).

Conclusions: ICG fluorescence cholangiography is safe and feasible in LLLS. It reduces biliary complications in both donors and recipients. The optimal ICG dose was 0.004 mg/kg, and 90 minutes after injection was the best observation time. ICG fluorescence cholangiography is recommended for routine use in LLLS.

Keywords: Laparoscopic living donor hepatectomy (LLDH); living donor liver transplantation (LDLT); real-time indocyanine green fluorescence cholangiography (real-time ICG fluorescence cholangiography)

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Introduction

Living donor liver transplantation (LDLT) has been widely conducted, especially in adult-to-child LDLT (1). LDLT technology has been very mature, and it has become the first choice for pediatric liver transplantation. With the development of laparoscopic technology, laparoscopic hepatectomy has been widely used in the field of liver surgery (2). Laparoscopic living donor hepatectomy (LLDH), especially laparoscopic left lateral sectionectomy (LLLS), is routinely conducted in large transplantation centers (3,4).

In addition to controlling bleeding and protecting the integrity of the graft vessel, the judgment of the division point of the bile duct has always been one of the difficulties of LLDH (5,6). If the division point is too close to the bifurcation point of the left and right hepatic ducts of the donor, it may lead to bile duct stenosis of the donor. When the division point is too close to the graft side, it may cut off in the secondary bile duct, resulting in two or more bile duct openings, which increases the difficulty of subsequent biliary intestinal anastomosis. In addition to routine magnetic resonance cholangiopancreatography (MRCP) before the operation to understand whether there is biliary tract variation, conventional X-ray cholangiography was implemented by cannulating the cystic duct or puncturing the biliary tract in open donor hepatectomy to visualize the bile duct division point in the past. However, the gallbladder is not routinely removed during the LLLS, and it is difficult to puncture the biliary tract under laparoscopy, which makes it inconvenient to perform cholangiography during laparoscopy.

Real-time indocyanine green (ICG) fluorescence imaging can be used for cholangiography (7). It was first used in laparoscopic cholecystectomy and can well visualize the shape of the bile duct (8-10). At present, ICG fluorescence cholangiography is also used in LDLT, but its dosage and injection time need to be explored (11,12). In this study, the primary aim was to analyze whether ICG fluorescence cholangiography would affect the occurrence of biliary complications in both donors and recipients in LDLT. The secondary aim was to explore the optimal dose and injection time point of ICG. We present this article in accordance with the STROBE reporting checklist (available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-23-288/rc).

Highlight box

Key findings

- Indocyanine green (ICG) fluorescence cholangiography can prevent the biliary complications in both donors underwent laparoscopic left lateral sectionectomy (LLLS) and its relevant recipients.

What is known and what is new?

- ICG fluorescence cholangiography contributed to visualize the bile ducts during operation.
- ICG fluorescence cholangiography may replace conventional X-ray cholangiography in LLLS. The optimal ICG dose was 0.004 mg/kg and 90 minutes after ICG injection was the best observation time.

What is the implication, and what should change now?

- Our research may provide more evidence for guidelines or consensus about ICG fluorescence imaging. ICG fluorescence cholangiography is recommended for routine use in LLLS.

Methods

Patient population and study design

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Before data collection, the study was approved by the Institutional Review Board of Huashan Hospital affiliated to Fudan University (IRB Reference Number: KY2022-562) and registered on the clinicaltrials.gov (NCT05506020). Individual consent for this retrospective analysis was waived.

This is a retrospective cohort study. From October 2016 to December 2022, the clinical data of 103 donors and relevant recipients who underwent LLLS for LDLT in the Department of General Surgery of Huashan Hospital, Fudan University, were retrospectively analyzed. ICG fluorescence cholangiography was used for all donors after we had had the endoscopic fluorescence imaging system since November 2019. All donors were divided into two groups according to whether ICG fluorescence cholangiography was used during the operation: with ICG fluorescence cholangiography (ICG group, cases after November 2019) and without ICG

fluorescence cholangiography (non-ICG group, cases before November 2019). The preoperative data and postoperative complications of the donors who underwent LLLS, as well as the data of the recipients, were prospectively collected. All donors and recipients were followed for more than 4 months.

