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ORIGINAL ARTICLE

Observational Study

Novel techniques of liver segmental and subsegmental pedicle anatomy from segment 1 to segment 8

Shao-Dong Wang, Li Wang, Heng Xiao, Kai Chen, Jia-Rui Liu, Zhu Chen, Xiang Lan

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Shao-Dong Wang, Heng Xiao, Kai Chen, Jia-Rui Liu, Zhu Chen, Xiang Lan, Department of Hepatobiliary Surgery, The First Affiliated Hospital of Chongqing Medical University, Chongqing 400016, China

Li Wang, Department of Obstetrics and Gynecology, The Third Affiliated Hospital of Chongqing Medical University (General Hospital), Chongqing 401120, China

Corresponding author: Xiang Lan, MD, PhD, Professor, Department of Hepatobiliary Surgery, The First Affiliated Hospital of Chongqing Medical University, No. 1 Youyi Road, Yuanjiagang, Yuzhong District, Chongqing 400016, China. lanxiangkeyan@163.com

Abstract

BACKGROUND

Laparoscopic anatomical liver resection has become more challenging because some subsegmental Glissonean pedicles are hard to dissect. Here, we introduce how to dissect every (sub) segmental Glissonean pedicle from the first porta hepatis and perform standardized (sub) segmentectomy [from segment 1 (S1) to S8].

AIM

To summarize our methods of laparoscopic anatomical segmental and subsegmental liver resection.

METHODS

The Glisson sheath and liver capsule were separated along the Laennec membrane. The Glissonean pedicle could be isolated and transected with little or no parenchymal damage through this extra-Glissonean dissection approach. The basin of the (sub) segment was determined by the ischemia demarcation line or indocyanine green staining. The hepatic vein or intersegmental vein was also used to guide the plane of parenchymal transection.

RESULTS

All segmental or subsegmental pedicles or even the pedicle of the cone unit could be dissected along the Laennec membrane using our novel technique through the first porta hepatis. The dorsal branches of S8, the branches of S4a and the paracaval portion branches (b/c vein) of the caudate lobe were the most difficult to dissect.

CONCLUSION
The novel techniques of liver segmental and subsegmental pedicle anatomy is feasible for laparoscopic liver resection and can help accurately guide (sub) segmentectomy from S1 to S8.

Key Words: Laparoscopic anatomical liver resection; Subsegmentectomy; Laennec membrane; Liver pedicle anatomy; Hepatocellular carcinoma

Core Tip: We achieved laparoscopic anatomical segmental or subsegmental liver resection through our novel techniques. Using this method, we can access the hepatic pedicle of each individual cone unit and perform resection of the portal vein basin associated with that cone unit. And we standardize the detailed steps of anatomical hepatic resection and show the acquisition of key points. It has a positive effect on the promotion and development of anatomical liver resection worldwide.

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INTRODUCTION

Over the past few decades, laparoscopic liver resection has become more widely accepted with a better understanding of liver anatomy and the rapid development of instruments associated with laparoscopic surgery[1]. Its applications are also gradually expanding, from benign diseases[2] to malignancies[3] and even including laparoscopic liver transplantation [4]. Compared with traditional open surgery, laparoscopic hepatectomy has the advantages of less intraoperative blood loss, faster postoperative recovery, lower complication rate, and long-term efficacy[5-9]. Recently, laparoscopic anatomical liver resection (LALR) has been recommended rather than local resection because of improved overall survival and reduced recurrence[10-12].

However, performing a standard LALR can be challenging. This process includes resection of all the liver parenchyma confined by tumor-bearing portal branches and the outflow of relevant segments[13]. The Glissonean pedicle transection method proposed by Takasaki[14] is one of these approaches used to guide anatomical liver resection. After the pedicles are transected, the corresponding segment will obtain an ischemic demarcation line, and the intrahepatic parenchyma can even be transected with the help of indocyanine green (ICG) staining[15]. Moreover, since Ryu and Cho[16] proposed a new segmental approach based on the portal vein system, some liver units can be divided into subsegments. Based on this new concept, subsegmentectomy has become feasible. However, subsegmental pedicles, especially those located on the cephalic side, are difficult to dissect through the first porta hepatis in the laparoscopic field of view, so approaches for dissecting these pedicles have not been reported before. Here, we first report a novel techniques of liver segmental and subsegmental pedicle anatomy from segment 1 (S1) to S8 that can allow us to dissect all the segmental or subsegmental pedicles from the first porta hepatis, performing standardized segmentectomy and subsegmentectomy from S1 to S8.

MATERIALS AND METHODS

Patient characteristics

The data of patients who underwent LALR between December 2020 and December 2022 were retrospectively analyzed. We included a total of 37 single (sub) segmentectomy cases, including 4 cases of segmentectomy 1, 4 cases of segmentectomy 2, 6 cases of segmentectomy 3, 2 cases of subsegmentectomy 4a, 2 cases of subsegmentectomy 4b, 3 cases of segmentectomy 5, 3 cases of segmentectomy 6, 6 cases of segmentectomy 7, 2 cases of subsegmentectomy 8 (ventral side) and 5 cases of subsegmentectomy 8 (dorsal side). If included patients were diagnosed with hepatocellular carcinoma, their diagnoses were required to conform to stage Ia-IIa of the China Liver Cancer Staging system[17] or stage 0-A of the Barcelona staging system[18]. Our study adhered to the tenets of the Declaration of Helsinki, was reviewed by the hospital ethics committee and registered with the China Clinical Trial Center. The basic and surgery-related information of the included patients is detailed in Table 1.

Surgical technique

Surgical procedures were described in our previous study[19]. Once the patients were draped, the table was turned by 30°-45° into a dorsal elevated position. Each patient was placed in position with the right side elevated approximately 30°. A five-trocar approach was used wherever the tumor was located. Hepatic inflow was blocked for 15 minutes and released for 5 minutes (intermittent Pringle). Parenchymal transection of the liver was performed with a harmonic scalpel

Table 1 Inclusion of basic patient information and surgery-related conditions (*n* = 37)

Characteristic	
Age (years), mean ± SD	56 ± 10
Sex, *n*	
Male	31
Female	6
Hepatitis B/C virus, *n*	
B	26
C	0
Neither	9
ECOG score, *n*	
0	37
Child-Pugh grade, *n*	
A	37
BCLC, *n*	
A	37
CNLC, *n*	
I	37
Operative time (minute), mean ± SD	281 ± 57
Intraoperative blood loss (mL), mean ± SD	245 ± 206
Blood transfusion (mL), *n*	0
Postoperative complications, *n*	
Infection	1
Bile leakage	2
Liver failure	0
Postoperative hospitalization time (days), mean ± SD	7 ± 1

BCLC: Barcelona Clinic Liver Cancer; CNLC: China Liver Cancer Staging; ECOG: Eastern Cooperative Oncology Group.

