FUJIFILM
Value from Innovation
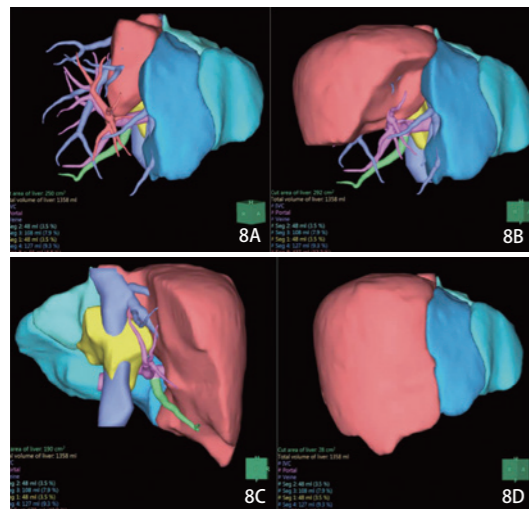
SYNAPSE 3D

◆ Figure 8

8A   8B

8C   8D

Figure 8: Detailed volumetric analysis demonstrating the total liver volume (1,358 ml) and the volumes of each studied segment in red

Fig 8A: Sub-segment 8a: 66 ml or 4.8%
Fig 8B: Segment 8: 437 ml or 32.2%
Fig 8C: Right anterior field: 679 ml or 49.9%
Fig 8D: Right lobe of the liver: 934 ml or 68.8%

Finally, this segmentation enables the precise location of the tumor site. Figure 9 shows a hepatocellular carcinoma located in S8, that is in the middle of four sub-segments 8 therefore requiring an extended anatomical 8 segmentectomy.
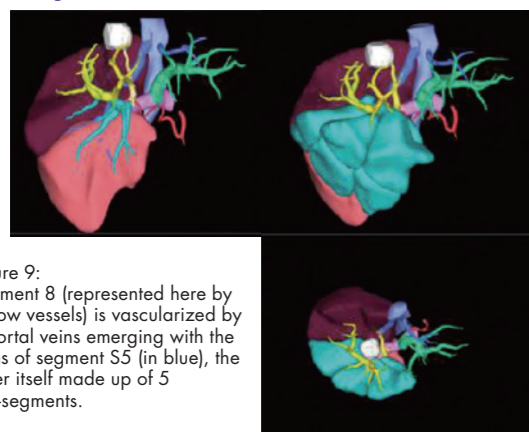
◆ Figure 9

Figure 9:
Segment 8 (represented here by yellow vessels) is vascularized by 4 portal veins emerging with the veins of segment S5 (in blue), the latter itself made up of 5 sub-segments.

c) Overall, all excisions can be simulated in the axial views or in reconstructed volumes. The focal attack of a wedge-shaped piece of liver tissue, the thickness of the resection margin, the surface of the slice or field plane can all be modified and validated in the native images. Last but not least, the prospective remaining hepatic volume is calculated with every change. (FRL).

d) The work and resulting images can be saved in image format at any time. Once the analysis is complete and the liver reconstructed in 3D, the processing can be saved in any file format such as PDF 3D or STL. These files are easy to send as attachments by e-mail, and can be printed automatically in 3D.

4) Other useful analytical tools for liver cancer surgery

The PET/CT viewer may be useful to improve the detection of very small lesions.
Comparison of 3D images over time, real oncologic imaging, making it possible to automatically analyze tumor changes during treatment according to different criteria: RECIST criteria for all tumors and mRECIST for hepatocellular carcinomas.

C – Requirements or restrictions

Synapse 3D is a solution designed to automate the 3D and volumetric analysis of the liver.

To extract and model the entire vascular structure, the acquisition of images in the arterial phase between 18 and 25 seconds and in the portal phase between 50 and 70 seconds is recommended.

A 3rd series of images (equilibrium phase) may be useful 3 minutes from the initial injection. This however is rarely asked, unless doubt persists regarding an angioma.

If combining MRI and CT images is desired, it is advised to acquire images in the same respiratory phase, ideally in expiration, to obtain best quality results.

The diameter of the arteries is largely underestimated because the lumen in the injected blood vessels is taken into account while the surgeon sees the outer wall of the blood vessels which doubles or triples the diameter for better appearance. The settings can perform any necessary adjustments.

We recommend that the surgeon focuses particularly on the vascular reconstructions possibly performed by a junior surgeon.

In fact, we determine our procedures and approach to the hilum of the liver based on the modeling performed with Synapse 3D.

Our low intraoperative laparoscopic bleeding complication rates, or our extremely low conversion rate won't make us go back anymore.

Why and how we use Synapse 3D in the field of Hepato-Biliary-Pancreatic surgery?

