MATRIX

Ten years experience with computer-assisted interventions from head to toe

Figure 1: Prof. Reto Bale, SIP-Lab Innsbruck.

By the Interdisciplinary Stereotactic Intervention and Planning Laboratory (SIP-Lab) at the Department of Radiology, Innsbruck, Austria

The future of interventional procedures is evaluated in the Interdisciplinary Stereotactic Intervention and Planning Laboratory (SIP-Lab) at the department of radiology I (Chairman: Prof. Werner Jaschke) at University Clinic Innsbruck, Austria. In 1994 Prof. Reto Bale started with the application of the first commercially available navigation system, the Viewing Wand, for computer-assisted videoendoscopic ENT surgery and neurosurgery.

Navigation systems consist of a workstation, a monitor and a 3D localisation system with different probes and instruments. They were originally developed for surgical disciplines (neurosurgery, orthopaedics, ENT,…) in order to guide the surgeon to the lesion and to avoid critical structures such as vessels and nerves. Similar to Global Positioning Systems (GPS) they provide the surgeon with orientation information in real-time. Medical navigation systems show the actual position of an instrument with respect to pre-operative imaging data during the surgical procedure.

The first patented targeting devices for the application of navigation systems, not only for surgery inside the body but also for precise percutaneous punctures ,were developed in Innsbruck in 1995 (patents by Bale and Vogele). Non-invasive immobilisation devices and modality (CT/MR/PET/SPECT) registration devices are a prerequisite for precise percutaneous procedures. For cranial interventions, a novel non-invasive immobilisation system based on an individualised vacuum dental cast was designed, the so-called Vogele-Bale-Hohner head holder. For the body, the vacuum-based BodyFix immobilization device was developed.

Using the optical-based Treon navigation system (Medtronic Inc., USA) in combination with the different immobilisation devices (Medical Intelligence GesmbH, Germany), nearly every point in the whole body can be reached with high accuracy. The path is planned on fused 3D CT/MR/PET/SPECT data, thus the needle can be placed in the active part of the tumour according to the PET data. In addition, image fusion of the post-treatment CT with preoperative CT/MR/PET/SPECT is performed in the treatment room.

The navigation system is used to register real-time acquired ultrasound images with CT and SPECT images for diagnosis of neck tumours and for percutaneous radiofrequency ablation of liver lesions. The ultrasound images are obtained real-time. Therefore the US probe is foreseen of tracking balls (detected by the camera of the navigation system). The combination of the two registered modalities proved very useful in the accurate detection of the tumour and – in case of liver lesions – it compensates for organ movements.

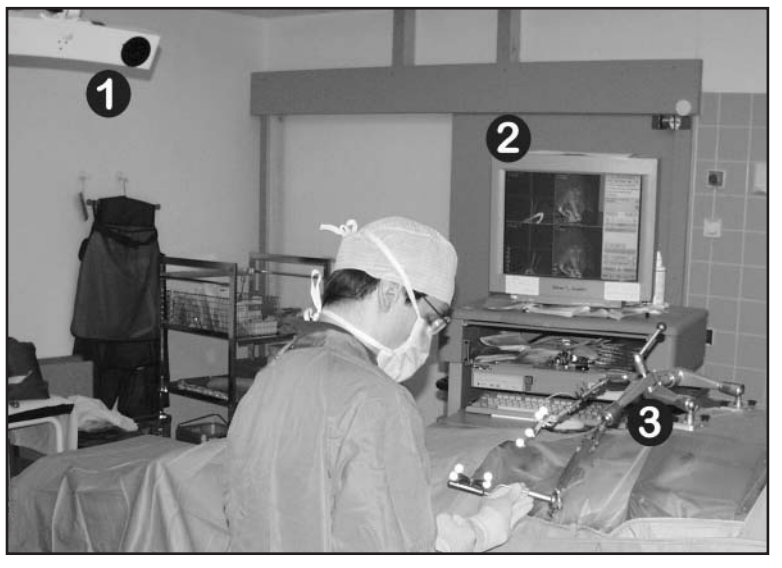

Figure 2: Computer-assisted bone tumour biopsy of a pelvic tumour in the CT scanner room: camera (1), monitor of navigation system (2), targeting device with tracker of navigation system (3). The patient is immobilized in the BodyFix in prone position.

