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● *Technical Note*

ULTRASOUND-GUIDED SPINE ANESTHESIA: FEASIBILITY STUDY OF A GUIDANCE SYSTEM

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Abstract—Spinal needle injections are guided by fluoroscopy or palpation, resulting in radiation exposure and/or multiple needle re-insertions. Consequently, guiding these procedures with live ultrasound has become more popular, but images are still challenging to interpret. We introduce a guidance system based on augmentation of ultrasound images with a patient-specific 3-D surface model of the lumbar spine. We assessed the feasibility of the system in a study on 12 patients. The system could accurately provide augmentations of the epidural space and the facet joint for all subjects. Following conventional, fluoroscopy-guided needle placement, augmentation accuracy was determined according to the electromagnetically tracked final position of the needle. In 9 of 12 cases, the accuracy was considered sufficient for successfully delivering anesthesia. The unsuccessful cases can be attributed to errors in the electromagnetic tracking reference, which can be avoided by a setup reducing the influence of the metal C-arm. (E-mail: purang@ece.ubc.ca) © 2016 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Model-based registration, Epidural needle insertions, Facet joint injections, Ultrasound, Guidance.**

INTRODUCTION

Needle insertions in the lumbar spine play an important role in pain management and regional anesthesia. Facet joint injections are commonly used to relieve pain in the lower back (Boswell et al. 2007), which is experienced by up to 80% of adults at least once in their lifetime (Rubin 2007). Epidural needle insertions are often applied for pain relief during labor and delivery, for surgical anesthesia and analgesia and for chronic pain management (Parr et al. 2009). Both procedures require careful placement of the injection needle to ensure effective delivery of therapy and to avoid damage to the spinal cord and nerves, dura and epidural vasculature. Conventionally, these procedures are either performed by solely relying on the sense of touch or under repeated fluoroscopic imaging and, thus, result in frequent needle re-insertions and exposure of the patient to radiation. Ultrasound guidance of these procedures has gained in popularity, but is still limited by its difficult interpretability (Yoon et al. 2013). Proposed ultrasound-based guidance techniques aim to enhance ultrasound images with information obtained from pre-operative images such as computed tomography and magnetic resonance imaging (Chen et al. 2010; Moore et al. 2009; Ungi et al. 2012). However, such pre-operative images are, especially in obstetric anesthesia, not always available.

In this study, we clinically evaluate our previously presented ultrasound guidance system for epidural needle insertions and facet joint injections (Rasoulian et al. 2015) on 12 patients. The system allows patient-specific augmentation of live standard 2-D ultrasound images with anatomical information from a statistical 3-D surface model of the lumbar spine and relation of this information to the position of the tracked injection needle.

METHODS

The study was approved by the institutional Medical Research Ethics Board under No. H13-01968 before patient enrollment started. Twelve patients (9 female, 3

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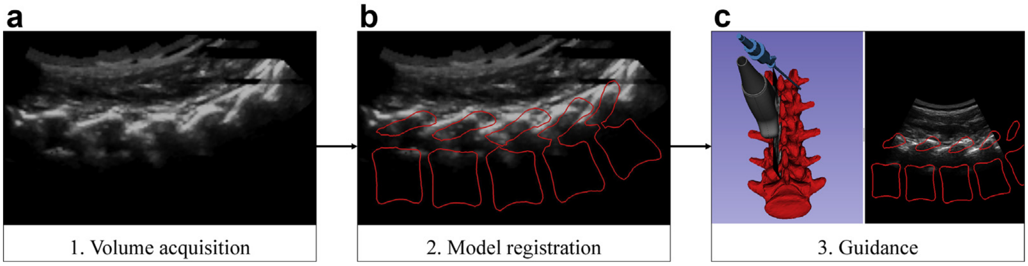

Fig. 1. Workflow of ultrasound-guided spine anesthesia. (a) An ultrasound volume is acquired from tracked 2-D ultrasound slices. (b) The statistical 3-D surface model of the lumbar spine (*red*) is optimized and registered to the reconstructed volume. (c) The registered statistical model of the spine is used to highlight anatomical features (in this case, the surface of the vertebrae on the right side) in the live 2-D ultrasound image and is visualized along with the tracked injection needle in the 3-D guidance interface (left side).

male) with an average age of 65 years undergoing a fluoroscopy-guided epidural needle insertion or facet joint injection participated in this study. Written informed consent was obtained from each subject in the study prior to the performed intervention. Although not excluded, no patients presented with scoliosis.