Preoperative donor assessments and operating procedures

The preoperative evaluation of donors included blood routine test, liver and kidney function, electrolyte, coagulation function, hepatitis markers, and blood typing test. All donors needed to undergo color Doppler ultrasonography to evaluate the degree of fatty liver, enhanced computed tomography (CT) three-dimensional reconstruction to evaluate vascular variation and MRCP to evaluate bile duct variation. If there was a serious biliary variant, the graft obtain operation would be transfer to open or even be given up. All the donors were directly related to the recipients and donated voluntarily. All donors and recipients who underwent surgery passed an ethical review among their relatives and signed an informed consent form for surgery.

All donors underwent LLLS by one surgical group who has a specific operating procedure. The detailed procedural operation process has been described in our previously published article (13). In the non-ICG group, after carefully dissecting the first hepatic hilum and separating the common hepatic duct and the left hepatic duct, the division point of the bile duct was determined. When the liver parenchyma was transected near the hepatic hilum, the left hepatic bile duct was isolated and severed. In the ICG group, the PINPOINT Endoscopic Fluorescence Imaging system/1588 Advanced Imaging Modalities Platform (Stryker Co., Michigan, USA) was used to perform ICG fluorescence cholangiography. The distance between the camera and the observed object was 10–15 cm. Focus and light intensity were automatically adjusted according to the environment. It could be switched to fluorescence mode at any time when the surgeon want to observe the fluorescence imaging. ALL donors in ICG group denied a history of iodine allergy. 0.05 mg/kg ICG according to the consensus guideline or 0.004 mg/kg ICG based on our experience were injected intravenously while anesthesia began (approximately 90 minutes before cutting the bile duct). The surgical images 30, 60 and 90 minutes after ICG injection were captured in the video, and the average fluorescence intensity of the liver and bile duct was measured using Image J software by three independent evaluators. The evaluators were blinded to the dose and timing of the ICG administration. The fluorescence intensity contrast value = (fluorescence intensity of bile duct – the fluorescence intensity of liver)/255 (14). At the beginning of the ICG injection, the green background of the liver was still obvious. When the bile duct was cut off 90 minutes later, the background of the liver was weakened, and the bile duct was obviously displayed. The common hepatic duct and left and right hepatic ducts can be clearly seen. So, the division point of the left hepatic duct was determined, which was at the beginning of the left hepatic duct, 2–3 mm far from the bifurcation of the left and right hepatic duct.

Postoperative procedures

Routine blood test, liver and kidney function and electrolytes were evaluated conventionally on postoperative Days 1 and 3 or 4. Ultrasound was performed on postoperative Day 3 or 4 to monitor the blood flow of the liver and observe whether there was effusion in the operation area. If there was no bile leakage or collection, the abdominal drain was removed after the ultrasound examination.

Statistical analysis

The severity of complications was based on the Clavien-Dindo scale system. Continuous data were compared using unpaired Student's *t*-test, while categorical data were compared using Fisher's exact test. All statistical analyses were performed using SPSS software, version 20 (SPSS Inc., Chicago, IL, USA). P values of <0.05 were considered statistically significant.

Results

In total, 165 LDLTs were performed in the Department of General Surgery of Huashan Hospital, Fudan University, from October 2016 to December 2022, among which 106 donors underwent LLDH. Two donors underwent pure laparoscopic right hemihepatectomy, one donor underwent laparoscopic left hemihepatectomy, and the other 103 donors underwent LLLS. None of them were converted to open surgery. Depending on whether ICG fluorescence cholangiography was used during operations, 103 donors who underwent LLLS were divided into two groups: the non-ICG group (n=46) and the ICG group (m=57).