(JNJ, Inc., NJ, United States). A Hem-O-lock ligating clip (nonabsorbable, JNJ, Inc.) was used to clamp the vessels or bile duct, or Prolene sutures were used to suture the hepatic vein (4/0, nonabsorbable, JNJ, Inc.).

The novel techniques of liver segmental and subsegmental pedicle anatomy

Our technology can achieve LALR. The key point of this technique is to first dissect the pedicle of the liver segment to be resected and then precisely remove the basin area of this pedicle according to the ischemic demarcation line. This idea can also be used to guide LALR. The Glisson sheath and liver capsule are separated along the Laennec membrane[20]. The Glissonean pedicle can be achieved and transected with little or no parenchymal damage through this extra-Glissonean-dissection approach[20-23]. In conjunction with anatomical marks such as Rouviere's sulcus, the cystic plate, the umbilic-alplate and the Arantius plate, the secondary, tertiary and even quaternary branches can be dissected from the first porta hepatis along the Laennec capsule. Ischemic lines are obtained by clamping the liver pedicles. The basin of the (sub) segment is determined by the ischemia demarcation line or ICG staining. However, subsegmental pedicle anatomy is still extremely difficult. Therefore, we describe the implementation of the novel technique in detail. For instance, by analyzing preoperative imaging features, precise intraoperative dissection of the ventral branch of Glissonean pedicle of segment 8 (G8v) and the dorsal side of G8 (G8d) is achieved. The hepatic vein or intersegmental vein (IV) is also used to guide the plane of parenchymal transection. In addition, intraoperative ultrasound is used to confirm the borders and tumor location prior to performing liver resection.

RESULTS

Segmentectomy 1

First, the liver is sufficiently mobilized, including the perihepatic ligament and the short hepatic veins. Then, the anatomy of the Laennec membrane is observed, starting from the hilar plate. The Spiegel lobe branch can be dissected easily from the dorsal and cephalic side of the left primary branch (Figure 1A). The paracaval portion branch can be lifted around the dorsal side of the right or left primary branch (Figure 1B). The caudate process branch can be lifted around the dorsal side of the right posterior branch (Figure 1C). Transection of the liver parenchyma is begun along the right paracaval plane (the right border line of the caudate lobe, Figure 1D and E), the Arantius plate (Figure 1F; green arrow: The direction of liver parenchyma resection) and the dorsal side of the left/middle/right hepatic vein (RHV) (Figure 1G) to achieve S1 resection (Supplementary material: Video segmentectomy 1).

Segmentectomy 2

The anatomy of the Laennec membrane is observed as beginning from the left side of the umbilical plate (Figure 2A, the white triangle), and then there is the caudal end of the Arantius plate (Figure 2B, the white asterisk). The Glissonean pedicle of segment 2 can be detached through the above two intervals (Figure 2C). Transection of the liver parenchyma is started along the ischemic demarcation line and branches of the left hepatic vein, thus completing the S2 resection (Figure 2D). Sometimes, ICG staining may be applied (Figure 2E and F) (Supplementary material: Video segmentectomy 2).

Segmentectomy 3

The Glissonean pedicle of segment 3 is revealed and ligated at the left side of the connection between the root of the round ligament (Figure 3A, the white triangle) and the umbilical plate (Figure 3B and C, the white asterisk). On the left side, the liver parenchyma is transected along the ischemic demarcation line and branches of the left hepatic vein (Figure 3D). On the caudal side, the liver parenchyma is transected along the ischemic demarcation line and the umbilical fissure vein (Figure 3E). Thus, S3 resection is completed (Figure 3F). ICG staining could also be applied (Figure 3G and H) (Supplementary material: Video segmentectomy 3).

Subsegmentectomy 4a

The Glissonean pedicle of segment 4a (G4a) is revealed by partial transection of the liver parenchyma starting from the right side of the connection between the root of the round ligament (Figure 4A, the white asterisk) and the umbilical plate (Figure 4B and C, the white triangle and the green shadow). G4a is located on the cephalic side of the Glissonean pedicle of segment 4b (G4b) (Figure 4C). The hepatic parenchyma is transected along the ischemic or ICG staining demarcation line (Figure 4D). The umbilical fissure vein and the middle hepatic vein (MHV) should be revealed on the section (Figure 4E) (Supplementary material: Video segmentectomy 4a).

Subsegmentectomy 4b

G4b is located on the caudate side of G4a and is easier to detach. The anatomy of the Laennec membrane also starts from the right side of the connection between the umbilical plate (Figure 5A, the white triangle) and the root of the round ligament (Figure 5B and C, the white asterisk). After we transected all the branches to the caudate and ventral side, the ischemic or ICG staining demarcation line was observed (Figure 5D and E). Sometimes there is an intermediate branch, between G4b and G4a, which can be classified according to the location of the tumor (Figure 5F). MHV branches should be revealed on the section (Figure 5G) (Supplementary material: Video segmentectomy 4b).

Segmentectomy 5

The Glissonean pedicle of segment 5 is usually divided into ventral and dorsal branches, with the former coming from the right anterior pedicle (AP) and the latter usually coming from the right posterior pedicle (PP), now known as PPa - the first caudal lateral branch of the right PP (Figure 6A and B). Therefore, when planning S5 excision, all S5 branches need to be carefully analyzed. The anatomy of the Laennec membrane also startsfrom the hilar plate between the left and right hepatic pedicles (Figure 6C, the white asterisk) and the hilar platebetween the anterior and PPs (Figure 6D, the white triangle). After we transected all the branches of S5, the ischemic or ICG staining demarcation line was observed (Figure 6E and F). The MHV, the RHV and even the IV between S5 and S8 should be revealed on the section (Figure 6G and H) (Supplementary material: Video segmentectomy 5).

Segmentectomy 6

The anatomy of the Laennec membrane starts from the ventral side of the PP (Figure 7A, white asterisk). The thick PPa (Glissonean pedicle of segment 5 dorsal portion) branches are usually located in Rouviere's sulcus (Figure 7B). In this case, the posterior branch trunk travels on the dorsal and cephalic side of the PPa (Figure 7B). The pedicles pointing toward the ventral and caudate sides should be considered the Glissonean pedicle of segment 6 and transected (Figure 7C). The ischemic or ICG staining demarcation line can be observed (Figure 7D and E). The segmental hepatic vein of S6/7 (Figure 7E, the white asterisk and blue shadow) and the caudate side of the RHV (Figure 7F, the white triangle and green shadow) should be revealed on the section (Supplementary material: Video segmentectomy 6).

