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A Percutaneous Portal Vein Puncture Under Artificial Ascites for Intraoperative Hepatic Segmentation Using Indocyanine Green Fluorescence: A Technical Report of Laparoscopic Anatomic Liver Resection

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Background: Laparoscopic liver resection have developed and is widely spread as standard procedure in these days, however, laparoscopic anatomic liver resection is still challenging, especially for posterosuperior lesions because of difficulties in segmental mapping and surgical techniques. Recently, the positive staining and negative staining method using fluorescent imaging techniques have been reported from experienced Asian centers, allowing to identify the tumor-bearing portal territory to be resected including the posterosuperior segment in laparoscopy. Those techniques are applicable in some cases; hence, it remains the room for improvement to establish as a feasible approach. Herein, we describe a percutaneous tumor-bearing portal vein puncture method under artificial ascites after the pneumoperitoneum for laparoscopic segmentectomy for segment 8.

Case Presentation and Surgical Procedure: A male patient in his 60s was admitted for an incidentally diagnosed hepatic mass in segment 8. Findings of the computed tomography scan showed a 2.5-cm-sized hepatocellular carcinoma lesion. Then, laparoscopic anatomic liver resection for segment 8 was planned. The segmentation of the segment 8 was performed through a percutaneous tumor-bearing portal vein puncture using indocyanine green injection with extracorporeal ultrasound guidance under artificial ascites. According to indocyanine green fluorescence navigation, anatomic liver resection was completed. Operative time was recorded as 375 minutes. The estimated intraoperative blood loss was 50 mL without the requirement for an intraoperative transfusion. The planned resections were successful with histologically negative surgical margins. The patient was discharged on the 19th postoperative day with normal liver function test results. There was no operation-related complication during hospitalization.

Conclusion: The intraoperative percutaneous portal vein puncture method under artificial ascites was useful for the identification of posterosuperior segment in laparoscopic anatomic segmentectomy.

Key Words: laparoscopic anatomic liver resection, artificial ascites, ICG fluorescence

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Laparoscopic liver surgery has been established as the standard procedure for hepatic malignancies and benign diseases, then expanding its limits from minor hepatectomy to the complicated anatomic liver resection (ALR).[1] The consensus meetings at Morioka in 2017 and Southampton in 2019 had declared laparoscopic ALR could be feasible and safe if in experienced hands.[2,3] Furthermore, recent research has shown laparoscopic anatomic resection for hepatocellular carcinoma (HCC) are associated with better long-term outcomes as compared with nonanatomic resection.[4] Recent published comprehensive difficulty score from Southampton University had the posterosuperior segmental lesion classified as a high-risk category for an intraoperative complication, which is associated with death in hospital.[5]

Indocyanine green (ICG) technology have been introduced for laparoscopic ALR recently, however, there are no established method for the identification of intersegmental line or the appropriate way of exposing the hepatic vein, both of which are the key for anatomic resection.[6,7] Herein, we presented our technique of laparoscopic posterosuperior segmentectomy helped by intraoperative percutaneous ultrasound (US)-guided tumor-bearing portal vein branch puncture and injection of ICG dye under the artificial ascites.

MATERIALS AND METHODS

Case Presentation

A male patient in his 60s was admitted for an incidentally diagnosed hepatic mass in segment 8 (S8). Most of the laboratory data were within normal limits (Table 1). It

TABLE 1. Preoperative Laboratory Data

Variables	Results
Total bilirubin (mg/dL)	0.6
Serum albumin (g/L)	4.2
Aspartate transaminase (U/L)	24
Alanine transaminase (U/L)	19
Prothrombin activity (%)	98
Hemoglobin (g/L)	14.2
Platelet count (/μL)	128,000
Indocyanine green (%)	22
Child-Pugh Classification	A
Alpha-fetoprotein (ng/mL)	6.0
Prothrombin induced by vitamin K absence-II (mAU/mL)	12

