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BRIEF REPORT

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Practical application of indocyanine green fluorescence imaging in left hepatopancreatoduodenectomy for cholangiocarcinoma with right-sided ligamentum teres

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Abstract: We report the surgical techniques and outcomes of hepatopancreatoduodenectomy (HPD) using indocyanine green fluorescence imaging (ICG-FI) for Bismuth type IIIb perihilar cholangiocarcinoma in a patient with right-sided ligamentum teres. ICG-FI was used in three ways: *i*) positive staining to delineate the liver transection line, *ii*) confirmation of vascular perfusion, and *iii*) visualization of the bile duct. Because the bile duct of the ventral region of the right paramedian sector (RPM) drained into the left hepatic duct, an extended left hepatectomy including resection of the ventral region of the RPM was planned. Although the anatomical anomaly made it difficult to identify the liver transection line between the ventral and dorsal regions of the RPM using landmarks such as the hepatic veins and the falciform ligament, positive staining of the dorsal region of the RPM enabled accurate delineation of the transection line. As there was suspected tumor invasion into the right side of the main portal vein, wedge resection and reconstruction with short-axis suturing were performed. Subsequently, fluorescence was observed to pass through both the right hepatic artery and the reconstructed portal vein uninterruptedly, indicating continuous blood flow. ICG-FI also facilitated identification of the right hepatic duct. It was divided at the root, and the resection margin was confirmed to be negative by intraoperative frozen-section examination. HPD was successfully completed, achieving R0 resection with an operative time of 789 minutes and blood loss of 650 mL. The patient developed a pancreatic fistula, which resolved with drain management and antibiotic therapy, and was discharged on postoperative day 36. Integrated use of ICG-FI provided useful adjunctive guidance in this technically challenging case.

***Keywords*:** indocyanine green, fluorescence-guided surgery, right-sided ligamentum teres

1. Introduction

Right-sided ligamentum teres (RSLT) is a rare congenital anatomical anomaly that arises when the umbilical vein connects to the right paramedian branch of the portal vein instead of left portal vein (*1*). Reported incidence of RSLT ranges from 0.2% to 1.2% (*2,3*). RSLT is frequently associated with anatomical variations of the portal vein, hepatic veins, and biliary system (*4,5*). Consequently, hepatic resection in patients with RSLT requires meticulous preoperative evaluation and intraoperative decision-making (*5*), and it is particularly challenging in cases of cholangiocarcinoma with complex biliary and vascular anomalies (*4*). When extensive resection such as left hepatopancreatoduodenectomy (HPD) is required, accurate intraoperative identification of the hepatic transection line and critical structures becomes essential for patient safety. Despite advances in preoperative imaging, intraoperative confirmation of functional anatomy remains limited, particularly in patients with rare anatomical variations such as RSLT.

Since introduction of indocyanine green (ICG) fluorescence imaging (ICG-FI) into surgical practice, there has been a substantial expansion of its clinical applications. In the field of hepatobiliary and pancreatic surgery, ICG-FI has been widely used to intraoperatively identify liver tumors (*6*), visualize hepatic segments (*7*), and delineate the biliary tract (*8*), thereby contributing to improved surgical safety and oncological radicality. Moreover, ICG-FI has recently been applied not only to liver parenchyma but also to evaluation of vascular perfusion in the hepatic artery, portal vein, and hepatic veins (*9*). The ICG-FI technique has attracted increasing attention as a real-time intraoperative modality for assessing organ perfusion and patency of reconstructed vessels.

Although individual applications of ICG-FI for hepatic demarcation, vascular perfusion assessment, and biliary visualization have been previously reported (*7-9*), to our knowledge, their integrated use during left HPD in a patient with RSLT has not previously been described. Herein, we present an integrated use of ICG-FI to safely perform left HPD in a patient with cholangiocarcinoma and RSLT.

