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EDITORIAL

Hepato-pancreato-biliary (HPB) Surgery: Pushing the Boundaries with Technology

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Hepato-pancreato-biliary (HPB) as the name suggests encompasses three broad fields, liver, pancreas, and the biliary tree. The field requires not only surgical dexterity but also a deep understanding of the variable anatomy of the region coupled with foresight and prompt recognition of the complications and its treatment. It is one of the most rapidly expanding fields in surgery with advances in surgical precision aided by technology, minimal access, and strong support coming in from intensive care specialists, state-of-art three-dimensional (3D) imaging reconstructions, and interventional radiology with potentially excellent outcomes after complex resections.

Over the years, the mortality has dropped from about 20% to less than 3–5% for most liver and pancreatic surgeries, although morbidity rates still remain high (30–50%). For improving immediate and long-term surgical outcomes, focus is currently on enhanced precision during surgery using artificial intelligence, pre-, and post-surgery rehabilitation programs that includes ERAS (Enhanced Recovery After Surgery) protocols now a part of most standard HPB & GI units along with advances in perioperative chemotherapy/radiotherapy/targeted therapy/immunotherapy in cancer patients.

Expanding the Limits in HPB Surgery

Although laparoscopic cholecystectomy is firmly established as a standard of care for benign gallbladder diseases, the uptake of minimally invasive surgery (MIS) in HPB oncology has been limited due to its steep long learning curve and potentially serious complications like hemorrhage, CO_2 embolism, challenging anastomosis, and concerns regarding resection margins. Fast pace advances in the field however are underway with MIS approach being successfully used for hepatectomies (even in cirrhotic patients), distal pancreatectomy, pancreaticoduodenectomy (PD), and in resection of complex perihilar cholangiocarcinomas in experienced centers. Robotic platforms offer the additional advantage of an endowrist with 7 degrees of freedom enabling easier access to postero-superior liver segments (like IVa, VII, VIII, I) and in hilar dissection although at a much higher cost [1].

Simultaneous expansion has occurred in the use of liver transplantation for hepatobiliary malignancies in otherwise incurable patients. Liver transplantation is now actively being considered for advanced stage intrahepatic cholangiocarcinoma, perihilar cholangiocarcinoma, liver limited colorectal liver metastasis, and liver metastasis from neuroendocrine tumors aside from hepatocellular carcinoma [2].

Artificial Intelligence in Liver Volume Assessment

Measurement of liver volume and future liver remnant (FLR) is an integral part of any major hepatic resection or liver transplant preoperative planning to avoid the dreaded complication of post-hepatectomy liver failure. This involves the expertise of a hepatic radiologist in delineating the Couinaud segments using contrast-enhanced computed tomography (CECT)/magnetic resonance imaging (MRI) images and manually calculating the liver volume and FLR which although is the gold standard but is time-consuming. Numerous studies have indicated discrepancy in the preoperative measured liver volumes viz-a-viz intraoperative measurements of weight and volume. Overestimation error of liver graft volumes in transplant and liver resection specimen may range from 14 to 53%. [3]

A number of semi-automated and automated software are now available to circumvent the shortcomings and have the

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advantage of being faster, with a fair degree of accuracy and reproducibility while negating the chances of inter- and intra-operator bias. Two illustrative examples are shown in the Figs. 1 and 2 [3, 4].

