Characterizing cerebellar tonsil motion during the cardiac cycle is important because its motion may contribute to the formation of syringomyelia in the Chiari I malformation. This study was designed to measure cyclic motion of the tonsils in the foramen magnum during the cardiac cycle with a cine MR imaging method, 2D fast imaging employing steady-state acquisition (2D FIESTA). The hypotheses tested were that tonsil motion is greater in patients with Chiari I than in controls and that tonsil motion is greater when syringomyelia is present.

Previous studies have reported divergent results for tonsil movement. For example, in patients undergoing craniocervical decompression, sonography has shown rapid tonsil motion. However, cardiac-gated phase-contrast MR (PC MR) imaging measurements suggested that the tonsils move minimally in healthy subjects during the cardiac cycle. Tonsil motion has also been measured with M-mode MR imaging and with echoplanar imaging. The motion of the cerebellar tonsils in patients with Chiari I has not, to our knowledge, been studied with cine methods such as those used in this report.

Methods

This study was performed with the approval of the local institutional review board, which granted a waiver of consent for the retrospective use of imaging data acquired as part of the clinical evaluations for diagnosis of possible Chiari I malformation. Inclusion criteria for classification as a patient with Chiari I were signs and symptoms of a Chiari I malformation and clinical improvement following craniocervical decompression. 2D FIESTA studies were performed in conjunction with routine MR brain imaging in 11 patients with a Chiari I malformation (4 men and 7 women, 29–50 years of age) and in 6 patients without tonsil ectopia (20–50 years of age). Four of the 11 patients with Chiari I had syringohydromyelia. The 6 subjects without tonsil ectopia, though referred because of its possibility, had no clinical symptoms or signs of a Chiari malformation.

Results

2D FIESTA Imaging

In subjects with a normal cerebellar tonsil position (controls) and in patients with Chiari I, small displacements of the tonsils were evident on inspection of the 2D FIESTA acquisitions that were not conspicuously different between patients and controls or between subjects with and without syringohydromyelia.

Plots of tonsil displacement from the initial image showed a biphasic change in tonsil position during the cardiac cycle (Fig 1). Tonsil displacement calculated from the pixel-shift...
program averaged 0.43 mm (± 0.06 mm) for the control subjects (Table). For patients with Chiari I, the tonsil motion averaged 0.57 mm (± 0.04 mm) or larger (33%). For patients with Chiari I without syringohydromyelia, tonsil motion averaged 0.5 mm (± 0.05 mm); and for patients with Chiari I with syringohydromyelia, it averaged 0.61 mm (± 0.03 mm) or larger (22%).

Discussion
The study shows that successive cephalad and caudad cerebellar tonsil motion is detectable on cine MR imaging during the cardiac cycle. Tonsil motion differed by submillimeter amounts between patients and controls. The study suggested a trend toward greater motion in patients than in controls and a weak trend toward greater displacement in patients with than without syringomyelia.

The results of this study agree with those of Levy,2 who found little movement of the tonsils and spinal cord during the cardiac cycle on PC MR images. Our findings are concordant with the theory that brain movement transfers directly to the spinal cord and tonsils.4,5 Our results differ from those of Oldfield et al,1 whose sonography studies after C1 laminectomy in patients with Chiari I demonstrated large displacements of the tonsils in those patients. Whether C1 laminectomy or general anesthesia increased tonsil motion in their subjects has not been determined.

The automated pixel-analysis program has a high degree of precision and accuracy for measuring rotations of vertebrae.8 For measuring soft-tissue displacements, the method has less accuracy and precision. Because motion is averaged over multiple voxels, the method may achieve greater precision than the in-plane dimensions of the voxel, that is, 0.5 × 0.78 mm. Because the differences between groups were small relative to the pixel size, P values were not calculated. Manual measurements concur with the automated measurements, though they have the drawbacks of reader bias and limited accuracy.

A limitation of the study is the small study population. The small differences we noted between groups might be significant if the statistical power of the study was greater. However, inspection of the 2D FIESTA images showed similar patterns of tonsil motion in patients and in controls. Sagittal PC MR magnitude images acquired regularly in MR imaging evaluation of the Chiari I malformation also showed submillimeter tonsil movement but, because of the poor contrast between tissue and CSF, did not permit ready measurement.

Conclusions
The cerebellar tonsils move biphasically less than a millimeter during the cardiac cycle in both control subjects and patients with Chiari I malformations. Preoperative 2D FIESTA imaging might be a useful adjunct to intraoperative sonography to determine the role of tonsil motion in the pathogenesis of syringohydromyelia.

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