The following computer-assisted percutaneous interventions are performed in an OR-converted CT scanner room by the SIP-Lab team in cooperation with the departments of neurosurgery, traumatology, orthopaedics, nuclear medicine and radiotherapy: Tumour biopsy from head to toe, radiofrequency ablation of bone and liver tumours, fractionated interstitial brachytherapy of ENT, bone and soft tissue tumours, retrograde drilling of osteochondral lesions of the talus, fixation of pelvic fractures including iliosacral screw placements, thermocoaguation of the Gasserian ganglion in patients with trigeminal neuralgia, placement of foramen ovale electrodes in patients with epilepsy of unknown origin.

A novel image guided template production technique for placement of dental implants was developed (Widmann, thesis) and has been transferred from phantom studies to initial clinical studies. The implants are planned based on preoperative CT. An individualised template with drill guides for the dentist is fabricated in the SIP-Lab using the navigation system in combination with a special targeting device.

In addition we are evaluating the latest prototype of the SENSIOM™ 6-arm robot (Medical Intelligence Inc., Schwabmünchen, Germany) for accurate biopsy and local tumour therapy in the whole body. It enables the user to quickly, safely and automatically guide an instrument along a desired trajectory to the target.

In conclusion, the interdisciplinary SIP-Lab team uses navigation systems for interventional procedures from head to toe on a routinely (daily) basis based on pre-operative CT-MR-SPECT-PET data. It is only a matter of time before these procedures are in practice in other hospitals. Interdisciplinary cooperation between navigation experts from the SIP-Lab and specialists from other departments (neurosurgery, orthopaedics, neurology, traumatology, ENT, radiotherapy, nuclear medicine, craniomaxillofacial surgery) is the key for a successful application of modern visualisation, navigation and robotic technology in order to improve patient outcomes.

Figure 3: Planning of 3 dental implants using the Treon navigation system (Widmann, thesis).

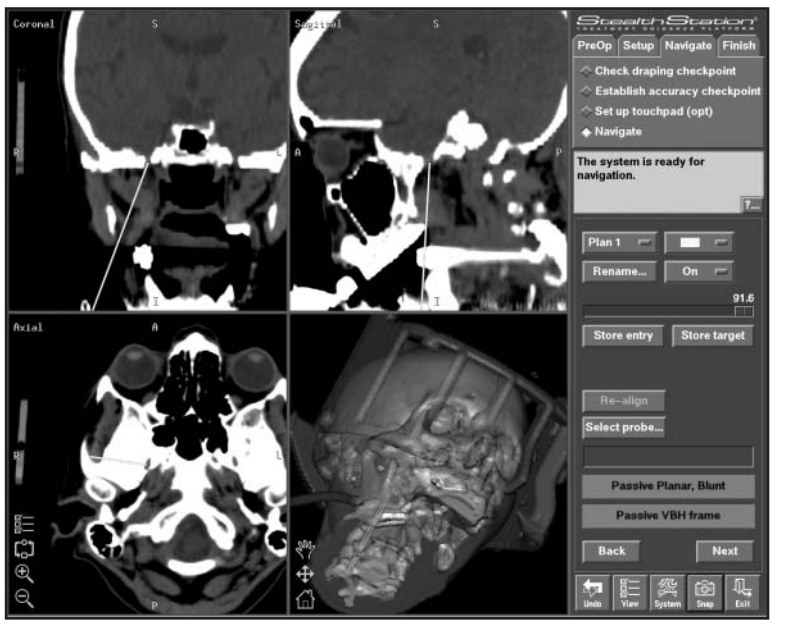

Figure 4: Electrocoagulation of the Gasserian ganglion: determination of path through the foramen ovale on the navigation system based on pre-operative CT data.

Figure 5: Individual template with drill guides for precise implantation of dental implants (Widmann, thesis).

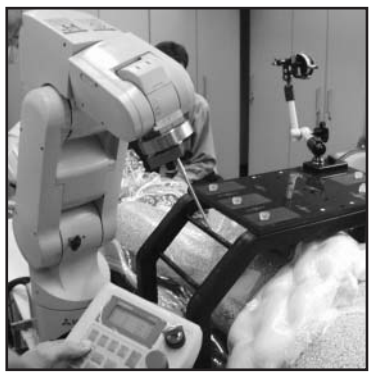

Figure 6: Sensiom 6-degree of freedom robot for precise automatic punctures.

The following persons are involved in the development and/or clinical applications of the SIP-Lab technology:
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