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Advances in Indocyanine Green Fluorescence Imaging for Laparoscopic Hepatectomy

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ABSTRACT

Indocyanine green (ICG) near-infrared fluorescence imaging enables real-time, repeatable, and radiation-free navigation during laparoscopic hepatectomy. Its applications have expanded from tumor localization to segmental staining, delineation of anatomical resection planes, margin assessment, biliary visualization, and evaluation of parenchymal perfusion. Current evidence indicates that ICG-guided surgery is associated with improved detection of small or superficial lesions, higher R0 resection rates, and improvements in selected perioperative outcomes. Nevertheless, performance is affected by liver function, dose and timing, lesion depth, staining strategy, and imaging-system characteristics. Evidence from robust randomized trials and long-term oncological follow-up remains limited. This narrative review summarizes the principles, clinical applications, evidence, limitations, and future directions of ICG fluorescence imaging in laparoscopic hepatectomy, with emphasis on Chinese- and English-language literature published from 2021 to 2025.

KEYWORDS

Indocyanine green; Near-infrared fluorescence; Laparoscopic hepatectomy; Anatomical liver resection; Liver neoplasm; Precision surgery

1. INTRODUCTION

Laparoscopic hepatectomy offers the advantages of reduced surgical trauma, faster postoperative recovery, and fewer incision-related complications, and is now widely used to treat hepatocellular carcinoma, liver metastases, and selected benign liver tumors. However, laparoscopic surgery lacks direct palpation and visualization is largely confined to the liver surface. In patients with cirrhosis, small tumors, or lesions in the posterosuperior segments, reliance on preoperative imaging and intraoperative ultrasonography alone may still result in difficult lesion localization, poorly defined anatomical boundaries, or uncertainty in margin assessment. Indocyanine green (ICG) fluorescence imaging converts otherwise invisible differences in tumor metabolism, portal venous territories, and bile flow into real-time visual signals, providing a new approach to these challenges. Chinese expert consensus integrates digital intelligence, molecular fluorescence navigation, and precision hepatectomy, while international consensus provides recommendations on indications and basic workflows for fluorescence imaging in hepatobiliary surgery [1, 2].

ICG fluorescence should complement, rather than replace, intraoperative ultrasonography and other established navigation methods. Its clinical value depends on effective integration with preoperative planning, intraoperative ultrasonography, hilar anatomy, low-central-venous-pressure anesthesia, and meticulous parenchymal transection. Recent research has shifted from simply asking whether

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fluorescence can be visualized to determining how administration should be standardized, whether margins and complications can be improved, and whether the technology provides long-term oncological benefit. A structured review of recent evidence is therefore needed to define the clinical scenarios in which ICG is most useful and the established methods it cannot replace.

2. SCOPE AND REVIEW APPROACH

This narrative review synthesizes Chinese- and English-language publications from 2021 through 2025. The cited literature was selected to represent recent consensus recommendations, clinical studies, comparative cohorts, and systematic reviews addressing the principal applications of ICG fluorescence in laparoscopic hepatectomy. The synthesis emphasizes clinical utility, technical limitations, and perioperative and oncological evidence; it is not intended as a systematic review or meta-analysis.

3. PRINCIPLES AND TECHNICAL BASIS OF ICG FLUORESCENCE IMAGING

3.1. Pharmacokinetic and Optical Basis

ICG is a water-soluble tricarbocyanine dye. After intravenous injection, it rapidly binds to plasma proteins, is taken up by hepatocytes, and is excreted almost entirely in bile without undergoing enterohepatic circulation. ICG fluoresces under near-infrared (NIR) excitation. Common NIR-I systems use excitation wavelengths of approximately 750-810 nm and detect emission at approximately 830-850 nm. Compared with visible light, near-infrared light is less affected by absorption by hemoglobin and water and can penetrate several millimeters to approximately 1 cm of tissue, making it suitable for visualizing surface liver lesions, segmental boundaries, and superficial bile ducts[2,3]. This penetration depth is also a fundamental limitation: deep tumors and vascular structures covered by thick liver parenchyma cannot be identified reliably by fluorescence alone.