2. Materials and Methods

2.1. Preoperative evaluation

A 77-year-old man with a medical history of hypertension, dyslipidemia, diabetes mellitus, and gastroesophageal reflux disease presented with brown urine and was diagnosed with Bismuth type IIIb perihilar cholangiocarcinoma. Liver function was well preserved (Table 1). Contrast-enhanced computed tomography (CT) revealed bile duct wall thickening, predominantly involving the root of the left hepatic duct (LHD) and extending to the confluence of the cystic duct (Figure 1). Imaging also revealed RSLT originating from the right portal branch, with the gallbladder located on its left side. The bile duct of the ventral region of the right paramedian sector (RPM) drained into the LHD, while the portal vein of this region drained into the right-sided umbilical portion. Therefore, an extended left hepatectomy including the ventral region of the RPM was planned. The future liver remnant volume after extended left hepatectomy was 568 mL, corresponding to 52% of the total liver volume. Figure 2 shows the preoperative simulation based on CT imaging and planned transection lines. Transection of the distal bile duct was initially planned at the superior border of the pancreas. If intraoperative frozen-section examination revealed malignancy at the distal bile duct margin, additional pancreatoduodenectomy with distal bile duct resection was planned. This strategy was explained to the patient preoperatively, and informed consent was obtained.

2.2. Intraoperative ICG-guided evaluation

RSLT was observed intraoperatively (Figure 3a). ICG-FI was applied for the following three purposes: *i*) positive staining to delineate the liver transection line by injecting ICG into the portal vein branch (*10,11*); *ii*) confirmation of vascular perfusion (*9*); and *iii*) identification of a hepatic duct (*8*). Method *ii*) was achieved through intravenous injection of ICG. Method *iii*) was subsequently performed using the same intravenous ICG injection, without additional administration. ICG-FI was performed using the IMAGE1 S™ Rubina® Lens system with IMAGE1 S™ 4U Rubina® camera head and Rubina® Lens, NIR/ICG Exoscope 90° (KARL STORZ, Tuttlingen, Germany). Fluorescence images were observed using the Overlay and Monochromatic display modes. Brightness and gain were automatically controlled by the imaging system, and no manual adjustments were performed or recorded.

2.3. Ethics statement

This study was approved by the Institutional Review

Table 1. Laboratory findings with normal reference ranges

Laboratory test	Result	Normal range	Unit
WBC	5,700	3,300–8,600	cells/μL
Hb	12.4	13.7–16.8	g/dL
Plt	24.2	15.8–34.8	$\times 10^4$/μL
Alb	4.2	4.1–5.1	g/dL
T-Bil	0.9	0.4–1.5	mg/dL
D-Bil	0.5	0.0–0.4	mg/dL
AST	23	13–30	IU/L
ALT	66	10–42	IU/L
ALP	245	38–113	IU/L
GGT	849	13–64	IU/L
LDH	115	124–222	IU/L
Cr	0.84	0.65–1.07	mg/dL
PT	82	70–130	%
CRP	0.36	0.00–0.14	mg/dL
CEA	3.6	≤ 5.0	ng/mL
CA19-9	6.0	≤ 37	U/mL
ICG-R15	7.1	0.0–10.0	%

Abbreviations: WBC, white blood cell; Hb, hemoglobin; Plt, platelets; Alb, albumin; T-Bil, total bilirubin; D-Bil, direct bilirubin; AST, aspartate aminotransferase; ALT, alanine aminotransferase; ALP, alkaline phosphatase; GGT, γ-glutamyl transferase; LDH, lactate dehydrogenase; Cr, creatinine; PT, prothrombin time; CRP, C-reactive protein; CEA, carcinoembryonic antigen; CA19-9, carbohydrate antigen 19-9; ICG-R15, indocyanine green retention rate at 15 min.

