Artificial Intelligence: A Potential Future Pillar of Complex HPB Surgeries

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Abstract

Advances in diagnostics and sophisticated perioperative management of Complex Hepato Biliary and Pancreatic Surgeries in last decade has taken success of those surgeries to new zenith. To add to armamentarium of advanced HPB surgery Artificial Intelligence is coming up is a big way and is already being utilized. In the present review article, we would look into possible application of AI in surgeries of biliary tract liver and pancreas.

Keywords: Artificial Intelligence (AI) • Liver surgery • Surgical innovation

Introduction

The contribution of AI to safe cholecystectomy can become a landmark to alleviate the devastating bile duct injuries which still continue to occur with a static incidence of 0.3 to 1.5. The application of Artificial Intelligence improves the capacity of a liver surgeon for precise, safe and feasible delivery of complex surgical procedures. AI can be utilized to diagnose, treat and prognosticate various liver related disorders specially CLD, AI can also revolutionize pancreatic surgery field. As 3D visualization of peri-pancreatic vessels relations preoperatively known to have decreased operative time, blood loss, and hospital stay significantly compared to patients who underwent surgery based on 2D image planning prior to pancreaticoduodenectomy.

Role of AI in cholecystectomy

The commonest biliary tract surgery performed worldwide countries to be cholecystectomy. Validation of AI for guiding safe laparoscopic cholecystectomy by high volume surgeries from SAGE safe Cholecystectomy task force utility 47 frames of 25 LC videos, recommended that AI can be used to identify safe and dangerous zones of dissection within the surgical field. It actually predicts a total of 60 forbidden areas and another 60 comparative safe zones [1]. The contribution of AI to safe cholecystectomy can become a landmark to alleviate the devastating bile duct injuries which still continue to occur with a static incidence of 0.3 to 1.5 percent. Rios *et al.* considered an interaoperative land mark system using YOLO V3, which is an algorithm for object detection based on deep learning from 2000 endoscopic images of Calots triangle from 76 videos of LC. The system could identify landmarks of cystic duct, common bile duct, lower edge of liver and rouviere's sulcus; wherein the intraoperative use of these landmark indication system makes the surgeons more aware of landmarks and proposed its use to prevent bile duct injury during LC [2]. When one considers injury during Cholecystectomy; poor implementation and subjective interpretation of critical view of safely actually contributes to a stable rate of bile duct Injuries. Mascagni Peter et al. documented the usage of AI for auto assessment of critical view of safety with average precision of 71.9% and balanced accuracy of 71.4%. This kind of precision also avoid any intraoperative perforation of gallbladder [3]. The trial in phase-III on laparoscopic cholecystectomy in a multicentric study was cancelled in December, 2023 (would compare ICG aided Cholecystectomy with incorporated AI intervention group; to surgeons guided only by ICG) and to a 3rd group without ICG looking into precision of accuracy of AI. Beyond occurrence of injury the secondary end points that can bemeasuredare length of procedure, conversion rate, occurrence of complication and length of hospital stay.

However, AI model successfully identified surgical phases in both simple and complex LC procedures with AI model for surgical phase recognition was 89% (95% CI 87.1%, 90.6%), comparable to the mean inter-annotator agreement of 90% (95% CI 89.4%, 90.5%) with a trend towards decreasing ability with more complexity of the procedure [4].

Role of AI in liver surgery

The application of Artificial Intelligence improves the capacity of a liver surgeon for precise, safe and feasible delivery of complex surgical procedures. AI can be utilized to diagnose, treat and prognosticate various liver related disorders specially CLD. When contemplating role of AI in surgical diseases of liver, tumors are best managed by surgical resection which at times can be challenging due to the complex hepatic anatomy and need of an adequate future liver remnant. The spatial relationship of tumor with the surrounding structures can be visualized by 3D reconstruction of images from CT or MRI [5,6]. Similarly, 3D printing techniques with the addition of machine learning have made virtual liver resection possible before actual surgery. The safety and outcome of a Living Donor Liver Transplant (LDLT) can be improved by predicting the requirement of vascular reconstruction. 3D printing models have been found useful in LDLT for small infants and neonates in assessing any size discrepancies between recipient and group [7,8].

