SENRS 2026 ANNUAL MEETING · ORAL PRESENTATION

Geometric Shape Analysis of the Posterior Cranial Fossa in Chiari I Malformation



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Background & Purpose

Chiari I malformation (CMI) is a structural abnormality characterized by caudal displacement of the rhombencephalon, with herniation of the cerebellar tonsils through the foramen magnum.

Additional structural abnormalities may include ventral flattening of the midbrain, pons, and medulla.

GAP & PURPOSE

Most morphometric exploration of Chiari malformation has occurred in the **midsagittal plane**.

Our work aims to identify other morphometric features that may distinguish Chiari malformation and are both (1) **outside the midsagittal plane** and (2) **evaluated in three dimensions**.

DIAGNOSTIC CRITERION

3–5 mm

tonsillar herniation below the foramen magnum

IMAGING

Diagnosis is based on cross-sectional imaging and cerebellar tonsil position; **MRI** is the preferred modality.

Methods: Cohort & CT Landmarking

CHIARI I

29

patients

34.8 ± 9.5 years

CONTROLS

27

age/sex-matched

39.5 ± 7.9 years

All participants were female.

CT segmentation & landmarking

01 CT scans segmented in **3D Slicer** using Hounsfield-unit thresholding

02 Manual inspection and cleaning was performed of each segmentation

03 Calvaria removed to expose the posterior cranial fossa for landmark placement

04 **113** homologous landmarks and semi-landmarks placed along the posterior cranial fossa

FIG 1 · SUPERIOR VIEW

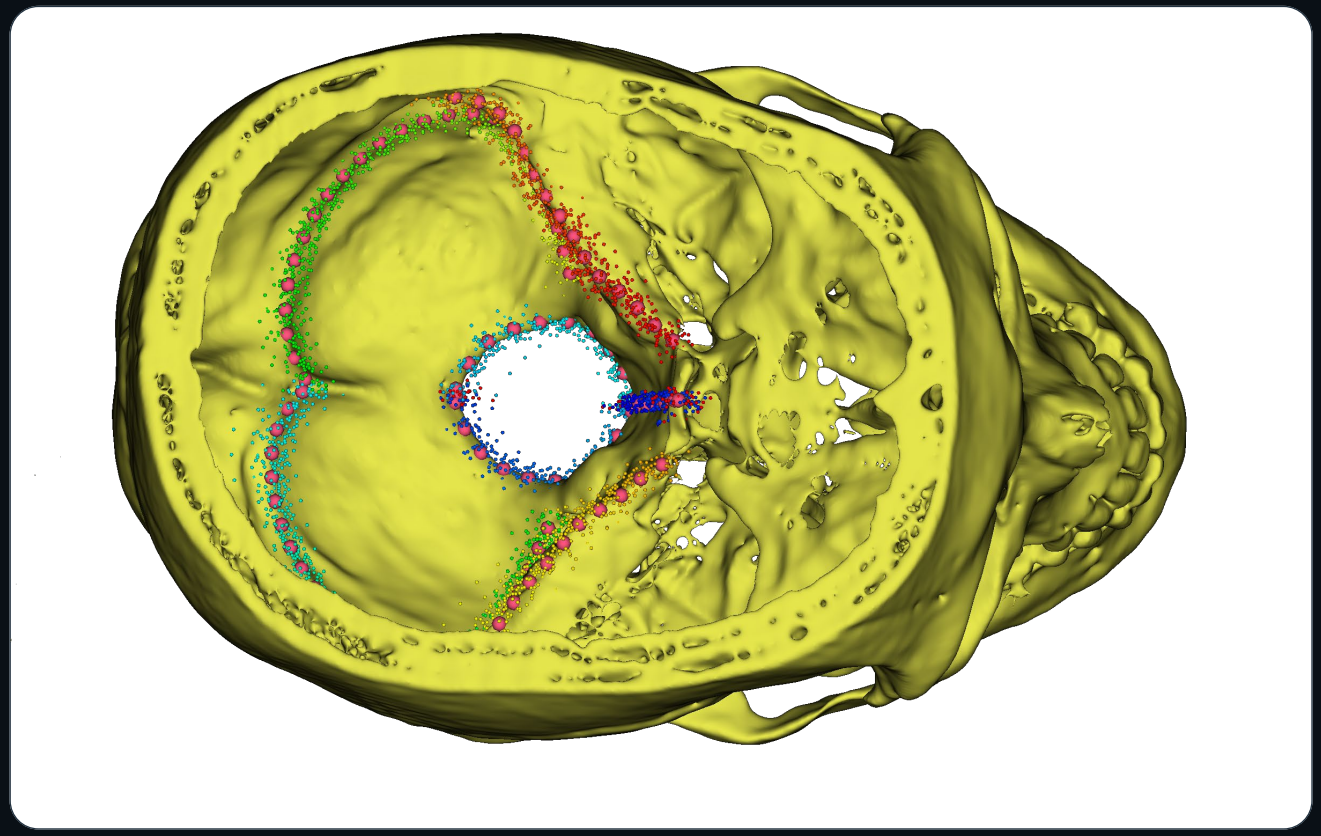


Figure 1: Landmark locations (mean – larger points). All data points represented by smaller spheres.

Methods: Shape Analysis & Statistics

STEP 01

Generalized Procrustes superimposition

Run in 3D Slicer with the **SlicerMorph** module, removing differences in position, scale, and orientation.

→ Procrustes-aligned coordinates

STEP 02

Principal component analysis

PCA performed on the Procrustes-aligned coordinates to capture the major axes of shape variation.

→ PC scores per specimen

STEP 03

Group comparison

Chiari I vs. control PC scores compared with the **Wilcoxon rank-sum test**.

