

Background

Syndromic bicoronal craniosynostosis presents complex challenges in achieving stable cranial expansion and preventing intracranial hypertension. While endoscopic strip craniectomy (ESC) and posterior vault distraction osteogenesis (PVDO) are established approaches, data on their combined staged use in infancy remain limited.

Beyond its clinical relevance, understanding volumetric cranial growth across staged interventions provides valuable educational insight for learning reconstructive sequencing in complex craniofacial surgery.

This study aimed to quantify changes in intracranial volume (ICV) across sequential ESC and PVDO and to illustrate their complementary effects on cranial growth using longitudinal imaging.

Methods

- Retrospective review (2020–2025) of syndromic patients with bicoronal craniosynostosis who underwent ESC (~1–3 months of age) with postoperative helmeting, followed by PVDO (~6–8 months).
- Virtual surgical planning (VSP) models were reviewed to contextualize volumetric changes with corresponding osteotomies.
- CT-derived cranial volumes were measured using the VisAR application (NOVARAD) and compared longitudinally across standardized time points: pre-ESC, post-ESC, and post-PVDO.
- Paired comparisons between stages were performed using the Wilcoxon signed-rank test.

Simulated Postoperative Anatomy

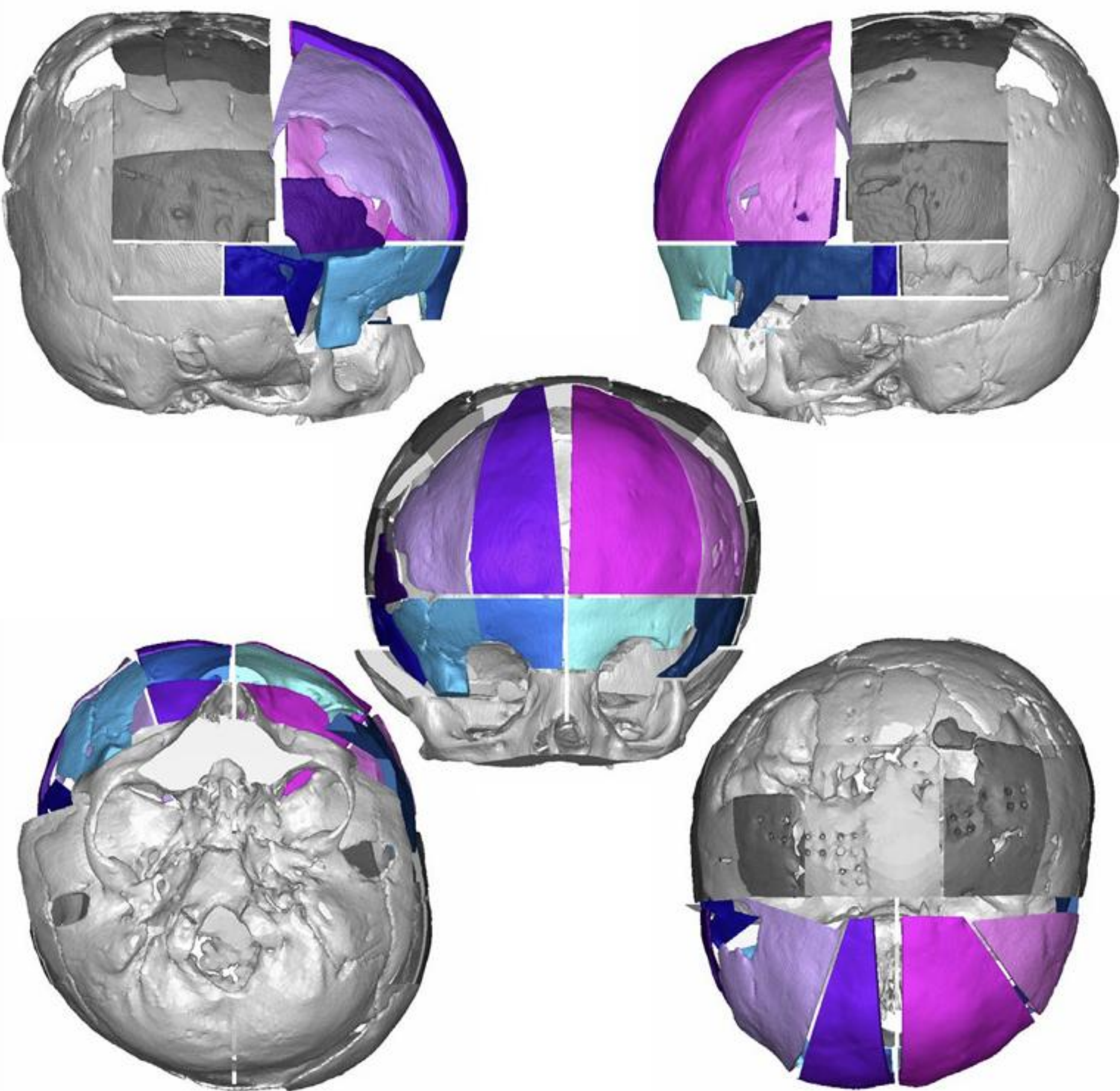


Figure 1. Virtual surgical planning model showing simulated postoperative anatomy with color-coded osteotomy segments.

Results

Five patients (2M, 3F): 3 Apert syndrome, 1 Muenke syndrome, 1 metopic craniosynostosis of unknown etiology. Mean adjusted age at ESC: 58.6 ± 25.1 days; at PVDO: 214.0 ± 37.4 days.

Table 1. Longitudinal ICV Measurements and Percent Changes

Pt	Pre-ESC (cc)	Post-ESC (cc)	Final (cc)	%Δ Pre→Post-ESC	%Δ Pre-PVDO→Final	%Δ Pre-ESC→Final
P1	542.4	1066.7	1279.3	96.7%	19.9%	135.9%
P2	475.9	1033.2	1336.8	117.1%	26.9%	180.9%
P3	381.6	467.8	990.2	22.6%	68.9%	159.5%
P4	560.2	1157.1	1293.2	106.6%	11.8%	130.9%
P5	358.1	922.9	1053.3	157.7%	14.1%	194.1%

Table 2. Summary Statistics by Stage

Comparison	Median %Δ (IQR)	Mean %Δ ± SD	Mean Δcc ± SD	p-value
Pre→Post-ESC	106.6% (96.7–117.1)	100.1 ± 49.2%	465.9 ± 213.9	0.063
Pre-PVDO→Final	19.9% (14.1–26.9)	28.3 ± 23.4%	233.2 ± 114.1	0.063
Pre-ESC→Final	159.5% (135.8–180.9)	160.2 ± 27.5%	726.9 ± 91.0	0.063

ICV increased steadily across all patients, with sharper gains following both ESC and PVDO. From pre-ESC to final, ICV increased by a median of 159.5% (IQR 135.9–180.9%), mean Δ 727.9 ± 109.6 cc.