Normal hepatocytes clear ICG rapidly, whereas hepatocellular carcinoma (HCC) and surrounding tissue may exhibit persistent fluorescence because of altered cellular uptake, impaired biliary excretion, or compression of bile canaliculi. Well-differentiated HCC commonly shows homogeneous or partial fluorescence, whereas poorly differentiated HCC and some metastatic tumors more often show rim-type fluorescence. Tumor type, differentiation, fibrotic background, and the interval between injection and surgery jointly determine the fluorescence pattern; fluorescence morphology can therefore suggest a lesion but cannot replace pathological diagnosis [2, 4].

3.2. Routes, Dose, and Timing of Administration

ICG administration for liver resection generally comprises preoperative intravenous injection and intraoperative targeted staining. Preoperative administration is mainly used for tumor localization and is usually performed several days before surgery, allowing the background signal in normal liver parenchyma to subside while tumor-related fluorescence persists. Clearance is delayed in patients with cirrhosis, cholestasis, or impaired liver function, and a longer interval or lower dose may be required. Late injection may produce an excessively strong background, whereas very early injection may weaken the signal from some lesions. Intraoperative intravenous injection is commonly used for negative staining and perfusion assessment, whereas injection into a portal venous branch is used for positive staining. Because device sensitivity, body weight, and liver function vary substantially, a fixed universal dose is inappropriate; administration should be adjusted to the imaging objective within an institutional protocol [1, 2, 5].

Before administration, clinicians should verify any history of ICG hypersensitivity, liver function, lesion location, and the planned staining method, and should be prepared to monitor and manage allergic reactions. Tumor localization, portal venous staining, and biliary imaging may be performed sequentially during the same operation; repeated injections increase background fluorescence, so the sequence and minimum effective dose should be determined in advance. The distance and angle between the fluorescence camera and the liver surface, ambient light, and gain settings also influence brightness. Imaging parameters should therefore be kept as consistent as possible for intraoperative comparisons.

Clinical quality control for ICG administration can be divided into assessment, implementation, and confirmation. During assessment, the protocol is selected according to liver function, bilirubin level, tumor depth, and the planned timing of surgery. During implementation, the dilution, actual dose, route, and time of injection are documented. During confirmation, previous administration details are checked before skin incision, and the entire liver is initially scanned at a standardized distance after abdominal access. If the background signal is unusually intense, observation conditions should first be adjusted and ultrasonography should be relied upon rather than immediately repeating the injection. When tumor visualization and segmental staining are both planned, the temporal relationship between the two signals should be incorporated into the preoperative workflow to prevent the later injection from obscuring information from the earlier one [1, 2].

4. MAJOR APPLICATIONS OF ICG FLUORESCENCE IN LAPAROSCOPIC HEPATECTOMY

4.1. Tumor Localization and Detection of Small Lesions

After preoperative ICG injection, the laparoscopic near-infrared mode enables rapid scanning of the liver surface despite the absence of palpation, helps localize small tumors identified on preoperative imaging, and may reveal subcentimeter or satellite lesions that are difficult to recognize under conventional white light. In recurrent liver cancer, scar adhesion on the liver surface, and lesions in the posterosuperior segments, fluorescence provides an intuitive surface projection and can reduce the time spent repeatedly searching for the lesion. Chinese clinical studies have reported that this technique assists localization and margin assessment during laparoscopic resection of primary liver cancer [6, 7]. Fluorescence-fusion imaging can also superimpose white-light anatomy and fluorescence information, reducing spatial-judgment errors caused by switching between two separate views [8].

Detection of an additional fluorescent nodule does not establish malignancy. Regenerative nodules in cirrhosis, inflammation, cholestasis, and focal abnormalities of hepatocellular excretion can all cause false-positive fluorescence, whereas lesions deeper than the effective penetration range may be false negative. Any fluorescence abnormality should therefore be evaluated together with preoperative contrast-enhanced CT or MRI, intraoperative ultrasonography, and, when necessary, frozen-section pathology. A rational workflow is to establish three-dimensional intrahepatic localization using preoperative imaging and ultrasonography, and then use fluorescence for surface confirmation and supplementary screening, rather than extending the resection solely because of a single fluorescent focus [2, 9].

