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Using Statistical Shape Models of the Posterior Cranial Fossa to Develop Robust Clinical Metrics for Chiari Malformation

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Purpose

The symptoms of Chiari malformation are often attributed to the overcrowding of the posterior cranial fossa (PCF). Overcrowding of the PCF has been quantified by 2D measurements taken from mid-sagittal MRI (Fig. 1A), however they have shown only a moderate association with patient symptoms, limiting their use in clinical practice.

3D measurements of the PCF may provide a more robust metrics as they will capture any lateral abnormalities that are currently neglected. This study examined the 3D shape of the PCF (Fig. 1B), and the distance of the hindbrain to the hard surfaces of the PCF, in patients with Chiari and matched controls.

Methods

3D models of the PCF and hindbrain were segmented from anatomical MRI scans (Fig. 1) of the head and neck of 21 symptomatic Chiari I patients (9 with a syrinx), and 12 age and sex matched healthy controls. To investigate shape differences between groups, all subject models were aligned to the same anatomical location and scaled to the size of the average skull, so only differences in shape remained.

Results

Shape analysis found no difference in the overall shape of the PCF between groups. However, in patients without a syrinx the lower surface of the cerebellum was 2.3 mm closer (1.7mL less CSF space) to the internal occipital crest than in controls (Fig 2A). Additionally, in patients with a syrinx, the anterior surface of the medulla oblongata was 1.3 mm (1.0mL less CSF space) closer to the clivus than controls (Fig 2B).

Conclusions

Analysis showed there were no differences in the shape of the PCF between subject groups. However, in Chiari patients the hindbrain was closer to bony surfaces of the PCF, reducing the cerebrospinal fluid (CSF) space about cerebral blood vessels, which may contribute to patient symptoms. Further analysis with a larger cohort and pre/post-operative data is required to demonstrate whether these shape measures are beneficial for clinical use.
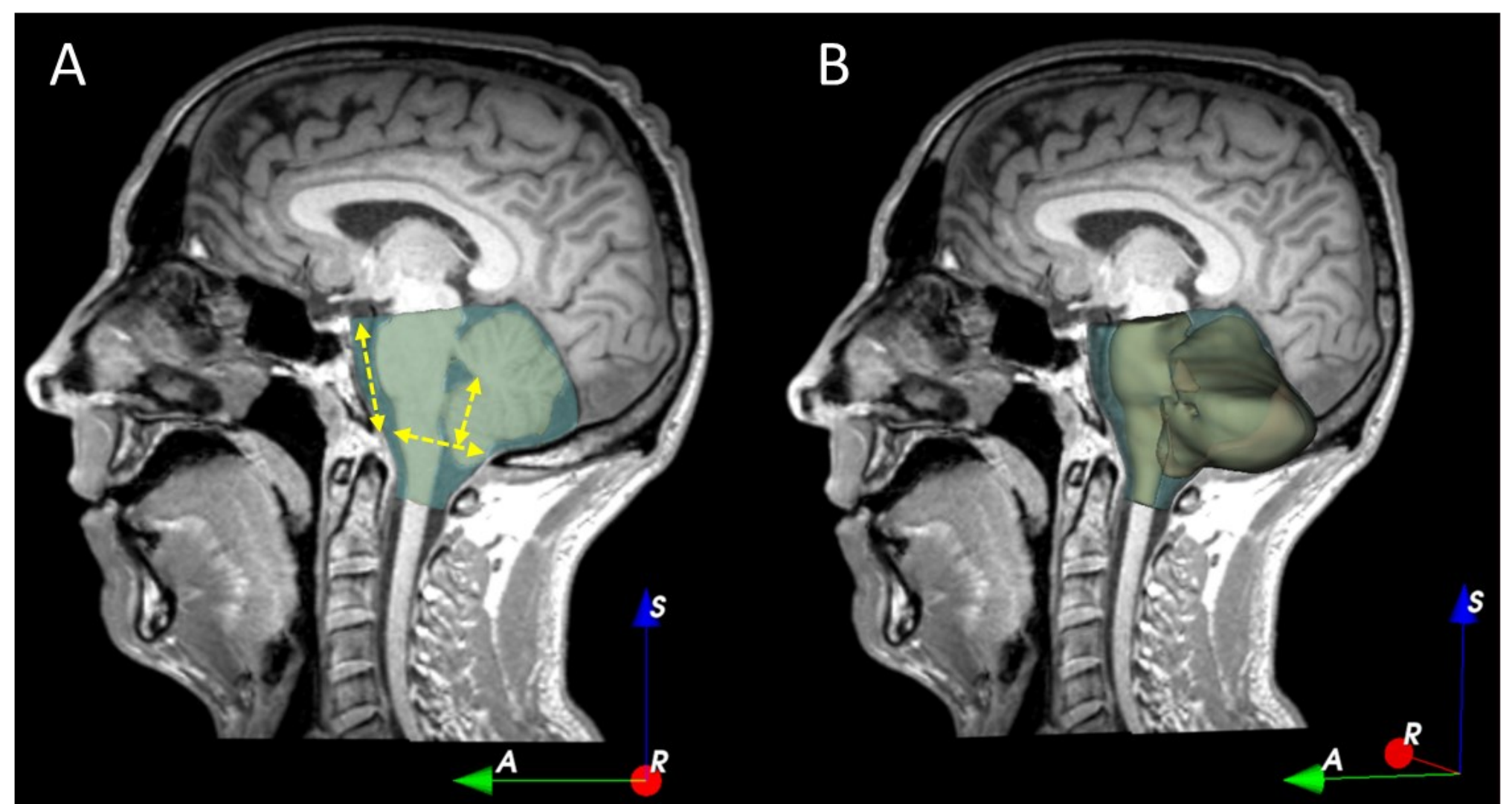

