Editorial

3D laparoscopy and fluorescence imaging can improve surgical precision for hepatectomy

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Laparoscopic hepatectomy for the treatment of hepatocellular carcinoma (HCC) has been shown to have superior short-term and comparable long-term outcomes compared with open hepatectomy in experienced centres (1). Short-term advantages include small incisions, reduced post-operative pain, faster recovery, reduced blood loss and lower risk of complications (2). However, the loss of tactile sensation makes it challenging to accurately locate lesions and define tumour margins.

Historically, laparoscopic surgery by default is understood as 2D. The surgical community has accepted 2D vision as a reference gold standard and this norm has remained unchanged until recent birth of robotic surgery. It is not widely acknowledged that standard 3D laparoscopy provides a similarly immersive experience with stereoscopic vision and depth perception as robotic surgery. The last decade has witnessed emergence of scientific literature endorsing the clinical utility of 3D laparoscopy, especially with its ability to enhance intracorporeal suturing and reducing learning curve (3). A recent systematic review comparing 2D with 3D laparoscopic liver resection (LLR) has reported that 3D LLR may reduce overall postoperative morbidity compared with 2D LLR (4). However, due to the paucity of included studies and small sample size (n=361), the results require validation.

Indocyanine green (ICG) was first used mainly in diagnosing hepatic function in the 1950s. The application of ICG in biliary surgery and colorectal surgery is widely reported. ICG cholangiography is reported as a safe and accurate modality to identify common hepatic duct during cholecystectomy (5). Aoki *et al.* reported that the boundary planes between liver segments could be clearly shown by injecting ICG into the portal vein for fluorescence staining during anatomic segmental hepatectomy (6). Ishizawa *et al.* reported that intraoperative fluorescence imaging was useful for tumour localization after preoperative ICG injection (7). Since then, ICG has been used for demarcating segments for anatomic resection, tumour identification to achieve negative resection margins, detection of small subcapsular nodules, extrahepatic metastatic lesions and fluorescence cholangiography (8) which is useful in compensating for the loss of tactile sensation of laparoscopic surgery.

In this paper, the authors describe their novel procedure of incorporating 3D laparoscopic system and 2D real-time ICG (r-ICG) using a conventional laparoscopic system (9). Their case series consists of 11 HCC patients treated by

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3D laparoscopic right posterior sectionectomy with 2D r-ICG guidance. ICG was administered intravenously after the Glissonian pedicle was clamped, allowing the planned resection portions to remain dark (negative staining). Liver resection then proceeded with 3D vision and simultaneous 2D ICG vision. All patients had no major complications or 90-day mortality. The authors are to be congratulated for integrating the benefits of 3D laparoscopy and ICG by combining two separate camera systems into a single technique. 3D LLR allows improved depth perception and spatial awareness and 2D r-ICG allows precise parenchymal transection based on the demarcation line. Their study has demonstrated the safety and feasibility of this technique. We briefly discuss the utility of 3D imaging in LLR.

Hepatobiliary and pancreatic surgical community was slow to embrace minimal access surgery due to technical complexity, steep learning curve, and patient safety concerns (10). Last two decades have witnessed an exponential increase in LLR due to an improved understanding of liver anatomy, the adoption of structured training curricula, a proliferation of fellowship training programs, advances in imaging and surgical technology, as well as the role played by social platforms like YouTube videos (11). Despite these advances, the migration from 2D to 3D laparoscopy is surprisingly lagging. At Tan Tock Seng Hospital in Singapore, a patient is charged a nominal $5 (Singapore dollars) for using 3D laparoscopy compared to 2D laparoscopy; however, only a few surgeons prefer 3D LLR. This could be due to the following limitations of 3D technology:

(I) The 3D camera system is fragile due to a flexible tip that is vulnerable to wear and tear during insertion and withdrawal of camera. This is aggravated when using reusable metal ports and sometimes surgeons use disposable ports to reduce the risk. This could contribute to rising healthcare carbon footprint (12).

(II) Using flexible tip camera system requires special training to provide good view for surgery.

(III) The 3D camera system is more expensive with an upfront capital cost which administrators may not be willing to approve, especially due to the lack of evidence that it actually improves clinical outcomes.

(IV) Robotic technology proliferated and spread very fast and eliminated the need for a separate 3D system, especially so because robotic platform has demonstrated superior clinical outcomes for certain surgical procedures and thus administrators are willing to pay for robotics. There is paucity of evidence of clinical gains from 3D technology.

(V) Some surgeons feel giddy or nauseous with 3D vision and they become demotivated to persist with 3D laparoscopy.

(VI) 3D laparoscopy technology has technical limitations that remain to be addressed. For example, if a surgeon stands on a platform, and the monitor is not at the eye-level, the image is blurred, making it difficult for surgeon to perform surgery. Further, if a camera has stains/smudge, the entire view becomes blurred despite stains only on a single eye, thus requiring more frequent camera clean maneuvers with a potential increase in operation time and increasing vulnerability to damage.

(VII) 3D laparoscopy requires special 3D glasses, which compete with goggles and causes inconvenience. During the coronavirus disease 2019 (COVID-19) pandemic, we have witnessed a trainee abandoning 3D surgery due to blurring of vision, later to be coached that 2D goggles should not be put over the 3D glasses!

(VIII) The video library on social medial platforms, routine computer and laptop screens, and almost all conference proceedings are conducted in 2D format; thus dissemination of 3D laparoscopy is challenging.

(IX) Theatre staff and biomedical engineering units have to handle the flexible camera system with more caution and diligence than the rigid camera systems.

Thus, despite potential benefits and relatively low cost compared to robotic surgery, 3D laparoscopy has not gained widespread use. However, units that have used 3D laparoscopy report it as safe and feasible. Combining 3D with ICG mimics robotic surgery and is a welcome idea for which the authors ought to be applauded. However, there are certain limitations. First, the need for two laparoscopic systems and an additional trained laparoscopic assistant increases the logistical requirements for the operation. This is in paradox with robotic technology where the role of camera assistant is minimal, while in 3D laparoscopy, one requires a higher skill set, and with a combination of 3D + 2D laparoscopy, the burden is even more. Second, the additional laparoscopic system necessitates an extra skin incision for a 10-mm port which is not insignificant for minimal access surgery. Every 10 mm incision is a potential site for port-site incisional hernia. This drawback can be mitigated by available technology that integrates 3D imaging with ICG capabilities, similar to a robotic platform. Finally, any form of minimal access surgery is technically difficult in patients with giant HCC (defined as ≥10 cm diameter) and not feasible in super-giant HCC (defined as ≥15 cm diameter) (13,14).

In conclusion, this study has demonstrated the safety and feasibility of incorporating a 3D laparoscopic system and 2D r-ICG using a conventional laparoscopic system in HCC resections but requires further studies to demonstrate clinical utility.

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Footnote

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