achieved a mean sensitivity and specificity of 39 and 98 % respectively. Large vessels (e.g. cross of the portal vein) were visually identifiable on the 3D US generated model. In 8/14 (57 %) datasets, alignment between the preoperative image data and the intraoperative situation was improved according to visual inspection (Fig. 2). Alignment did not improve in 34 % of the cases, attributed to insufficient amount of vessel information in the acquired ROI (e.g. large tumours) (28 %), non-convergence of alignment algorithm due to poor US image quality (7 %), and an unclear technical failure of the algorithm (7 %). US acquisition, vessel segmentation and automatic registration required 49 s of time on average. A more quantitative assessment for alignment accuracy is currently under development.

Conclusion

We present the first results on the evaluation of an automatic US based registration approach. This will allow for precise alignment of the intraoperative situation with the pre-operative image data. First qualitative results indicate that its precision is better than those in existing (manual) alignment approaches. Involved clinicians confirmed the general usability of the presented framework in clinical routine. More data sets are currently collected to assess the precision of the approach.

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Development of a surgical template system for application in image guided liver surgery

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Keywords Liver surgery · CALS · Patient-specific template

Purpose

Although surgical resection remains the treatment of choice for malignant liver tumors, around 80 % of patients are considered unresectable because of various reasons, among which the size and location of the lesion [1]. By increasing the effective spatial accuracy during surgical resections and ablations of liver tumors, surgical instrument guidance systems may increase the number of patients eligible for surgery, and thus substantially improve patient outcome. A main challenge of their application is the transfer of the preoperative planning data (based on CT or MRI) to the intraoperative setting. This is particularly challenging in liver surgery, as the liver shape and size can differ greatly between the preoperative imaging and the surgery.

Patient-specific 3D templates are routinely used in the context of implant placement in dental and orthopedic surgery. Such templates are created from the negative 3D surface of the bone and can be used as guides for cutting, milling or drilling the bone according to the preoperative planning [2, 3].

In this work, we propose such a template for liver surgery. Placed around the liver, it can exactly reproduce the shape of the liver (known at the time of imaging) and enable the tracking of the organ during the surgery.

Methods

A first mesh was designed and produced for a patient scheduled for surgical resection of liver metastases.

The liver surface was segmented in the pre-operative CT and then meshed, resulting in a 3D grid reproducing the shape of the liver. The mesh was reduced to the parts relevant for maintaining the organ shape and separated in 3 sub parts to be mounted on the liver. From this 3D model, a biocompatible, sterilisable, polymer-based plastic mesh was produced using a rapid-prototyping process. In the final step, four retro-reflective spheres were added on the surface of the mesh (Fig. 1) in order to enable its tracking by a surgical instrument guidance system (CAScination, Bern, CH) using optical tracking [4].

Results

The mesh was successfully placed around the liver and mounted during surgery. It was qualitatively observed that the template successfully constrained the organ to its preoperative shape and size, even after complete mobilization (Fig. 2).

The liver was co-registered to its image data (MeVis, Bremen, Germany) by identifying corresponding landmarks on the model and in the situs. Landmarks were chosen both on the liver and on the mesh, leading to a fiducial registration error of 1.8 mm, compared to a median error of 6.3 mm when the registration uses standard anatomical landmark registration. After registration, the system was used to navigate the ultrasound imaging (Fig. 3).

