Development of a Virtual Reality Educational Module Using a Scoliosis Patient-Specific Three-Dimensional Model

Catharine Keim MD[1], Parhesh Kumar BS[2], Ingharan Siddarthan MD[1], Rohan Jotwani MD[1], Robert White MD[1], John Rubin MD[1]

[1] Department of Anesthesiology, Weill Cornell Medicine, New York-Presbyterian Hospital, New York, NY

[2] Weill Cornell Medical College

Background

- Scoliosis is commonly encountered in the obstetric population and can make neuraxial anesthesia challenging, especially for trainees
- Understanding the 3D distortion of scoliosis is paramount to planning a safe and effective approach; however teaching this concept using conventional modalities is difficult[1]
- Previously, we implemented a virtual reality (VR) curriculum for neuraxial procedural training into our obstetric anesthesia rotation for trainees[2]
- Here we expand upon this curriculum with the development of a scoliosis module using a patient-specific 3D model of scoliosis

Figure 1 from reference [2]
(a-b) Images of trainees using VR headsets
(c-d) Images within VR environment

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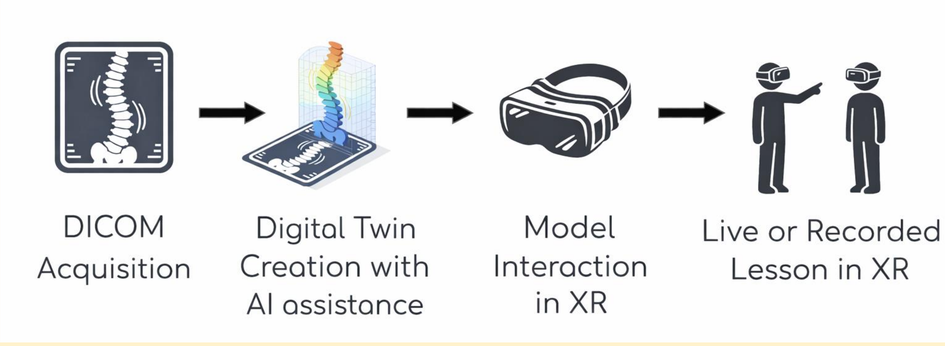
Methods

- A patient with severe scoliosis was identified and informed consent for use of imaging data was obtained
- High-resolution CT images in DICOM format were imported into Medical Holodeck's Medical Imaging XR software
- Using a combination of AI-driven and manual optimization, images were segmented to isolate relevant spinal anatomy
- Different tissues (e.g., bone, muscle, ligament) were colorized using gradient-based lookup tables to emphasize anatomic clarity
- Once refined, the model was loaded into a VR environment on a Meta Quest headset along with additional elements (e.g., 2D radiographs) prior to recording
- An immersive educational module was recorded in the VR environment



Key steps of the pipeline from individual patient imaging to patient-specific medical education

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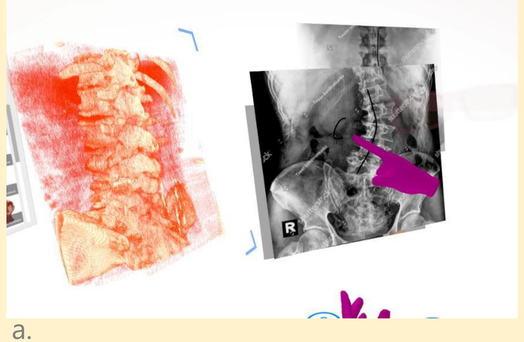
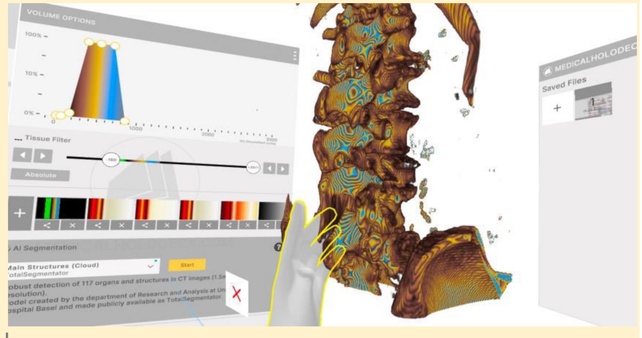
Results

- The final product is an 8-minute, instructor-led, spatially anchored learning experience
- The lesson begins with an external view of a scoliotic spine, noting physical exam findings that can be used to mentally map underlying anatomy
- Spine anatomy and vertebral rotation is then explored using plain radiographs, noting the limitations of this view
- Moving to the 3D model, anatomy is contextualized in space using functions such as draw, rotate, splice, and zoom
- Vertebral rotation is explored through axial cross-sections and 3D drawing is used to demonstrate needle path in different approaches (e.g., midline vs. paramedian)



a.



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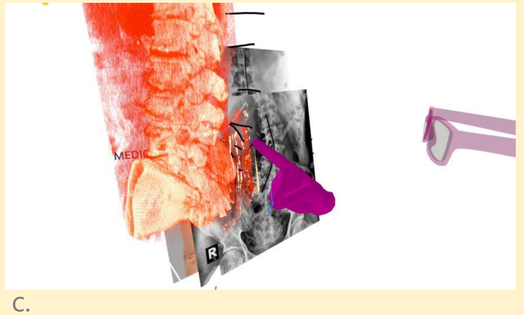

c.

(a.-c.) Screenshots from a live session of the learner's point of view interacting with the RXR lesson

a. Learner viewing lesson from instructor's point of view
b. Learner independently interacting with 3D scoliosis model
c. Learner viewing lesson from a different point of view than instructor

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Conclusions

- ❖ Proof-of-concept process demonstrating the development of a "digital twin" model as an educational tool
- ❖ Technical pipeline integrates patient-specific imaging with artificial intelligence-based segmentation and virtual reality technology
- ❖ The final educational product is reusable and can be uploaded and viewed on any compatible VR headset

Future Directions

- ➢ **Short-Term Outcomes:** Assess educational effectiveness, user feedback (e.g., pre-/post- knowledge assessment, post-intervention satisfaction survey), integrate into current VR neuraxial curriculum
- ➢ **Long-Term Outcomes**: Assess knowledge retention and transfer to clinical practice (e.g., confidence performing neuraxial in patients with scoliosis)
- ➢ **Haptic Technology**: Integrate force-feedback devices for realistic tactile sensations
- ➢ **Expand VR Curricula**: Develop modules for other pathologies (e.g., lumbar spine surgery, disc disease, spondylolisthesis/spondylolysis)
- ➢ **Clinical Applications**: Utilize technology for procedural planning for complex cases (e.g., lumbar spinal fusion)

References

1. Rubin JE, White RS, Boyer RB, Jotwani R. Obstetric anesthesiology and extended reality: an introduction to future uses of spatial computing in obstetric anesthesiology. *Int J Obstet Anesth*. 2024;57:103959.
2. Rubin JE, Jotwani R. Curriculum for neuraxial procedural training using medical extended reality. *Br J Anaesth*. 2025;134(6):1797-1800.