Ultrasound-based vertebral landmark localization using deformable spine models

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PURPOSE: Identifying vertebral landmarks in ultrasound (US) is non-trivial. Landmarks may be hidden or difficult to identify in patients with diseased spines [1]. We propose to assist the user in discerning spinal geometry through overlay of a visual aid in the US image space during landmark identification.

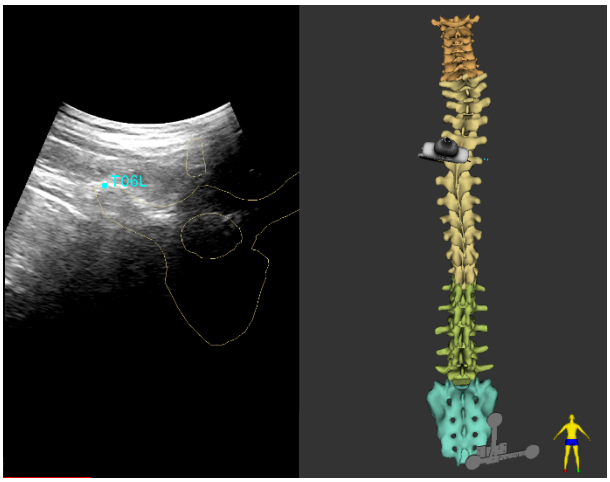

Figure 1. US image with overlay of T6 vertebrae.

METHODS: Users identify several prominent landmarks to create deformably registered generic healthy spine model in the US space with Church *et al.*'s method [2]. This model is overlaid on the images to provide visual aid to the operator for remaining landmarks (Fig. 1). With each identified landmark, the registration is re-computed. A tracked US system was developed using the open-source 3D Slicer application platform and the PLUS toolkit [3, 4] (Fig. 2). Six operators identified vertebral landmarks using US images, and using visualizations and US images. A one tailed Student's t-Test for independent unpaired samples compared the mean landmark identification rate between all operators. Analysis of time to task completion is also presented. Software usability was assessed through a questionnaire following the study.

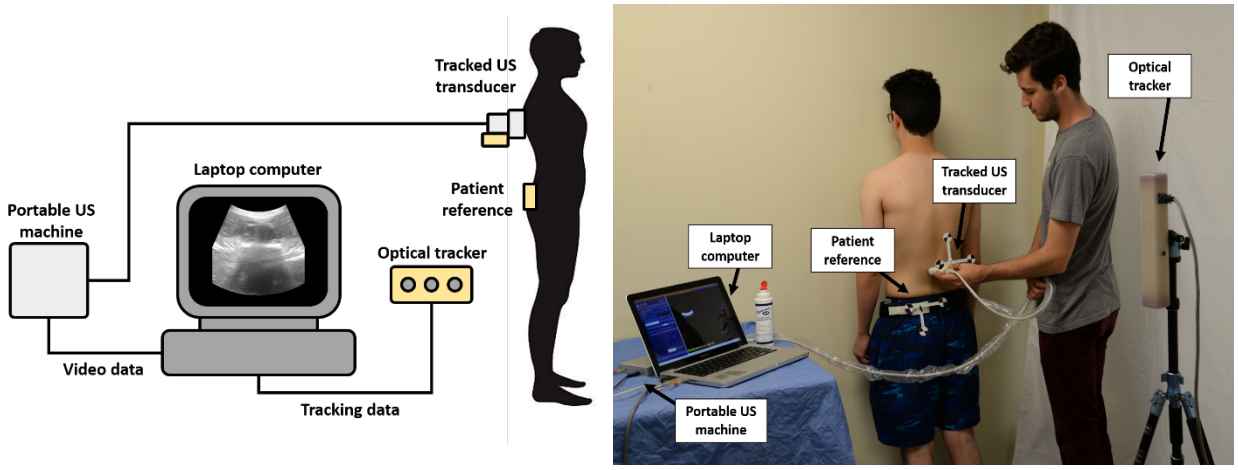

Figure 2. *Left*: Schematic diagram of the tracked US imaging system. *Right*: The tracked US imaging system in use.

RESULTS: The mean landmark identification rate of operators using visualizations and US was significantly higher than US only (82 [72 – 94] % *vs* 51 [37 – 67] %, respectively; $p = 0.001$). Additionally, time to completion was higher using visualizations and US than US only (842 [448 – 1136] s *vs* 612 [434 – 785] s, respectively; $p = 0.047$). Operators found visualizations helpful in landmark identification, and in visualizing the spine.

CONCLUSION: A three-dimensional visual aid was developed to assist in vertebral landmark identification in a tracked US system by deformably registering and visualizing a healthy spine model in US space. Operators found visual aids useful and they were able to identify significantly more vertebral landmarks than without it.

REFERENCES: [1] Ungi *et al.*, "Spinal curvature measurement by tracked ultrasound snapshots," *Ultrasound in Medicine & Biology*, 2014. [2] Church *et al.*, "Visualization of scoliotic spine using ultrasound-accessible skeletal landmarks," SPIE Medical Imaging, 2017. [3] Kapur *et al.*, "Increasing the Impact of Medical Image Computing using Community-based Open-access Hackathons: The NA-MIC and 3D Slicer Experience," *Medical Image Analysis*, 2016. [4] Lasso *et al.*, "PLUS: open-source toolkit for ultrasound-guided intervention systems," *IEEE Transactions on Biomedical Engineering*, 2014.