Spine Visualization from Transverse Process Landmarks

Ben Church, Andras Lasso, Christopher Schlenger, Daniel P. Borschneck, Parvin Mousavi, Gabor Fichtinger, Tamas Ungi
Queen's University, Kingston, Canada

Introduction

- The spine is often visualized by X-ray and CT, resulting in radiation exposure or MRI, having limited availability.
- Ultrasound is a safe, inexpensive, and accessible imaging modality where spine landmarks such as transverse processes can be localized [1].
- Spinal curvatures can be measured from ultrasound landmarks (Fig 1).
- Anatomic landmarks alone do not allow visualization of the spine in a familiar manner to the clinician and patient.

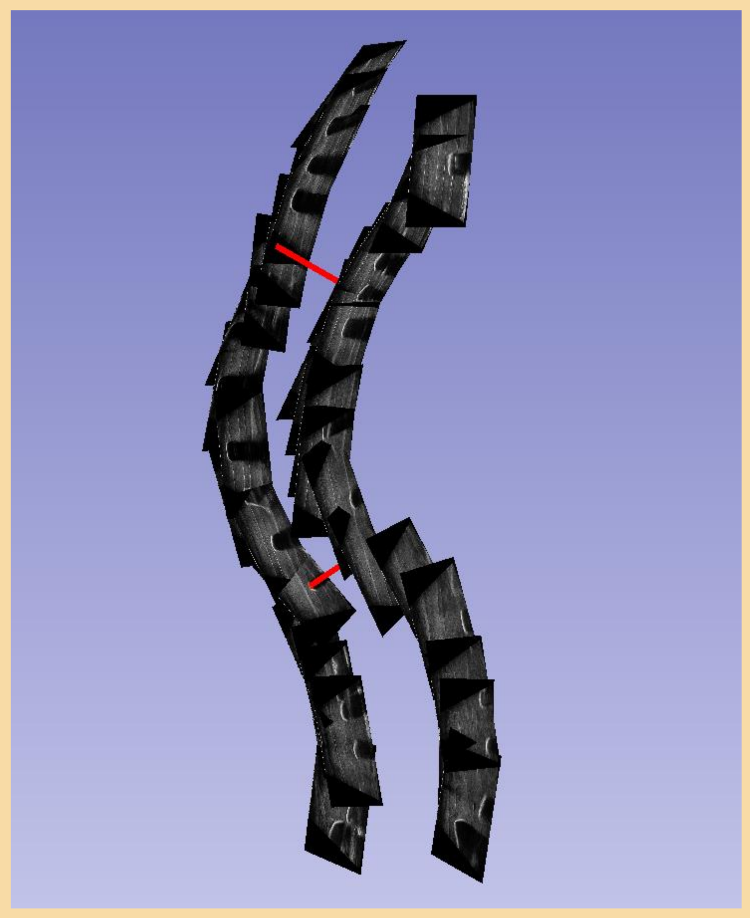

Fig 1. Series of ultrasound snapshots for locating transverse processes, with curvature angle illustrated in red

Objective

To visualize full spinal anatomy, in the presence of severe deformities, using sparse ultrasound-accessible landmarks (transverse processes) alone, without the need for ionizing radiation.

Methods

- **Key Contribution:** Anchor points automatically extrapolated from sparse landmarks could be used to warp a healthy spine model to patient anatomy to enable visualization of the full spine.
- For ground-truth, 5 CT volumes with spinal deformities were used.
- Transverse processes were manually located on CTs; for each process an anchor point was computed by the cross product of vectors along the axis of the spine and those across the spine (Fig. 2).

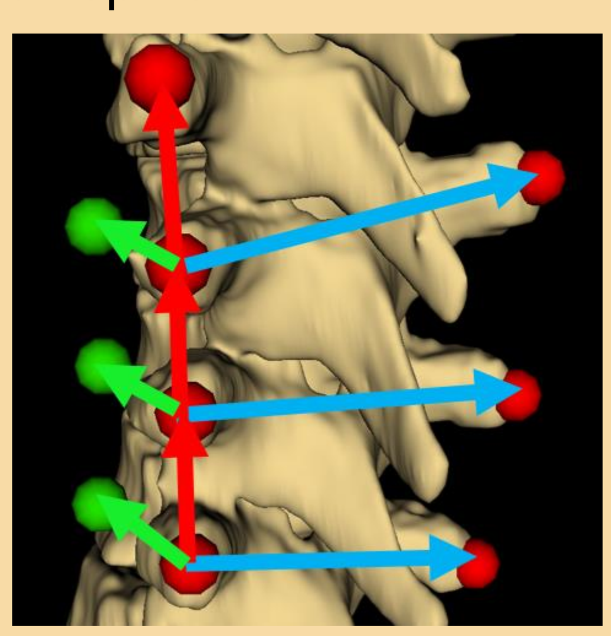

Fig 2. Transverse processes (red), anchor points (green)

- Anchor points allowed the subsequent landmark based registration to represent anterior-posterior anatomic scale.
- Model to patient landmark registration interpolated with thin-plate spline produced a 3D displacement field and was used to warp the model to the patient anatomy. (Fig 3).