Ultrasound guidance system overview

The main idea behind the evaluated guidance system is to simplify interpretation of spinal ultrasound scans by augmentation with anatomical information of the target structure obtained by registering a statistical 3-D surface model of the lumbar spine covering the statistical variations in shape and pose of the vertebrae to the ultrasound space (Fig. 1). The model is built from 32 computed tomography segmentations of the lumbar spine from which shape and pose statistics are calculated separately by applying a principal component analysis on the ensemble of the lumbar vertebrae both on the point cloud (shape) and in the Lie space for the similarity transformations (pose) (Rasoulian et al. 2013). The lth vertebra of the model can be instantiated by applying different weights (shape coefficients w_k^s, pose coefficients w_k^p) to the kth principal component,

$$s_l = \Phi(\vec{w}^s, \vec{w}^p) = \Phi_l^p\left(\Phi_l^s(\vec{w}^s); \vec{w}^p\right) \qquad (1)$$

where $\Phi_l^p(\vec{w}^p)$ denotes the similarity transformation, and $\Phi_l^s(\vec{w}^s)$ is a shape representation of the lth vertebra.

For registration with an unseen 3-D US volume, (i) the bone surfaces in US are extracted as the point cloud Y using the bone enhancement approach presented by Foroughi et al. (2007); (ii) the model is initialized in the US volume by a single landmark-based registration, assuming that the patient is oriented in prone position

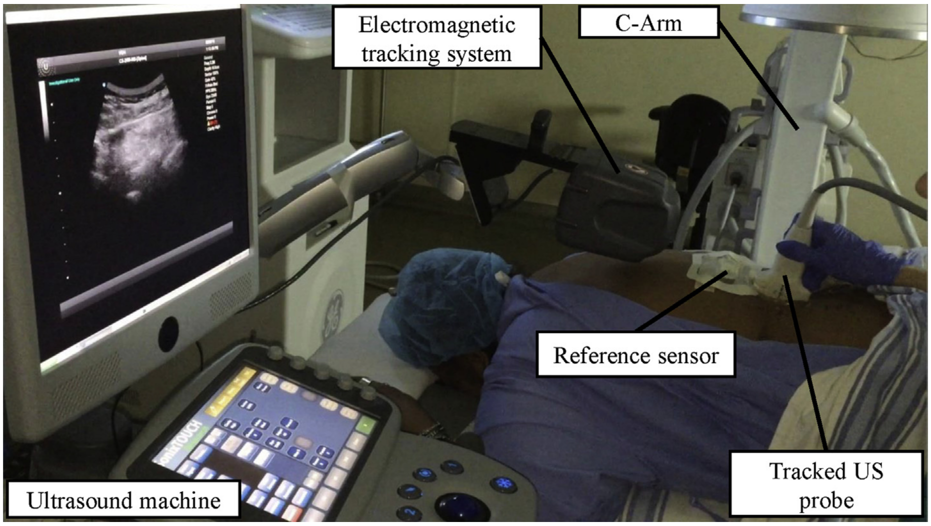

Fig. 2. Setup of the guidance system within the conventional setting in the intervention room. The fluoroscopic C-Arm was used for the conventional needle positioning procedure. The field generator of the electromagnetic tracking system was positioned near the T12 vertebra of the spine. The sonographer grabbed the ultrasound volume using a tracked 2-D ultrasound probe connected to the ultrasound machine. The reference sensor was used to achieve a consistent orientation of the reconstructed volume.