REGIONAL ANAESTHESIA IN VIRTUAL ENVIRONMENTS

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Introduction: The successful accomplishment of regional anaesthesia (RA) requires profound theoretical knowledge and repeated performance of RA to gain sufficient manual skills [1]. Despite the increasing use of simulators to learn and improve medical skills, the adoption of mannequins for RA training is limited by patient variance, inaccurate representation of biological tissue, and physical wear from repeated use. However, interactive virtual reality (VR) simulators are potentially valuable to overcome these constraints [2]. In an interdisciplinary approach, we therefore launched the Regional Anaesthesia Simulation (RASim[a], http://www.rasim.info/) project [3, 4].

Methods: Individual subject-specific data is obtained non-invasively without contrast agent from magnetic resonance imaging (MRI) and magnetic resonance angiography (MRA) representing morphology and vascular structures, respectively. For data handling, registration, and segmentation, an application is developed on the basis of the Medical Imaging Interaction Toolkit (MITK), the Insight Segmentation and Registration Toolkit (ITK), and the Visualization Toolkit (VTK). Additional segmentation algorithms are integrated, and a hierarchical tree data structure is created to simulate the flexible anatomical structures of peripheral nerve cords. The simulator is implemented in the VR toolkit ViSTA. Several modules for collision detection, virtual humanoids, interaction, and visualization are applied. To simulate needle interaction and electric impulse transmission, a novel approach based on electric distances is developed. A pilot study among ten residents, who had to perform a femoral nerve block, is carried out with the simulator (Figure 1a) and systematically evaluated using a 24-item questionnaire on a 5 point Likert-scale ranking between 1 (best) and 5 (worse). Furthermore, our individualized image data is compared with a current state-of-the-art commercial dataset (Zygote, USA), [5] that consists of geometry and textures representing the anatomy of a male subject (Figure 1b). The PHANTOM Omni Haptic Device (SensAble Technologies, USA) is used for realistic control of the instruments and to provide the optional force feedback. Results are expressed as mean ± SD.

Results: MRI and MRA data were obtained from 5 individuals from the inguinal region. Relevant data were successfully extracted employing our new software. Further differentiation of anatomical structures was realised using an ontology subdividing and describing tissue types as well as cavities. As nerves cannot be sufficiently visualized, virtual nerve cords were modelled according to a hierarchical data structure along anatomical landmarks. The simulator utilized this data and consistently applied the developed modules for collision detection, virtual humanoids, interaction, and visualization. Needle interaction and electric impulse transmission was simulated realistically.

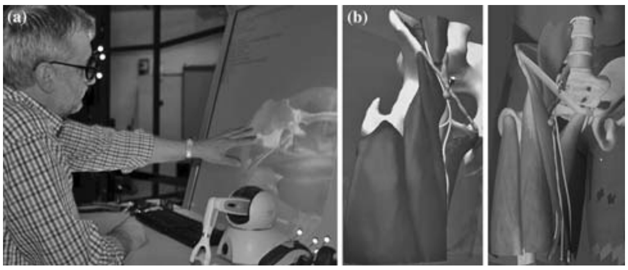

Fig. 1. (a) User exploring the VR-based simulator (left); (b) A manual segmented dataset (middle) and the commercially available Zygote dataset (right) are shown.

The user study showed an overall acceptance (1.8 ± 1.6) with the ease of use of the simulator. Also the anatomy and identification of landmarks were highly rated (2.2 ± 1.6), both for our and the Zygote datasets. Further, we did not reveal any advantage of the commercial dataset. Despite the use of a 3D navigation, 90% of the participants stressed the importance of the incorporation of sophisticated haptic feedback allowing the tactile perception of tissue resistance.

Discussion: In order to create a VR-based simulator, we successfully introduced a highly flexible software structure using sophisticated algorithms and multimodal representations of anatomy. This approach allows creating individualised VR patients for training a variety of RA blocks to enhance realism and user acceptance. The success of this concept was also confirmed by our pilot study, which further showed, that the quality of our imaging approach is comparable to commercial available data sets. Prospective research will include the extension of other anatomical regions and the integration of ultrasound to perform peripheral nerve blocks.

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