How to Use the Latest Image Analysis Functions in the Field of Hepato-Biliary-Pancreatic Surgery:

Novel 3D Simulation Fusion with MRCP

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Introduction

Determination of the appropriate surgical methods for treating diseases of the hepatobiliary system, requires extensive understanding of the relationship between the anatomy of the hepatic hilus and lesions in individual patients. The visualization of the bile ducts can hardly be extracted on multi-detector row CT (MDCT). Using direct cholangiography with CT, in which CT scans are taken after infusing a contrast agent through a percutaneous transhepatic biliary drainage (PTBD) tube or an endoscopic nasobiliary drainage (ENBD) tube, or 3D cholangiography using drip infusion cholecystocholangiography CT (DIC-CT) has been reported to be useful for surgical simulation for diseases of the biliary system.[1-3] However, some problems, including side effects to contract agents (e.g., anaphylactic shock), cholangitis, and radiation exposure, have been indicated; therefore, the development of a new modality is anticipated.

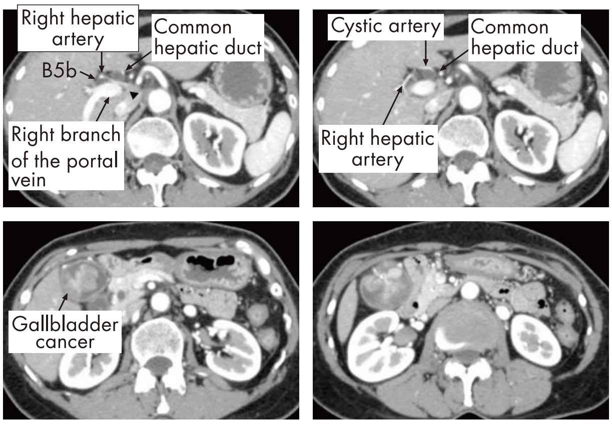
Recently, a new 3D simulation using fusion of MRI and CT images, which was previously unfeasible, has become possible through image registration of normalized mutual information applicable to two different modalities. We use this technique to perform preoperative simulation in patients undergoing surgery of the biliary system. In this article, we present a case of a patient with gallbladder cancer that was surgically resected in our department.

Case

Patient : A 73-year-old female.
Complaint : Abdominal discomfort.
Imaging Examination : MDCT and magnetic resonance cholangiopancreatography (MRCP) were performed.
MDCT imaging method : The CT scanner IDT-16 imager (Philips Medical Systems) was used. The scan settings included a multi-row detector configuration of 16 × 0.75 mm, a scan time of 0.75 s/rotation, a beam pitch of 1.06, and a table speed of 12.5 mm/rotation. The patient received 100 mL of contrast agent (iopamidol) with an iodine concentration of 370 mg/mL at 4 mL/s via a peripheral intravenous route. For scan timing, images of the three phases:, arterial phase, portal vein phase, and equilibrium phases, were obtained. The arterial phase image was taken 5 see after aortic peak enhancement, the portal vein phase image was taken 70 see after initial injection of the contrast agent, and the equilibrium phase image was taken 180 see after initial injection.
MRCP imaging method: MRI was performed on a 1.5 T MRI imager (Achieva Nova Dual, Philips Medical Systems) using 5-mm slices to obtain images.

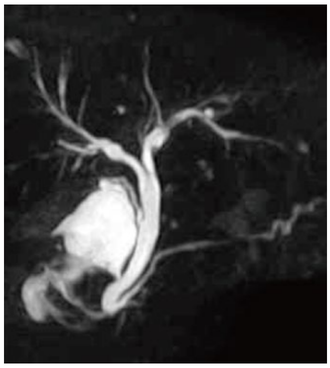
For 3D image processing, we used a 3D image analysis system, SYNAPSE 3D, manufactured by FUJIFILM Corporation. The liver analysis software on this workstation was developed for 3D visualization of the liver and vascular systems and for virtual hepatectomy. In addition, it is equipped with the volumetry function based on blood vessel dominant regions. The structures of the liver, the portal vein, the hepatic artery, the hepatic vein, and the tumor are extracted from the CT DICOM data imported into SYNAPSE 3D and visualized in a 3D image.
The fusion image method was implemented in four steps. We first combined the heavily T2-weighted MRCP images with the axial thin slice 3D-T1 TFE images. Second, we combined the axial thin slice 3D-T1 TFE images with the axial CT images, resulting in the creation of the fusion images of MRCP and CT in the presence of the axial thin slice 3D-T1 TFE images. Third, we roughly corrected the fusion images of the bile ducts by focusing on the hepatic hilus. Fourth, we confirmed that there were no positional gaps between the portal vein and the bile duct by

◆Fig. 1



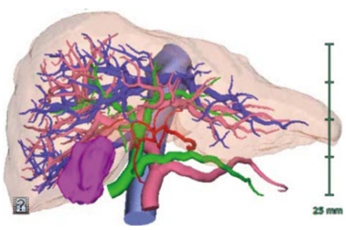
Abdominal CT (arterial phase): No invasion of gallbladder cancer into the vascular channels is observed. The right hepatic artery runs across the back of the common bile duct (black arrowhead).