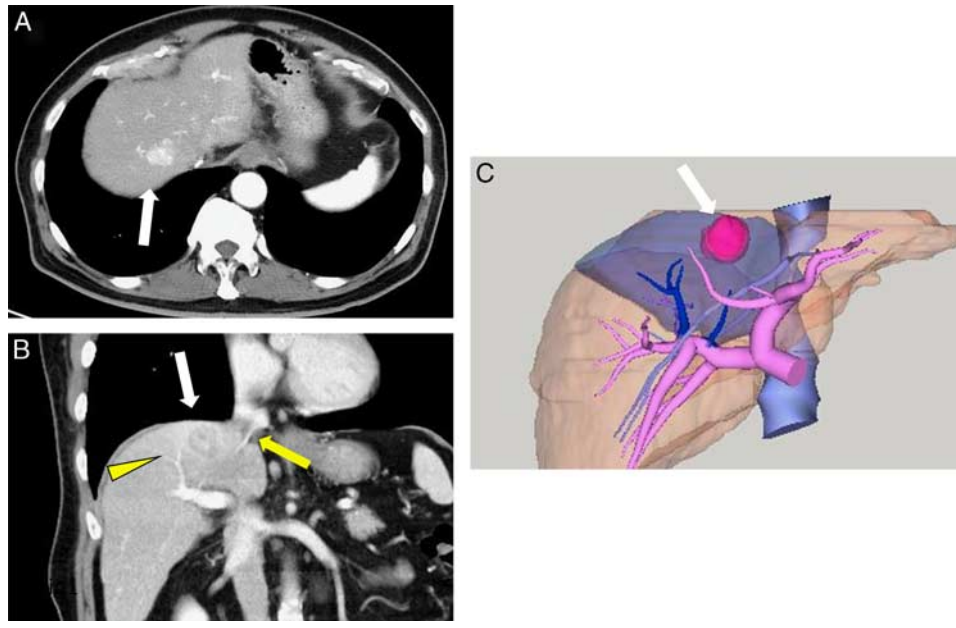

FIGURE 1. Computed tomography showed 2.5 cm tumor enhanced in early phase followed by washout in portal phase (A, B: white arrows). Portal branch of segment 8 (B: yellow arrowhead) feeding and middle hepatic vein (B: yellow arrow) running close to tumor. 3-dimensional computed tomography: tumor located in segment 8 (C: white arrow).

also showed a good liver function (Child-Pugh Classification A). Computed tomography scan findings revealed a 2.5-cm-sized HCC (Figs. 1A, B) and exactly indicated that the portal pedicle of S8 (P8) was feeding the tumor. The 3-dimensional (D) images of the liver and HCC were displayed using workstation software (Synapse Vincent; Fujifilm Corporation, Japan), as shown in Figure 1C. In line with the above information, laparoscopic anatomic S8 segmentectomy was planned.

Operative Procedures

The patient was left half-lateral, and total 5 ports have been placed for the operation. Intraoperative ultrasound (IOUS) examination revealed that the tumor was located in S8 and indicated the tumor-bearing portal branch of S8 (P8). First, the liver right lobe was mobilized by dissecting the right adrenal gland. Then, after stopping the pneumoperitoneum, the injection of normal saline into surgical space was subsequently started to get rid of carbon dioxide. Then, the position of the patient was changed into the Trendelenburg position. With B-mode US (Toshiba Medical Systems, Japan), percutaneous tumor-bearing portal vein puncture for P8 was performed, and 0.25 mg of ICG dye and 5 mg of indigo carmine was injected (Figs. 2A, B). Thereafter, the pneumoperitoneum started again; thus fluorescence-enhanced liver parenchyma was confirmed by the PINPOINT endoscopic fluorescent imaging system (Stryker, Germany) (Fig. 3). According to the fluorescence border, the parenchymal dissection with ultrasonic shears have been done until exposing the middle hepatic vein, and the Glissonean pedicle (G8) was finally divided (Figs. 4A–C). After complete resection, the specimen of S8 was retrieved by a camera port through an additional 2 cm incision followed by fascial closure, then the skin was closed.

RESULTS

The operation was completed without any intraoperative complication and intraoperative blood transfusion. The operative time was 375 minutes. The estimated intraoperative blood loss was 50 mL. A histologically negative surgical margin was achieved. The patient was discharged on the 19th

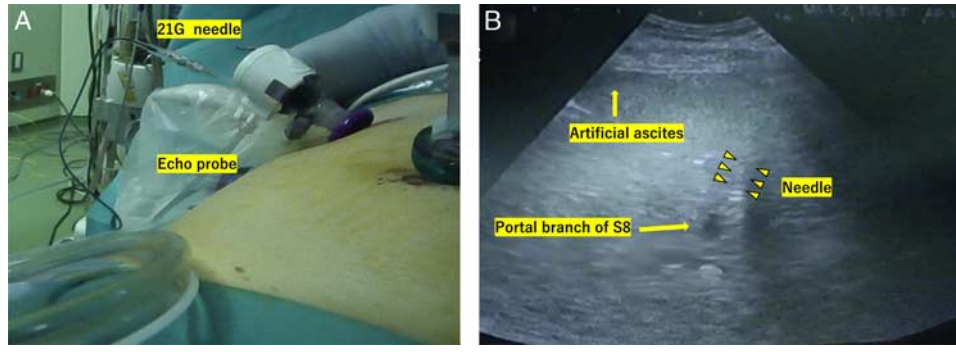

FIGURE 2. Percutaneous transhepatic portal vein puncture and indocyanine green injection (A). The echographic image showed artificial ascites, needle, and portal branch segment 8 (B).