In practice, the entire abdomen and liver surface can first be examined under white light, followed by fluorescence scanning in a systematic lobe-by-lobe sequence, with each fluorescent focus matched to its coordinates on preoperative imaging. If a known lesion is fluorescence-negative, lesion depth, the injection interval, and device status should be checked; lack of fluorescence does not exclude a tumor. If a focus is fluorescence-positive but has no ultrasonographic correlate, changing the camera angle, briefly compressing the liver surface, and repeating ultrasonography may help confirmation. Tissue sampling may be appropriate before undertaking an extensive resection. The pathological positivity

rate of newly detected fluorescent lesions is a more informative quality metric than simply reporting the number of additional nodules found [2, 6, 9].

4.2. Segmental and Sectional Staining in Anatomical Liver Resection

Anatomical liver resection aims to remove the target segment or subsegment completely along its portal venous territory. The conventional ischemic demarcation line shows only a surface color change and is often indistinct in cirrhotic livers or on deep transection planes. ICG staining converts a vascular territory into a persistent fluorescent boundary, allowing repeated correction of the transection direction during parenchymal division. The two basic strategies are positive and negative staining, selected according to target-territory size, accessibility of the portal venous branch, and operator experience.

Positive staining involves ultrasonography-guided puncture of the target portal venous branch and injection of diluted ICG so that the target territory fluoresces. This method is suitable for subsegmentectomy and for marking small deep regions, and can theoretically provide a three-dimensional boundary consistent with portal perfusion. However, the needle-tip position, injection pressure, and venous backflow all affect staining. Extravasation or inadvertent injection into an adjacent branch can cause overstaining and obscure the true boundary. Portal venous anatomy should be confirmed before puncture; injection should use a small dose at low pressure while early fluorescence spread is observed. If staining fails, the resection plan should be reassessed using ultrasonography and anatomical landmarks rather than repeatedly administering a large additional dose.

For negative staining, ICG is injected intravenously after division or clamping of the target Glissonean pedicle, causing the preserved liver parenchyma to fluoresce while the target territory remains dark. The technique is relatively straightforward and is particularly suitable for hemihepatectomy, sectionectomy, and resection of larger segments. A comparative study of positive and negative staining during laparoscopic anatomical liver resection for malignancy showed that both techniques can guide the transection plane, although success depends heavily on portal pedicle control and intraoperative ultrasonography [10]. A study of laparoscopic right posterior sectionectomy likewise showed that ICG can assist identification of the right posterior section boundary and the direction of deep transection [11].

Staining failures mainly include nonvisualization, blurred boundaries, inadvertent staining of adjacent territories, and an excessively bright whole-liver background. Causes include incomplete control of the target pedicle, patent communicating portal branches, inappropriate pedicle-management technique, excessive ICG dose, and unsuitable camera-system parameters. A review summarized common staining abnormalities and corrective strategies during laparoscopic anatomical liver resection [5]. A Chinese study of 91 laparoscopic anatomical hemihepatectomies reported a negative-staining success rate of 75.8% and found that extra-Glissonean pedicle dissection and a lower ICG dose were associated with better staining [12]. Thus, visualization of a boundary is not automatic; the quality of pedicle control remains central to the technique.

Fluorescence boundaries in complex liver segments should ideally be cross-validated with three-dimensional reconstruction, intraoperative ultrasonography, and the course of the hepatic veins. Three-dimensional models display portal venous variants and the planned resection volume before surgery, ultrasonography provides real-time deep localization, and fluorescence supplies a continuous boundary at the surface and in shallow tissue. Chinese research suggests that combining three-dimensional visualization with ICG navigation can facilitate planning of a precise laparoscopic resection pathway [13]. Cross-validation among modalities reduces the blind spots of any single technique, particularly for subsegmentectomy and resection of posterosuperior segments such as segments 7 and 8.

4.3. Resection Margin Navigation and Identification of Residual Lesions

In HCC and metastatic liver tumors, ICG can indicate the surface projection of a tumor before transection and help maintain spatial separation between the fluorescent lesion and the transection line. After resection, the specimen side and liver-bed side can be examined separately. Fluorescent foci in the specimen can be matched to the preoperative target, whereas residual fluorescence in the liver bed may indicate residual tumor, satellite lesions, or cholestasis and requires further assessment with ultrasonography and frozen-section pathology. This workflow is particularly useful for irregular lesions, tumors close to major vessels, and lesions requiring parenchymal-sparing resection.