◆Fig. 2



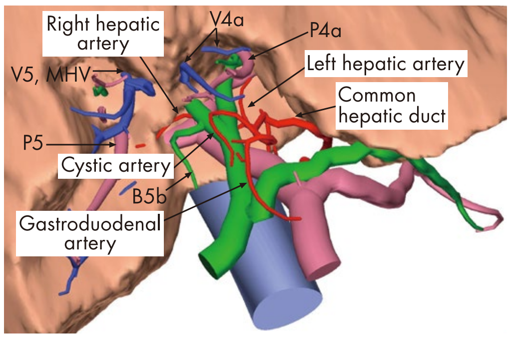
MRCP: No invasion of the tumor into the bile ducts is observed.

◆Fig. 3



3D MRCP fusion image: By adding the bile ducts (green), the dimensional position of the tumor (dark pink), the hepatic arteries (red), and the portal veins (light pink) can be anatomically clarified.

◆Fig. 4



Virtual hepatectomy image: With the addition of the bile ducts, the dimensional position of the arteries, the bile ducts, and the portal veins at the hepatic hilus can be confirmed. With the simulation of the S4aS5 subsegmentectomy, the vascular systems can clearly appear on the cut plane image.

establishing the following three landmarks: 1) the main portal vein, 2) the umbilical portion of the portal vein (whether the lateral segmental bile duct branch runs supraportally or infraportally), and 3) the horizontal portion of the right portal vein (whether the posterior segmental bile duct branch runs supraportally or infraportally). No side effects to the contrast agent, such as rash and other allergic symptoms, associated with the CT and MRI scanning were observed.

Abdominal CT (Fig. 1): No tumor invasion into the vascular systems was observed. The right hepatic artery ran across the back of the common bile duct.

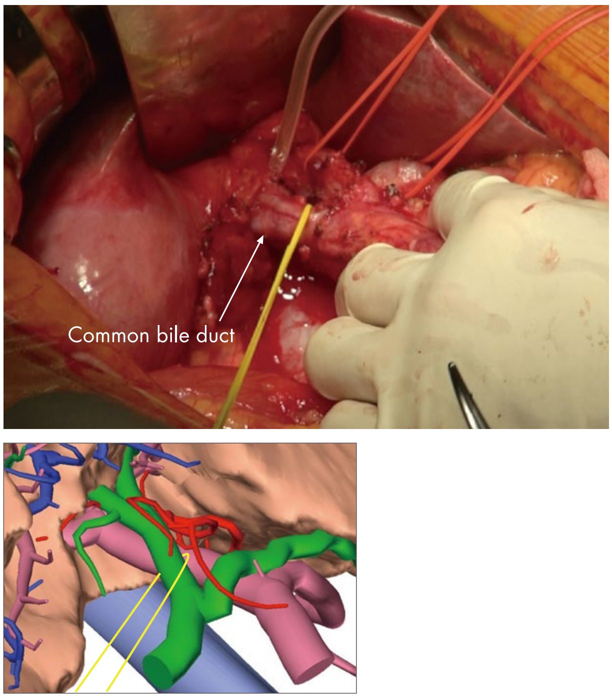
MRCP (Fig. 2): No tumor invasion into the bile ducts was observed.

3D fusion image (Fig. 3): Using MRCP, the image of the bile ducts can be added, and it is easy to visually confirm the anatomical position of the bile ducts, the portal veins, and the hepatic arteries. The patient was preoperatively diagnosed with stage II (T2N0M0) gallbladder cancer. We performed an S4aS5 subsegmentectomy of the liver and extrahepatic bile duct resection.

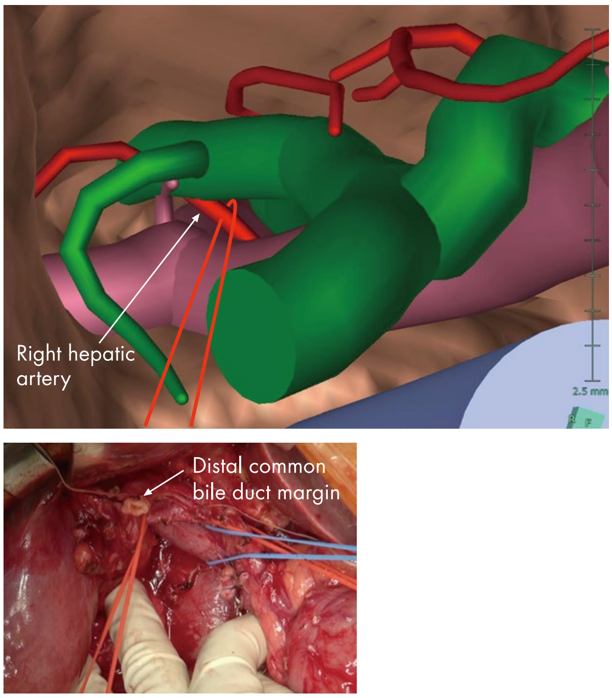
Virtual hepatectomy image (Fig. 4): We simulated the planned S4aS5 subsegmentectomy of the liver. The vascular systems to be resected were clearly observed on the simulated cut plane image. Three-dimensional positions of the bile ducts, the arteries, and the vascular systems at the hepatic hilus could be confirmed.