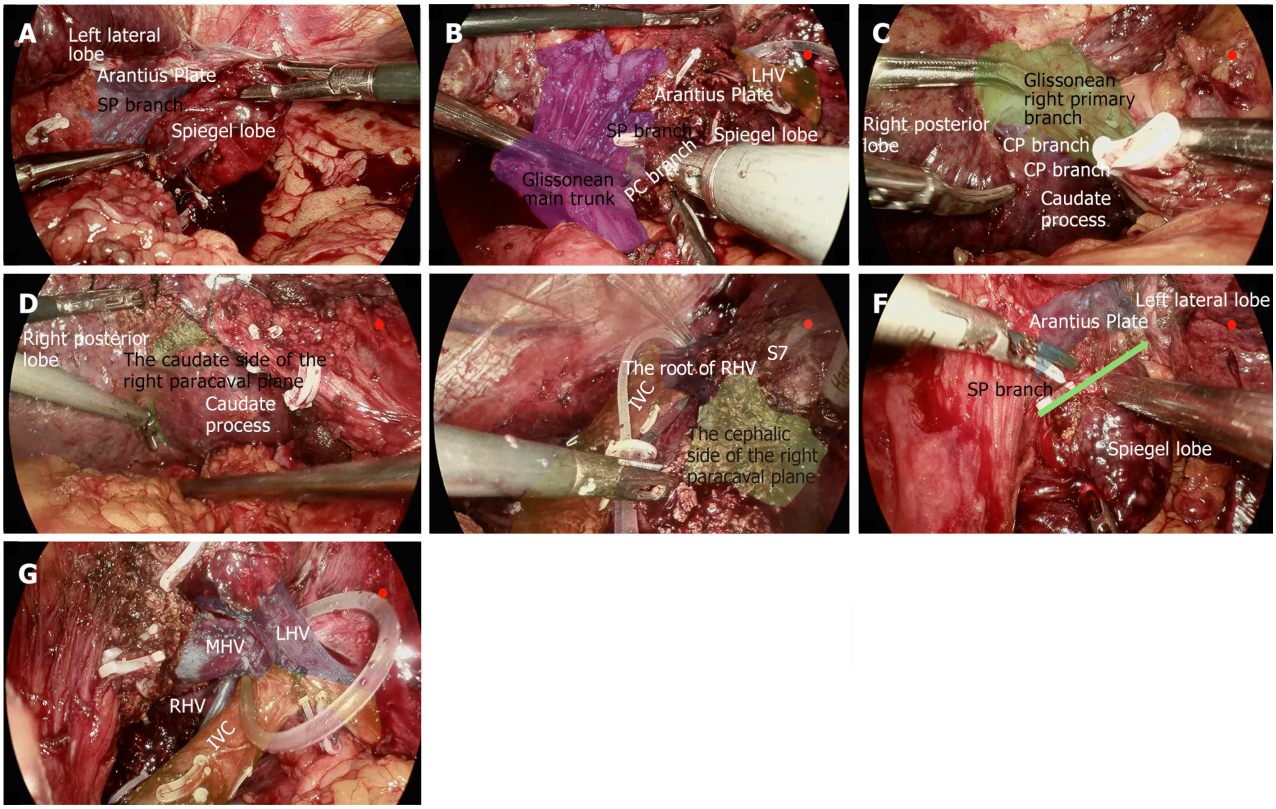

Figure 1 Segmentectomy 1. A: Dissecting the spiegel lobe branch; B: Dissecting the paracaval portion branch; C: Dissecting the caudate process branch; D: Liver parenchyma resection along the markings; E: Liver parenchyma resection along the markings; F: Liver parenchyma resection along the markings; G: Liver parenchyma resection along the markings. SP: Spiegel lobe; CP: Caudate process; LHV: Left hepatic vein; MHV: Middle hepatic vein; RHV: Right hepatic vein; IVC: Inferior vena cava; S7: Segment 7.

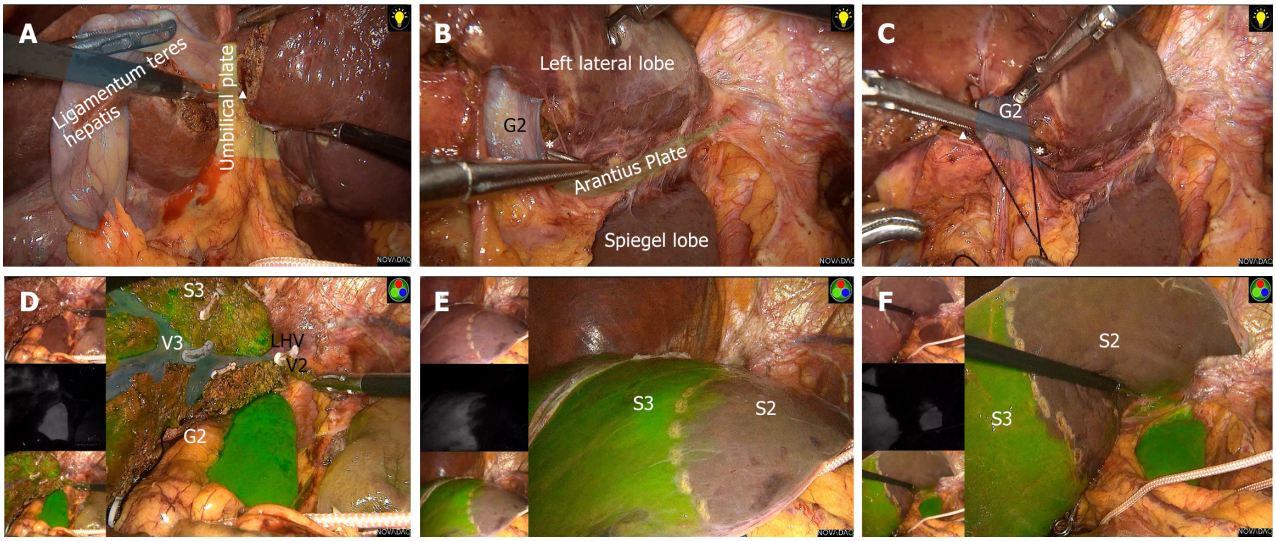

Figure 2 Segmentectomy 2. A: Beginning from the umbilical plate; B: Exposing the caudal end of the Arantius plate; C: Dissecting the Glissonean pedicle of segment 2; D: Liver parenchyma resection along the markings; E and F: Indocyanine green staining. G2: Glissonean pedicle of segment 2; S2: Segment 2; S3: Segment 3; V3: Hepatic vein of segment 3; LHV: Left hepatic vein.