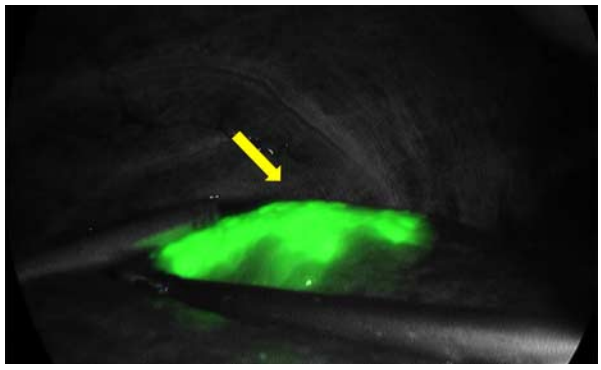

FIGURE 3. Indocyanine green (fluorescence segment 8: yellow arrow).

postoperative day with normal liver function tests. There were no operation-related complications during hospitalization.

DISCUSSION

ALR has been performed as a standardized procedure for HCC since Makuuchi et al[8] first reported the details in 1985. At present, various studies have reported the short-term and long-term benefits of ALR, including less blood loss, less complication, improved disease-free survival, and postoperative overall survival as compared with nonanatomic resection.[9]

The classic Makuuchi technique comprises intraoperative identification of tumor-bearing portal territory by US-guided portal branch puncture and injection of indigo carmine with temporal clamping of the hepatic artery to delay the washout of dye and the removal of all tumor-bearing liver parenchyma.[8] In contrast, the Glissonean pedicle approach was reported by Takasaki et al,[10] in which the Glissonean pedicle served as the tumor-bearing segment was extrahepatically encircled and clamped before liver transection inducing the ischemic demarcation area as the tumor-bearing territory. Both of 2 techniques have been widely accepted as commonly performed operation for ALR in worldwide, whereas there are a couple of drawbacks. First, in Makuuchi's method, the dying by indigo carmine can be diminished within several minutes due to early washout by hepatic blood flow and results in the identification of only superficial intersegment borderline, not the intrahepatic intersegmental plane. Similarly, Takasaki's method also has difficulty in the access to the target Glissonean pedicle depending on the patient's anatomic variation, especially for the posterosuperior segment. Moreover, the detection of the dying or ischemic demarcation line are quite difficult in case that there is heat degeneration of the liver surface by additional surgical procedures such as adhesionectomy.

In 2008, Aoki et al[11] have introduced ICG and near-fluorescence technology for anatomic resection offering an effective solution in terms of segment identification owing to the specific biochemical character. This liver-specific dye is almost completely absorbed by the hepatic cell remaining from 2 to 14 days, then finally excreted into the bile duct.[12] An ICG near-infrared fluorescence camera reveal the fluorescence-enhanced portal territorial borderline of not only the liver surface but also the intrahepatic parenchyma.

Currently, several experienced hepatobiliary centers have reported a variety of methods for laparoscopic ALR combined with ICG technology.[6,11,13] Ishizawa et al[6] have reported the positive and negative staining method in laparoscopic ALR: The former is a modified Makuuchi's technique, meaning that a US-guided portal vein puncture and the injection of ICG is followed by the removal of all liver parenchyma visualized by fluorescence. In contrast, the later method is a modified Takasaki's procedure, which involves an ICG systemic injection following to the dissection of the Glissonean pedicle feeding the tumor-bearing segment, which induces the ischemic nonfluorescence lesion.[6]

Although the positive or negative staining method have recently been adapted for laparoscopic ALR, there is still discussion remained about the better approach. A series of laparoscopic ALR including posterosuperior segmentectomy from Xu