The basic characteristics of the donors were described and analyzed (*Table 1*). The mean age of the donors was

Table 1 Demographic characteristics and postoperative outcomes of donors

Demographic characteristics and postoperative outcomes	Non-ICG group (n=46)	ICG group (n=57)	P value
Age (years)	30.5±6.6	31.2±5.0	0.51
Sex (male/female)	13/33	26/31	0.10
BMI (kg/m^2)	21.3±7.3	23.1±6.2	0.18
Blood tests before operation			
TB (μmol/L)	10.5±2.0	11.1±3.2	0.26
ALT (U/L)	18.7±5.0	19.2±9.9	0.73
AST (U/L)	16.3±4.8	17.4±5.1	0.26
A (g/L)	46.5±2.6	46.5±3.2	>0.99
PT (seconds)	11.6±0.4	11.7±0.5	0.21
Operation time (min)	157.5±30.5	138.8±24.6	<0.001
Blood loss (mL)	154.8±89.5	133.9±63.7	0.17
Intraoperative transfusion (mL)	0	0	
Warm ischemia time (min)	4.8±1.1	4.3±0.7	0.008
Graft weight (g)	231.5±42.3	235.4±40.8	0.63
GRWR (%)	2.9±0.9	2.7±0.6	0.16
Multiple bile duct openings	4	0	0.0369
Blood tests after operation			
Peak TB (μmol/L)	26.1±10.7	24.3±9.7	0.37
Peak ALT (U/L)	275.4±166.0	267.4±175.5	0.81
Peak AST (U/L)	209.7±144.4	218.1±135.2	0.76
Trough A (g/L)	39.9±3.4	39.9±3.3	0.98
Peak PT (seconds)	13.1±0.8	13.0±0.7	0.52
VAS score	3.6±1.1	3.4±0.9	0.34
Length of hospital stay (days)	6.1±1.4	5.4±1.2	0.012
Complications			
Grade 1	7	5	0.36
Bile leakage	2	0	0.20
Gastric retention	2	1	0.58
Wound problem	2	3	>0.99
Atelectasis	1	1	>0.99
Grade 2			
Portal vein partial thrombus	1	0	0.45
Grade 3			
Bile leakage	1	0	0.45
Grade 4	0	0	>0.99

Data are presented as n or mean ± standard deviation. ICG, indocyanine green; BMI, body mass index; TB, total bilirubin; ALT, alanine aminotransferase; AST, aspartate aminotransferase; A, albumin; PT, prothrombin time; GRWR, graft volume/recipient body weight ratio; VAS, visual analog scale.