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■ ■ ■

A - The argument in favor of reconstruction software

Modern medicine often refers to the 4Ps: Predictive, Personalized, Preventive and Participatory. The personalized feature in surgery results in an anatomically based approach. The anatomy learned in textbooks describes the anatomy most commonly found in humans, but in practice no individual has a textbook type anatomy.

Fortunately, these anatomical variations are increasingly better understood thanks to ultrasounds or the cross-sectional imaging of Computed Tomography and MRI. These two techniques have the advantage of performing separate analyses and allow reconstructions, whereas radiologists' post-processing tools are either difficult to use or not readily accessible to surgeons.

To address the challenges of abdominal surgery, modern surgery endorses an increasingly minimal invasive approach which makes it possible to obtain significantly better clinical results whether performed by video-assisted percutaneous surgery or interventional endoscopy.

Many surgeons find it difficult to follow this approach, which is very clearly the case for liver surgery because a hepatectomy is a complex procedure. Currently, some experts estimate that only 50% of hepatectomies can be performed laparoscopically. Nonetheless, our team performs almost all minor or major hepatectomies laparoscopically - 96% of the previous 500 procedures. This is possibly thanks to the contribution of Synapse 3D which we use almost routinely!

B - The different functions of Synapse 3D

The Synapse 3D software is especially comprehensive and perhaps a complex tool. Its major benefit is that it is mainly automatic, however always grants the surgeon the possibility to check the relevance of options on native images, to modify or remove any error and to manually or semi-automatically correct any omission. (Fig 1)

This benefit is essential for us surgeons.
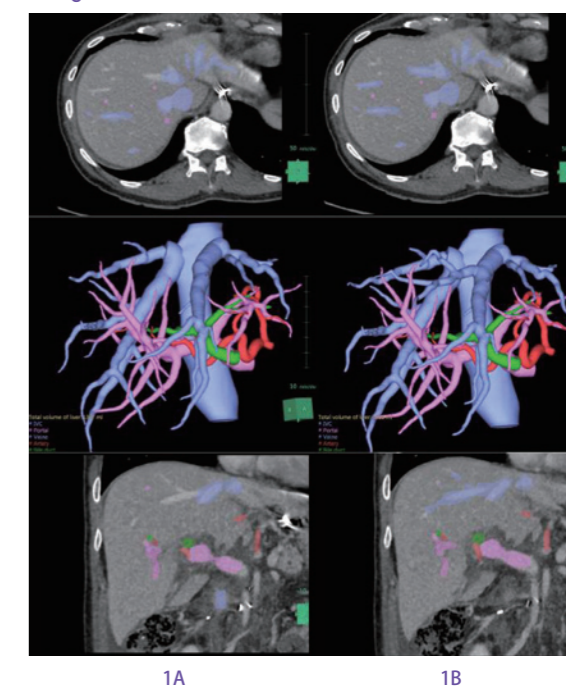
◆ Figure 1

1A   1B

Figure 1:
1A: On the initial reconstruction, in the median hepatic vein, the hepatic vein draining segment 8 is almost constantly missing.
1B: After adjustment. Should this vein have gone unnoticed, we're able to understand the risk of bleeding from performing a right hepatectomy, via the anterior approach, or an anatomical segmentectomy for S8.

1) The laparoscopic simulator

Laparoscopic surgery can be difficult, for example should the trocars be misplaced for the caudal pancreatic arteries. The single projection of a 3D image of the abdominal contents on the wall does not provide the extent of depth of the surgical field. Synapse 3D includes a laparoscopic surgery simulator which allows to perform a virtual laparoscopy, almost from start to finish. We begin by showing relevant and personalized human organ systems i.e. the pancreas, the adrenals, etc. either automatically (bone, skin, vessels, liver, spleen, tumor) or with semi-automatic tools. We will then perform a custom pneumoperitoneum because its characteristics may vary depending on the musculature, fat and morphotype (Fig 2).
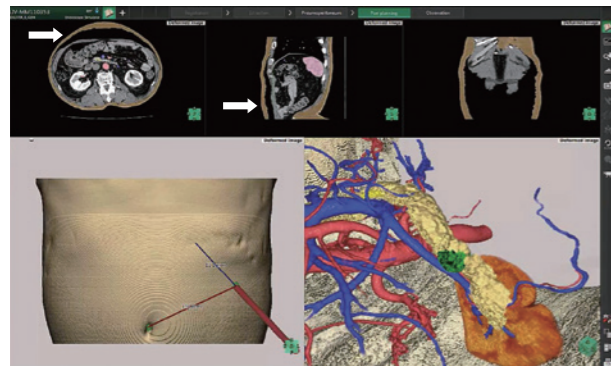
◆ Figure 2

Figure 2: Screen recording during virtual laparoscopic distal pancreatectomy. The white arrows show the customizable pneumoperitoneum created with the software.

