



Initial Evaluation of a Novel Slot-Scanning Technology for Pediatric Scoliosis Imaging

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BACKGROUND

Scoliosis is a three-dimensional spinal deformity characterized by lateral curvature and axial vertebral rotation [1]. It affects approximately 2-3% of children and adolescents, with adolescent idiopathic scoliosis representing the most common pediatric subtype and accounting for about 80% of pediatric scoliosis cases [2].

Radiography remains the primary imaging method for assessment of spinal alignment and deformity progression. The EOS biplane slot-scanning system (EOS imaging, France) is widely used due to its ability to provide true-size measurement along the scan direction and lower radiation dose. However, as legacy EOS systems reach end-of-life and the new EOSedge system suffers from high cost and limited exam versatility, alternative solutions are needed.

Recently, the True2Scale (T2S) feature became available on the Multitom Rax system (Siemens Healthineers, Germany). T2S performs slot-scanning using a 5 cm beam width with an ultra-small-angle tomosynthesis reconstruction. It is designed to acquire frontal images in the anterior-posterior (AP) projection but could potentially support posterior-anterior (PA) imaging if the spine is within a certain distance from the detector and the patient can remain still and stable in the upright position.

This project aims to evaluate the T2S feature using phantom experiments and to compare T2S with EOS for pediatric scoliosis imaging in a retrospective patient study.

METHODS

First, an anthropomorphic phantom study was performed to evaluate radiation dose and image quality across seven T2S size-specific protocols (Figure 1). T2S uses fixed kVp and mAs settings with additional 0.3 mm Cu filtration (except 0.1 mm Cu for the largest size protocol). Entrance exposure was measured using a RaySafe X2 dosimeter system (Unfors RaySafe GmbH, Sweden). Effective dose was estimated using PCXMC (STUK, Finland) and compared with EOS.

Image quality across five convolution kernels was assessed both qualitatively by a radiologist and using signal/noise ratio (SNR) and contrast/noise ratio (CNR) from two 12 mm diameter regions of interest (ROI) at fixed locations within the ilium and adjacent soft tissue.



Figure 1. Representative photograph of the anthropomorphic phantom setup.

METHODS *cont.*

Second, 25 adolescent idiopathic scoliosis patients who underwent imaging exams on both systems within one year were retrospectively identified. Images were anonymized and randomized for a blinded reader study, in which two radiologists rated image quality across 16 anatomy sites, overall exam quality, and implant depiction using four-point scales, and noted Risser scores. T2S and EOS images from the same patient were reviewed in separate sessions. Patient organ doses and effective dose were estimated using PCXMC software.

Inter-reader agreement was evaluated by intraclass correlation coefficients (ICCs). Linear mixed model (LMM) analyses were conducted to identify factors influencing image quality and effective dose.

Table 1. Anatomy sites evaluated and corresponding image quality scoring criteria used in the radiologist review.

	Specific anatomy scores	Overall quality scores	Hardware scores
T1-T7 vertebrae	Vertebral body Pedicles Spinous process	1. Structure not detectable	1. Minimal to no visualization of hardware structure details
T8-T12 vertebrae	Vertebral body Pedicles Spinous process	2. Structure visible but features not perceptible	2. Moderately decreased visualization of hardware structure details
L1-L5 vertebrae	Vertebral body Pedicles Spinous process	3. Features discernible but not clearly defined	3. Slightly decreased visualization of hardware structure details, not critical for the task
Pelvis	Iliac crest Femoral heads	4. Features clearly defined	4. All anticipated hardware structure details well seen
Others	Cranio-cervical junction Clavicles Rib cage Cervico-thoracic junction Lumbo-sacral junction		

RESULTS

Similar effective dose was observed between comparable T2S and EOS protocols. For example, the combined PA and lateral ultra-low-dose protocol (i.e., EOS microdose mode with small patient size and T2S baby protocol) both yielded effective doses of 15 μ Sv.

Phantom SNR and CNR results are shown in figure 2. Convolution kernel 2 achieved the highest SNR and CNR and was also ranked best by radiologist review. Accurate length measurement along the scan direction was also confirmed. A size-based technique chart using convolution kernel 2 was developed for clinical implementation.