Segmentectomy 7

After the Glissonean pedicle of segment 6 branches are detached from the right PP, the terminal branches toward the dorsal and cephalic side are the Glissonean pedicle of segment 7 (Figure 8A, the blue arrow). The anatomy of the Laennec membrane starts from the dorsal side of the PP. After we transected branches of S7, the ischemic or ICG staining demarcation line was observed (Figure 8B-D). The segmental hepatic vein of S6/7 and the cephalic side of the RHV should be revealed on the section (Figure 8E-G) (Supplementary material: Video segmentectomy 7).

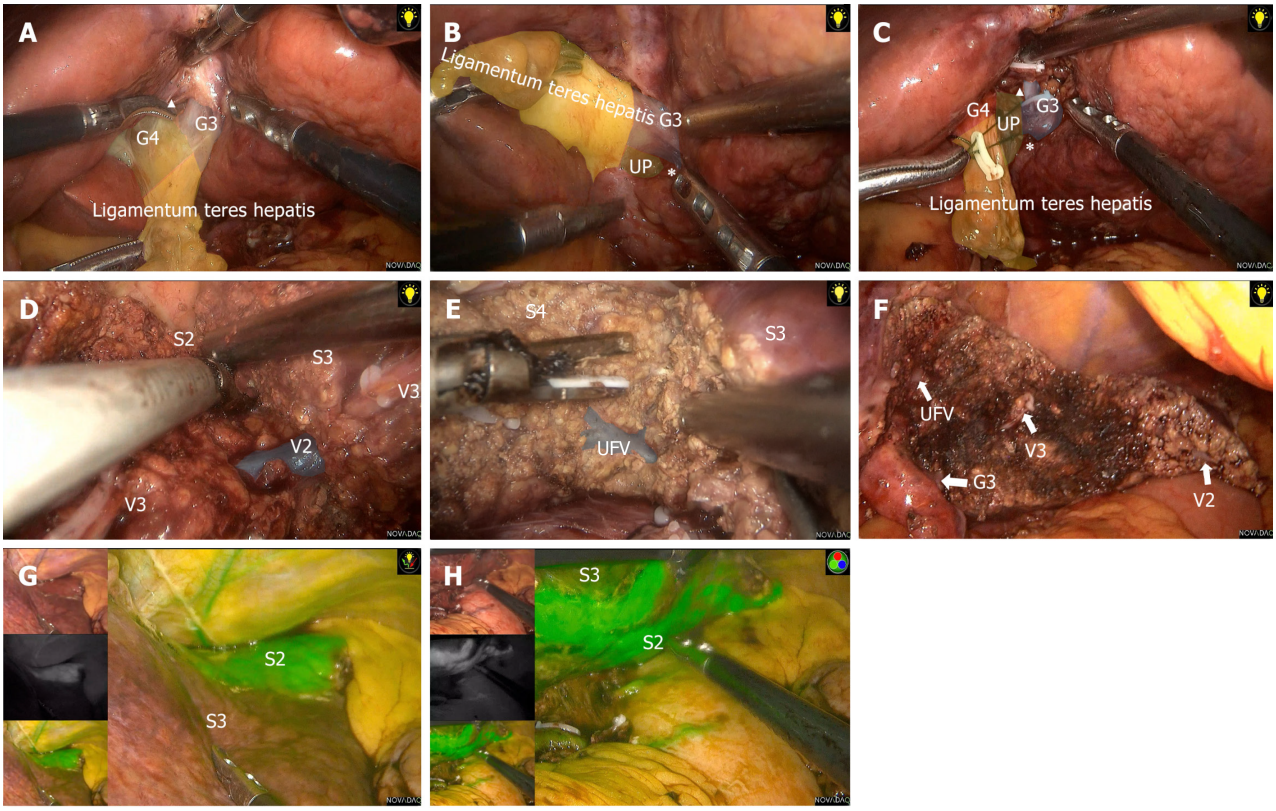

Figure 3 Segmentectomy 3. A: Exposing the root of the round ligament; B: Exposing the umbilical plate; C: Dissecting the Glissonean pedicle of segment 3; D: Liver parenchyma resection along the markings; E: Liver parenchyma resection along the markings; F: Segment 3 resection is completed; G and H: Indocyanine green staining. G3: Glissonean pedicle of segment 3; G4: Glissonean pedicle of segment 4; V2: Hepatic vein of segment 2; UFV: Umbilical fissure vein; UP: Umbilical plate; S3: Segment 3.

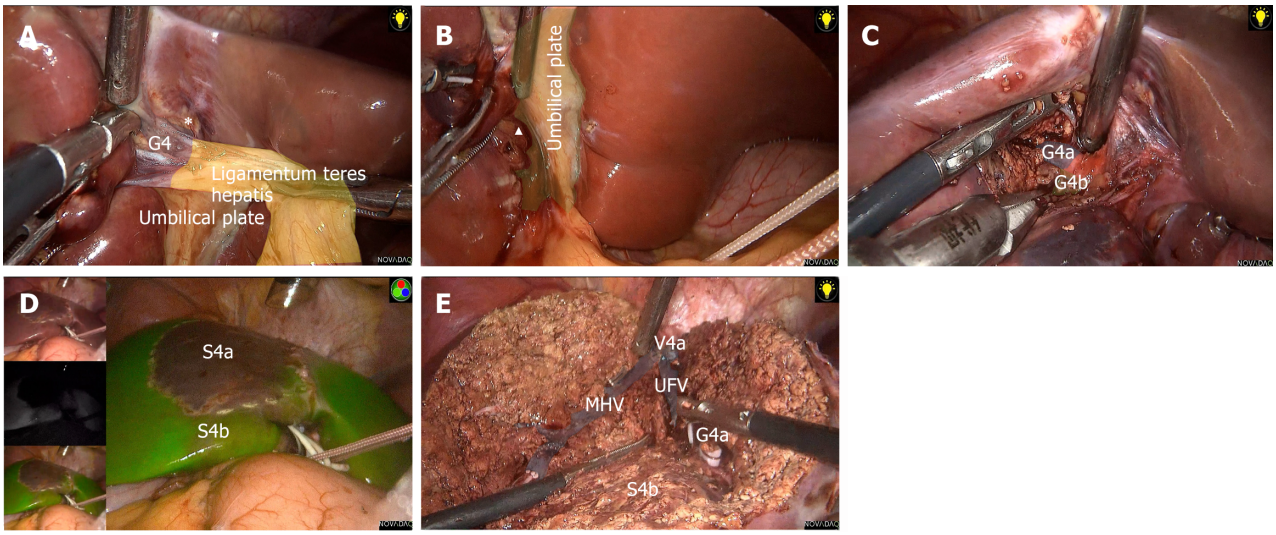

Figure 4 Subsegmentectomy 4a. A: Exposing the root of the round ligament; B: Exposing the umbilical plate; C: Dissecting the Glissonean pedicle of segment 4a; D: Indocyanine green staining; E: Segment 4a resection is completed. G4: Glissonean pedicle of segment 4; G4b: Glissonean pedicle of segment 4b; G4a: Glissonean pedicle of segment 4a; MHV: Middle hepatic vein; UFV: Umbilical fissure vein; S4a: Segment 4a; S4b: Segment 4b; V4a: Hepatic vein of segment 4a.