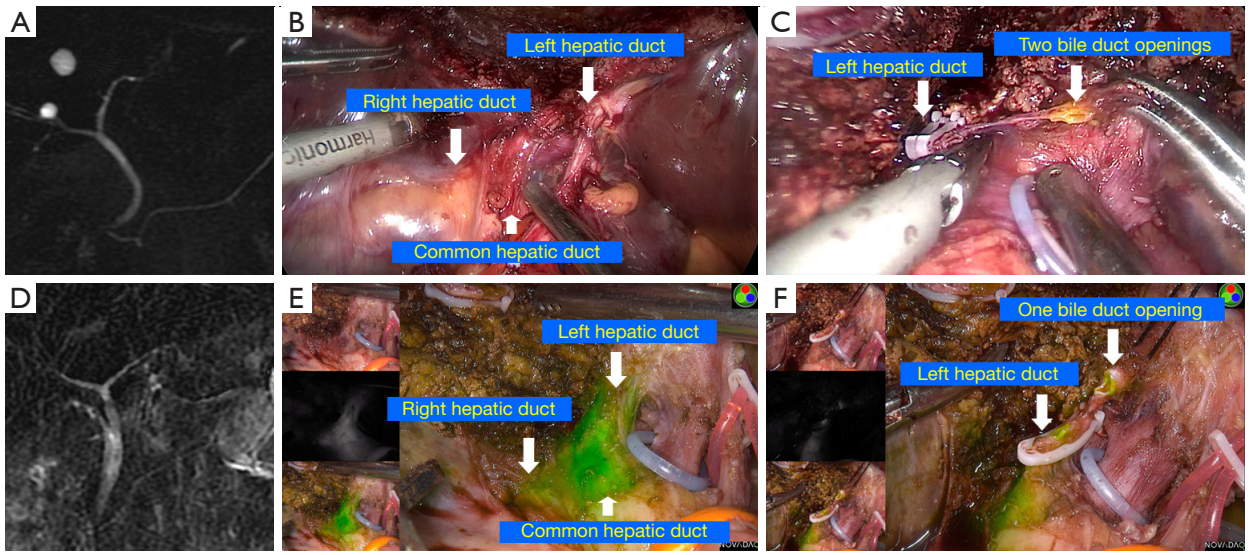

Figure 1 Judgment of the dissection point of the bile duct in non-ICG group and ICG group. (A) MRCP of the donor in non-ICG group. (B) Judgment of the dissection point of the bile duct without ICG fluorescence cholangiography. (C) Two bile duct openings of the graft in the non-ICG group. (D) MRCP of the donor in ICG group. (E) Judgment of the dissection point of the bile duct with ICG fluorescence cholangiography. (F) One bile duct opening of the graft in the ICG group. ICG, indocyanine green; MRCP, magnetic resonance cholangiopancreatography.

30.5±6.6 years in the non-ICG group and 31.2±5.0 years in the ICG group (P=0.51). There were 13 males in the non-ICG group and 26 males in the ICG group (P=0.10). The body mass index (BMI) was 21.3±7.3 kg/m^2 in the non-ICG group and 23.1±6.2 kg/m^2 in the ICG group (P=0.18). There were no significant differences in total bilirubin (TB), alanine aminotransferase (ALT), aspartate aminotransferase (AST), albumin (A) or prothrombin time (PT) before the operation between the non-ICG group and the ICG group. The mean operation duration was 138.8±24.6 minutes in the ICG group, which was shorter than that in the non-ICG group (157.5±30.5 minutes, P<0.001). There was no significant difference in blood loss between the non-ICG and the ICG groups (154.8±89.5 *vs.* 133.9±63.7 mL, P=0.17). None of the donors had blood transfusions in these two groups. The warm ischemia time in the ICG group was shorter than that in the non-ICG group (4.3±0.7 *vs.* 4.8±1.1 minutes, P=0.008). The graft weight and graft volume/recipient body weight ratio (GRWR) in the non-ICG group were 231.5±42.3 g and 2.9%±0.9%, respectively, which were similar to those in the ICG group (235.4±40.8 g and 2.7%±0.6%). Peak TB, peak ALT, peak AST, trough A, and peak PT after operation were similar in the non-ICG group and ICG group. The visual analog scale (VAS) for pain was similar in the non-ICG and ICG groups (3.6±1.1 *vs.* 3.4±0.9, P=0.34). The length of hospital stay in the ICG group was shorter than that in the non-ICG group (5.4±1.2 *vs.* 6.1±1.4 days, P=0.012).

Four grafts (case 12, 31, 39, 44) had multiple bile duct openings in the non-ICG group, as compared to none in the ICG group (P=0.0369). The four in the non-ICG group had no bile duct variations (Figure S1). In the non-ICG group, the shape of bile duct could not be clearly distinguished, which eventually led to the multiple bile duct openings (*Figure 1A-1C*). On the contrary, in the ICG group, we could accurately determine the division point of the bile duct with the help of ICG fluorescence cholangiography. As a result, the left hepatic bile ducts were transected in the primary branch and had only one bile duct opening (*Figure 1D-1F*).

Three donors in the non-ICG group (case 8, 35, 41) suffered postoperative bile leakage. Two of them were observed on the second day after the operation by monitoring abdominal drainage, and abdominal drainage was maintained for 5 and 7 days until bile leakage was eliminated. Another was observed 2 weeks later using ultrasound because the patient had a high fever. She underwent percutaneous drainage of the effusion, and the drainage tube was retained for 8 days. However, no bile

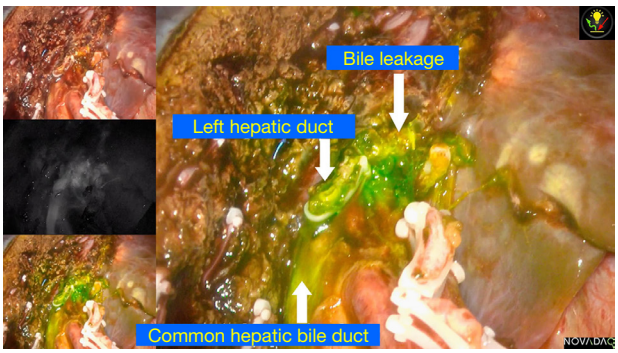

Figure 2 ICG fluorescence imaging used to check for the occurrence of bile leakage. ICG, indocyanine green.