Augmented Reality (AR) and Intraoperative Surgical Navigation

Ever since Marescaux et al. conceptualized 3D imaging for delineating liver anatomy in 1998, 3D reconstruction from usual 2D CECT and MRI images is routinely used in HPB

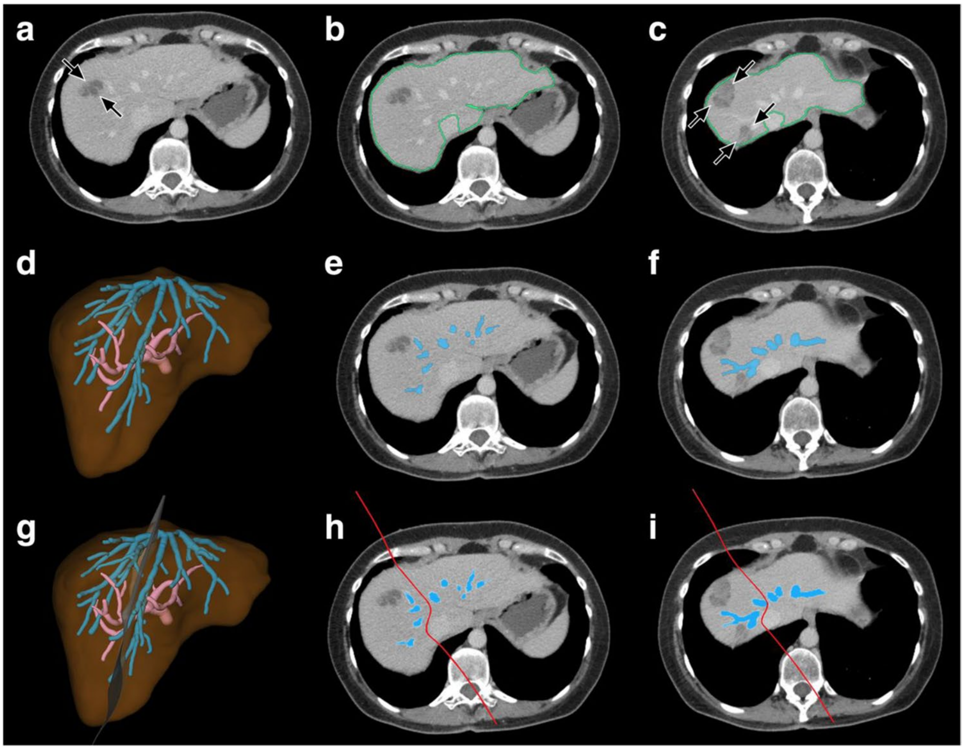

Fig. 1 Segmentation process in a patient planned for right hemi-hepatectomy without resection of the MHV due to metastases of GCT. **a** Plain axial CT image shows a hypo-attenuated metastasis in liver segment 8 (black arrows). **b** and **c** Detection of the liver outline. Further metastases are depicted at the level of the proximal MHV in **c** (black arrows). **d**–**f** Detection of the intrahepatic PV (in pink) and HV (in blue). **g**–**h** Definition of the transection plane (in red) [3] MHV: Middle hepatic vein; GCT: Granulosa cell tumor; PV: Portal vein; HV: Hepatic vein(s)