Fluorescence cannot directly measure the microscopic surgical margin. Moreover, rim fluorescence may arise from compressed liver tissue surrounding a tumor; interpreting a bright rim as the tumor itself may therefore lead to incorrect estimation of the safe distance. Systematic reviews and meta-analyses suggest that ICG navigation is associated with a higher R0 resection rate [14, 15], although the result is influenced by study design, disease composition, type of resection, and surgeon-selection bias. A fluorescence-positive boundary should therefore be regarded as a risk zone requiring verification, while the final margin assessment should rely on specimen orientation, intraoperative ultrasonography, and pathology.

4.4. Identification of Biliary Anatomy and Adjunctive Assessment of Bile Leakage

Because ICG is excreted in bile, it can be used for near-infrared cholangiography to assist identification of the extrahepatic bile ducts during hilar dissection, cholecystectomy, or complex liver resection. Following intravenous or intrabiliary administration, fluorescence may show superficial bile ducts and some bile-leak points on the transection surface, providing guidance for clipping, suturing, or repeat inspection. The method is radiation-free and repeatable, but tissue penetration is limited; active bleeding, fat coverage, and intense liver-parenchymal background reduce contrast [2, 3]. Evidence that this approach lowers the rate of clinically relevant bile leakage after hepatectomy remains insufficient, and it cannot replace conventional bile-leak testing, cholangiography, or postoperative drain monitoring.

4.5. Evaluation of Hepatic Parenchymal Perfusion and the Future Liver Remnant

After intravenous ICG injection, dynamic observation of liver-surface perfusion can help define the ischemic territory after pedicle control and identify focal hypoperfusion in the future liver remnant. When a portal venous or hepatic arterial branch is managed close to a tumor, fluorescence may reveal perfusion differences before a color change is visible under white light. A study using negative-staining navigation during laparoscopic segmentectomy found a strong correlation between the fluorescence-predicted resection volume and the actual specimen volume, with particular value for controlling transection planes in the posterosuperior segments [16]. Nevertheless, surface fluorescence cannot fully represent deep microcirculation or functional liver reserve and must be interpreted together with preoperative liver function, remnant-liver volume, and intraoperative blood-flow assessment.

5. CLINICAL EVIDENCE AND OUTCOME EVALUATION

Early evidence consisted mainly of single-center retrospective cohorts and was strongly influenced by case selection and the learning curve. A 2021 meta-analysis suggested that ICG fluorescence-guided laparoscopic hepatectomy may offer advantages in lesion detection, margin status, and selected perioperative outcomes [17]. Subsequent propensity-score-matched studies attempted to control for confounders such as tumor size, extent of resection, and degree of cirrhosis. One study reported improved short-term outcomes with ICG-assisted laparoscopic anatomical liver resection

[18], while another matched cohort of patients with HCC evaluated both short- and long-term outcomes and provided additional evidence regarding oncological safety [19].

A recent systematic review of patients with HCC included 17 studies involving 1,620 patients, including four randomized controlled trials. Compared with conventional laparoscopic hepatectomy, ICG navigation was associated with mean reductions of approximately 23 min in operative time and 51 mL in blood loss, lower risks of transfusion and overall complications, and a higher R0 resection rate, while length of hospital stay did not differ significantly [15]. Another meta-analysis focused on surgical margins in malignant liver tumors also found a higher R0 resection rate in the ICG group but no clear difference in overall complications [14]. These findings support the perioperative value of ICG as a navigation tool, although effect estimates are limited by heterogeneity in technical protocols and study quality.

Not all studies have reached consistent conclusions. A single-center propensity-score-matched study in HCC found no significant between-group differences after propensity-score matching in margin status, blood loss, complications, length of stay, overall survival, or recurrence-free survival; operative time was longer in the ICG group [20]. This discrepancy may relate to study period, case complexity, injection protocol, and the surgeon learning curve, and may also indicate that conventional intraoperative ultrasonography and mature laparoscopic techniques already provide a high baseline standard. A cautious interpretation is that ICG improves intraoperative visual information and procedural certainty in selected complex settings, but its independent contribution to long-term survival has not been established.

Future outcome evaluations should not simply compare use versus nonuse. They should stratify by imaging objective, tumor type, anatomical versus nonanatomical resection, positive versus negative staining, and operator experience. Standardized endpoints should include the pathological positivity rate of newly detected lesions, staining success, deviation between actual and planned resection volumes, R0 resection, bile-leak grade, 90-day complications, and long-term recurrence patterns. Only by reducing technical heterogeneity can the patients who truly benefit be identified.