Table 2 Demographic characteristics and postoperative outcomes of recipients

Demographic characteristics and postoperative outcomes	Non-ICG group (n=46)	ICG group (n=57)	P value
Age (months)	18.0±19.2	13.5±14.4	0.18
Sex (male/female)	30/16	34/23	0.68
Weight (kg)	8.7±3.3	9.0±2.8	0.69
Complications			
Artery thrombosis	1	0	0.45
Portal vein complication	0	0	>0.99
Biliary complication	4	0	0.0369
Bile leakage	2	0	0.20
Bile duct stenosis	2	0	0.20
Chylous leakage	0	1	>0.99
Infection	1	1	>0.99
Cerebral hernia	1	0	0.45
Tension pneumothorax	0	1	>0.99
Mortality	1	1	>0.99

Data are presented as n or mean ± standard deviation. ICG, indocyanine green.

leakage occurred in the ICG group. ICG fluorescence cholangiography could not only display the morphology of biliary tract, but also detect subtle bile leakage (*Figure 2*). Gastric retention occurred in two donors in the non-ICG group and one in the ICG group. Wound bleeding also appeared in two donors in the non-ICG group and one in the ICG group. One donor in the non-ICG group and ICG group suffered from atelectasis. Portal vein partial thrombus was observed in one donor in the non-ICG group using ultrasound the first day after the operation because of elevated ALT and AST levels. The thrombus disappeared after two months of treatment with low-molecular-weight heparin and warfarin. There was no biliary stenosis, portal vein stenosis, postoperative intraperitoneal hemorrhaging or other serious complications in either donor group.

The mean age of the recipients was 18.0±19.2 months in the non-ICG group and 13.5±14.4 months in the ICG group (P=0.18). There were 30 males in the non-ICG group and 34 males in the ICG group (P=0.68). The mean weight of the recipients was 8.7±3.3 kg in the non-ICG group and 9.0±2.8 kg in the ICG group (P=0.69). One recipient in the non-ICG group developed an arterial embolism and underwent thrombectomy and reanastomosis. There was no portal vein thrombosis or stenosis in either the non-ICG group or the ICG group. Biliary complications were observed in four recipients in the non-ICG group, who received grafts with multiple bile duct openings, and none in the ICG group (P=0.0369). Two recipients with bile leakage were observed 2 days after the operation, and abdominal drainage was maintained for 15 and 22 days. Another two recipients with bile duct stenosis were found 10 and 14 days after the operation because of obstructive jaundice, and reoperations for bilioenteric anastomosis were implemented nearly a month after the first operation. One case of chylous leakage occurred in the ICG group, which was resolved by fasting and anti-inflammatory therapy. One recipient in the non-ICG group died because of cerebral hernia and serious infection, while another recipient in the ICG group died of tension pneumothorax (*Table 2*).

Eighteen donors were injected intravenously with a dose of 0.05 mg/kg ICG according to the consensus guideline. The other 39 donors were given a dose of 0.004 mg/kg ICG based on our experience after exploration. The fluorescence intensity of the liver was 108.1±17.6 with the dose of 0.004 mg/kg 90 minutes after injection, which was significantly weaker than the dose of 0.05 mg/kg 30 minutes (200.3±17.6, P=0.001) and 90 minutes after injection (140.2±15.4, P=0.001). However, the fluorescence density of the bile duct did not decrease over time (from 30 to 90 min) at doses of 0.05 mg/kg (159.2±15.3 *vs.* 160.1±14.1, P=0.86) or 0.004 mg/kg (134.4±18.2 *vs.* 133.0±20.3, P=0.75). The fluorescence intensity contrast value at a dose of 0.004 mg/kg 90 minutes after injection was stronger than that at a dose of 0.05 mg/kg 90 minutes after injection (0.098±0.032 *vs.* 0.078±0.022, P=0.021) (*Figure 3*).

