Impact of body mass index on cerebellar tonsil position in healthy subjects and patients with Chiari malformation

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OBJECT It is unclear if there is a relationship between Chiari malformation Type I (CM-I) and body mass index (BMI). The aim of this study was to identify the relationship between BMI and cerebellar tonsil position in a random sample of people.

METHODS Cerebellar tonsil position in 2400 subjects from a cohort of patients undergoing MRI was measured. Three hundred patients were randomly selected from each of 8 age groups (from 0 to 80 years). A subject was then excluded if he or she had a posterior fossa mass or previous posterior fossa decompression or if height and weight information within 1 year of MRI was not recorded in the electronic medical record.

RESULTS There were 1310 subjects (54.6%) with BMI records from within 1 year of the measured scan. Of these subjects, 534 (40.8%) were male and 776 (59.2%) were female. The average BMI of the group was 26.4 kg/m², and the average tonsil position was 0.87 mm above the level of the foramen magnum. There were 46 subjects (3.5%) with a tonsil position ≥ 5 mm below the level of the foramen magnum. In the group as a whole, there was no correlation (R² = 0.004) between BMI and cerebellar tonsil position.

CONCLUSIONS In this examination of 1310 subjects undergoing MRI for any reason, there was no relationship between BMI and the level of the cerebellar tonsils or the diagnosis of CM-I on imaging.

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The association between an increased body mass index (BMI) and Chiari malformation Type I (CM-I) is not clear. There are several individual reports of obese individuals with CM-I, which have led some authors to speculate that an elevated BMI may be a causative factor for CM-I. The authors of 2 recent case series found that patients with CM-I frequently had a BMI in the obese range, and they postulated that an elevated BMI may play a pathophysiological role in CM-I, syrinx formation, or CM-I symptoms. CM-I is defined on imaging by determining the inferior extent of the cerebellar tonsils with respect to the foramen magnum; a measurement of ≥ 5 mm is generally considered consistent with an imaging diagnosis of this condition. To our knowledge, there has never been an analysis of the role of BMI in cerebellar tonsil position or CM-I in any study that included individuals who were not selected for CM-I evaluation. The true relationship between CM-I and elevated BMI, if any, is therefore unclear. Our objective was to determine the relationships, if any, among BMI, tonsil position, and CM-I.
Methods

After approval by the University of Michigan Institutional Review Board, we performed a search of our imaging database, which contains data on 62,533 consecutive patients who underwent brain or cervical spine MRI for any reason over an 11-year interval at our institution. From this cohort, 300 patients from each of 8 age cohorts (0–10, 11–20, 21–30, 31–40, 41–50, 51–60, 61–70, and > 71 years) were selected randomly. Ages were determined at the time of MRI. The subjects were chosen from the database by matching the last 2 digits of their randomly assigned record numbers to randomly generated 2-digit numbers. Randomization was completed when the target cohort size was achieved.

Our initial analysis of tonsil position in these patients was reported previously. The current analysis of the role of BMI in tonsil position was carried out in this cohort. Patients were excluded from the initial cohort of 2400 randomly selected patients if there was imaging evidence of any significant posterior fossa comorbidity that would influence tonsil position. Excluded patients included those with a posterior fossa tumor (n = 26), a posterior fossa arachnoid cyst (n = 45), previous posterior fossa surgery other than CM decompression (n = 23), previous CM decompression (n = 17), a significant mass effect from a primarily supratentorial process (including untreated hydrocephalus) (n = 17), volume loss from previous stroke (n = 9), or developmental abnormality (including CM Type II) (n = 14). MRI scans of 2551 patients were reviewed to assemble 8 groups of 300 patients each (2400 total patients) for the initial analysis. Furthermore, to be included in this subsequent analysis of the role of BMI and tonsil position, each patient must have had a height and weight measurement within 1 year of the index MRI scan. A total of 1310 subjects had BMI records from within 1 year of the measured scan; 1090 were excluded because of insufficient height (n = 104 patients), weight (n = 5), or height and weight (n = 981) data points.