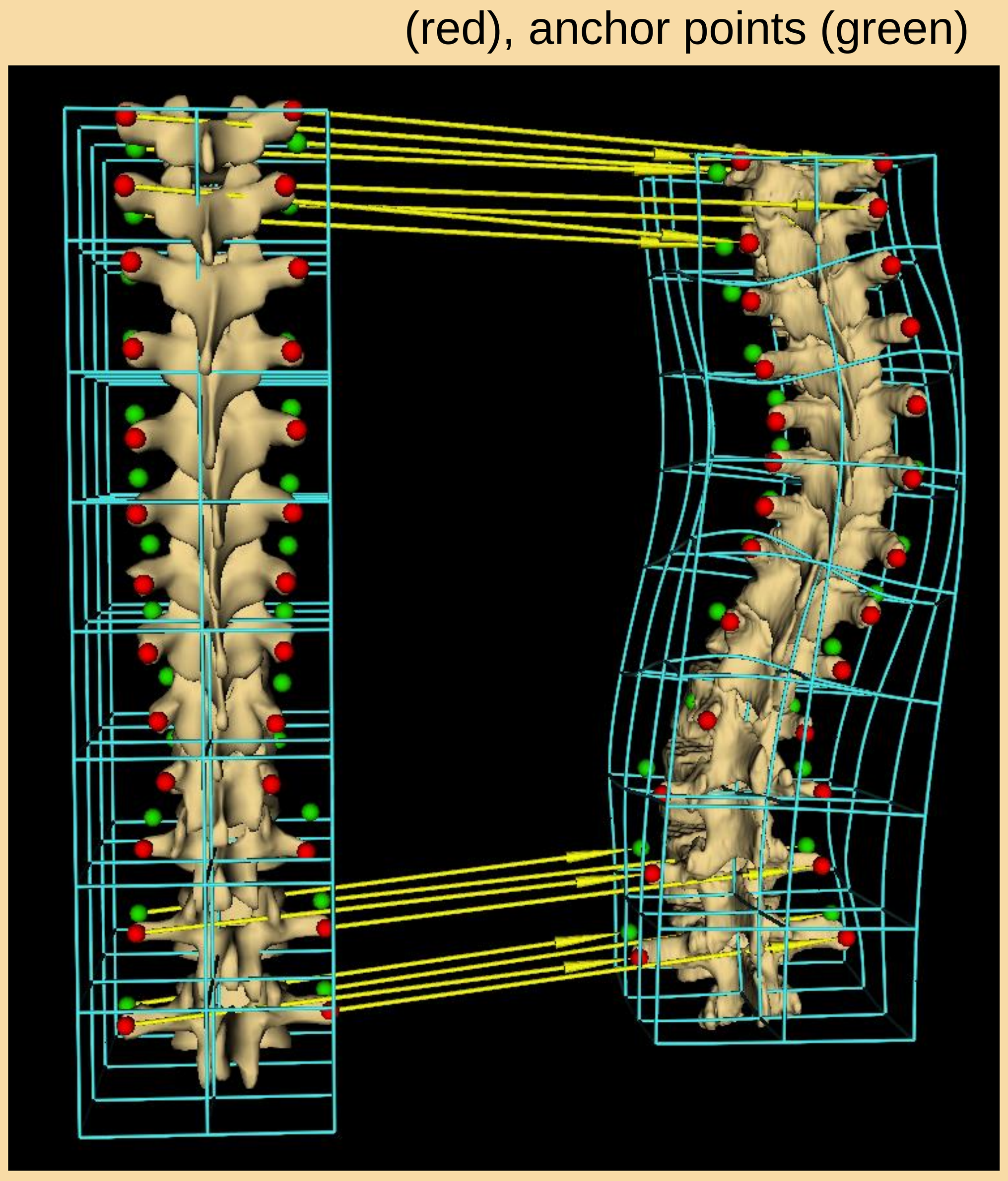

Fig 3. Yellow arrows show sample landmark registration. Wireframe is the displacement field

Results

- Ground-truth segmentations were used to evaluate registration.
- Surface registration errors are displayed as heat maps over corresponding patient visualizations (Fig 4).