$\alpha = 0.05$

→ p-value · effect size (r)

Results: Principal Components

15
principal components from the PCA

46.47%
of sample variation explained by PCs 1–4

p = 0.055
PC3: borderline significance (Wilcoxon rank-sum)

TABLE 1 · RESULTS OF THE FIRST FOUR PCs

Principal Component	Variance explained (%)	p-value	Effect size (r)	Result
PC1	15.58	0.512	−0.103	n.s.
PC2	11.70	0.682	0.065	n.s.
PC3	11.04	0.055	−0.300	Borderline
PC4	8.15	0.987	0.004	n.s.

INTERPRETATION

No other PCs were statistically significant; their shape variation was driven by factors other than clinical diagnosis.

Results: PC3 Shape Changes

PC3 scores for the Chiari malformation group exhibited:

01 “Flattening” of the occipital squamae

02 Posterior displacement of the foramen magnum

03 Blunting of the internal occipital crest

FIG 2 · SUPERIOR VIEW PC3 WARP · CMI ⇔ CONTROL

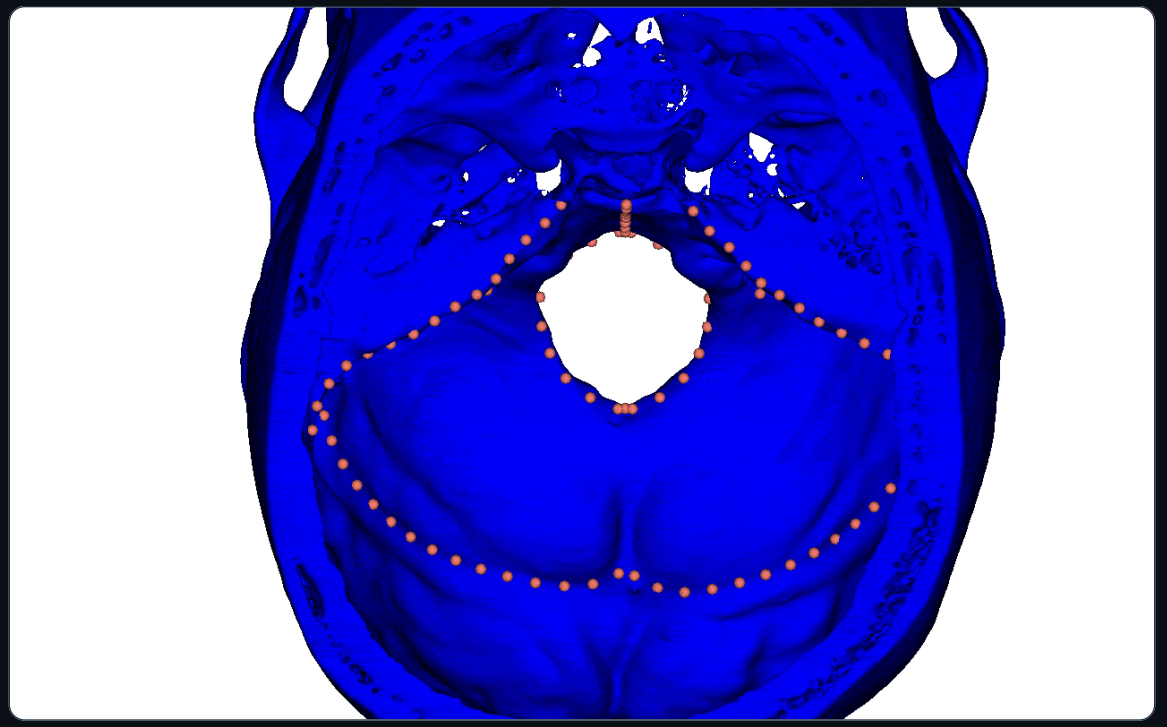


Figure 2. Superior view of the skeletal warp along PC3 (changing configurations between Chiari and controls).

Conclusions

The Chiari I posterior fossa appears to be, in part, characterized by **flattened occipital squamae**, **posterior displacement of the foramen magnum**, and **blunting of the internal occipital crest**.

MECHANISM

Posterior displacement of the foramen magnum draws the clivus into a horizontal position, as often seen in CMI patients.

Limitations & Future Directions

LIMITATIONS

One subsample of a larger study

- This subsample is part of a **larger, ongoing study**.
- It sacrifices sample size for **greater anatomical resolution**: a more complex landmarking scheme allows more granular examination of the anatomy.
- Shape variables in this subsample did not predict specific symptoms or surgical outcomes; larger samples may allow these analyses.

FUTURE DIRECTIONS

Using larger morphometric datasets

1. Assess **multidimensional** morphometric variables (3D, or 2D planes outside the midsagittal plane) in CMI morphology
2. Evaluate relationships between new morphometric variables and **symptomatology** or other conditions (e.g., syringomyelia)
3. Use new morphometric variables to begin exploring **patient-specific surgical approaches**

Clinical Applications for Neuroradiology

01

Perioperative CT morphometrics

MRI is the diagnostic standard. Many surgical candidates undergo CT imaging to best evaluate bony architecture. The morphometric data from the perioperative CT scans can eventually help guide decompression planning.

02

Anatomy meets clinical indices

Future studies could correlate anatomy with symptom severity, indication for posterior fossa decompression, and post-op outcomes.

03

Predictive modeling

A machine learning model could then estimate symptom burden and likely surgical benefit for a new patient, based on patients with similar anatomy.

Acknowledgements

IMAGING DATA

Chiari1000 database

Thank you to all the Chiari patients who contributed to the formation of the Chiari1000 imaging database.

CONTROL SCANS

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