The MRI scans of each of the selected patients were then reviewed, and tonsil position measurements were recorded as detailed in our previous report. For purposes of this analysis, tonsils that extended caudally to the basion-opisthion line were assigned a value of 0. CM-I was defined on imaging as a cerebellar tonsil position ≥ 5 mm below the basion-opisthion line. Measurements were recorded to the nearest millimeter. Two tonsil measurements were taken for each patient, one in the midsagittal plane and one in the parasagittal plane that corresponded to the lowest tonsil position on the left or right side. Each image was measured, and the measurement was agreed upon by 2 investigators, one of whom was a board-certified pediatric neurosurgeon.

SAS 9.2 statistical software (SAS Institute) was used to generate reports and figures based on the data. Mean differences were evaluated for statistical significance using t-test analysis. Simple descriptive statistics were generated using the means procedure.

Results

Of the subjects who met all the inclusion criteria, 534 (40.8%) were male and 776 (59.2%) were female. The mean BMI was 26.4 kg/m². Of the 1310 included subjects, there were 963 adults (≥ 18 years) with an average BMI of 28.5 kg/m² (SD 6.9 kg/m²) and 347 children with a mean BMI of 20.4 kg/m² (SD 6.4 kg/m²) (Fig. 1). There were 46 subjects (3.5%) with a tonsil position ≥ 5 mm below the level of the foramen magnum. The mean BMI for all subjects with a tonsil position ≥ 5 mm below the foramen magnum was 27.5 kg/m² (SD 9.8 kg/m²) compared with 26.4 kg/m² (SD 7.5 kg/m²) for those with tonsils above the 5-mm line (p = 0.57) (Fig. 2). In our group, a BMI of at least 41.6 kg/m² was > 2 SDs from the mean. The percentages of subjects with BMI of at least 2 SDs above the mean and BMI of at least 2 SDs below the mean did not differ (p = 0.98) between the CM-I group (n = 2 [4.3%]) and the non–CM-I group (n = 54 [4.3%]). In the group as a whole, there was no correlation (R² = 0.004) between BMI and tonsil position (Fig. 3). When children and adults were considered separately, we still found no effect. The pediatric (R² = 0.0003) and adult (R² = 0.0005) groups both showed no correlation between BMI and tonsil position.

Excluded were 104 patients—86 adults and 18 children—because their heights were not recorded within 1 year of the scan. Adult subjects excluded for this reason had a mean weight of 78.5 kg (SD 20.8 kg), and the adults included in the study had a mean weight of 80.4 kg (SD 20.6 kg). The weights of the included and excluded adults did not differ significantly (p = 0.41). Children excluded for this reason had a mean weight of 49.6 kg (SD 27.2 kg), and the children included in the study had a mean weight of 40.9 kg (SD 28.6 kg). The weights of the included and excluded children did not differ significantly (p = 0.21). In the excluded subjects, the mean tonsil position was 1.2 mm above the level of the foramen magnum (SD 3.2 mm). In the subjects included in the analysis, the mean tonsil position was 0.9 mm above the level of the foramen magnum (SD 3.5 mm).

Most of the patients with a tonsil position at least 5 mm below the foramen magnum had no syrinx (41 of 46 [89.1%]). Those patients with CM-I but no syrinx had a mean tonsil position 7.7 mm (SD 3.1 mm) below the foramen magnum and a mean BMI of 26.3 kg/m² (SD 9.6 kg/m²). The mean BMI in the subjects with CM-I and no syrinx who were ≤ 18 years of age was 19.6 kg/m² (SD 5.2 kg/m²), and for adults with CM-I and no syrinx who were > 18 years of age, the mean BMI was 31.1 kg/m² (SD 9.1 kg/m²). Five of the 46 patients with CM-I also had a spinal syrinx. The mean BMI for the patients with a syrinx was 21.2 kg/m². Of the 5 patients with a syrinx, 4 (80.0%) were ≤ 18 years old, and each had a BMI of ≤ 20 kg/m². Patients with a syrinx had a mean tonsil position 14.2 mm (SD 4.1 mm) below the foramen magnum, which is significantly lower than the position in those without a syrinx (7.7 mm [SD 3.1 mm]; p ≤ 0.0001).