Patient #	Avg. Hausdorff (mm)	Max. Hausdorff (mm)
1	2.8	20.0
2	2.3	24.0
3	2.4	17.7
4	2.9	18.1
5	3.3	23.8

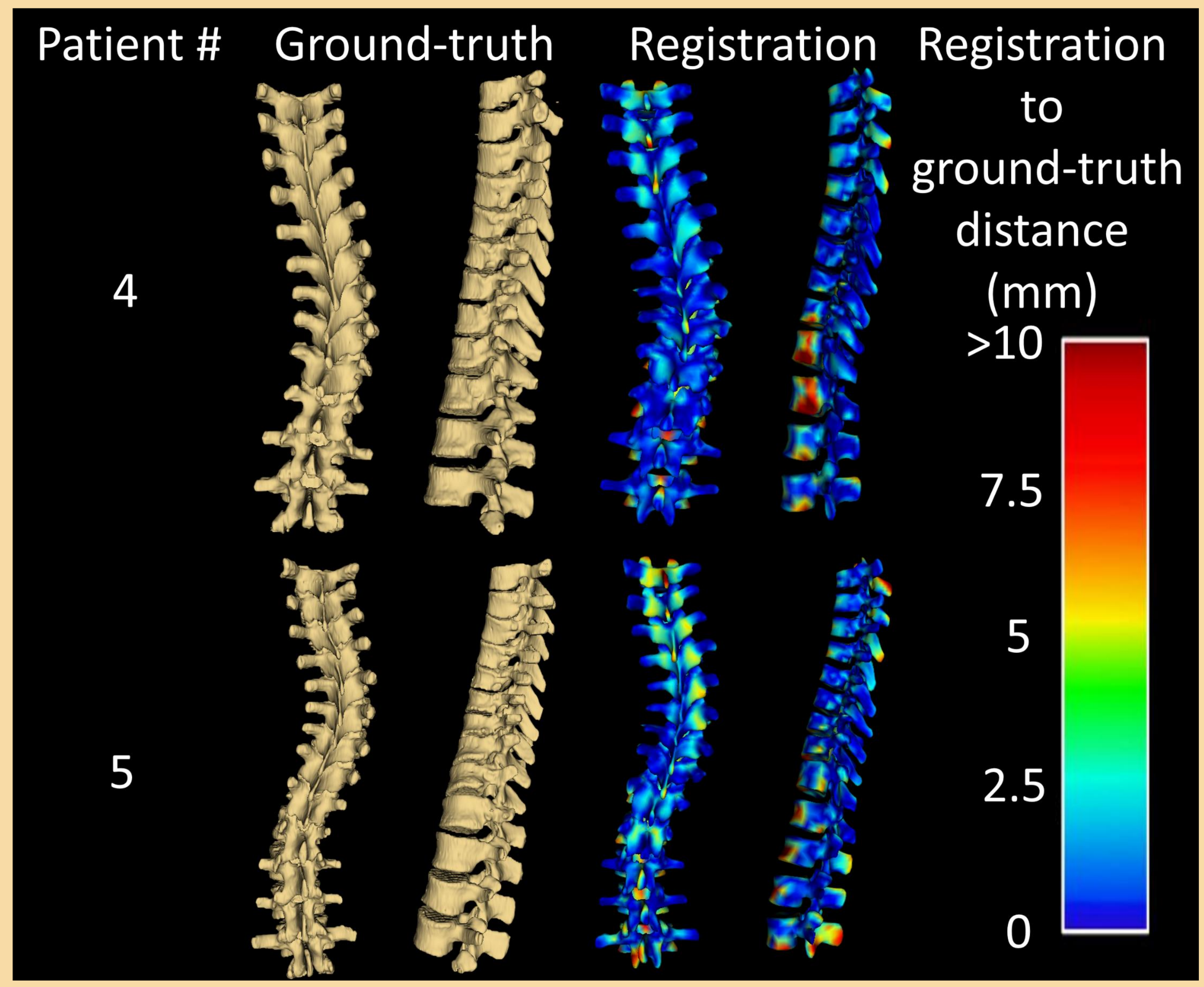

Fig 4. Registrations compared to CT-derived patient ground-truth. Heat map shows the distances between surfaces from blue (most accurate) to red (least accurate).

Conclusion

- Using sparse landmarks, we were able to extrapolate anchor points and constrain the registration of a healthy model to patient anatomies with severe deformities.
- The resulting visualizations convey the overall form of the anatomy, suitable for assessment of pathologic deformation.
- Our method is being improved by automatic landmarking, and handling cases with missing or incorrectly placed landmarks.

Acknowledgement

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Reference

[1] Ungi T et al. Spinal curvature measurement by tracked ultrasound snapshots. Ultrasound in medicine and biology. 2014 Feb;40(10):447-545.

[2] An N. Human spine. https://grabcad.com/library/human-spine-1

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