3D Morphometric Analysis of Affected Versus Unaffected Scapulae in Sprengel's Deformity

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INTRODUCTION: Sprengel's Deformity is a rare congenital condition classically described as an undescended, hypoplastic scapula with a hooked superomedial corner and an inferior tilt, accompanied by the presence of an omovertebral connection that may be soft tissue, cartilaginous, or ossified. This description of Sprengel's deformity has come from plain radiographs and clinical experience. Considering the complexity of these deformities, little has been done to characterize morphological changes in the scapula of patients with Sprengel's deformity. To address this gap, we conducted a detailed 3D assessment to compare affected vs unaffected scapulae in patients with Sprengel's deformity.

METHODS: Following IRB approval, A retrospective case series of patients with Sprengel's deformity seen between June 2014 and October 2024 at a tertiary pediatric referral center was collected. Patients 0 to 18 years of age with unilateral Sprengel's deformity and CT imaging of the spine and scapulae were included. Patients were excluded if they had undergone a surgical procedure on the scapula prior to imaging. The CT imaging was segmented using a 3D UNet–based convolutional neural network with an average Dice coefficient of 0.96. The segmented masks were then converted to a surface mesh to reconstruct 3D models of the affected and unaffected scapulae. Morphometric measurements, including surface area and volume, were then conducted in order to compare the affected and unaffected scapulae/

RESULTS: A total of 14 patients with Sprengel's deformity were included. Paired t-tests comparing the affected and unaffected scapulae revealed no statistically significant differences in glenoid version (mean difference: -4.32°, p=0.220), glenoid inclination (mean difference: 1.37°, p=0.782), scapular height (mean difference: 0.55 units, p=0.560), or medial-to-lateral scapular width (mean difference: 0.56 units, p=0.794). The affected scapula exhibited a slightly larger mean surface area in 9 out of 14 patients and greater volume in 7 out of 14, though these differences did not reach statistical significance (surface area mean difference: 800.10 units, p=0.084; volume mean difference: 527.22 units, p=0.583). Across all other measured dimensions and ratios, no consistent or significant differences were observed between the affected and unaffected sides. There was considerable individual variability in scapular morphology within the cohort

DISCUSSION: Contrary to traditional descriptions of Sprengel's deformity, which emphasize a smaller scapula on the affected side, our results demonstrate that scapular size and morphology are highly variable. The affected scapula may be larger, smaller, or similar in dimension compared to the unaffected side, with no systematic difference in glenoid orientation, height, or width. These findings highlight the importance of individualized 3D imaging assessment and pre-operative planning for patients with Sprengel's deformity, as anatomical variation cannot be reliably inferred from classical descriptions alone.

SIGNIFICANCE: This study challenges classical descriptions of Sprengel's deformity by revealing highly variable scapular morphology on 3D CT, underscoring the need for individualized imaging assessment to guide surgical planning.
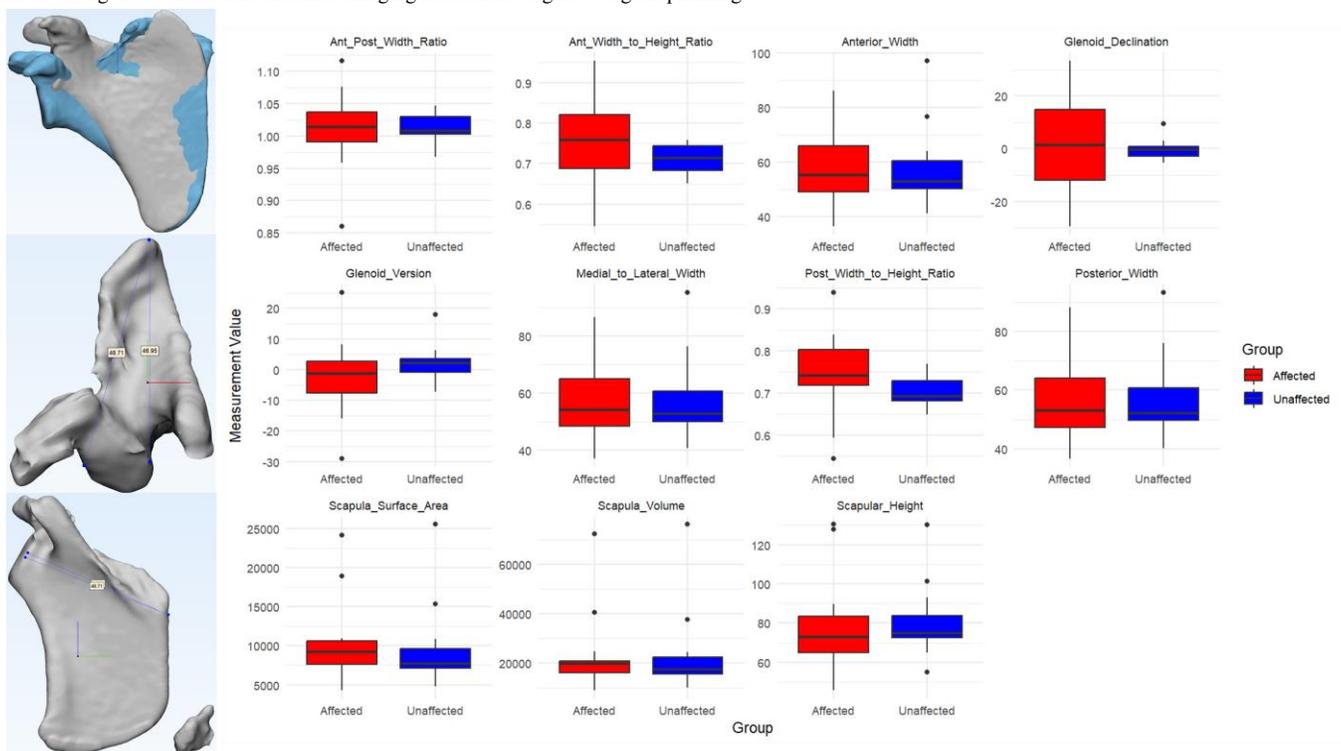

Figure 1: Left: The study aligned affected and unaffected scapulae using coronal and sagittal planes to measure glenoid version, declination, and scapular dimensions. Scapular height, width ratios, and medial-lateral distances were calculated to quantify structural differences. Negative or positive side-to-side differences indicated glenoid undergrowth or overgrowth, respectively. **Right:** Boxplots comparing affected and unaffected scapular measurements in patients with Sprengel's deformity. Red and blue boxes represent affected and unaffected sides, respectively. The plots show individual variability and no consistent significant differences across key parameters, highlighting the anatomical heterogeneity and need for individualized assessment.