Of the 46 patients with CM-I, 7 (15.2%) were considered possibly symptomatic by the treating physician and 6 (13.0%) underwent surgical decompression. Five patients had CM-I surgery at our institution, and 1 decompression was performed at another hospital. The mean tonsil position in symptomatic patients was 13.6 mm (SD 3.7 mm).
below the foramen magnum, and for those with asymptomatic CM-I, it was 7.5 mm (SD 3.0 mm). Seventeen patients had a history of headaches recorded in the medical record, and most of these patients (15 of 17 [88.2%]) had a neurological evaluation. In most cases, the headaches were long-lasting and lacked significant tussive characteristics. Three patients had headaches with a tussive component; 2 of them had a BMI in the normal range, and 1 was obese. The mean BMI for all the patients with CM-I with a recorded headache history was 27.6 kg/m², and the mean BMI for the 3 patients with tussive headaches was 26.3 kg/m². Of the patients with any report of tussive headache, 1 patient had only tussive-type headaches, and 1 patient presented with long-lasting holocranial headaches with a relatively minor tussive component; the patient with the holocranial headaches had a normal BMI (20.2 kg/m²) and underwent surgical treatment because of an associated syrinx and scoliosis. Two patients had typical tussive-type headaches that were associated with the CM-I and underwent CM-I decompression surgery. Both of these patients were adults at the time of diagnosis. One of these patients had a normal BMI (17.4 kg/m²), and the other had a BMI in the obese range (41.3 kg/m²). The mean tonsil position below the foramen magnum was 16.3 mm for the patients with tussive headaches and 6.2 mm for those with headaches without a significant tussive component.

Discussion

Some authors have suggested that CM-I or its symptomatic presentation may be associated with an elevated BMI.⁴⁹,¹⁸ We analyzed cerebellar tonsil positions and BMIs in a large series of patients of all ages who underwent MRI for any reason to explore the relationship between low tonsil position or CM-I and BMI. We found no relationship between tonsil position and BMI. The mean tonsil position with respect to the foramen magnum can be expected to vary according to the ages of the population studied but is not affected by BMI. We also found no convincing evidence that an elevated BMI is associated with syrinx in those with CM-I.

The authors of 2 recent case series found that the mean BMI of patients who underwent CM-I decompression was above the normal range. Batzdorf et al.⁹ found that the mean BMI for 177 adult patients who underwent CM-I decompression at their institution was 26.4 kg/m². Similarly, Arnautovic et al.⁴ reported on 60 adults who underwent CM-I decompression, and they found a mean BMI of 30.4 kg/m². In both reports, these authors focused on the patients who underwent CM-I decompression and did not provide a control group. In our population, the mean BMI for all patients regardless of tonsil position was 28.5 kg/m², not substantially different than the BMI for those patients with CM-I.

The basis of the putative relationship between an elevated BMI and CM-I rests on theories of the relationship between CM-I and elevations in intracranial pressure (ICP). There is robust evidence for an association between obesity and idiopathic intracranial hypertension (pseudotumor cerebri).¹²,¹³,¹⁷,¹⁸,³⁰,³¹ Just as obesity has been linked to
Chiari malformation type I and BMI