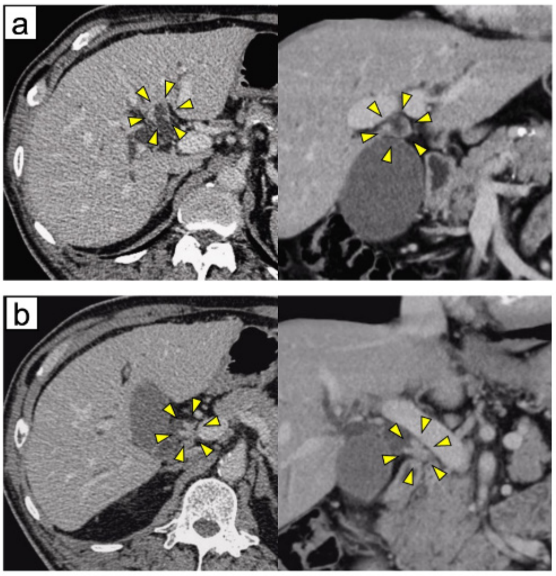

Figure 1. Preoperative contrast-enhanced computed tomography. Axial (left) and coronal (right) images reveal bile duct wall thickening, predominantly involving the root of the left hepatic duct **(a)** and extending to confluence of the cystic duct **(b)**. The lesion is indicated by yellow arrowheads. There was no tumor invasion of the right hepatic artery.

Board of Osaka Metropolitan University Hospital (approval #2020-227) and was conducted in accordance with the Declaration of Helsinki, as revised in 2013. Written informed consent was obtained from the patient prior to surgery for use of the clinical data and for publication of case details and accompanying images.

3. Results and Discussion

3.1. Surgical technique

Although the RSLT originated between the ventral and dorsal regions of the RPM, the falciform ligament was attached toward the left hepatic lobe. Consequently, the falciform ligament was not applicable as a reliable landmark for determining the liver transection line (Figure 3b). Furthermore, there were no clear anatomical landmarks, such as hepatic veins, present between the ventral and dorsal regions of the RPM. It was considered technically difficult to perform extrahepatic isolation and division of the portal vein branch supplying ventral region of the RPM; therefore, positive staining was employed. As it would have been technically challenging to puncture the portal vein branch supplying the ventral region of the RPM, the portal vein branch supplying the dorsal region of the RPM was punctured under ultrasonographic guidance, and a mixture of 0.25 mg of ICG and 5 mL of indigo carmine was injected. Immediately after injection, the dorsal region of the RPM was selectively stained, clearly delineating the boundary between ventral and dorsal regions, which corresponded to the planned liver transection line (Figure 3b). Because there was suspected tumor invasion into the right side of the main portal vein, wedge resection and reconstruction with short-axis suturing were performed. In addition to intraoperative Doppler ultrasonography for blood flow assessment, ICG (2.5 mg) was intravenously injected to evaluate blood flow in the preserved right hepatic artery and reconstructed portal vein. Fluorescence was observed to pass through both vessels uninterruptedly (Figure 4a). Hepatic parenchymal transection was performed along the line visualized by positive staining, enabling identification of the umbilical portion. After division of the RSLT continuous with the umbilical portion, the Glissonian pedicle of the ventral region of the RPM extending from the umbilical portion toward

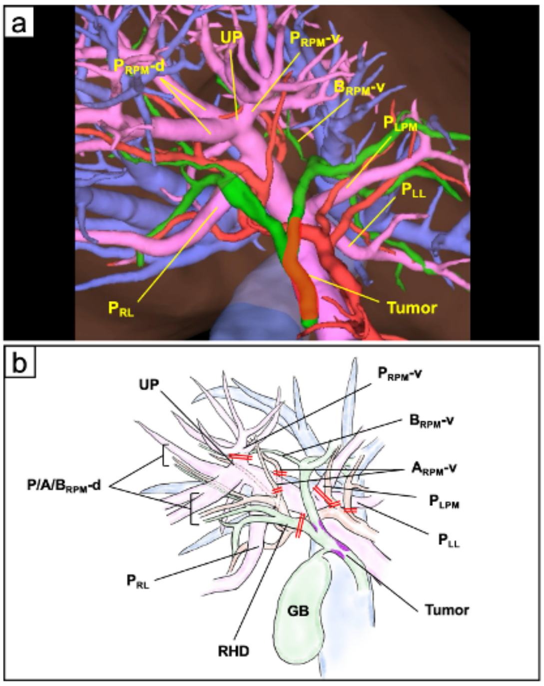

Figure 2. Preoperative evaluation. (a) The portal vein, bile duct, hepatic vein, and hepatic artery are shown in purple, green, blue, and red, respectively, on three-dimensional reconstructed contrast-enhanced computed tomography imaging. Extent of tumor is indicated by the red region of the bile duct. **(b)** Preoperative schematic showing planned resection line (double red line). *Abbreviations*: UP, umbilical portion; P/A/B_{RPM}-d, dorsal branch of the right paramedian portal vein/hepatic artery/bile duct; P_{RPM}-v, ventral branch of the right paramedian portal vein; B_{RPM}-v, ventral branch of the right paramedian bile duct; A_{RPM}-v, ventral branch of the right paramedian hepatic artery; P_{LPM}, left paramedian portal vein; P_{LL}, left lateral portal vein; P_{RL}, right lateral portal vein; RHD, right hepatic duct; GB, gallbladder.