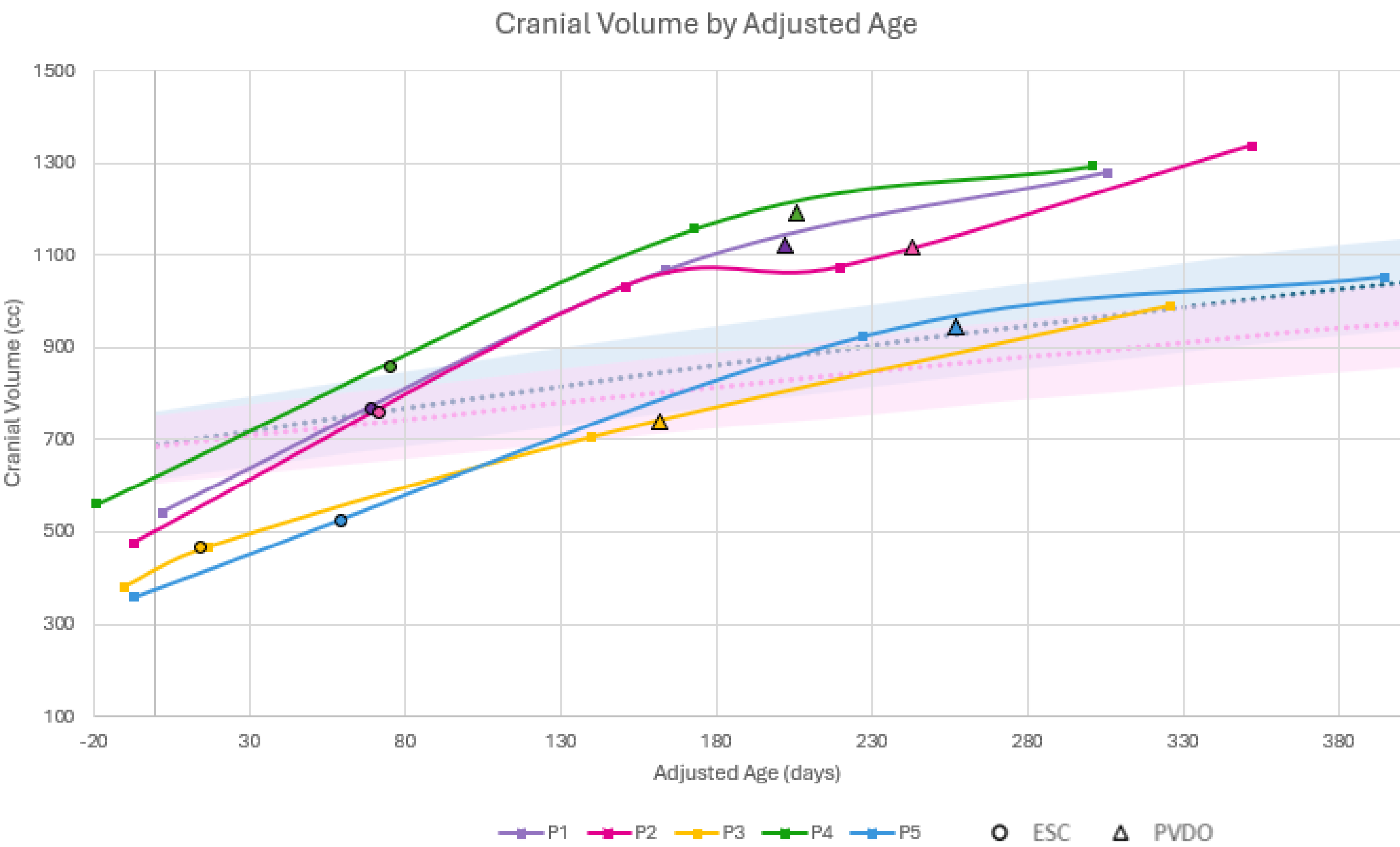


Figure 2. Cranial volumes over time. Cranial volume (cc) was calculated at multiple time points and plotted against patient age in days. Each line represents an individual patient (P1–P5). The curves demonstrate progressive increases in cranial volume with age, with variability in growth trajectories among patients.