Fig. 1: MRI of a patient with Chiari malformation, highlighting the volumes of the hindbrain (brown) and CSF space (blue). A) Shows the areas covered on the mid-slice, with examples of common 2D measurements. B) A 3D view of the CSF and hindbrain volumes for reference.
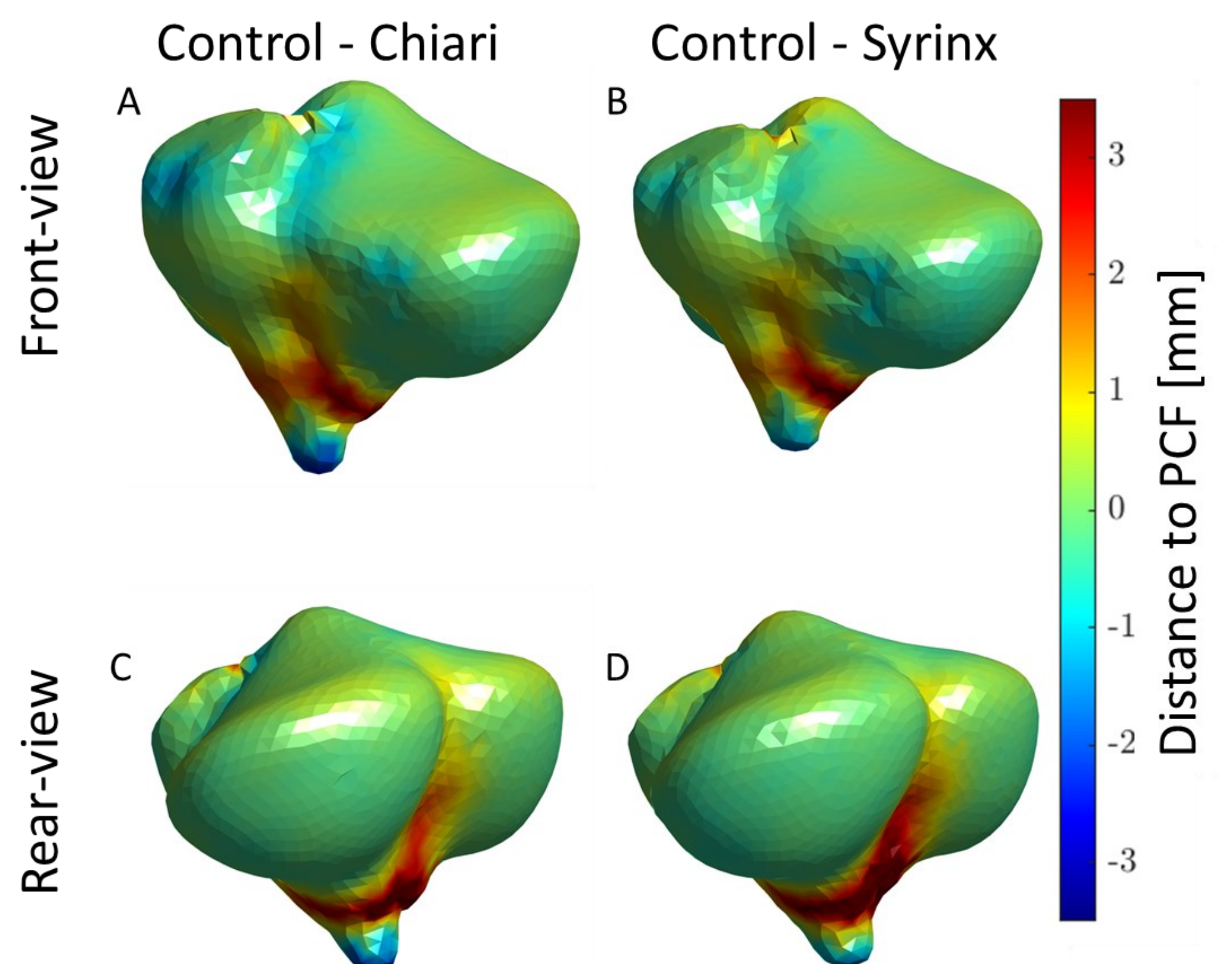

Fig. 2: The surface models highlight where the position of the hindbrain in healthy controls is different from patients with (B,D) and without a syrinx (A,C). Where red and blue indicates that the hindbrain is either closer to or further from the PCF compared to healthy controls.