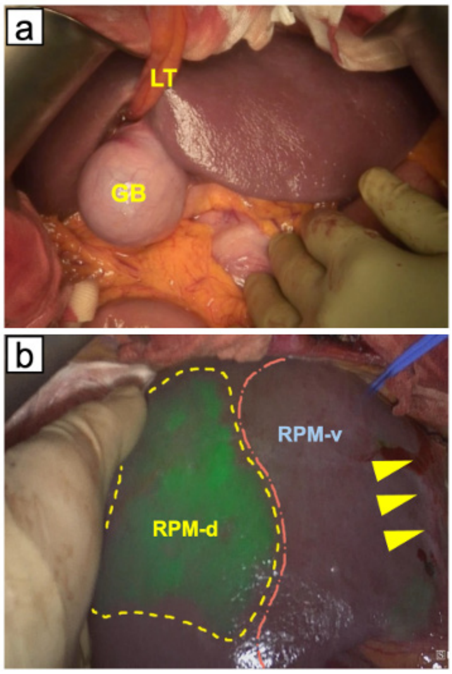

Figure 3. Intraoperative findings. (a) The ligamentum teres is located on the right side of the gallbladder. **(b)** Positive staining of dorsal region of right paramedian sector (RPM). Indocyanine green fluorescence is observed in the dorsal region of the RPM (dotted yellow line) using a positive staining technique. Liver transection line (orange point-and-line representation) is delineated along boundary between ventral and dorsal regions of the RPM, which differs from adjacent portion of the ligamentum teres (yellow arrowheads). *Abbreviations*: LT, ligamentum teres; GB, gallbladder; RPM-d, dorsal region of the right paramedian sector; RPM-v, ventral region of the right paramedian sector.

the resected liver side was identified and divided, thereby completing the planned hepatic parenchymal transection. Using ICG-FI, the right hepatic duct within the hilar plate was visualized and divided at its root (Figure 4b). Intraoperative frozen-section examination confirmed no malignancy at the right hepatic duct margin. After portal vein reconstruction and before hepatic parenchymal transection, intraoperative frozen-section examination of the distal bile duct margin on the duodenal side revealed adenocarcinoma rather than atypical cells. Given the possibility of vertical tumor invasion, including pancreatic invasion, we determined that R0 resection could be achieved by adding pancreatoduodenectomy, as anticipated in the preoperative surgical plan. Left hepatectomy was therefore continued, followed by pylorus-preserving pancreatoduodenectomy after removal of the liver specimen. Operative time was 789 minutes, and estimated blood loss was 650 mL. The total intraoperative dose of ICG was 2.75 mg, consisting of 0.25 mg for positive staining and 2.5 mg administered intravenously.

3.2. Postoperative outcomes

The patient developed a postoperative pancreatic fistula that was classified as Grade B according to International Study Group of Pancreatic Surgery classification (*12*) and Grade IIIa according to Clavien–Dindo classification. The pancreatic fistula resolved with antibiotic therapy and appropriate drain management, including drain replacement and repositioning. There were no other postoperative complications such as liver failure. The patient was discharged on postoperative day 36. Contrast-enhanced CT performed on postoperative day 41 demonstrated patency of both the right hepatic artery and portal vein, with no evidence of hepatic ischemia. Although adenocarcinoma was detected at the distal bile duct margin on the duodenal side, additional resection resulted in histopathologically negative proximal and final distal bile duct margins, confirming an R0 resection. Final pathological diagnosis was pT2aN0M0, stage II disease according to the 8th edition of the UICC TNM Classification of Malignant Tumours. At 18 months postoperatively, there is no evidence of recurrence.