Intraoperative photos and 3D images (Fig. 5): No tumor invasion into the vascular systems was observed, and the result of the rapid intraoperative pathological diagnosis of the bile duct margin was negative; therefore, we could perform the S4aS5 subsegmentectomy as per the simulation. The positional relationship between the common bile duct and the right hepatic artery had no deviation from the simulation, indicating that the right hepatic artery ran across the back of the common bile duct (Fig. 5a & 5b). The vascular systems that appeared on the transection plane were similar to those in the simulation of the cut plane image (Fig. 5c & 5d).

◆ Fig. 5 : Comparison between intraoperative photos and 3D preoperative simulation images



(a) Tape around the common bile duct.

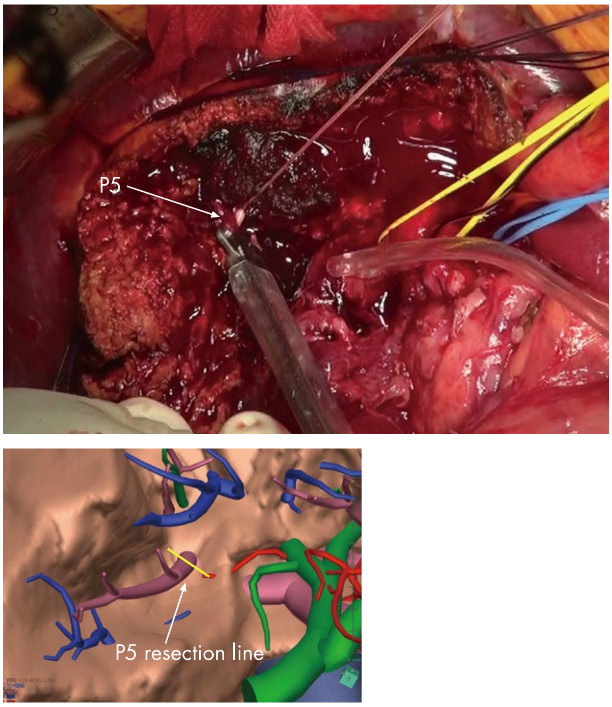


(b) The right hepatic artery runs across the back of the common bile duct with no deviation from the simulation image.

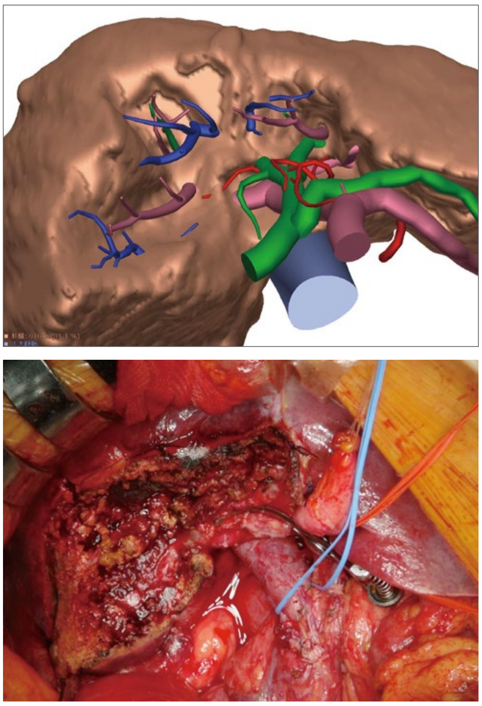
Discussion

Using the newly developed MRI fusion method, we could construct 3D models of the portal veins, the hepatic arteries, the hepatic veins, and the bile ducts and perform the simulation as opposed to using a direct cholangiography with CT or DIC-CT. It is difficult to obtain a superimposed image with 100% image registration taken by various modalities. The crucial aspect of this new fusion method is taking the CT images when a patient holds his/her breath in the expiratory phase of respiration, similar to that during MRI (MRCP). Thus, a positional gap can be minimized. In addition, the image processing, useful as simulation, is made possible by prioritizing the most important image registration at the hepatic hilus to which surgeons observe during surgery of the hepatobiliary system. Although SYNAPSE 3D is already equipped with the function to fuse the images of the arterial, and portal veins, and the equilibrium phases, the 3D simultaneous visualization of the whole images can be performed by adding the bile ducts to the MRCP fusion. Moreover, each image can be separately displayed, thus allowing one to view and rotate 360 degrees in every plane for unlimited times on this work station. Using simulation with the preoperative MRCP fusion images for gallbladder cancer, we could accurately understand the relationship among the tumor, the bile ducts, the portal veins, and the hepatic arteries. We conclude that the 3D image-guided surgical simulation superimposed CT and MRCP is useful.

◆Fig. 5 : Comparison between intraoperative photos and 3D preoperative simulation images



(c) P5 appeared on the transection plane as a simulated image.



(d) Configuration of the transection plane of the liver is the same as that of the simulated cut plane image.