3D Back Surface Topographic Metrics Predict Scoliosis Progression

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INTRODUCTION: Adolescent Idiopathic Scoliosis is a 3D spinal deformity that is commonly evaluated through serial radiographs. Repeated radiation exposure can result in modest increases to a child cancer risk in their formative years. To reduce radiation exposure, alternative imaging modalities such as surface topography (ST) have been employed. ST uses anatomic landmarks of the spine and contours of the back to create software generated spine models. The goal of this study was to develop a mathematic predictive model to evaluate changes in the progression of idiopathic scoliosis employing 3D ST metrics.
METHODS: This study was approved by IRB committee at Children's Wisconsin. Retrospective review was conducted, and patient were included if they were between the ages of 8-18-year-old with known diagnoses with IS or spinal asymmetry. Radiographic imaging was collected using EOS Radiographs imaging system. 3D spine models were reconstructed using sterEOS software. ST was evaluated by DIERS formetric 4D and analyzed by software. A linear mixed effect model was fitted to relate some demographic and ST variables including age, gender, axial surface rotation (ASR) from T1 to L5, scoliotic angle, pelvis surface rotation to Cobb angle. Patients were stratified into three categories based on the difference of their scoliotic curves between initial evaluation and most recent radiographic follow up visit in terms of Scoliosis Research Society's criteria: Progression ≤ -6°; Stable -5° to 5°; Improving: ≥ 6°. Using proportional odds logistic modeling and variable selection by Akaike information criterion (AIC) the probability of a patient's future curve progression was determined.
RESULTS: 38 children had both x-ray and ST measurements at least two visits. The average age was 13.8-year-old (SD=1.6) with 27 being female (71.05%). The average follow up was 13.9 months (±9.9) for radiographs and 6.2 months (±6.7) for ST. After AIC variable selection to stratify patients into Progression, Stable, or Improving, six predictors were included in the measure: Age and ASR at T8, T9, T10, L3, and L4 during the initial visit were included. Based on variable selection, $log\left(\frac{Pr(Progressing)}{1-Pr(Progressing)}\right) = -12.00 + 0.75Age - 1.25T8 + 2.77T9 - 1.74T10 + 0.72L3 - 1.19L4$ and $log\left(\frac{Pr(Progressing\ or\ Stable)}{1-Pr(Progressing\ or\ Stable)}\right) = -8.35 + 0.75Age - 1.25T8 + 2.77T9 - 1.74T10 + 0.72L3 - 1.19L4$ were constructed. Pr(Progression) is the probability that a patient belongs to the progressing group, Pr(Progression or Stable) is the probability that a patient belongs to the Progression group or the Stable group.
Progression: $Y_1 = \frac{\exp(-12.00+0.75Age-1.25T8+2.77T9-1.74T10+0.72L3-1.19L4)}{1+\exp(-12.00+0.75Age-1.25T8+2.77T9-1.74T10+0.72L3-1.19L4)}$, Improving: $Y_3 = \frac{1}{1+\exp(-8.35+0.75Age-1.25T8+2.77T9-1.74T10+0.72L3-1.19L4)}$
Stable: Y2=1-Y1-Y3. Where Y1, Y2 and Y3 are the predicted probabilities of the Progression, Stable and Improving groups, respectively. Thus, based on this the patient would be assigned to the group in which they have the highest predicted probability. Based on this model, 27/38 patients were correctly classified into their future scoliotic curve progression groups (Table 1).
DISCUSSION: These results demonstrate the potential in the creation of a radiation free risk stratification model for the evaluation of AIS. The model was able to correctly classify 27/38 or 71% patients. The Improving group was only accurately predicted 45% of the time with the remaining being classified as Stable. Thus, the overall performance of the model is stronger for those with Stable and Progressing curves leaving room for improvement in the Improving category classification.
SIGNIFICANCE/CLINICAL RELEVANCE: ST-based modeling provides a strong and novel risk assessment in the prediction of progression of idiopathic scoliosis without radiation.

IMAGES AND TABLES:

Table 1: Stratified prediction for idiopathic scoliosis using proportional odds logistic modeling (n=38)

True group	**Classification based on the model**			**Incorrectly classified n (%)**
	Progression n (%)	Stable n (%)	Improving n (%)	
Progression	6 (75%)	2 (25%)	0 (0%)	2 (25%)
Stable	1 (5%)	16 (85%)	2 (10%)	3 (15%)
Improving	0 (0%)	6 (55%)	5 (45%)	6 (55%)
Overall accuracy 27/38=71%				