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## Computer assisted image guided stereotactic radiofrequency ablation of liver tumors

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**Keywords** Image guided interventions · Image guided tumor ablation · Liver

### Purpose

Computer assisted image guided stereotactic radiofrequency ablation (SRFA) of liver tumors may have the potential to improve treatment planning, electrode positioning, and operator performance and should allow for effective and safe treatment of even large lesions, lesions in proximity to large vessels and in subcapsular locations. Purpose was to evaluate technique effectiveness, safety and inter-operator difference of SRFA in a retrospective clinical review.

### Methods

In fully anaesthetized patients, after placement of skin markers, a contrast-enhanced helical CT scan is obtained with respiratory motion control during temporary endotracheal tubus (ETT) disconnection. Pathways for multiple probes are planned on the 2D and 3D reconstructions of the CT data. After sterile washing, draping and registration the Atlas needle holder (Medical Intelligence, Schwabmünchen, Germany) is adjusted using the Treon optical navigation system. One after another coaxial needle is advanced through the adjusted aiming device to the pre-planned depth during short ETT disconnections. After verification of correct needle placement by means of a native control CT and image fusion, a maximum of six RFA probes with an active tip of 3 cm are introduced into the coaxial needles to the pre-planned depth. An empirically calculated amount of RFA energy is applied at every probe position. In the case that the required necrosis is larger than the active tip, step-by-step retraction and ablation is performed according to the virtual plan. After RFA a contrast-enhanced CT scan is obtained with the coaxial needles in place, in order to compare the size of the induced necrosis with the original tumor size. After verification of the necrosis covering the tumor and a safety margin of approximately 1 cm, one after another coaxial needle is removed with tract ablation.

### Results

During the period from Jan 1st 2008 until Jan 1st 2010, in 90 consecutive patients (61 male, 29 female, mean age 61.1 years, range 22–85 years) a total of 106 SRFA for 177 lesions (72 HCC, and 105 metastases; lesion size mean 2.9 cm, max. 11 cm) were completed by two operators. Technique effectiveness, as evaluated on contrast-enhanced CT 1 month after SRFA, was 95.5%. Early local tumor progression at 3 months was 0% and local tumour progression at 6 months was 1.1%. Analyzed groups showed no significant difference when divided into lesions <3 cm versus 3–5 cm, but significant differences were found for lesions <5 cm (96.7%) versus >5 cm (87.5%) ($p$ 0.044). No significant difference of clear parenchymal lesions compared to vessel vicinity ($p$ 0.349), and subcapsular locations ($p$ 0.532) were found. Significant difference was found for organ vicinity with a mean tumor size of 4 cm ($p$ 0.020).Major complication rates were 6.6%, mortality was 0.9% (1 patient, sepsis and multi organ failure). There were no significant inter-operator differences.

### Conclusions

Technique effectiveness after a single session SRFA for even multiple lesions per patient and large liver lesions was 95.5%. Large and irregular lesions, as well as lesions in vessel vicinity and subcapsular location could be successfully treated. Due to a more aggressive approach SRFA provided slightly higher morbidity to conventional RFA. SRFA showed high reliability as there were no significant differences between the highly experienced and less experienced interventionalist. The preliminary results of SRFA are promising and should be confirmed in long-term clinical studies.

## Joint visualization of navigated ultrasound and segmented computer tomography data for image-guided liver surgery

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**Keywords** Image guided surgery · Liver surgery · Visualization · IGLS · CALS

### Purpose

The use of a surgical navigation system enables the fusion of pre- and intra-operative image data in a registered 3D context. In the case of navigated liver surgery, pre-operative computer tomography (CT) data is used for surgical planning and for the optimization of resection plans. This results in a set of detailed anatomical models of tumours, vessels and the liver surface which are complemented by virtual structures representing the surgical planning data. During surgery, intra-operative ultrasound (US) data is acquired directly on the organ and provides additional information about tumours which were not visible in pre-operative imaging. The fusion of the high-resolution CT data with the less detailed information but real-time information from US provides a surgeon an optimal representation of the surgical situation and supports decision making for a suitable surgical strategy.

Such data fusion leads to a large amount of information represented on the screen and it can be hard for a surgical user to interpret the resulting scene. We therefore aim to provide an intuitive and efficient visualization of the different image sources on the navigation system. The visualization on the navigation screen should require minimal interaction from the surgical user whilst providing a high amount of relevant information which can be used for the treatment decisions. Our solution aims to visualize the ultrasound images data in the usual way a surgeon looks at these images and to complement it with the 3D surface models of the pre-operative scenario. In order to avoid excessive complexity in the 3D scene, overlying structures are removed and vessels are shown as hollow objects for enabling unobstructed view on the ultrasound images.

### Methods

A surgical navigation system composed of an optical tracking system (Polaris Vicra, Northern Digital Inc., Canada), a miniaturized ultrasound system (Terason T3000 system with a 8IOA intra-operative probe, Terason Inc, Burlington MA, USA), a bare bone PC, a touch screen monitor and a set of custom tools for liver surgery was developed within our group [1]. Accurate navigated ultrasound imaging is achieved through a clinically applicable calibration framework [2] and registration between the image data and the camera coordinate system is achieved by a locally-rigid, landmarked-based registration on the organ surface [1].