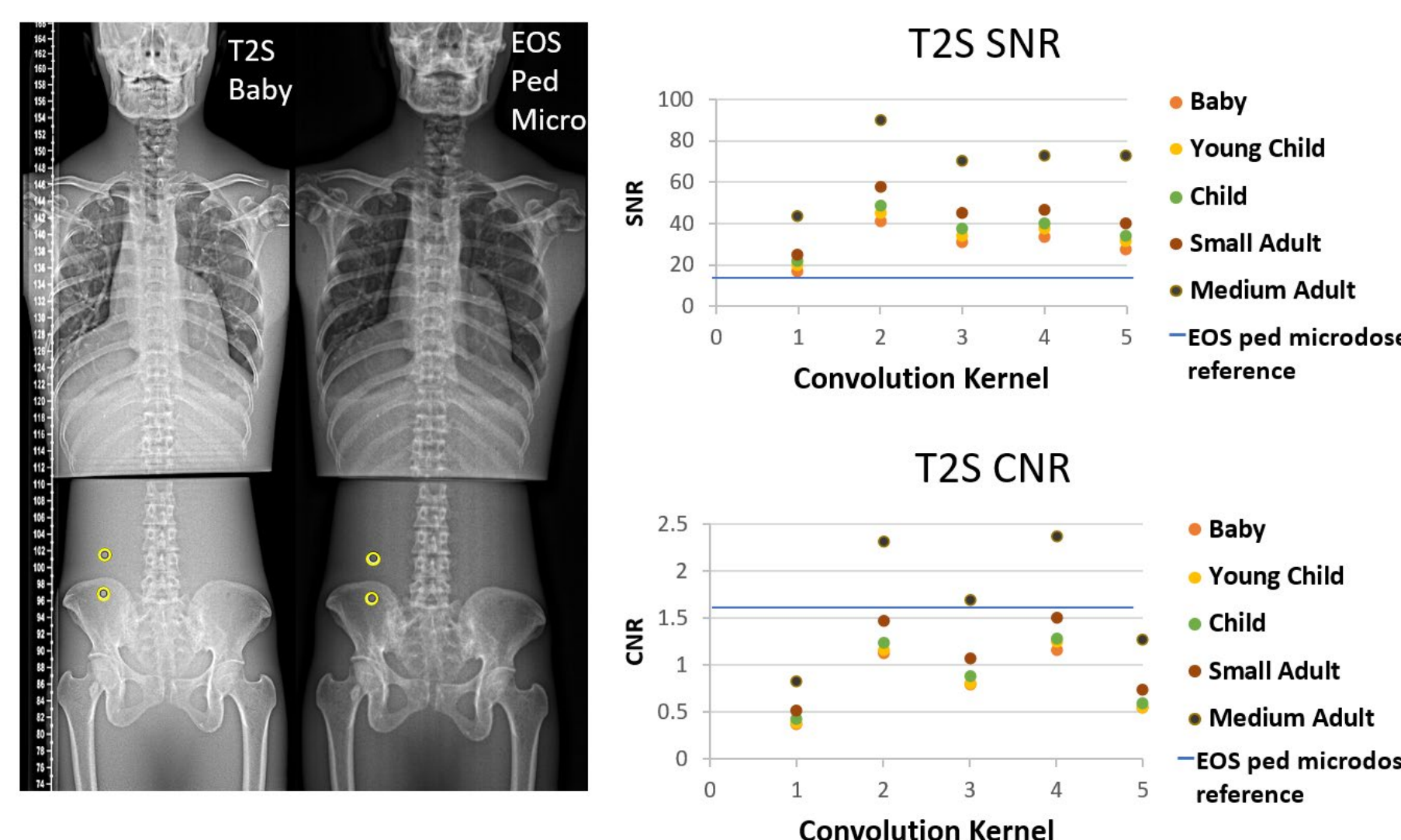


Figure 2. Representative phantom images using ultra-low-dose protocols (i.e., EOS microdose and T2S baby protocol with convolution kernel 2), along with SNR and CNR results for five T2S size-specific protocols and five convolution kernels from the fixed ROIs (yellow circles).