After placing the optics trocar in the proper axis, Synapse 3D makes it possible to identify the distances on the skin's surface from the umbilicus or edge of the ribs. We can then simulate the organ's resection to properly determine the surgical risks.

2) The liver analysis tool

The viewing of a 3D liver with its blood vessels in addition to one or several lesions is mainly automatic.

a) The first step of the analysis is the liver extraction process, which is best performed from the portal or equilibrium phase images of the CT scan; a combination of CT scan and MRI images is also possible and extremely useful for the analysis and location of bile ducts or tumors, especially with a metastatic growth which is usually more visible on an MRI than a CT scan. The option to integrate the slices from the diffusion MRI makes it possible to differentiate actual missed metastases (invisible to the scan and MRI) from those which responded well to chemotherapy but still remain, even if minimally. This is all the more useful since missed metastases are often also invisible in a standard intraoperative ultrasound.

b) The second step is the extraction of the hepatic artery, the portal vessels and the hepatic veins with their branches (Figure 3). The extraction of the vena cava and gallbladder is semi-automatic. Therefore, after validation imposed by the software of the origin or termination of the various vessels, the liver is fully reconstructed automatically in 3D. The bile ducts, if dilated, can be easily traced on axial slices, otherwise they can be extracted from an MRCP (Magnetic Resonance Cholangiopancreatography) that Synapse 3D will merge.
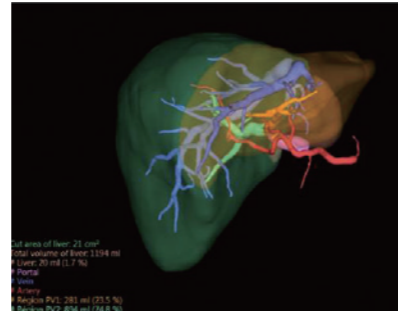
◆ Figure 3

Figure 3: After extraction of the hepatic artery, hepatic veins and portal trunk, hepatic segmentation started with the left lobe and the right lobe of the liver.

c) The last step is to locate the hypervascular or hypovascular tumors. While this step is usually automatic, the surgeon must sometimes complete this step manually, especially after chemotherapy, however it's very quick. Thereafter, the liver is reconstructed with its volume and all structures can be viewed from all angles. We ask our students to present the liver in the video-assisted laparoscopic angle of view. This is excellent practice for students and valuable assistance at the time of dissection of the hilum of the liver (Figure 4).
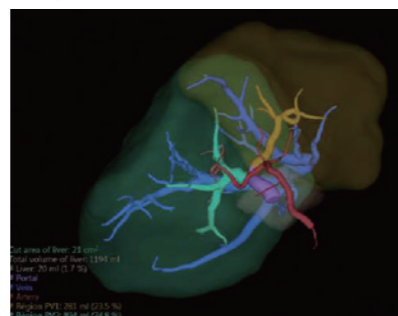
◆ Figure 4

Figure 4: The liver viewed from the laparoscope's angle

3) The benefits of a liver's analysis for the surgeon

a) The first benefit of this software is to improve safety by very easily locating the anatomical variations. These are very important for the surgical procedure: the emergence of the portal veins or arteries, their branches and sliding, or not, downward or leftward in the extrahepatic or intrahepatic ducts. Still the number and site of the hepatic veins in particular the presence of 1 or 2 median hepatic veins, the exact site of drainage of the S8 vein(s) if a right hepatectomy or a segmentectomy 8 is required, the crossing of the epiportal or hypoportal bile ducts, in front or behind the right anterior vein for example, etc. In fact the variations are countless and, especially for, but not only, a young clinician, the added value of a quality reconstruction is priceless.

Here are several examples of anatomical variations that are potentially dangerous. Arterial changes: Figure 5A and 5B
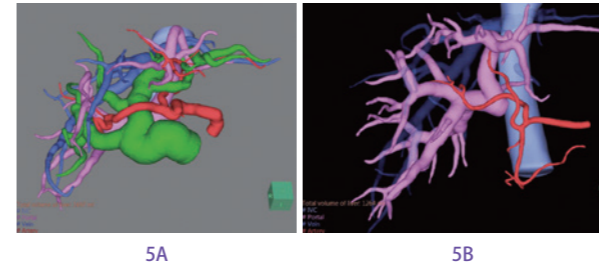
◆ Figure 5

5A   5B

Figure 5: Arterial changes
Fig 5A: The right hepatic artery crosses in front of the bile duct (pancreatic cancer).
Fig 5B: The left hepatic artery emerges right from the right artery.