Subsegmentectomy 8 ventral portion

G8v is more difficult to dissect than that of the Glissonean pedicle of segment 7. The anatomy of the Laennec membrane starts from the hilar plate between the left and right hepatic pedicles (Figure 9A, white asterisk). The short hilar vessel is transected (Figure 9B). The dissection should be along the ventral side of the AP and proceed to its cephalic side (Figure 9C). In a laparoscopic view, the G8v is located on the left and cephalic side of the Glissonean pedicle of segment 5 ventral (Figure 9D). The ischemic or ICG staining demarcation line was observed (Figure 9E). The MHV and the anterior fissure vein should be revealed on the section (Figure 9F) (Supplementary material: Video segmentectomy 8v).

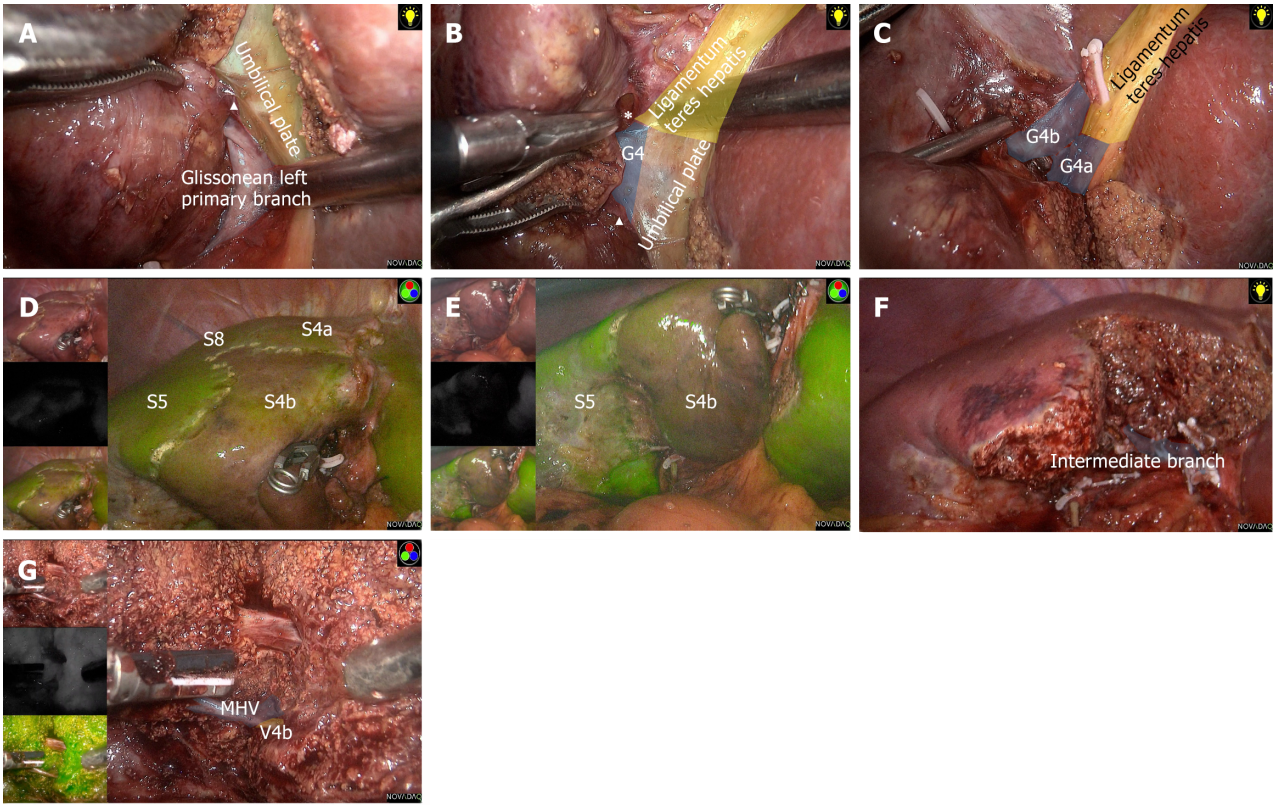

Figure 5 Subsegmentectomy 4b. A: Exposing the umbilical plate; B: Exposing the root of the round ligament; C: Dissecting the Glissonean pedicle of segment 4b; D and E: Indocyanine green staining; F: The intermediate branch; G: Segment 4b resection is completed. G4: Glissonean pedicle of segment 4; G4b: Glissonean pedicle of segment 4b; G4a: Glissonean pedicle of segment 4a; MHV: Middle hepatic vein; S5: Segment 5; S8: Segment 8; V4b: Hepatic vein of segment 4b.

Subsegmentectomy 8 dorsal portion

G8d is more difficult to dissect than any other pedicle. The right AP is fully mobilized and suspended (Figure 10A). The assistant pulls the right AP to the left (Figure 10B, the blue arrow) and ventral side (Figure 10B, the green arrow). G8d is located on the dorsal and cephalic side of the right AP (Figure 10C). The ischemic or ICG staining demarcation line is observed (Figure 10D). The anterior fissure vein and the RHV should be revealed on the section (Figure 10E and F) (Supplementary material: Video segmentectomy 8d). The position of G8d is not constant; it is sometimes on the dorsal right side of the right anterior hepatic pedicle and sometimes on the dorsal left side. The latter position is more difficult to dissect than the former in the laparoscopic view. To better dissect G8d, we summarized the imaging characteristics corresponding to the different positions of G8d (Supplementary material: Case 1 and case 2).

DISCUSSION

Although laparoscopic hepatectomy has developed rapidly in recent years, LALR remains challenging, especially for special liver segments. Anatomical liver resection is the complete resection of the liver parenchyma corresponding to the responsible portal vein area, including sectionectomy, segmentectomy, and subsegmentectomy[13]. However, achieving success with LALR requires precise preoperative localization of tumors, detailed preoperative planning of vascular variants, and solid expertise on the part of the surgeon. Preoperative visualization techniques and augmented reality can be used to preoperatively assess liver volumes, identify key anatomical landmarks and plan surgery to improve its accuracy[24,25]. However, it is most important to determine the target liver pedicle intraoperatively, as well as the exposure of the hepatic or IVs.