RESULTS *cont.*

PA projection was acquired in 22 EOS and 2 T2S exams out of 25 patients. Ultra-low-dose protocols were used in 3 EOS and 5 T2S exams per institutional follow-up procedures. Median effective dose (Quartile1, Quartile3) for EOS vs. T2S was 0.125 (0.112, 0.156) vs. 0.094 (0.070, 0.280) mSv from 18 two-view exams, and 0.068 (0.055, 0.072) vs. 0.033 (0.023, 0.067) mSv from 7 frontal-only exams.

ICC between readers were 0.757 and 0.955 for image quality and Risser scores, respectively (both $p < 0.001$). There was no statistically significant difference in implant visualization ($p = 0.10$). LMM analyses revealed lower effective dose with ultra-low-dose protocol ($p < 0.001$) and PA projection ($p < 0.05$), as expected, but not with scanner system. Scanner system differences did not significantly influence image quality. Motion or other artifacts were noted in 3 EOS and 3 T2S exams.



Figure 3. EOS and T2S image examples from two patients with the standard low-dose protocol (A) and ultra-low-dose protocol (B).

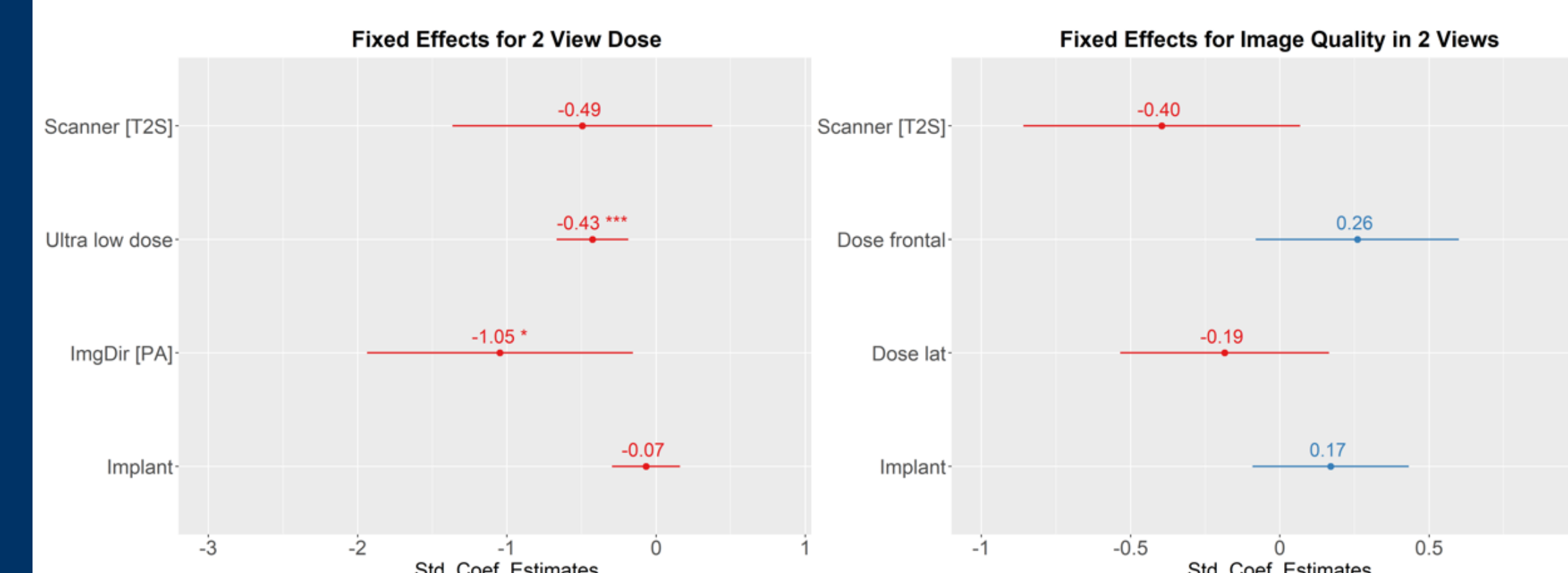


Figure 4. Fixed effects plots from LMM analyses for two-view effective dose and image quality. Red indicates an inverse association; blue indicates a positive association (* $p < 0.05$ and *** $p < 0.001$).

CONCLUSIONS

With appropriate protocol setup, T2S demonstrated radiation dose and image quality comparable to EOS. Development of PA projection capability on T2S will further reduce patient dose.

REFERENCES

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In memory of Dr. Nathan C. Hull.

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