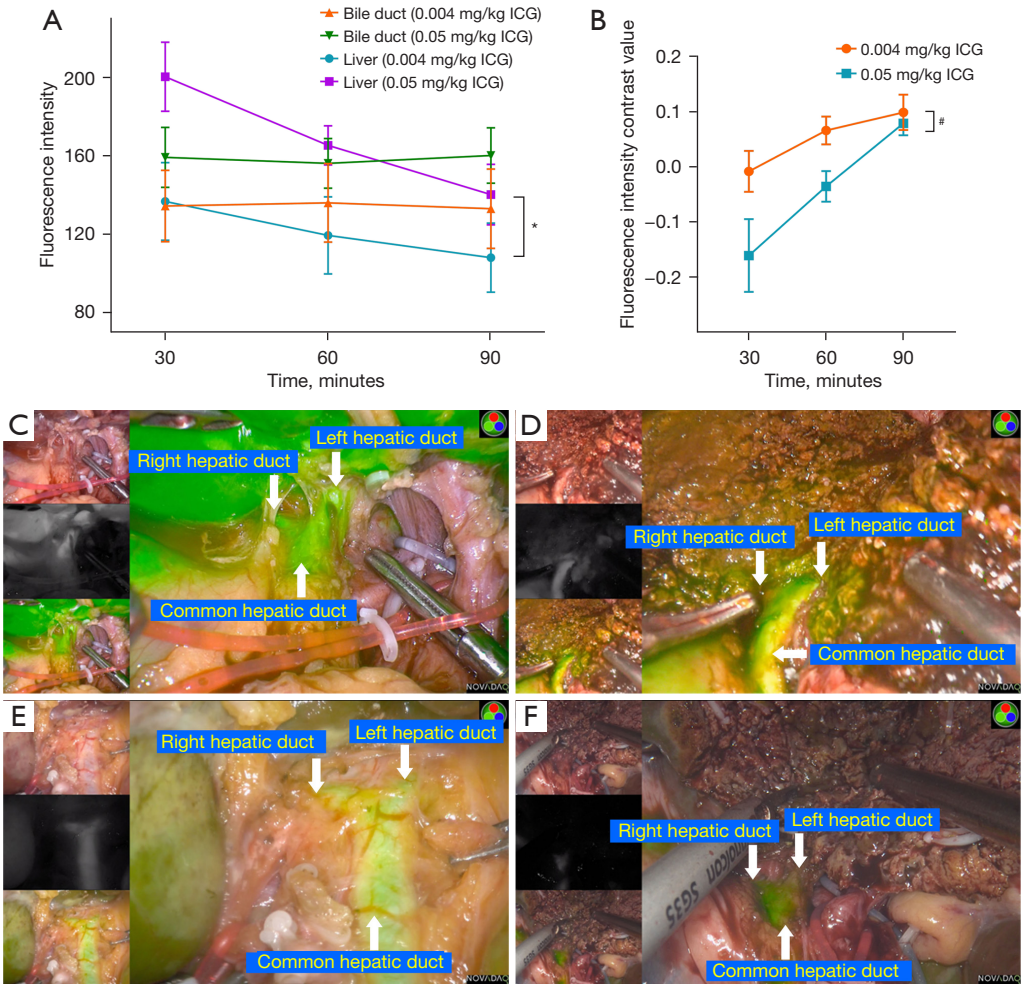

Figure 3 ICG fluorescence intensity of the liver and the bile duct at different concentrations and time points. (A) Fluorescence intensity of the liver and the bile duct at different concentrations and time points. (B) Fluorescence intensity contrast value at different concentrations and time points, fluorescence intensity contrast value = (fluorescence intensity of the bile duct – fluorescence intensity of the liver)/255. (C) ICG fluorescence imaging of the liver and the bile duct with the dose 0.05 mg/kg 30 minutes after injection. (D) ICG fluorescence imaging with the dose 0.05 mg/kg 90 minutes after injection. (E) ICG fluorescence imaging with the dose 0.004 mg/kg 30 minutes after injection. (F) ICG fluorescence imaging with the dose 0.004 mg/kg 90 minutes after injection. *, significant difference of fluorescence intensity of the liver between different concentrations at the same time and different time points with the same concentration; #, significant difference of fluorescence intensity contrast value between different concentrations at the same time and different time points with the same concentration. ICG, indocyanine green.