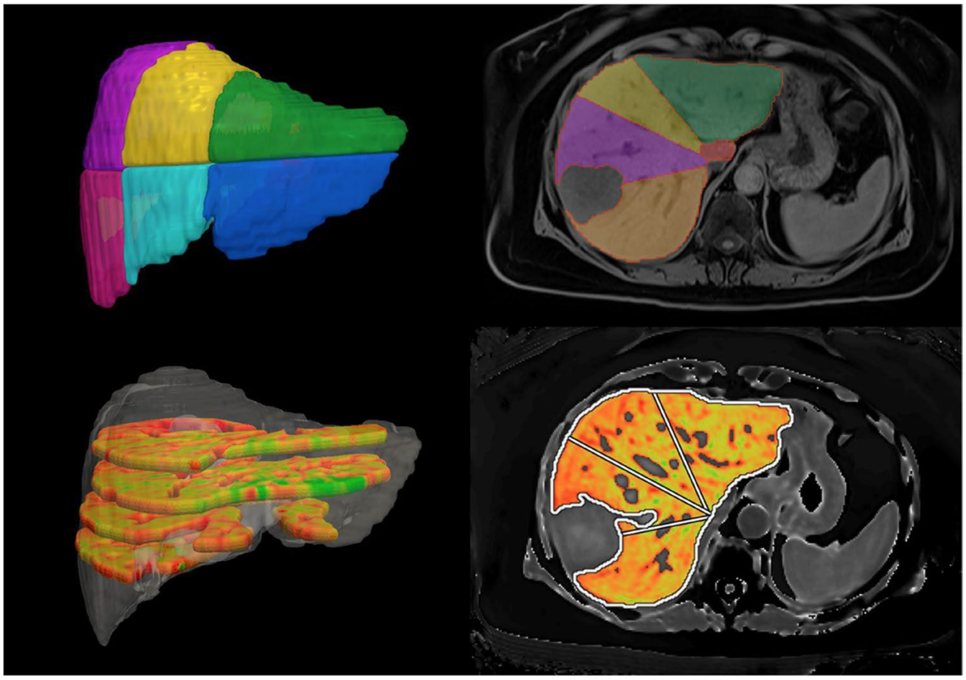

Fig. 2 Example of Couinaud segment delineations from Hepatica™ on non-contrast-enhanced T1-weighted MR and cT1 images [4]

units to carefully visualize the liver tumor w.r.t. intrahepatic vasculature and biliary anatomy that can be highly variable. It also helps in understanding the spatial relationship of a pancreatic tumor with surrounding vessels including the course and size of main pancreatic duct thus helping in reducing chances of surgical surprise and facilitating accurate planning (even enabling virtual hepatic resections) and margin-negative resection. The basic disadvantage that remains is that this 3D visualization is still on a 2D projection. Hence, real physical models (1:1 ratio) using 3D printing are also being used for planning complex hepatic resections, locating precisely small, multiple liver lesions, and in liver transplants to assess the graft size in pediatric patients, among others. These models can be easily brought in to the operative room to assist the operating team in real time (Fig. 3). Zein et al. first reported the technique in 2013 [5, 6].

Intraoperative ultrasound and indocyanine green (ICG) fluorescence are commonly used to assist liver resection and are particularly useful in minimally invasive resections that lack haptic feedback. A further step forward is to integrate preoperative high quality 3D imaging data (from CECT/MRI/PET-CT) with real-time intraoperative images using landmarks/reference markers to the merge the images, called augmented reality (AR). The concept is revolutionary in the sense that it really augments surgeon's dexterity essentially by better visualization of the operative field in real time, e.g., the architecture (vasculature and biliary network) of a complex solid organ like liver in relation to the area of interest (tumor) [7]. AR also helps in accurate port placements according to the patient's anatomy by projecting the virtual 3D image of the liver on the skin surface after establishment of pneumoperitoneum. AR technology is also being evaluated in localizing disappearing colorectal liver metastases and for needle placement in percutaneous ablation of liver tumors. The precise overlaying of 3D imaging data on to the operative field remains a challenge and requires a variety software for calibration, tracking, and registration so that the combined image in real time can be seen by the surgical team using different 3D display technologies commonly either video-based or see-through display (Fig. 4) [7, 8].

AR has been extensively used in neuronavigation for last several years and its application now has expanded to orthopedic (e.g., in precise placement of nails), urology (in partial nephrectomy), and otolaryngology, and is slowly upcoming in HPB surgery. The technique, which is still evolving looks promising, and has been successfully used in open, laparoscopic, and robotic platforms with encouraging results. The main limitations include the production cost, increased time and effort in planning and execution, disturbed image fusion due to ventilation, instrument and surgeon movements, short battery life, cumbersome equipment/cables, and the latency of the system. The technology also holds promise in mentoring surgical trainees via simulation platforms.

