Title

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**ABSTRACT**

# Introduction

Lumbar spine injections are widely used to deliver pain relief to patients suffering from facet joint pain, and for epidural anesthesia during labor. The target injection site’s size, depth, and proximity to the spinal cord and nerves make these procedures challenging, often requiring multiple insertion attempts and causing nerve damage. The difficulty and risks associated with such injections have caused fluoroscopy and CT to emerge as the standard imaging modalities for guiding these procedures. However, fluoroscopy and CT imaging result in repetitive exposure of practitioners to ionizing radiation. The health and safety standards made necessary by the risks associated with these imaging techniques increase their cost, and decrease their availability.

The safety, low cost, and accessibility of ultrasound imaging has attracted research investigating it as an alternative imaging modality for guiding a these procedures. Loizides et al. [Loizides2011] present a method for locating lumbar injection sites using ultrasound. Ungi et al. [Ungi2012b] extend basic ultrasound by adding spatial tracking to the ultrasound and needle, allowing images to be captured, and the needle positioned without the need to manage the probe simultaneously. Despite these methods allowing for the location of injection sites without ionizing radiation, they have not gained widespread use, partly due to the difficulty of interpreting ultrasound images. Addressing this difficulty, more recent work by Nagpal et al. [Nagpal2015] and Zettinig et al [Zettinig2016], investigated generating 3D surface visualizations of patient spines by registering CT-derived surface models to patients’ tracked ultrasound scans. However, the need for a CT scan of the patient to register makes these methods unsuitable for reducing radiation exposure.

Behnami et al [Behnami2016] and Seitel et al. [Seitel2016] generated similar visualizations, but by registering statistical atlas spine models to patient ultrasound, eliminating the need for prior CT scans, and ionizing radiation with them. Statistical atlas registration is feasible in cases where the geometry of the spine is normal, as the availability of previous CT scans of such spines provides enough data to generate the atlas. This is not the case in states of disease causing abnormal geometry, such as scoliosis. The wide variety of shapes possible in diseased spines makes the collection of sufficient data to generate an atlas challenging. [Anon2017] presented a method for generating surface visualizations of spines by deforming a generic, healthy-shaped spine model to patient anatomy, based on only the patient’s transverse process locations. [Anon2017] produced qualitatively informative visualizations, testing their method on four patients, however the visualization accuracy was not validated for interventional navigation.

There remains the need for a method which produces spinal visualizations for interventional guidance without using ionizing radiation, and which is suitable for cases of abnormal anatomic geometry. We address this need in the remainder of the paper, which is organized as organized as follows.

# Methods

# Results

# Discussion

# Conclusions

# References

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