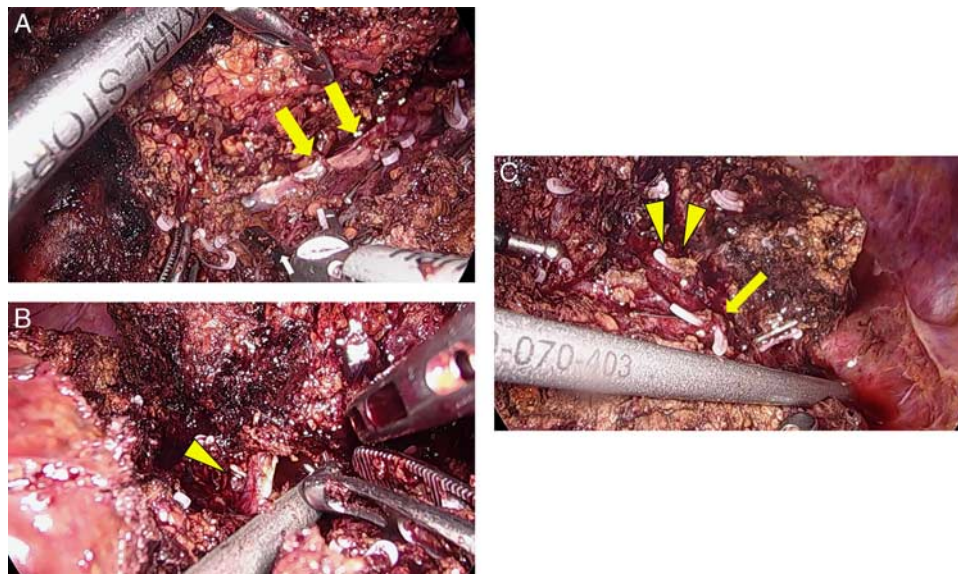

FIGURE 4. Middle hepatic vein was exposed (A: yellow arrows) and the Glissonean pedicle of segment 8 (G8) was identified (B: yellow arrowhead). The liver surface after operation showed the stump of G8 and middle hepatic vein (C: G8; arrowheads, middle hepatic vein; arrow).

et al[13] have reported the success rate of the positive and negative staining method at 67% and 44%, respectively. By contrast, Aoki et al[7] reported that the success rate of their modified, preoperative, percutaneous portal vein puncture method was 86%, which is much higher than that from Xu et al,[13] whose punctual techniques was nonpercutaneous methods under pure laparoscopic IOUS. This is understandable because, in percutaneous portal vein puncture, the interpretation of percutaneous B-mode US is relatively simple, and the adjustment of the needle to target portal vein is feasible as compared with laparoscopic IOUS. Therefore, a high success rate had been achieved, as the report from Aoki and colleagues had shown. Aoki focused on "a preoperative approach," not "an intraoperative approach" to avoid acoustic impedance by the pneumoperitoneum. Hence, in our experience, intraoperative injection of saline into the surgical field made it possible to get rid of both oxygen and carbon dioxide from the abdominal cavity allowing clear IOUS images like preoperative images.

Artificial ascites has recently been recognized as a useful device for percutaneous radiofrequency ablation as the treatment of HCC to enhance the US visualization.[14] The combination of artificial ascites with laparoscopic liver surgery have initially been described for laparoscopic segment 6 segmentectomy by Sakoda et al[15] to solve the difficulties encountered in laparoscopic IOUS. The details of the procedure were almost same as our technique except for the injection type. They used the indigo carmine alone, while we used the ICG dye. Their first report of this novel technique remains the only study in the current literature. There were no other case reports to the best of our knowledge. The possible reason is the technical complexity of clamping the hepatic artery in laparoscopic surgery, which are an essential technique for prevent the early fading of the dying and maintaining the mapping during the injection. Classic indigo dying can be rapidly washed out by the hepatic blood inflow in contrast that the biochemical character of ICG allows the fluorescence border to persist for several hours despite of the presence of hepatic arterial flow, then clear identification can be attained throughout the surgery.[13] Although our ICG system still requires switching the video-mode to confirm the fluorescence borderline interrupting the operation (Supplemental Digital Content 1, http://links.lww.com/SLE/A301), a newly developed laparoscopic system allows to overlay the fluorescence images on the visible surgical field simultaneously.[13] However, those system had only been introduced in the limited centers at that time. Thus, with the step-by-step improvement of surgical devices involving ICG technology, percutaneous portal vein puncture under artificial ascites becomes more practical and feasible, especially for laparoscopic posterosuperior segmentectomy.

Limitation of this method is that the success rate of percutaneous portal vein puncture is <100% because some cases have very small portal branch and multiple tumor-bearing portal branches, as reportedly.[7] For these reasons, other strategies such as 3D preoperative simulation, including 3D printing navigation or augmented reality navigation, should be prepared for difficult cases.[16]

CONCLUSION

The percutaneous portal vein puncture method under artificial ascites was useful for the identification of posterosuperior segment in laparoscopic ALR.

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