Perioperative Patient Optimization

ERAS is a multimodal, multidisciplinary fast-track clinical pathway involving intensive perioperative care that includes active interventions during pre-, intra-, and postoperative period, and has shown to reduce surgical stress response and improve patient outcomes like fewer medical complications, faster recovery, reduced length of hospital stay (LOS), and related costs, although surgical morbidity remains largely unchanged. The ERAS concept was introduced by Kehlet et al. in 1997 and was first validated for colorectal surgery. So promising were the outcomes that it was quickly widely adapted across different surgical specialties [9]. There is now enough data to support implementation of ERAS recommendations in HPB surgery and international guidelines are available for PD and liver surgery [10, 11]. ERAS seems to be feasible after resection of perihilar cholangiocarcinoma, although the presence of bilio-enteric anastomosis often with major hepatectomy, vascular resections, high preoperative bilirubin, and perioperative drains makes it challenging

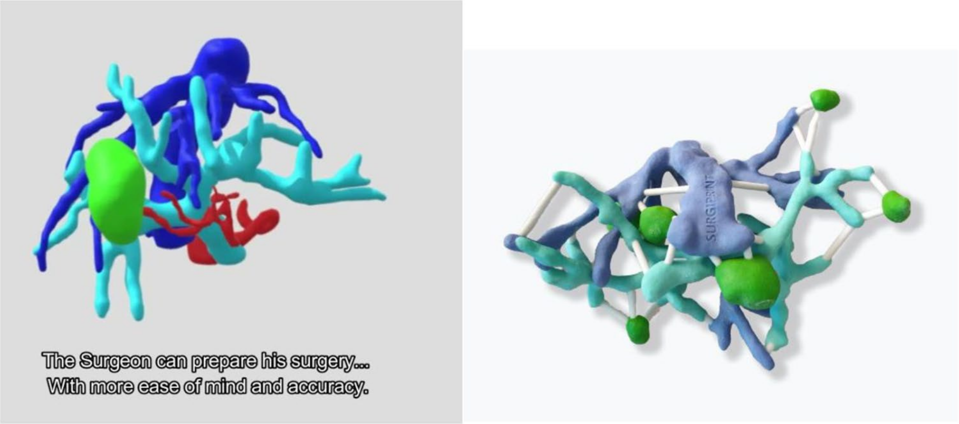

Fig. 3 The two 3D models depict liver metastases in light green in relation to complex intrahepatic vasculature. More pictures and videos can be accessed at http://www.surgiprint.com/ [5]