In the causal pathway, fluorescence most directly affects lesion detection, boundary recognition, and transection trajectory, and only subsequently may influence recurrence and survival through margins, blood loss, or complications. Improvement in short-term technical endpoints without a difference in long-term outcomes is therefore not contradictory. Future studies should prospectively stratify the degree of cirrhosis, lesion depth, major versus minor hepatectomy, and primary versus repeat surgery, and should report use of conventional intraoperative ultrasonography. Blinded pathological assessment and adequate follow-up are also needed to distinguish the effect of ICG itself from the effects of surgeon experience, device updates, and case selection [15, 19, 20].

6. LIMITATIONS, RISKS, AND KEY POINTS FOR STANDARDIZATION

First, penetration depth is limited. NIR-I fluorescence primarily reflects surface and shallow information; deep tumors, hepatic-vein roots, and bile ducts covered by thick parenchyma still require intraoperative ultrasonographic localization. Second, specificity is limited. ICG is a functional tracer rather than a tumor-specific probe, and inflammation, regenerative nodules, and cholestasis may all fluoresce. Third, background intensity and boundary definition depend on administration. An excessive dose, a short interval, or impaired hepatic clearance can produce diffuse background fluorescence, whereas extravasation during positive staining and incomplete pedicle control during negative staining can generate false boundaries. These limitations should be incorporated into institutional protocols and preoperative counseling.

Fourth, equipment and image interpretation have not been standardized. Laparoscopic platforms differ in excitation intensity, detector sensitivity, automatic gain, and fusion-display mode, and the same apparent brightness cannot be compared directly across devices. Most studies still depend on

the surgeon's subjective judgment of bright versus dark and lack calibrated signal-to-background thresholds and quality control. White-light, pure-fluorescence, and fusion images should be stored intraoperatively, together with the ICG brand, dose, injection time, liver function, imaging distance, and device model, to support multicenter comparisons and review of failed cases.

Fifth, the learning curve and process safety cannot be ignored. Positive staining requires precise ultrasonography-guided puncture of a small portal venous branch, whereas negative staining requires reliable control of the target Glissonean pedicle; indiscriminate additional dye usually only increases background fluorescence. Teams should begin with larger anatomical territories and superficial lesions, then progress to subsegmental and posterosuperior resections, while maintaining a contingency plan that returns to ultrasonography, ischemic demarcation, and venous landmarks if staining fails. ICG is generally well tolerated, but it should not be used in patients with known ICG hypersensitivity, and administration must occur where severe allergic reactions can be recognized and treated. Markedly impaired liver function also increases the risk of imaging bias caused by delayed clearance.

A standardized workflow can be summarized as follows: define the objective, individualize administration, perform multimodal cross-checking, interpret cautiously, and document completely. Before surgery, determine whether ICG will be used for tumor localization, segmental staining, biliary imaging, or perfusion assessment. During surgery, confirm anatomy and ultrasonographic findings before evaluating fluorescence. When a fluorescence abnormality is encountered, decisions to modify the procedure should be based on imaging, ultrasonography, and pathological evidence. Consensus documents and recent reviews emphasize that ICG should be embedded in the overall decision pathway of precision hepatectomy rather than used in isolation from the clinical context [1-3].

7. INTEGRATION WITH EMERGING TECHNOLOGIES AND FUTURE DIRECTIONS

Near-infrared-II (NIR-II) imaging generally uses longer-wavelength emission signals, which can reduce tissue scattering and autofluorescence and improve spatial resolution and the signal-to-background ratio. A Chinese expert consensus has addressed the use of ICG near-infrared-II fluorescence imaging in liver cancer resection and has provided recommendations on equipment, workflow, and clinical research [4]. Potential advantages include clearer visualization of small vessels and tumor boundaries; however, actual penetration remains constrained by tissue and system performance, and device calibration, dose standards, and clinical benefit require validation in prospective studies.