3.3. Clinical implications of ICG-FI during surgery

This report demonstrates that integrated use of ICG-FI provided useful adjunctive guidance in this particular technically challenging case involving complex biliary and vascular anomalies associated with RSLT. The present case was classified as the bifurcation type in the portal system and the symmetrical type in the bile system based on previous reports (*4,5*). The patient had multiple

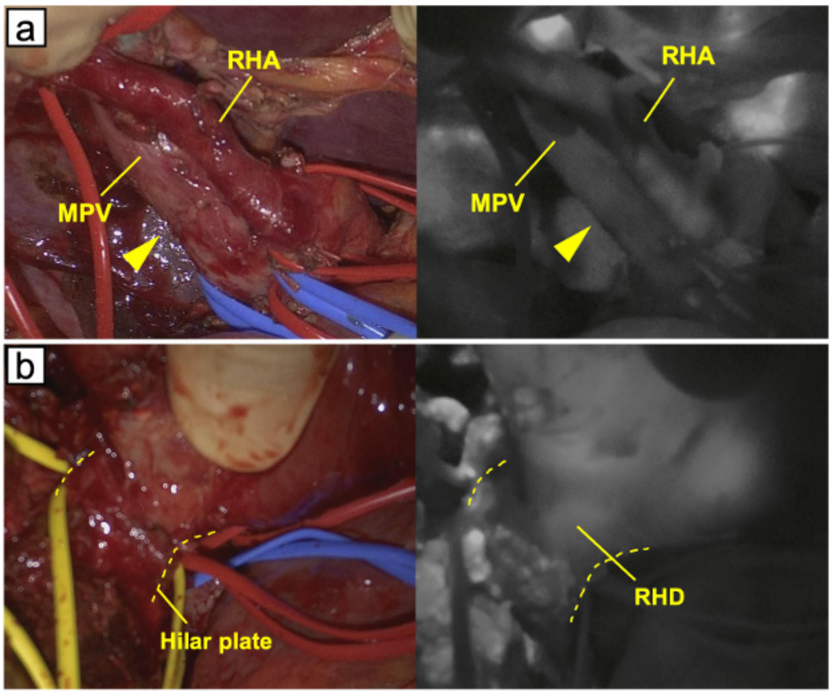

Figure 4. Indocyanine green fluorescence imaging performed to confirm vascular perfusion and visualize the bile duct. (a) Indocyanine green fluorescence imaging (ICG-FI) in Monochromatic display mode demonstrated uninterrupted fluorescence passage through right hepatic artery and reconstructed portal vein (yellow arrowhead) after wedge resection of main portal vein. Blood flow was assessed in combination with intraoperative Doppler ultrasonography. Following intravenous ICG injection, fluorescence was observed in right hepatic artery at 30 seconds and in reconstructed portal vein at 40 seconds, with uninterrupted passage through both vessels. **(b)** ICG-FI in Monochromatic display mode shows right hepatic duct within the hilar plate (dotted yellow line), visualized 95 minutes after intravenous injection of 2.5 mg of ICG. *Abbreviations*: RHA, right hepatic artery; MPV, main portal vein; RHD, right hepatic duct.

anatomical variations, namely RSLT and anomalous biliary drainage in which only the bile duct from the ventral region of the RPM drained into the LHD. Based on these anatomical findings and extent of tumor spread, liver transection along the boundary between the ventral and dorsal regions of the RPM was required. Despite the ligamentum teres originating between the ventral and dorsal regions of the RPM, the falciform ligament was deviated and attached toward the left hepatic lobe. As a result, there was no reliable anatomical landmark to delineate the boundary between these regions during extended left hepatectomy. Therefore, positive staining with ICG was used to accurately identify and define the liver transection line. ICG-FI enabled clear visualization of the intended transection line, allowing precise and safe hepatic parenchymal transection without excessive or insufficient resection (*7*).