Discussion

The development of LDLT has brought hope to patients who are waiting for liver transplantation due to end-stage liver diseases. LLDH reduces the trauma of donors and is more easily accepted by donors. Since Cherqui reported the first two laparoscopic left lateral sectionectomies in 2002 (15), laparoscopic left hemihepatectomy, laparoscopic right hemihepatectomy, laparoscopic right posterior lobectomy and laparoscopic segment II sectionectomy for LDLT have been conducted in major transplantation centers (16,17). How to control intraoperative bleeding and protect the graft vessel and bile duct are the core technical problems of LLDH. Among which, protecting the biliary tract has always been the most important problem in LLLS.

In the past, X-ray cholangiography was routinely

performed during living donor hepatectomy in LDLT to obtain information on the morphology of the bile duct and determine the division point (18). However, it is relatively inconvenient to perform cholangiography in LLLS. Cholangiography could be performed through cystic duct intubation after cholecystectomy in laparoscopic right hemihepatectomy. However, it could be performed only through extremely difficult ultrasound-guided bile duct puncture in LLLS. Therefore, intraoperative cholangiography was abolished in LLLS in our center. After carefully dissecting the first hepatic hilum and separating the common hepatic duct and the left hepatic duct, the division point of the bile duct was determined.

Real-time ICG fluorescence imaging has been widely used in hepatobiliary surgery (19). It can be used for tumor imaging, fluorescence-guided anatomical liver resection, fluorescence cholangiography, etc. As for the application of fluorescence cholangiography, it was first used in a laparoscopic cholecystectomy. ICG fluorescence cholangiography avoids the need for incision and cannulation of the biliary tract, so that it avoids potential injury to the biliary tree. It also avoids the radiation and can be repeated many times by simply switching the light wavelength and gives a real-time visualization of the anatomy (20). Fluorescence cholangiography is safer and more feasible than traditional cholangiography in laparoscopic cholecystectomy, and it indeed prevent bile duct injury (9). Real-time ICG fluorescence cholangiography was regularly used in LLLS in the latter period in our center.

Commonly, biliary complications remain a disadvantage of LDLT, with overall incidence ranging between 5% and 60% worldwide (21-24). Once biliary complications occur, they will be a serious strike to both donors and recipients. Gautier *et al.* (25) reported 103 cases of LLLS in a single center. Intraoperative cholangiography was not performed routinely. As a result, the incidence of multiple bile duct openings in open surgery and laparoscopic surgery was 57.1% and 51.4% respectively. Zhang *et al.* (26) revealed that laparoscopic surgery can more frequently lead to multiple biliary tracts in the graft and its impact on the prognosis of recipients remains uncertain. After ICG fluorescence cholangiography using, it was revealed that the number of multiple bile duct openings was significantly reduced to 8% (27). It was found that ICG fluorescence cholangiography can clearly visualize the shape of the bile duct, which helps the surgeon to judge the division point of the bile duct during operation (11). When the judgment of the bile duct division point was not accurate, the secondary or tertiary branches of the bile duct may be cut off, resulting in multiple bile duct openings in the graft, which makes subsequent bile duct anastomosis or cholangiojejunostomy very difficult. Data from our center showed that the ICG group had a significantly reduced proportion of multiple bile duct openings in the graft compared with the non-ICG group. This demonstrated that ICG fluorescence cholangiography could help the surgeon real-time visualizing the shape of the bile duct more clearly and determine the division point of the bile duct accurately.

In addition, ICG fluorescence cholangiography can also be used to check for the occurrence of bile leakage. In the past, we could only judge whether there was bile leakage by observing the color of the cotton pledget after wiping the incisal edge with it (28). Now, we can observe whether there was bile leakage through ICG fluorescence cholangiography. Many studies have confirmed that ICG fluorescence cholangiography could avoid the incidence of bile leakage both in laparoscopic cholecystectomy and LLLH (29-31).

