Clinical feasibility of pediatric scoliosis monitoring using portable ultrasound

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INTRODUCTION: Continual spinal curvature monitoring is essential in making treatment decisions in scoliosis. Monitoring entails radiographic examinations, however repeated ionizing radiation exposure has been shown to increase the risk of cancer later in life. Ultrasound does not emit ionizing radiation and thus is a safer alternative for spinal curvature monitoring. We investigated a clinical sonography protocol and challenges associated with position-tracked ultrasound in spinal curvature measurement in paediatric scoliosis.

METHODS: Lateral ends of transverse processes (TPs) were localized in 3-D space with cross sectional ultrasound snapshots using 3D Slicer software. The transverse process angle (TxA) – the angle between the line joining the midpoint of two opposite TPs and the transverse plane – was determined for each vertebra. Based on the orientation of each vertebra, the overall Cobb angle was determined and compared to the radiographically determined Cobb angle. We tested our methodology on five patients in a local pediatric scoliosis clinic.

RESULTS: Despite correlation between radiographic and ultrasound measurements in phantom studies, we encountered new challenges in the clinical setting, chiefly, differentiating TPs from ribs during landmarking. We observed up to 13° angle variability for a single vertebra and a 9.85° ± 10.81° difference between ultrasound and radiographic Cobb angles for thoracic curvatures. We explored two alternative sonography strategies: (1) landmarking the midpoint of the most medially visible ultrasound snapshot of the TPs (medial TP method) and (2) landmarking the center of two laterally equidistant points from each spinous process (lateral equidistant TP method). Testing on a *healthy volunteer* (14 vertebrae), we observed average TxA values within 3.29° ± 3.01° of expected values for the medial TP method and within 4.80° ± 4.24° for the lateral equidistant TP method. This suggests the medial TP method may yield more accurate Cobb angles; however, further testing is required. We also tested landmark visualization with two machines: the Telemed MicrUs EXT-1H and the Sonix Touch. We found the results to be comparable. Additionally, we were unable to visualize landmarks in the lumbar region where superficial tissue depth was 25-35mm. As a solution, we used a lower frequency transducer with greater penetrative ability. Testing at 5MHz (rather than 10 MHz) on a *healthy volunteer* (11 thoracic and five lumbar vertebrae), we observed average lumbar vertebra angles within 4.03° ± 3.56° of expected values, while we could not evaluate lumbar TxA angles when scanning at 10MHz. When we tested the thoracic region, we observed TxA values within 2.62° ± 2.56° of expected values at 5MHz and angles within 5.29° ± 4.27° at 10MHz. This suggests that scanning at 5MHz, especially in areas with thick soft tissue, might improve accuracy, although more testing is needed. Finally, in volunteers with large Cobb angles (greater than 40° thoracic and 60° lumbar), we observed spinal protrusions, incomplete probe-skin contact, and partial ultrasound images not suitable for landmarking. To mitigate this, we propose using an acoustic standoff pad taped onto the participant's back to create a smooth contour. We tested a 1cm deep standoff pad with a lumbar phantom. The average TxA angle obtained using the pad was found to be within 1.11° ± 0.61° of the TxA angle obtained without using the standoff pad, suggesting this can be a viable strategy to mitigate this challenge.

CONCLUSIONS: Our clinical investigation revealed three main challenges that have not been previously reported in literature on US scoliosis monitoring phantom studies. These include: TP/rib differentiation and accurate anatomical landmarking in the thoracic region, visibility of bony structures in regions with thick soft tissue, and maintaining full probe to skin contact over surface contour protrusions in severe scoliosis. We offer possible solutions to these obstacles. These challenges must be resolved before a clinically practical sonography and angle measurement protocol can be developed for scoliosis monitoring.

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