ICG-FI was also useful for intraoperative visualization of blood flow in the reconstructed portal vein and preserved hepatic artery, demonstrating uninterrupted fluorescence passage through these vessels in real time. In this case, vascular flow was assessed using ICG-FI in conjunction with intraoperative Doppler ultrasonography. This complementary assessment may be helpful for intraoperative evaluation of reconstructed vessels and in determining need for revision of vascular reconstruction (*9*). In addition, even in cases with anatomical vascular and biliary variations, such as those requiring identification of the course of the right hepatic duct, ICG-FI may serve as a valuable real-time navigation tool to facilitate intraoperative understanding of complex anatomy (*9,13,14*).

We acknowledge that each application of ICG-FI used in this case—hepatic demarcation, vascular perfusion assessment, and biliary visualization—has been previously reported (*15-18*). However, the novelty of this report lies not in the technique itself, but in its strategic integration and application in a rare and complex anatomical setting. When performing HPD, even minor errors in hepatic transection or vascular reconstruction can lead to fatal outcomes, as reflected by high morbidity and mortality rates of HPD despite recent advances in perioperative management (*19-22*). Moreover, in challenging HPD cases such as those involving RSLT, conventional anatomical landmarks may be unreliable. In addition to preoperative imaging evaluation, ability to confirm hepatic perfusion and biliary anatomy in real time may reduce reliance on subjective anatomical interpretation and enhance procedural safety.

3.4. Limitation of this study

This report has several limitations. First, interpretation of fluorescence findings was qualitative and therefore subject to operator-dependent judgment. Second, near-infrared fluorescence has limited tissue penetration, which may restrict visualization of deeper anatomical structures. Third, this report is based on a single case performed at an experienced hepatobiliary-pancreatic center, which may limit generalizability of our findings to other patients or institutions. Nevertheless, integrated ICG-FI may serve as a useful adjunct in cases with rare and complex anatomical variations.

4. Conclusion

Integrated use of ICG-FI provided useful adjunctive guidance in this technically challenging case of left HPD for perihilar cholangiocarcinoma with RSLT. Specifically, ICG-FI assisted in delineating the hepatic transection line and anatomically identifying the right hepatic duct. Uninterrupted fluorescence passage was observed through the preserved right hepatic artery and reconstructed portal vein, while vascular flow was assessed in conjunction with intraoperative Doppler ultrasonography. These findings illustrate feasibility of combining complementary ICG-FI applications in this individual case; further cases are required to evaluate reproducibility and broader clinical utility of this approach.

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Conflict of Interest: The authors have no conflicts of interest to disclose.

References

1. Lin HY, Lee RC. Is right-sided ligamentum teres hepatis always accompanied by left-sided gallbladder? Case reports and literature review. Insights Imaging. 2018; 9:955-960.
2. Nagai M, Kubota K, Kawasaki S, Takayama T, Bandai Y, Makuuchi M. Are left-sided gallbladders really located on the left side? Ann Surg. 1997; 225:274-280.
3. Maetani Y, Itoh K, Kojima N, Tabuchi T, Shibata T, Asonuma K, Tanaka K, Konishi J. Portal vein anomaly associated with deviation of the ligamentum teres to the right and malposition of the gallbladder. Radiology. 1998; 207:723-728.
4. Shindoh J, Akahane M, Satou S, Aoki T, Beck Y, Hasegawa K, Sugawara Y, Ohtomo K, Kokudo N. Vascular architecture in anomalous right-sided ligamentum teres: Three-dimensional analyses in 35 patients. HPB (Oxford). 2012; 14:32-41.
5. Nishitai R, Shindoh J, Yamaoka T, Akahane M, Kokudo N, Manaka D. Biliary architecture of livers exhibiting right-sided ligamentum teres: An indication for preoperative cholangiography prior to major hepatectomy. HPB (Oxford). 2016; 18:929-935.
6. Ishizawa T, Fukushima N, Shibahara J, Masuda K, Tamura S, Aoki T, Hasegawa K, Beck Y, Fukayama M, Kokudo N. Real-time identification of liver cancers by using indocyanine green fluorescent imaging. Cancer. 2009; 115:2491-2504.
7. Aoki T, Yasuda D, Shimizu Y, Odaira M, Niiya T, Kusano T, Mitamura K, Hayashi K, Murai N, Koizumi T, Kato H, Enami Y, Miwa M, Kusano M. Image-guided liver