Commonly accepted LALR methods include the Glissonean pedicle transection method, ultrasound-guided intraoperative puncture of the target portal branch[26], and the parenchymal-first approach[27]. Although each method has its specific advantages, the Glissonean pedicle transection method is more widely used and is recommended by experts worldwide[28]. Compared to other approaches, the Glissonean pedicle transection method offers shorter operative times, fewer patients with positive postoperative margins, shorter hospital stays and lower complication rates[29,30]. The degree of difficulty in dissecting the liver pedicles varies from one liver segment to another. For the cephalic subsegmental pedicles, especially G8v, G8d and G4a, dissection from the first porta hepatis is more difficult due to their specific locations, so the parenchymal-first approach or ultrasound-guided intraoperative puncture of the portal vein combined with ICG staining is more commonly used to guide resection[31,32]. However, with the parenchymal-first approach, exposure at the beginning of the procedure is difficult, the overall precision is relatively poor, disorientation may easily occur intraoperatively, and establishing the intersegmental/sectional plane may be difficult, especially when dealing with

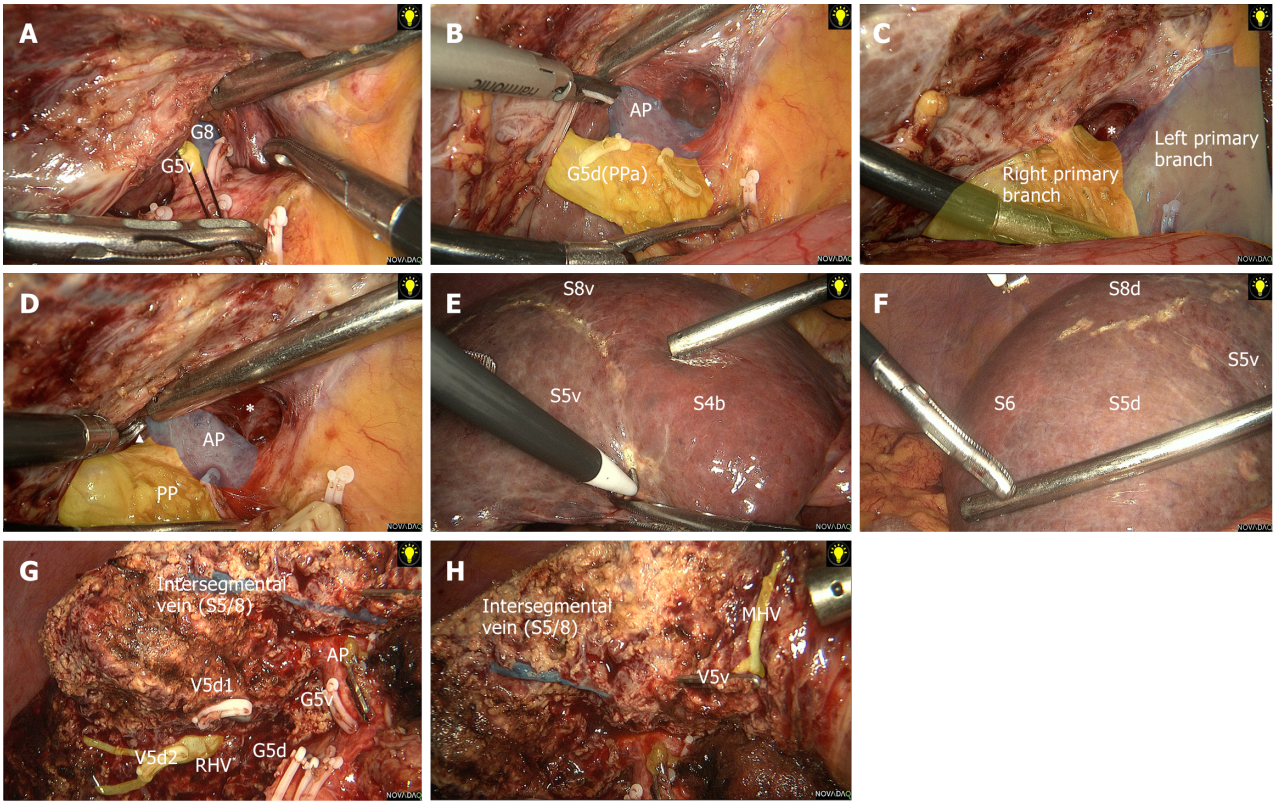

Figure 6 Segmentectomy 5. A: Dissecting the Glissonean pedicle of segment 5 ventral; B: Dissecting the Glissonean pedicle of segment 5 dorsal; C and D: Lowering the hepatic hilar plate; E: The ischemic line (between segment 5 ventral portion and segment 4b); F: The ischemic line (between segment 5d and segment 6); G: Segment 5 resection is completed; H: Segment 5 resection is completed. AP: Anterior pedicle; PP: Posterior pedicle; G8: Glissonean pedicle of segment 8; G5v: Glissonean pedicle of segment 5 ventral; G5d: Glissonean pedicle of segment 5 dorsal; RHV: Right hepatic vein; MHV: Middle hepatic vein; V5v: Hepatic vein of segment 5 ventral portion; V5d: Hepatic vein of segment 5 dorsal portion; S5v: Segment 5 ventral portion; S5d: Segment 5 dorsal portion; S6: Segment 6; S8v: Segment 8 ventral portion; S8d: Segment 8 dorsal portion; PPa: First caudal lateral branch of the right posterior pedicle.