Changes in the portal veins are just as numerous and risky (Figures 6A, 6B, 6C, 6D), while changes in the hepatic veins increase the risk of injury to the inferior vena cava (Fig 7A and 7B)
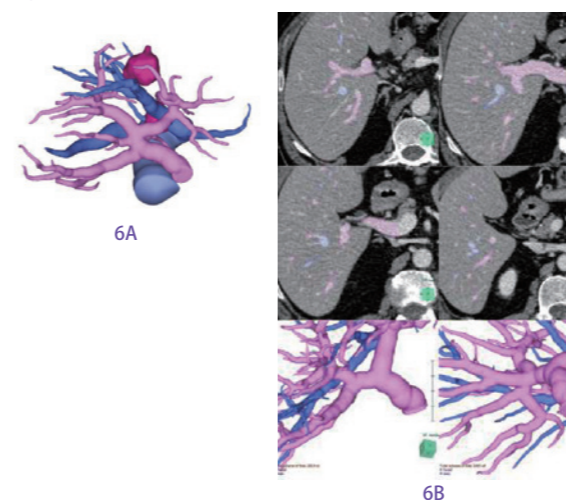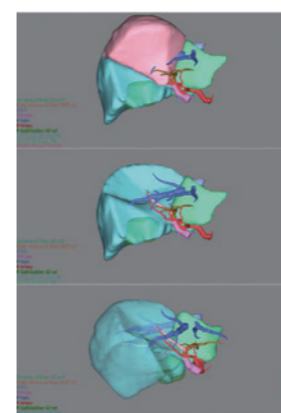
◆ Figure 6

6A

6B

Figure 6: Changes in portal veins
Fig 6A: There is no right portal vein. There is however a quadrifurcation of veins P6 and P7 which emerge separately. Fig 6B: A trifurcation of the right portal vein hidden in the front view (see picture below left). After rotation (see picture below left) portal vein trifurcation is observed.

6C

6D

Fig 6C: Three surgical views of the right portal vein dissection for a right hepatectomy. Double clip in the right anterior vein. Then appearance of a "normal" right posterior vein. In fact in the third image we see the P7 veins which emerge with a major risk of injury during the vascular control.

Figure 6D: Sliding of the portal vein S8 which emerges from the left portal vein. In case of a left hepatectomy, there is a risk of liver failure if this change is ignored.
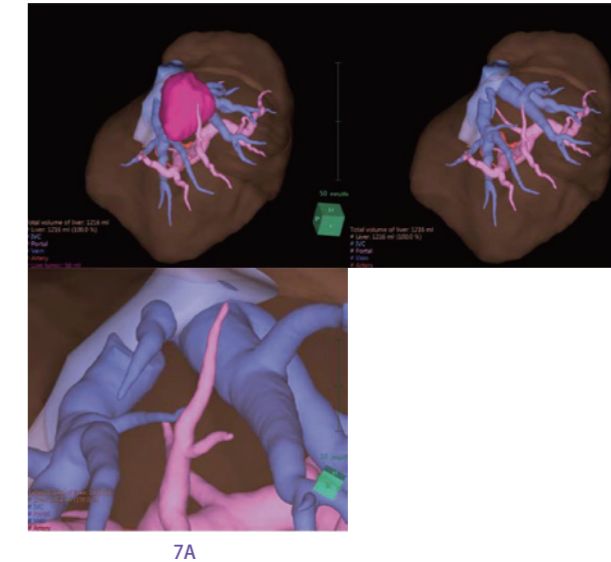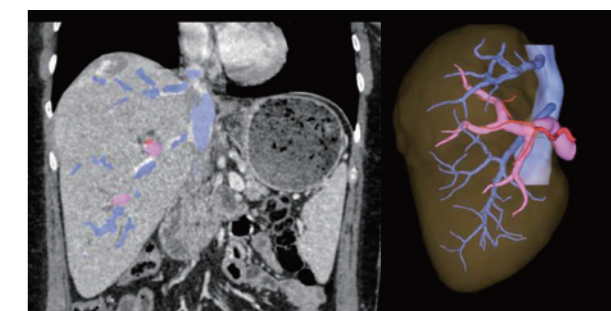
◆ Figure 7

7A

Figure 7: Changes in the hepatic veins
Fig 7A: V8 direct anastomosis to the inferior vena cava

7B

Fig 7B: 2 right hepatic veins; An upper vein for S7 + S8 and a lower vein for S5 + S6

b) The second benefit concerns anatomical hepatectomies. Starting from the portal veins, the software shows the anatomical limits and the volume of each vascularized part. For example the volume of the apical subsegment 8 (S8a), segment (S8), the right anterior field (S5 + S8), the right lobe (S5 + S6 + S7 + S8) in absolute value or as a ratio of total liver (Fig 8). In these calculations, if desired, the system can include the volume of the vessels or tumor.