Once registration is achieved for an area of interest on the liver, the surgical planning data can be visualized together with the intra-operative ultrasound image data. The ultrasound data is imported into the navigation system though a Firewire interface and the all ultrasound imaging parameters are controlled from the touch screen of the navigation system. The control of all imaging parameters ensures correct calibration of the ultrasound probe throughout the intervention. The 3D data is visualized in a Coin3D viewer where surface models are shown together with a texture representation of the ultrasound image. When the surgeon enables the image fusion mode, the 3D scene is rotated such that a perpendicular view on the US image is achieved and automatic zooming to adjust for seeing the US at constant size (Fig. 1, left). The complexity of the scene is then reduced by cropping objects lying between the camera and a plane located 5 mm in from of the US image plane (Fig. 1, right). This visualization the detailed vessel information with intra-operative findings from navigated ultrasound and enables the interpretation of the data without further interaction.

A qualitative evaluation of the visualization approach was performed off-line using image data from 8 navigated interventions performed in 2009 and 2010 where the patient registrations as well as US images and tool positions were recorded.

**Results**

The proposed visualization solution could be integrated in the existing navigation system for liver surgery (Fig. 2). Once fusion imaging was activated (one interaction step on the touch screen), the ultrasound probe could be moved freely while the view on the US image was kept stable and different 3D contents could be selected (vessels, tumours, resection planes). The resulting update rate for the 3D display was >25 Hz in all situations and the adjustment of visualization parameters could be performed without a visible delay.

A quantitative evaluation of the overlay accuracy showed that misalignment between the ultrasound image contents and the preoperative image data was visible, especially at higher depth within the liver (misalignment of the blue portal vein in Fig. 2). However, it was possible to identify corresponding structures between US and CT and a mental fine alignment of the visualized data could be performed by the surgeon.

**Conclusion**

We herein present a simple and intuitive visualization of US and CT data in navigated liver surgery. The fusion display provides the surgeon all the relevant information for treatment planning an execution

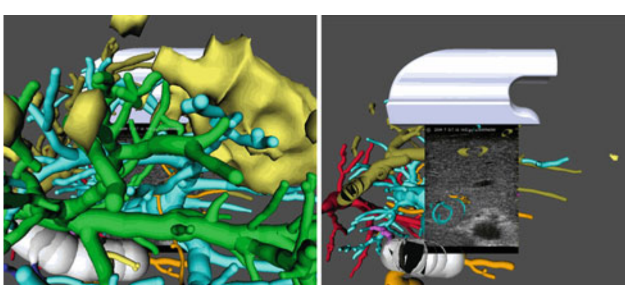

Fig. 1 Virtual cameras adjustment for perpendicular view on the ultrasound imaging plane (left image). Complexity reduction by removing structures located between the virtual camera and the ultrasound plane (right image)

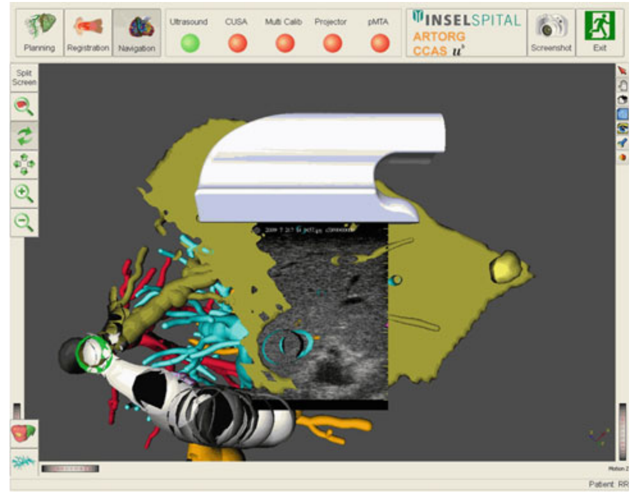


Fig. 2 Screenshot of the navigation interface showing the ultrasound image together with tumours, the three vessel systems of the liver and the planned resection plane (green)

on one screen and removes the need for manual adjustment of the viewing parameters. The accuracy of the overlay display is compromised by the assumption of locally rigid registration which was used when acquiring the test data. The development of an ultrasound-based registration approach is planned in order to cope with this problem. The visualization solution is available in a clinically applicable surgical navigation system and will be evaluated in real surgery during the next months.

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## Usefulness of a real-time virtual reality navigation system using an open magnetic resonance imaging: tumor ablation therapy for 50 liver cancers

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**Keywords** Real-time navigation · Liver cancer · Tumor ablation therapy · Open MRI

**Purpose**

A novel real-time virtual reality (VR) navigation system utilizing an open magnetic resonance imaging (open MRI) operating theatre has recently been developed. We report here the clinical results of percutaneous ablation therapies under the navigation system for 50 liver cancers, and evaluate the usefulness of the system.