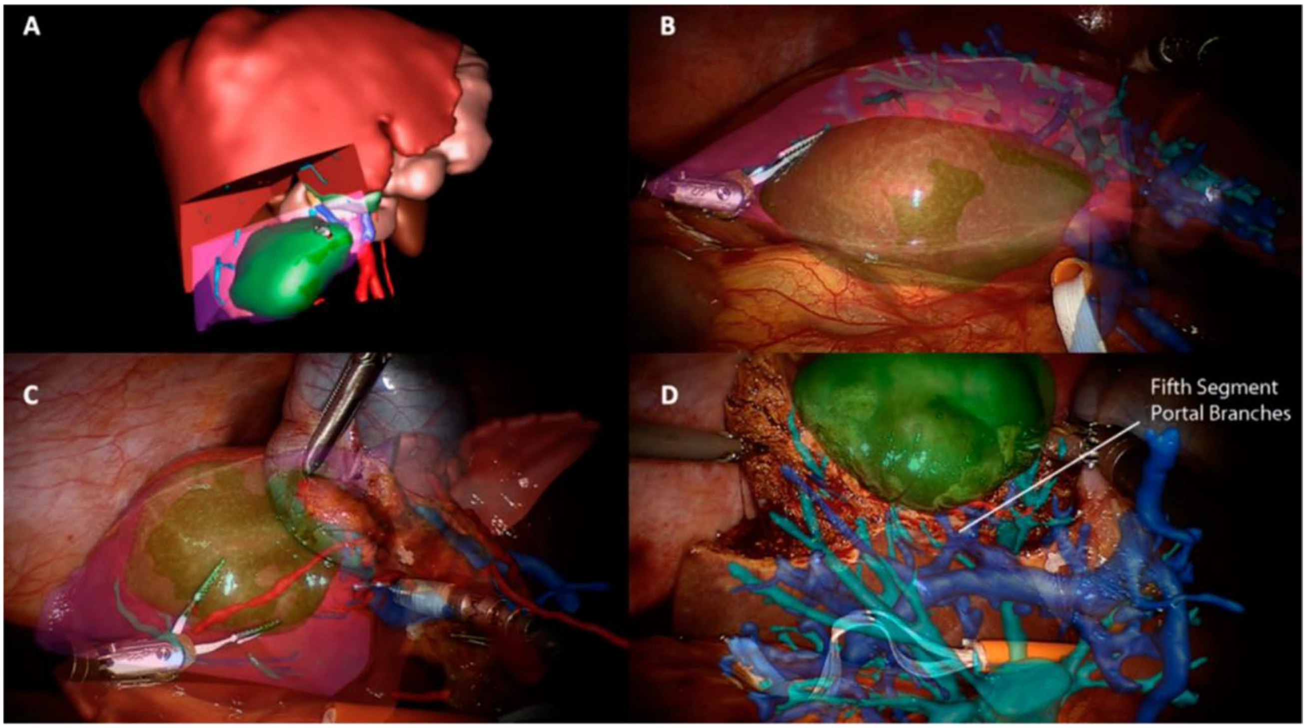

Fig. 4 **A** Surgical preoperative planning through 3D reconstruction of an anatomical S5 segmentectomy. The tumor is colored in green and the resection plane in red. **B**–**D** Intraoperative superimposition of planned resection area rendering. Vascular and biliary structures are projected during different phases of parenchymal transection, with the identification of the S5 vascular pedicle [8]

as we await more data on this subgroup. We routinely follow ERAS protocol for all oncological resections in our unit and have published our results for PD [9]. Another study ongoing in our unit is for gallbladder cancer.

ERAS has various components and essentially includes preoperative patient rehabilitation (home-based physical exercises, spirometry, smoking, and alcohol cessation), attention to perioperative nutritional requirements, psychological counseling, minimizing patient's fasting time before surgery, preoperative carbohydrate loading, multimodal analgesia avoiding opiates and anxiolytics, goal-directed fluid therapy, minimal to no use of prophylactic nasogastric tubes and drains, early extubation, early removal of urinary catheter, avoiding hypothermia, proper glycemic control, antibiotic and antithrombotic prophylaxis, prevention of postoperative nausea and vomiting, encouraging early oral intake and mobilization, use of MIS in experienced centers (though the level of evidence is not strong), and regular audit to name a few [10, 11].

Survivorship

Addressing long-term treatment-related side effects assumes importance owing to improved survival rates after curative resection of HPB cancers. Aside from enormous psychological stress, there are major malnutrition and malabsorption issues because of the alteration of the GI tract due to surgical resection and reconstruction resulting in weight loss and sarcopenia. Perioperative chemotherapy/radiotherapy only exacerbates impairment in physical status and quality of life (QOL) in most patients. We analyzed postoperative exocrine insufficiency (PEI) in our patients who had undergone PD for cancer and found that all had moderate to severe PEI, hence underscoring the need for pancreatic enzyme replacement therapy (PERT) [12]. An ongoing RCT by O'Neil et al. is underway (ReStOre II) on cancer-free survivors of esophagus, stomach, pancreas, and liver cancer with the aim to assess if their 12-week active rehabilitation program is superior to standard care w.r.t. cardiorespiratory and physical fitness and QOL [13].

Thus, innovations in medical science are a continuum of change as we strive to provide maximal benefit of technology to our patients enabling complex precise resections with minimal morbidity, high cure rates coupled with long-term care.

Declarations

Conflict of Interest The authors declare no competing interests.

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