Stratifying Progression Risk in Congenital Scoliosis: A Multicenter Decision Tree and Regression-Based Predictive Model

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INTRODUCTION: Congenital scoliosis exhibits a highly variable natural history. Predictive modeling based on radiographic features could improve individualized care and timing of intervention. The natural history by McMaster and Ohtsuka remains the framework for scoliosis treatment, and we sought to confirm and expand upon it. We assessed X-Ray images obtained from a large cohort of patients to develop and validate a data-driven model to predict curve progression in congenital scoliosis.

METHODS: This retrospective multicenter study included 464 patients with congenital scoliosis with baseline and follow-up X-rays. Patients with neurological conditions were excluded. Deformities were classified using McMaster's system. The primary outcome was a Cobb angle ≥50° assessed at final follow-up. A Kaplan-Meier survival analysis was used to analyze curve progression by deformity type. A Chi-squared Automatic Interaction Detection (CHAID) decision tree was used to find predictors of progression based on baseline Cobb angle and deformity type. A multivariable logistic regression model was used to assess independent associations between progression and baseline age, and gender. A receiver operating characteristic (ROC) analysis was performed to assess the accuracy of baseline Cobb angle cutoffs in predicting progression to ≥50°.

RESULTS SECTION: Of the participants included, 261 (56.3%) were female. The mean baseline and follow-up ages were 3.5 ± 3.5 years and 8.8 ± 4.7 years, respectively. Most patients underwent surgical correction (55.3%), followed by observation (40.1%) or casting/bracing (4.5%). Baseline and follow-up Cobb angles averaged 46.5° ± 18.9° and 51.3° ± 22.9°, respectively. The Kaplan-Meier analysis found unilateral unsegmented bars with and without hemivertebra (HV) were at greatest risk of progression. CHAID analysis revealed baseline Cobb angle as the strongest predictor of progression through recursive analysis in determining the following cutoffs:
Cobb ≤38°: Low progression risk (20.8%), especially in block vertebra, incarcerated HV, and complex anomalies (6.9%).
Cobb 38–54°: Moderate progression risk (53.2%), with higher risk in patients with semisegmented HV, wedge, and unilateral unsegmented bar deformities (70.6%).
Cobb >54°: High risk of maintenance at >50° (92.2%) regardless of deformity type.
ROC analysis confirmed strong predictive accuracy (AUC = 0.85). Multivariable logistic regression model confirmed that higher baseline Cobb angle (OR 1.12 per degree increase, $p < 0.001$), **d**eformity type ($p = 0.041$), and female gender (OR 2.02, $p = 0.006$) were independent predictors of progression.

DISCUSSION: Baseline Cobb angle is a robust predictor of curve progression in congenital scoliosis. Deformity classification adds prognostic value in mid-range curves.

SIGNIFICANCE/CLINICAL RELEVANCE: These findings offer a clinically applicable framework for early risk stratification and individualized treatment planning.

REFERENCES: 1. Herring, John A. Tachdjian's Pediatric Orthopaedics: From the Texas Scottish Rite Hospital for Children: 2-Volume Set. Elsevier Health Sciences, 2020. 2. McMaster, M. J., & Ohtsuka, K. (1982). The natural history of congenital scoliosis. A study of two hundred and fifty-one patients. The Journal of bone and joint surgery. American volume, 64(8), 1128–1147.
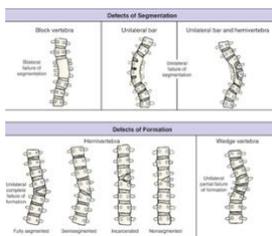
IMAGES AND TABLES:

Figure 1: Classification Examples from our Current Understanding of the Natural History of Congenital Scoliosis. If the deformity did not fall into these classifications or was an amalgamation of 4 or more distinct, separate classifications, it was classified as "complex". This figure was taken from Tachdjian's Pediatric Orthopaedics: From the Texas Scottish Rite Hospital for Children: 2-Volume Set.
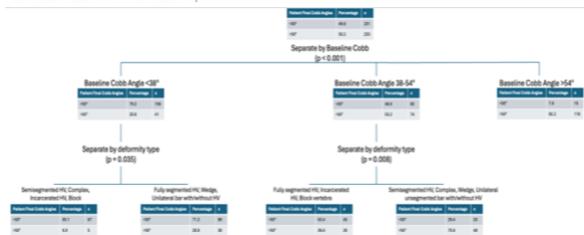

Figure 2: CHAID Analysis for Deformity Progression from Baseline Cobb Angle and Deformity Type. Baseline Cobb angles less than 38 degrees were unlikely to progress, while baseline Cobb angles over 54 degrees were highly unlikely to regress. For curves with baseline Cobb angles less than 54 degrees, deformity type was predictive in whether the curve would progress to greater than 50 degrees.