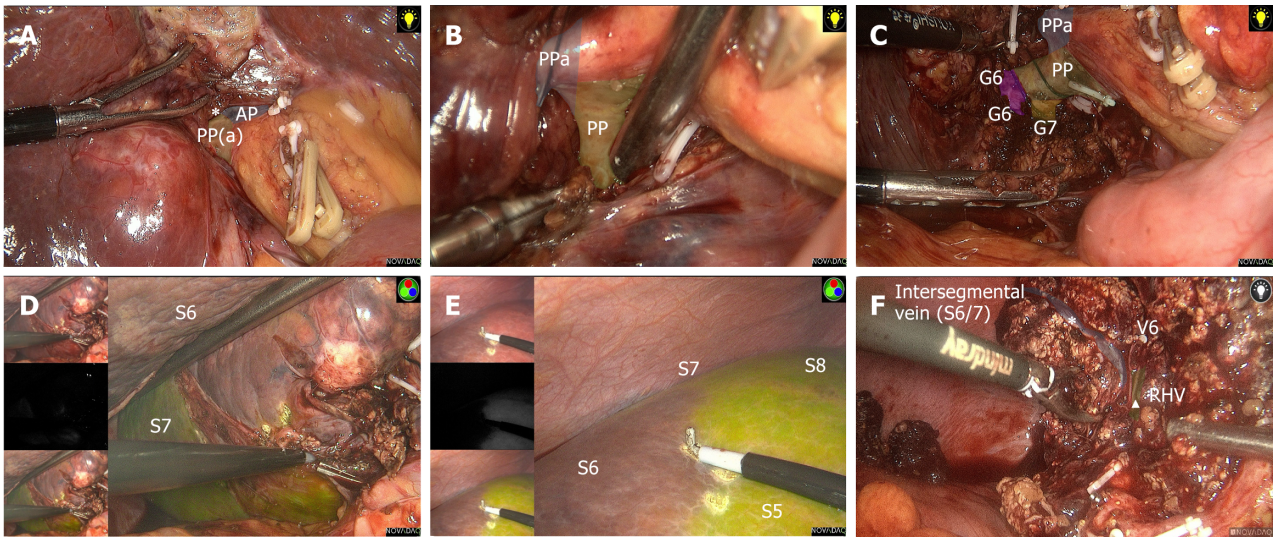

Figure 7 Segmentectomy 6. A and B: Lowering the hepatic hilar plate; C: Dissecting the Glissonean pedicle of segment 6; D and E: Indocyanine green staining; F: Segment 6 resection is completed. AP: Anterior pedicle; PP: Posterior pedicle; RHV: Right hepatic vein; G6: Glissonean pedicle of segment 6; S6: Segment 6.

the hepatic divide between S5 and S8, during which Glissonean pedicle of segment 5 can easily be injured accidentally. Likewise, the ultrasound-guided intraoperative puncture method is demanding in terms of puncture angle and depth, resulting in a low overall success rate. The Glissonean pedicle transection method, however, may provide the most anatomically precise resection and is the key to achieving subsegmental resection[33]. Combining the advantages and disadvantages of the above methods, our team has improved the Glissonean pedicle transection method and created the novel technique. Compared with other approaches to LALR, the greatest advantage of our method lies in the ability to

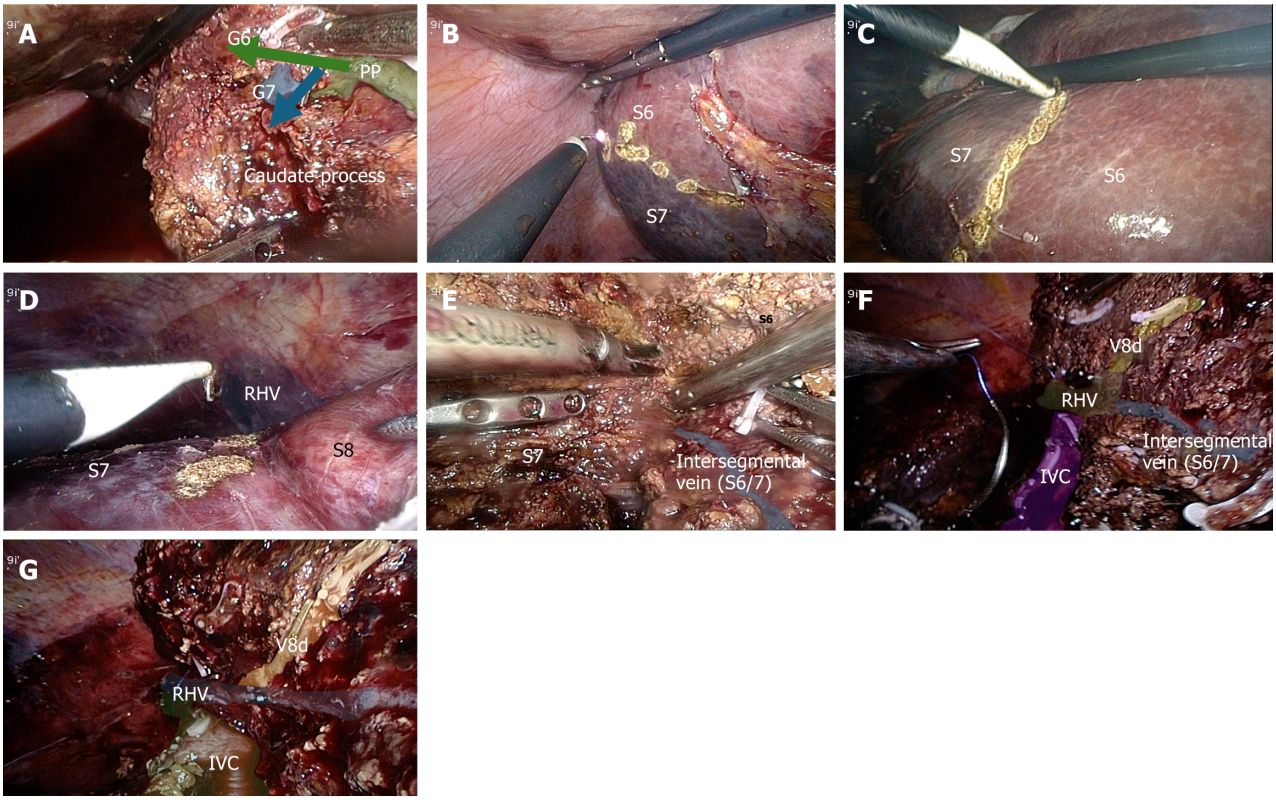

Figure 8 Segmentectomy 7. A: Dissecting the Glissonean pedicle of segment 7; B: The ischemic line (dorsal side between segment 6 and segment 7); C: The ischemic line (ventral side between segment 6 and segment 7); D: The ischemic line (between segment 7 and segment 8); E: Liver parenchyma resection along the markings; F and G: Segment 7 resection is completed. V8d: Hepatic vein of segment 8 dorsal portion. G6: Glissonean pedicle of segment 6; PP: Posterior pedicle; RHV: Right hepatic vein; IVC: Inferior vena cava; S6: Segment 6.