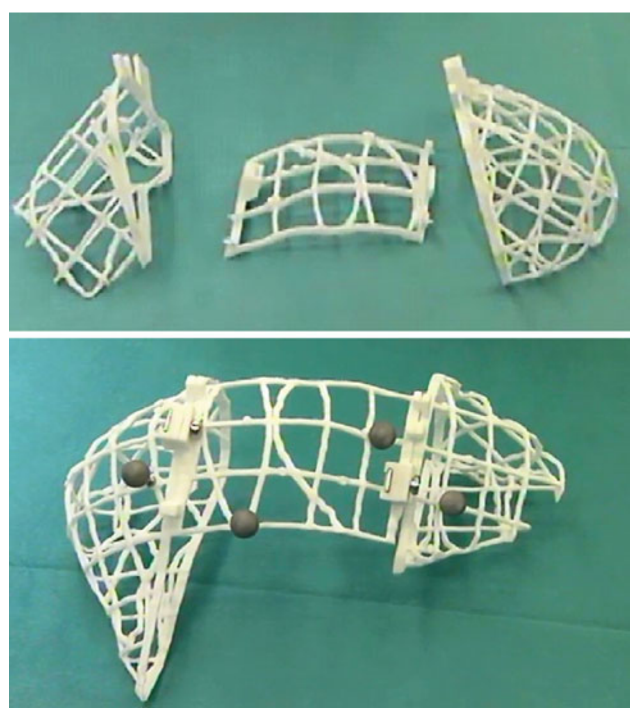

Fig. 1 Unmounted (*top*) and mounted (*bottom*) 3D mesh

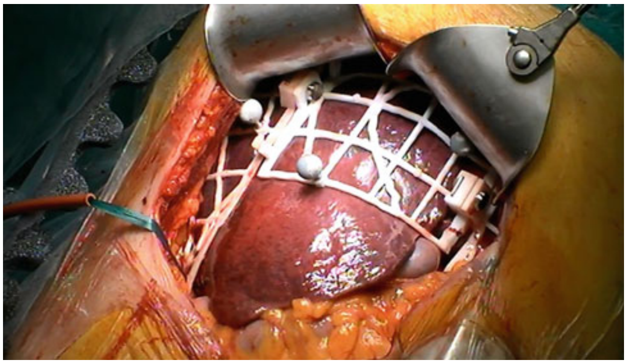

Fig. 2 3D mesh placed around the liver

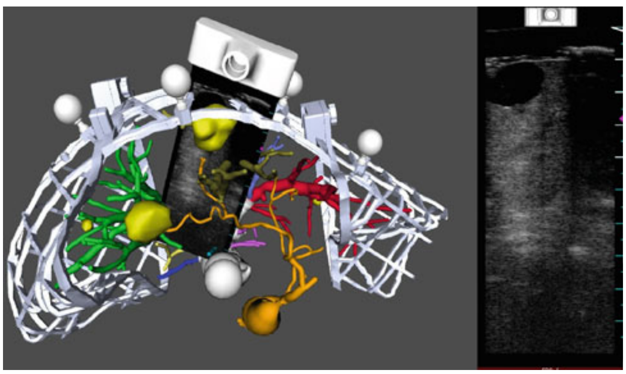

Fig. 3 Navigation interface showing a joint display of the three vessel systems of the liver, tumors, the 3D mesh and the ultrasound probe and image, together with a larger view of the ultrasound image

Conclusion

We presented a successful initial attempt to use patient specific surgical templates during open surgical liver interventions. We showed that such templates are relatively simple to design, manufacture and apply. Preliminary tests also indicate that such templates could increase the accuracy of the patient-to-image registration, resulting in more precise instrument guidance. Future work will show whether this method meets the requirements of standard clinical routine, and investigate the gain in registration and guidance accuracy on a statistically significant level.

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Novel portal vein pressure monitoring method for patient with portal hypertension using computational fluid dynamics

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Keywords Computational · Fluid dynamics · Portal vein pressure · Portal hypertension

Purpose

For patients with portal hypertension, monitoring portal vein pressure (PVP) is crucially important to determine a therapeutic strategy. Hepatic venous pressure gradient (HVPG) is one of the most common methods to monitor PVP, however, it is problem that HVPG is an invasive examination which has complication, such as bleeding, and needs hospitalization. Computational fluid dynamics (CFD) can provide detailed predictions of hemodynamics using 3 dimensional artificial vessel model and input/output parameters derived from medical information. Many researchers have reported that CFD was useful for investigate possible correlations between simulated hemodynamics and various medical outcomes, risk of rupture or growth of intracranial aneurysms, the development of peripheral artery disease, and vascular pathophysiological events related to bulk flow. The purpose of this study was to simulate and assesse the PVP using CFD models of portal veins.

Methods

Seven patients with portal hypertension were enrolled in this study. All patients were measured HVPG during the treatment, such as balloon-occluded retrograde transvenous obliteration. CFD models of seven portal veins were reconstructed from sequentially obtained contrast enhanced computed tomography images. Velocity waveforms derived from ultrasonograph were extracted and mapped to define boundary conditions. The 3D transient Navier–Stokes equations were solved by using the finite control-volume software, ANSYS®-CFX™. Blood was assumed to be incompressible, with density $q = 1{,}060$ kg m^{-3}, and Newtonian, with viscosity $l = 0.0035$ Pa s. For all velocity-based BCs a flat velocity profile was applied, in line according to the past reports. Arterial walls were assumed to be rigid. Pressure and velocity values, were monitored at several points within the portal vein. Figure 1 shows the meshes, pressure, and velocity line used and calculated in the analyses. Simulated and calculated pressure at the main body of portal vein was regarded as simulated portal vein pressure (sim-PVP). To study correlations between sim-PVP and actually measured HVPG, simple linear regression analyses were performed. Statistical analysis was performed using Stat View version 5.0 (Abacus Concepts, Berkeley, CA, USA). $p < 0.05$ (two-tailed test) was used to infer statistical significance.

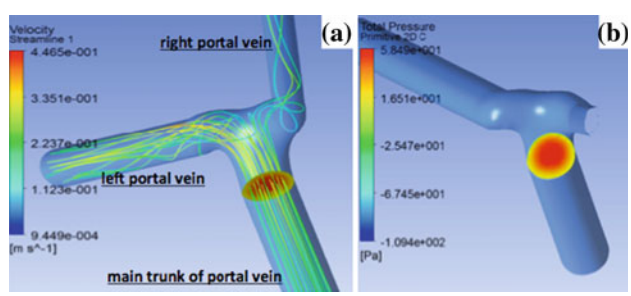

Fig. 1 Artificial 3D model of portal vein and the results of computational fluid dynamics. **a** Velocity streamline. **b** Pressure at the main trunk of portal vein