mapping using fluorescence navigation system with indocyanine green for anatomical hepatic resection. World J Surg. 2008; 32:1763-1767.
8. Ishizawa T, Bandai Y, Kokudo N. Fluorescent cholangiography using indocyanine green for laparoscopic cholecystectomy: an initial experience. Arch Surg. 2009; 144:381-382.
9. Fujimoto H, Kinoshita M, Ahn C, *et al*. Real-time blood flow assessment using ICG fluorescence imaging during hepatobiliary and pancreatic surgery with consideration of vascular reconstruction. Cancers (Basel). 2025; 17.
10. Inoue Y, Arita J, Sakamoto T, Ono Y, Takahashi M, Takahashi Y, Kokudo N, Saiura A. Anatomical liver resections guided by 3-dimensional parenchymal staining using fusion indocyanine green fluorescence imaging. Ann Surg. 2015; 262:105-111.
11. Ishizawa T, Zuker NB, Kokudo N, Gayet B. Positive and negative staining of hepatic segments by use of fluorescent imaging techniques during laparoscopic hepatectomy. Arch Surg. 2012; 147:393-394.
12. Bassi C, Marchegiani G, Dervenis C, *et al*. The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 Years After. Surgery. 2017; 161:584-591.
13. Rompianesi G, Pegoraro F, Ramaci L, Ceresa CD, Montalti R, Troisi RI. Preoperative planning and intraoperative real-time navigation with indocyanine green fluorescence in robotic liver surgery. Langenbecks Arch Surg. 2023; 408:292.
14. Avella P, Spiezia S, Rotondo M, Cappuccio M, Scacchi A, Inglese G, Guerra G, Brunese MC, Bianco P, Tedesco GA, Ceccarelli G, Rocca A. Real-time navigation in liver surgery through indocyanine green fluorescence: An updated analysis of worldwide protocols and applications. Cancers (Basel). 2025; 17:872.
15. Ishizawa T, Saiura A, Kokudo N. Clinical application of indocyanine green-fluorescence imaging during hepatectomy. Hepatobiliary Surg Nutr. 2016; 5:322-328.
16. Strigalev M, Tzedakis S, Nassar A, Dhote A, Gavignet C, Gaillard M, Marchese U, Fuks D. Intra-operative indocyanine green fluorescence imaging in hepatobiliary surgery: A narrative review of the literature as a useful guide for the surgeon. Updates Surg. 2023; 75:23-29.
17. Itoh S, Tomiyama T, Morinaga A, Kurihara T, Nagao Y, Toshima T, Morita K, Harada N, Mori M, Yoshizumi T. Clinical effects of the use of the indocyanine green fluorescence imaging technique in laparoscopic partial liver resection. Ann Gastroenterol Surg. 2022; 6:688-694.
18. Guan J, Liang R, Peng Y, Yu X, Yuan R, Hu Z, Wu H, Zhou B, Qiu Y, Wang K. An evaluation of the effectiveness of 3D virtual imaging combined with intraoperative ultrasonography to guide liver staining in anatomic segmental hepatectomy. Glob Health Med. 2025; 7:315-323.
19. Welch JC, Gleeson EM, Karachristos A, Pitt HA. Hepatopancreatoduodenectomy in North America: are the outcomes acceptable? HPB (Oxford). 2020; 22:360-367.
20. Fancellu A, Sanna V, Deiana G, Ninniri C, Turilli D, Perra T, Porcu A. Current role of hepatopancreatoduodenectomy for the management of gallbladder cancer and extrahepatic cholangiocarcinoma: A systematic review. World J Gastrointest Oncol. 2021; 13:625-637.
21. Nakagawa A, Sugawara G, Ebata T, Yokoyama Y, Igami T, Shingu Y, Nagino M. Hepatopancreatoduodenectomy with arterial reconstruction for extrahepatic cholangiocarcinoma with celiac axis obstruction: Report of a case. Surg Today. 2014; 44:2374-2377.
22. Endo I, Hirahara N, Miyata H, *et al*. Mortality, morbidity, and failure to rescue in hepatopancreatoduodenectomy: An analysis of patients registered in the National Clinical Database in Japan. J Hepatobiliary Pancreat Sci. 2021; 28:305-316.

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