How to show the bile duct more clearly by ICG fluorescence cholangiography during operation? There are two methods of ICG fluorescence cholangiography, biliary injection and intravenous injection (12). The advantage of biliary injection was that it could prevent the interference of the liver background; however, the disadvantage was that it was difficult to perform biliary puncture. The advantage of intravenous injection was that it could be operated simply, but the disadvantage was that it needed to be injected in advance, and the dose along with the injection time required exploration to avoid the interference of liver background. ICG fluorescence cholangiography during cholecystectomy mainly revealed the relationship between the extrahepatic common bile duct, common hepatic duct and cystic duct. The liver background had little effect on it. However, during LLLS, ICG fluorescence cholangiography mainly shows the relationship between the common hepatic duct and the left and right hepatic ducts, especially when the bifurcation of the left and right hepatic ducts is high, the liver background has a great influence on its observation.

Most studies of ICG fluorescence cholangiography, including the consensus guideline (19), recommended an ICG dose from 0.05 to 0.2 mg/kg. The concentration of ICG used for fluorescence cholangiography in the initial donors was 0.05 mg/kg. However, the dose of ICG was too high, which made it difficult to observe the bile duct due to interference from the liver background. So, it was diluted 50, 25 and 12.5 times. Finally, the best dose (0.004 mg/kg)

of ICG was found and used in the latter donors. The observation time was reported from 30 minutes to 12 hours which was associated with the ICG dose (9,31-34). Our data showed that the optimal injection time point was approximately 90 minutes before cutting the bile duct when anesthesia was induced. This was the most appropriate time since the liver background had almost faded, and the bile duct could still be seen. We found that the fluorescence intensity of the liver background decreased with time, while the fluorescence intensity of the bile duct did not change significantly. The higher the fluorescence intensity contrast value was, the more obvious the fluorescence imaging of the bile duct was. Moreover, it was not recommended to use ICG-guided hemihepatectomy or sectionectomy simultaneously, which would lead to interference from the liver background (35). Due to the weak penetration of ICG, careful dissection of the fat and connective tissue on the surface of the bile ducts at the hilum may be required before ICG fluorescence cholangiography. This was the only disadvantage of using ICG fluorescence cholangiography compared with X-ray cholangiography (36).

The operation duration and the warm ischemia time were shorter in the ICG group than in the non-ICG group, which may be due to the learning curve because ICG fluorescence cholangiography was only performed in the latter period (37). However, we believe that the learning curve of LLLS only requires about 25–30 operations. Our previous study helped to confirm the above conclusions. It was showed that the operation duration of the subsequent 25 operations was significantly shorter than that of the initial 25 operations (144.8±18.3 *vs.* 170.2±33.6 minutes; P=0.01), and the intraoperative blood loss was significantly reduced (134.8±89.2 *vs.* 186.0±100.5 mL; P=0.05) (13). However, no further improvement was made later. The operation duration in the ICG group which was performed in the latter period was as same as the subsequent 25 operations (138.8±24.6 *vs.* 144.8±18.3 minutes, P=0.84). Similarly, there was no difference of the intraoperative blood loss and the warm ischemia time between the ICG group and the subsequent 25 operations (133.9±63.7 *vs.* 134.8±89.2 mL, P=0.85; 4.3±0.7 *vs.* 4.5±0.8 minutes, P=0.70). In addition, it was reported that in pure laparoscopic living donor right hepatectomy, learning curve which increases proficiency and cooperation only has a greater impact on reducing operation duration, while it has no influence on the accurate judgment of the division point of bile duct (4).

Of course, our research also has some defects. First of all, this is not a randomized control trial study. There may be some bias in case selection. Secondly, there is no compare between ICG fluorescent cholangiography and conventional X-ray cholangiography. We also hope that there will be more randomized control trials to give us evidence-based information.

Conclusions

In conclusion, ICG fluorescence cholangiography is safe and feasible in LLLS. It helps in real-time visualizing the shape of the bile duct, determining the division point for the donor bile duct, checking for bile leakage, and significantly reducing biliary complications in both donors and recipients compared with no ICG fluorescence cholangiography. The optimal ICG dose was 0.004 mg/kg, and 90 minutes after injection was the best observation time. ICG fluorescence cholangiography is recommended for routine use in LLLS.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-23-288/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-23-288/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The present study was performed in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Huashan Hospital

affiliated to Fudan University (IRB Reference Number: KY2022-562) and individual consent for this retrospective analysis was waived. This study was also registered on the clinicaltrials.gov (NCT05506020).

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