3D printed liver models have been utilized in past for teaching trainees the anatomy and various hepatectomy surgeries yielding a better learning efficacy. Bio-printing of human pluripotent stem cell and their differentiation into hepatocytic live cells for further making of mini livers in 3D has been studied that can be explored further to be away for developing artificial livers and help manage patients with liver failure [9,10]. Preoperative 3D reconstructive images can be combined with intraoperative findings by utilizing the application of Augmented Virtuality (AV) and Augmented Reality (AR). The oncologic safety can be improved by defining the ideal dissection plan and anatomical structures in real time. Augmented reality superimposes real time intraoperative images with computer generated preoperative 3D virtual images, thereby guiding the resection of missed colorectal liver metastasis as reported by Ntourakis D *et al.* [11,12]. Laparoscopic Hepatectomy Navigation System (LHNS) was developed by Zhang et al. and involves the fusion of preoperative 3D surgical plan and intraoperative undocyamic green fluorescence imaging. The authors found that LHNS group of patients had significantly less blood loss, loss intraoperative blood transfusion rate and a shorter postoperative hospital stay then the non-LHNS group. Post Hepatectomy Liver Failure (PHLF) is a common cause of postoperative morbidity after major hepatectomies. Predicting PHIF risk before surgery is a major advantage and was studies by Mai RY *et al.* by using artificial neural network model [13,14]. Organ availability has been a limiting feature in various liver transplant prognosis and the allocated is presently based on MELD//MELD-Na serves utilizing the principle of "Sickest Fist". MELD system has a major drawback as it does not incorporate the donor information. Bertsimas *et al.* developed the Optimized Prediction of Mortality (OPOM) model which is an optimal classification tree model [15]. This model reduced waiting list morality on average by 417.96 deaths per year, utilizing more variables than MELD based on AI. AI techniques can provide high accuracy in predicting graft survival by incorporating patient and donor information and have an additional advantage by being dynamic, ability to be trained and validated across different populations [16]. The use of AI in medical image analysis, pathological examination, and surgery could aid in the early detection of tumors. Furthermore, AI could assist in predicting survival time, recurrence risk, metastasis, and therapy response to improve the prognosis of PC patients [17,18]. Radiomic analysis has the potential to detect and diagnose illness through the identification of lesions, as well as forecast outcomes such as treatment response and survival rates by assessing radiological features that correspond with genomic, transcriptomic, or proteomic traits. The conventional process for implementing radiomics generally involves four steps: image capture, segmentation, attribute extraction, and analysis [19,20]. In a study by Ikeda *et al.*, they used a neural network classifier to differentiate between pancreatic ductal adenocarcinoma and mass-forming pancreatitis with an AUC of 0.866. Meanwhile, Chen *et al.* fused enhanced CT texture analysis with imaging characteristics, selected features with LASSO and RFE-Linear SVC algorithms, and achieved an AUC of 0.932 while distinguishing between pancreatic serous cystadenomas and pancreatic mucinous cyscystadenomas [21,22].

Role of AI in pancreatic surgery

AI can also revolutionize pancreatic surgery field. The 3D visualization of peri-pancreatic vessels relations preoperatively known to have decreased operative time, blood loss, and hospital stay significantly compared to patients who underwent surgery based on 2D image planning prior to pancreaticoduodenectomy (p=0.024) and distal pancreatectomy (p=0.026) [23,24]. Assessment of resectablity of the borderline resectable tumors (with involvement of surrounding vessels) is cornerstone as one fourth of the patients explored intraoperatively are considered unresectable at laparotomy. There is a significant disadvantage to using 3D reconstruction and printing techniques in surgeries, as it can be challenging to associate the reconstructed images or physical models with the actual surgery. Insufficient synchronization between the two technologies is the main reason behind this limitation [25]. However, computer guiding software can overcome these obstacles by combining preoperative 3D reconstructive images with real-time intraoperative information. Two methods for achieving this are Augmented Virtuality (AV) and Augmented Reality (AR), both of which display virtual environments and information based on real images of the patient. This is a relatively new and underutilized technology in the field of HPB surgery. It can also improve oncological safety by helping surgeons identify the ideal dissection plane and anatomical landmarks and achieve safe margins with maximum functional preservation. AV, AR, and mixed reality (MR) offer a safe and reliable surgical navigation method, which reduces the chances of misinterpretation between the 3D reconstruction model and actual operating space. A total of 19 patients underwent pancreatectomy using AR-based navigation surgery as reported by Okamoto *et al*. [26,27]. During the surgery, reconstructed preoperative images were superimposed on the actual organs displayed on the monitor, providing useful information for challenging cases such as small pancreatic neuroendocrine tumors, deep liver lesions, and microwave coagulation therapy planning. In a separate pilot study, Ntourakis *et al*. [28-30] found that AR was helpful in detecting missing lesions caused by modern chemotherapy for CRLM and achieving a negative margin with no local recurrence at a median follow-up of 22 months [30]. For laparoscopic pancreatic surgeon, loss of depth perception with monocular cameras is also major disadvantage leading to longer operative times [31,32]. These limitations could be countered by the help of AR and MR technology. This will not only help in finding the position of intra-parenchymal lesions but it also provides a better field of view making surgery easier. This can also facilitate the oncological R0 resection and limit the risk of intraoperative bleeding [33]. To conclude, it is just a matter of time before the AI systems are incorporated in the management of HPB disease and how surgeons accept this automation going against either clinical decision at times remains to be seen. AI has potential to enable surgeons in providing precise and personalized care to patients which can revolutionize the way Liver, Billiary and Pancreatic diseases are practically dealt with.

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