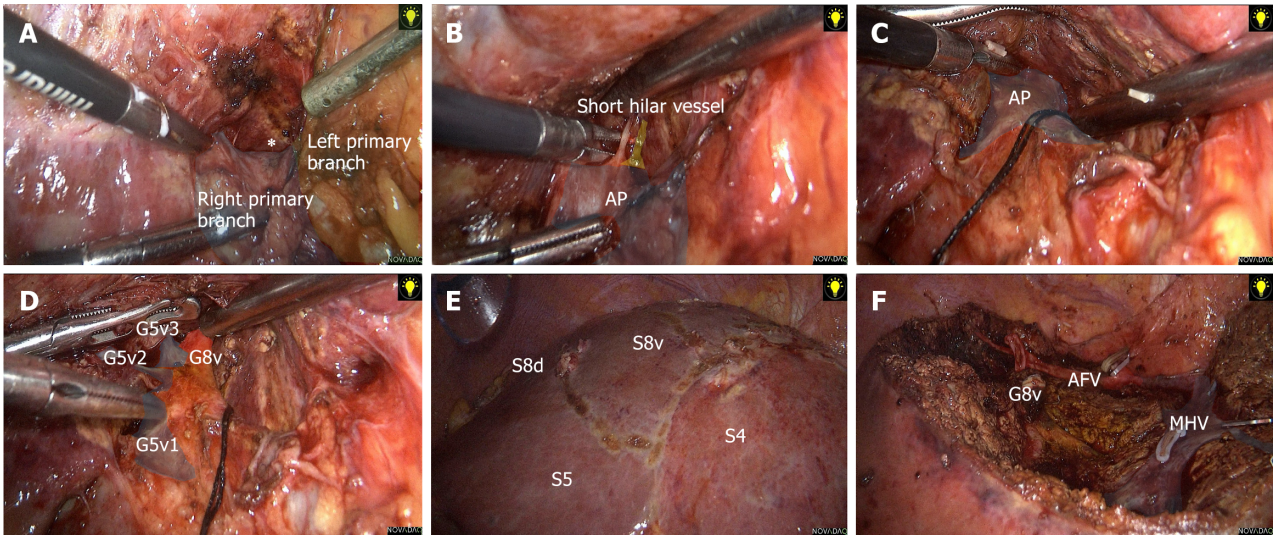

Figure 9 Subsegmentectomy 8 ventral portion. A-C: Lowering the hepatic hilar plate (A and C), the short hilar vessel is transected (B); D: Dissecting the Glissonean pedicle of segment 8 ventral portion; E: The ischemic line; F: Segment 8 ventral resection is completed. AP: anterior pedicle; G8v: Glissonean pedicle of segment 8 ventral portion; S4: Segment 4; AFV: Anterior fissure vein; S8d: Segment 8 dorsal; S8v: Segment 8 ventral; MHV: Middle hepatic vein.

perform precise resections. Before the liver parenchyma is transected, we can evaluate the correctness of the dissected pedicle through the ischemic demarcation line. By performing ICG fluorescence staining, visual guidance both on the liver surface and in the liver parenchyma of the target liver segment during resection is feasible. These processes can reduce the probability of intraoperative disorientation and ensure that safe and accurate surgical margins can be obtained [34-36]. Due to limitations in the understanding of intrahepatic anatomy and the limitations of the surgical instruments used, the application of approaches to dissect the liver pedicles of cephalic segments, especially cephalic subsegments, from the first porta hepatis has hardly been reported in the past. In our practice, we found that the beginning of the liver

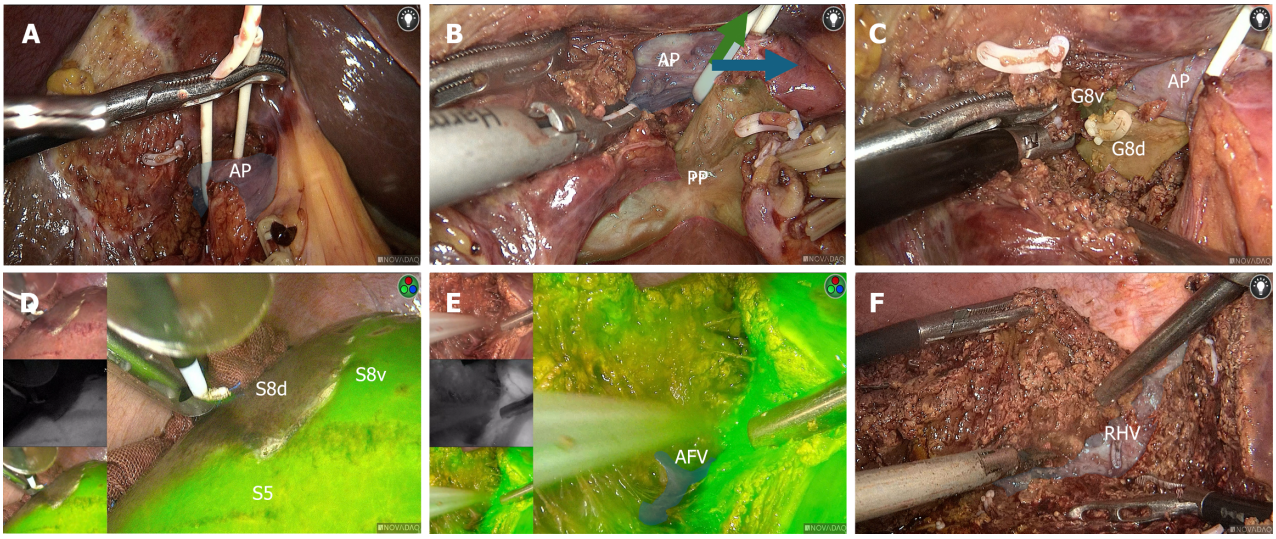

Figure 10 Subsegmentectomy 8 dorsal portion. A: Dissecting the right anterior pedicle; B: Pulling the right anterior pedicle; C: Dissecting the Glissonean pedicle of segment 8 dorsal; D: Indocyanine green staining; E: Liver parenchyma resection along the markings; F: Segment 8 dorsal resection is completed. AP: Anterior pedicle; PP: Posterior pedicle; G8d: Glissonean pedicle of segment 8 dorsal; G8v: Glissonean pedicle of segment 8 ventral; S5: Segment 1; S8d: Segment 8 dorsal; S8v: Segment 8 ventral; AFV: Anterior fissure vein; RHV: Right hepatic vein.

pedicles of the cephalic hepatic (sub) segments are not far from the first hepatic hilar in most patients. With consistent training and standardized methods, we were able to dissect these pedicles from the first porta hepatis and thus achieve precise anatomical liver resection. This is the first time that surgeons have the ability to dissect these subsegmental liver pedicles with no need to transect the liver parenchyma using our novel technique under laparoscopy. We now summarize these methods in the hope that they will be useful for the promotion of laparoscopic precise liver resection. Of course, this technique has its drawbacks: Bile leakage due to short portal vessel injury, identification of the target pedicle, and the need for a deep understanding of intrahepatic anatomy. In future applications, we will gradually overcome these difficulties.

CONCLUSION

The novel techniques of liver segmental and subsegmental pedicle anatomy from S1 to S8 are safe and feasible. Combined with fluorescence staining and other methods, it can help us achieve precise liver resection. It can also be replicated under standardized operations.

FOOTNOTES

Author contributions: All authors contributed to the study concept and design. Lan X performed all surgeries, supervised the research process and revised the article critically for important intellectual content; Wang SD, Xiao H, Chen K, Liu JR, and Chen Z contributed to the material preparation, data collection and analysis; Wang L made the video; Wang SD wrote the first draft of the manuscript. All authors commented on previous versions of the manuscript, read and approved the final manuscript.

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Country of origin: China

ORCID number: Shao-Dong Wang 0009-0002-3550-2097; Heng Xiao 0000-0002-8384-4027; Xiang Lan 0009-0004-5016-1301.

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