Three-dimensional reconstruction, augmented reality, and fluorescence fusion can superimpose static preoperative planning on dynamic intraoperative information. A three-dimensional model depicts the relationship between deep vessels and the tumor, fluorescence shows real-time surface perfusion and the resection territory, and ultrasonography corrects for liver deformation. If stable registration algorithms can be established, surgeons may simultaneously view the planned transection plane, critical vessels, and the true fluorescence boundary during parenchymal division. Artificial intelligence may also support automatic segmentation of fluorescent regions, quantification of the signal-to-background ratio, and recognition of abnormal dye spread, enabling a shift from subjective brightness assessment to reproducible quantitative navigation.

Another direction is the development of tumor-specific fluorescent probes and multichannel imaging so that tumors, bile ducts, and vessels can be displayed simultaneously with distinct signals. Clinical research should meanwhile prioritize three questions: whether the optimal dose and timing can be stratified by liver function; which types of resection provide reproducible perioperative benefit; and whether the additional costs of equipment and workflow translate into better long-term outcomes.

Multicenter randomized trials, standardized imaging datasets, and health-economic evaluations will determine whether the technology can progress from an experience-dependent adjunct to a standardized navigation platform.

8. CONCLUSION

ICG fluorescence imaging expands the laparoscopic surgeon's real-time perception of liver-surface tumors, portal venous territories, biliary anatomy, and perfusion status, and is an important adjunct to precision liver resection. Current evidence supports its use for tumor localization, delineation of anatomical resection boundaries, and margin assessment, and suggests that selected perioperative outcomes may improve. However, limited tissue penetration, nonspecific signals, heterogeneity in administration and equipment, and insufficient long-term evidence mean that it cannot replace intraoperative ultrasonography, standardized anatomical technique, or pathological assessment. Through individualized administration, multimodal integration, quantitative imaging, and high-quality clinical research, ICG fluorescence navigation may progress from making structures visible to making them accurately visible, consistently usable, and demonstrably beneficial.

REFERENCES

[1] Digital Medicine Branch of the Chinese Medical Association, Liver Cancer Professional Committee of the Chinese Medical Doctor Association, Minimally Invasive Surgeon Committee of the Surgeon Branch of the Chinese Medical Doctor Association, et al. (2022). Chinese expert consensus on digital intelligence combined with indocyanine green molecular fluorescence-guided hepatectomy (2021 edition) (in Chinese). Chinese Journal of Practical Surgery, 42(3), 274-284. https://doi.org/10.19538/j.cjps.issn1005-2208.2022.03.02

[2] Wang, X., Teh, C. S. C., Ishizawa, T., et al. (2021). Consensus guidelines for the use of fluorescence imaging in hepatobiliary surgery. Annals of Surgery, 274(1), 97-106. https://doi.org/10.1097/SLA.0000000000004718

[3] Wang, Y. Q., Zhuo, Y., & Lu, L. Y. (2023). Advances in the clinical application of indocyanine green fluorescence laparoscopy (in Chinese). Chinese Journal of Medical Instrumentation, 47(6), 659-663. https://doi.org/10.3969/j.issn.1671-7104.2023.06.013

[4] Nuclear Medicine Branch of the Chinese Medical Association, Digital Medicine Branch of the Chinese Medical Association, Liver Cancer Professional Committee of the Chinese Medical Doctor Association, et al. (2023). Expert consensus on indocyanine green near-infrared-II fluorescence imaging for liver cancer resection (in Chinese). Chinese Journal of Nuclear Medicine and Molecular Imaging, 43(7), 418-425. https://doi.org/10.3760/cma.j.cn321828-20220210-00041

[5] Wang, X. Y. (2022). Fluorescence staining failures and countermeasures during laparoscopic anatomical liver resection (in Chinese). Chinese Journal of Practical Surgery, 42(9), 1001-1004. https://doi.org/10.19538/j.cjps.issn1005-2208.2022.09.11

[6] Yao, C., Zhang, D. Y., Sun, W. L., et al. (2021). Application of indocyanine green fluorescence imaging in laparoscopic hepatectomy for primary liver cancer (in Chinese). Chinese Journal of General Practice, 19(7), 1121-1124. https://doi.org/10.16766/j.cnki.issn.1674-4152.002000

[7] Xin, F. L., Ke, Q., Liu, H. Z., et al. (2021). Application of indocyanine green fluorescence imaging in laparoscopic hepatectomy (in Chinese). Journal of Abdominal Surgery, 34(4), 271-275, 290. https://doi.org/10.3969/j.issn.1003-5591.2021.04.005

[8] Chen, X. N., Sun, X. J., Zhang, Z. W., et al. (2022). Application of indocyanine green fluorescence-fusion imaging in laparoscopic hepatectomy (in Chinese). Journal of Hepatobiliary and Pancreatic Surgery, 34(12), 731-734.