Elevated ICP, at least in some cases, there have also been several reports that have linked elevated ICP with CM-I. It is probable that symptoms of CM and the formation of spinal syrinxes are the result of crowding at the foramen magnum, which results in abnormal cerebrospinal fluid flow at the craniocervical junction. Theoretically, elevations in ICP may exacerbate this condition and lead to an increased risk of syrinx. Because an elevated BMI may be associated with increased ICP in certain cases, some authors have speculated that an elevated BMI may contribute to syrinx formation. In a series reported by Arnautovic et al., the length of the syrinx was slightly shorter in 7 individuals with a normal BMI (BMI 18.5–24.9 kg/m²) than in 5 overweight individuals (BMI 25–29.9 kg/m²). In that study, however, the syrinx length was actually shortest in 14 obese individuals (BMI ≥ 30 kg/m²), which casts doubt on any real causative relationship. Similarly, the authors found no correlation between syrinx width and BMI and no difference in BMIs between those with and those without a syrinx. Arnautovic et al. also reported on a single case of syrinx improvement after weight loss. Because spontaneous syrinx improvement has been reported, it is difficult to draw any conclusions from individual case reports. Despite the theoretical basis for such a relationship, we did not find any association between elevated BMIs and risk of syrinx in our own series. On the basis of these findings and our own data, we suggest that no association between BMI and syrinx formation in patients with CM-I can be proven with the existing data. If such a relationship exists, its effect must be small.

Many patients with a tonsil position > 5 mm below the foramen magnum are asymptomatic, and the factors that contribute to symptomatic presentation have been the subject of continued debate. A relatively small percentage of our patients with CM-I were symptomatic, which is consistent with previous reports of different cohorts from our institution. Batzdorf et al. recently reported BMI data for 106 adult patients with CM-I who were all treated surgically. In that group, the authors found that an elevated BMI was associated with an increased likelihood of exertional headache, a symptom that was present in a majority of their patients. In our own analysis, we focused on all patients who were undergoing imaging rather than on a selected group of patients who were deemed good candidates for CM-I decompression. It therefore was not surprising that we found a much smaller headache burden in our patients with cerebellar tonsils ≥ 5 mm below the foramen magnum. Only 3 patients in our series presented with Chiari-type exertional or tussive headaches. Examining the BMI data for all 17 patients with headache and the 3 patients with tussive headache failed to reveal any conclusive difference in BMI or weight for these patients compared with the subjects without headache or with a “normal” tonsil position.

There are several limitations to our analysis. Selection bias must be considered in any interpretation of these results. All patients in this analysis were selected from a population of those who were undergoing imaging. The method for measuring the tonsil position in this group cannot be expected to exactly match that of the population as a whole. The detection of tonsil position must be considered when comparing analyses of the prevalence of CM. In our previous studies of the prevalence of CM-I in children who were undergoing imaging, we found different prevalences of CM according to the methods used in our searches. Direct examination of the MR images with measurement of tonsil positions resulted in an increased rate of patients with a tonsil position ≥ 5 mm below the foramen magnum over that from analyses that we performed by searching the text of radiology records. We acknowledge that this study could be improved with a

**FIG. 3.** Scatterplot showing the relationship between tonsil position and BMI.
larger sample size. A power analysis was performed, and our sample could detect a 0.3-mm difference between the groups with adequate (0.8) power. Although a larger sample size would have allowed us to detect smaller differences between the groups, we believe that our sample size was powered adequately to detect any clinically significant effects.

There is much to dislike about the current definition of CM-I. First, as noted by several other groups, CM-I does not meet the usual definition of a malformation.\textsuperscript{9,10,22,23} Furthermore, on the basis of recent information, the imaging diagnosis of this condition, once a straightforward matter of measuring the tonsils below the foramen magnum, is also a fair subject for debate. In this analysis, the diagnosis of CM-I via imaging was made in the usual way by determining the cerebellar tonsil position to be \( \geq 5 \) mm below the foramen magnum.\textsuperscript{1,8,10,12,28} It is likely that patients with CM-I have a reduced posterior fossa volume, which results in crowding at the foramen magnum.\textsuperscript{5,21,25,27} Although cerebellar tonsil position is a convenient marker for crowding at the foramen magnum, the correlation is not exact.\textsuperscript{26} In some cases, patients with \(< 5\) mm of descent can have a clinical presentation of Chiari syndrome and even syringomyelia caused by crowding at the foramen magnum.\textsuperscript{21} Nevertheless, to make our analysis clear and consistent with other analyses in the literature, we followed the usual custom of considering those with tonsils that are \( \geq 5 \) mm below the foramen magnum as a separate group.

Conclusions

For most patients, cerebellar tonsil position is not influenced by BMI.

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References

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