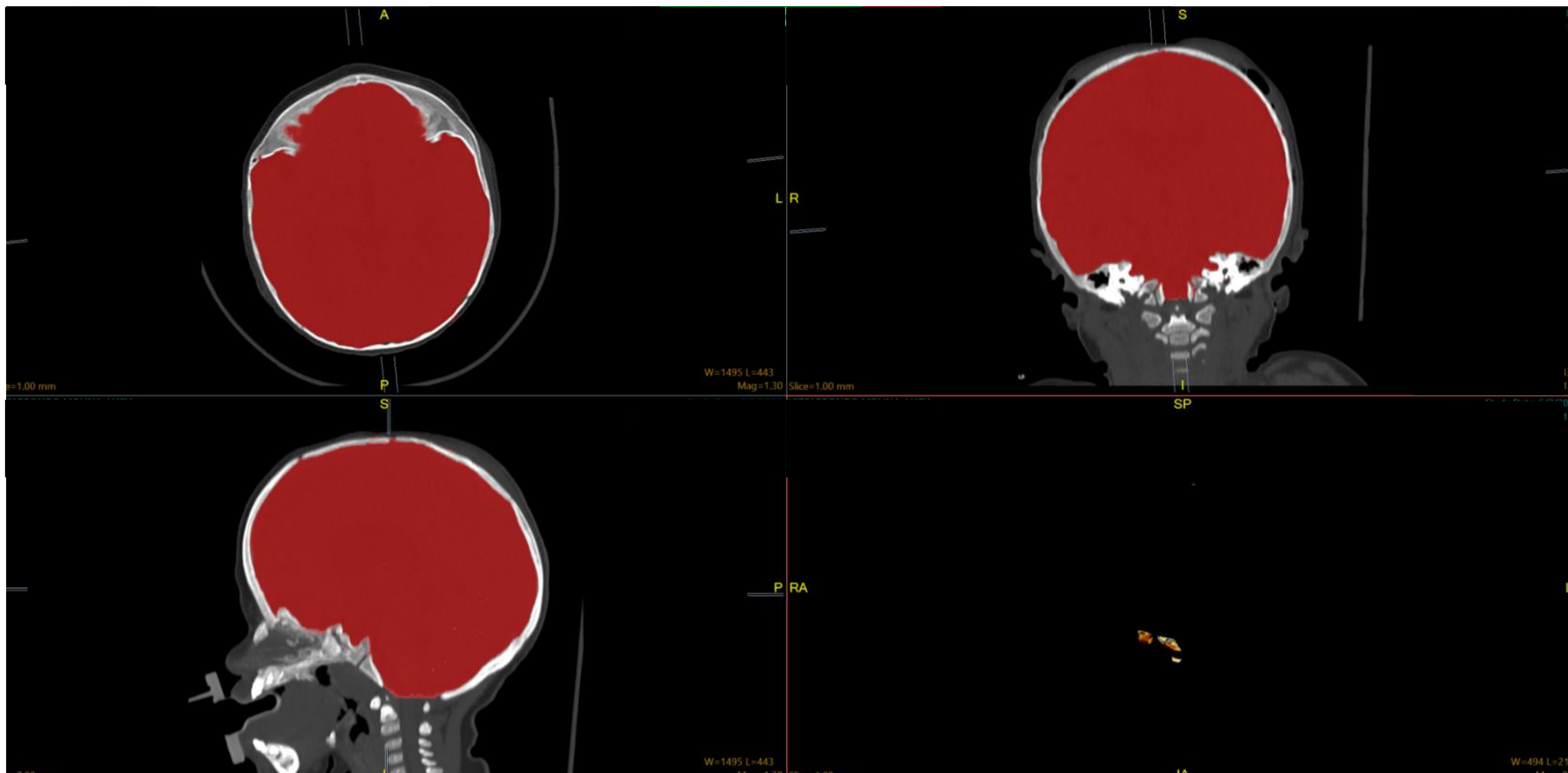


Figure 3. CT-derived intracranial volume measurement using VisAR (NOVARAD). Red shading indicates measured intracranial volume across axial, coronal, and sagittal views.

Conclusion & Discussion

Sequential ESC followed by PVDO produced consistent, clinically meaningful intracranial volume expansion, reflecting both physiologic growth and surgically guided remodeling.

The substantial ICV gain after ESC (median 106.6%) demonstrates the effectiveness of early minimally invasive suture release in creating initial cranial decompression, while subsequent PVDO provided additional targeted expansion (median 19.9%) in the posterior vault.

The combined staged approach yielded a cumulative median ICV increase of 159.5%, suggesting that staged reconstruction leverages both growth-permissive biology and mechanical distraction to achieve balanced cranial development.

These quantitative findings provide a visual framework for understanding how staged reconstruction supports balanced cranial development, serving as both a clinical guide and an effective teaching aid for growth-guided cranial reconstruction.

References

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