[9] Lan, W. F., Chen, Z. J., Hong, H. Y., et al. (2021). Application of indocyanine green in laparoscopic hepatectomy (in Chinese). Chinese Archives of General Surgery (Electronic Edition), 15(4), 309-312. https://doi.org/10.3877/cma.j.issn.1674-0793.2021.04.016

[10] Felli, E., Ishizawa, T., Cherkaoui, Z., et al. (2021). Laparoscopic anatomical liver resection for malignancies using positive or negative staining technique with intraoperative indocyanine green-fluorescence imaging. HPB, 23(11), 1647-1655. https://doi.org/10.1016/j.hpb.2021.05.006

[11] Li, J., Li, X., Zhang, X., et al. (2022). Indocyanine green fluorescence imaging-guided laparoscopic right posterior hepatectomy. Surgical Endoscopy, 36(2), 1293-1301. https://doi.org/10.1007/s00464-021-08404-2

[12] Lu, Z. Y., Sun, J., Du, J. L., et al. (2024). Effects of hepatic-pedicle management and indocyanine green dose on fluorescence staining during laparoscopic anatomical hemihepatectomy (in Chinese). Journal of Surgery Concepts and Practice, 29(2), 138-142. https://doi.org/10.16139/j.1007-9610.2024.02.08

[13] Liu, Y. C., Zhao, D. T., Sun, Q. F., et al. (2021). Three-dimensional visualization combined with indocyanine green fluorescence navigation in precision laparoscopic surgery for primary liver cancer (in Chinese). Journal of Practical Hepatology, 24(4), 561-564. https://doi.org/10.3969/j.issn.1672-5069.2021.04.027

[14] Tangsirapat, V., Kengsakul, M., Udomkarnjananun, S., et al. (2024). Surgical margin status outcome of intraoperative indocyanine green fluorescence-guided laparoscopic hepatectomy in liver malignancy: A systematic review and meta-analysis. BMC Surgery, 24(1), 181. https://doi.org/10.1186/s12893-024-02469-1

[15] Hu, M., Chen, Z., Xu, D., et al. (2025). Efficacy and safety of indocyanine green fluorescence navigation versus conventional laparoscopic hepatectomy for hepatocellular carcinoma: A systematic review and meta-analysis. Surgical Endoscopy, 39(3), 1681-1695. https://doi.org/10.1007/s00464-024-11518-y

[16] Araki, K., Watanabe, A., Harimoto, N., et al. (2024). Advantages of laparoscopic segmentectomy of the liver using ICG fluorescent navigation by the negative staining method: A comparison with open procedure. Annals of Gastroenterological Surgery, 8(4), 691-700. https://doi.org/10.1002/ags3.12786

[17] Liu, Y., Wang, Q., Du, B., et al. (2021). Meta-analysis of indocyanine green fluorescence imaging-guided laparoscopic hepatectomy. Photodiagnosis and Photodynamic Therapy, 35, 102354. https://doi.org/10.1016/j.pdpdt.2021.102354

[18] Zhou, Y., Zhang, C., Wang, Y., et al. (2023). Effects of indocyanine green fluorescence imaging of laparoscopic anatomic liver resection for HCC: A propensity score-matched study. Langenbeck's Archives of Surgery, 408(1), 51. https://doi.org/10.1007/s00423-023-02781-z

[19] Liu, F., Wang, H., Ma, W., et al. (2023). Short- and long-term outcomes of indocyanine green fluorescence navigation-versus conventional-laparoscopic hepatectomy for hepatocellular carcinoma: A propensity score-matched, retrospective, cohort study. Annals of Surgical Oncology, 30(4), 1991-2002. https://doi.org/10.1245/s10434-022-13027-5

[20] Wang, J., Zou, X., Zheng, Z., et al. (2022). Indocyanine green fluorescence-guided laparoscopic hepatectomy versus conventional laparoscopic hepatectomy for hepatocellular carcinoma: A single-center propensity score matching study. Frontiers in Oncology, 12, 930065. https://doi.org/10.3389/fonc.2022.930065