

Normative Cerebellar Tonsil Morphology: A Cadaveric Study of Bilateral Volume, Shape, and Three-Dimensional Spatial Relationships

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ABSTRACT

Morphological features such as cerebellar tonsillar descent, increased volume, and a peg-shaped configuration are frequently described in Chiari malformation type I (CMI); however, their presence in the normal population remains insufficiently characterized. To define normative anatomical parameters of cerebellar tonsil morphology and determine the prevalence of features commonly associated with CMI in structurally normal adult brains.

Thirty formalin-fixed adult brain specimens were analyzed. Tonsils were categorized as round or peg-shaped. Bilateral tonsillar volumes were calculated using ellipsoid modeling, and spatial relationships to the obex, cerebellar vermis, and inferior cerebellar peduncle were recorded.

The right tonsil had significantly greater volume than the left ($1199.8 \pm 463.1 \text{ mm}^3$ vs. $1060.5 \pm 400.7 \text{ mm}^3$; $p = 0.023$), primarily due to increased width ($11.2 \pm 2.3 \text{ mm}$ vs. $9.8 \pm 2.7 \text{ mm}$; $p < 0.001$). Round-shaped tonsils were larger than peg-shaped ones on the right ($p = 0.048$), and a similar trend was observed on the left ($p = 0.061$). Peg-shaped tonsils were present in 35% of all specimens examined. Only left tonsillar volume correlated with obex distance ($r = -0.385$, $p = 0.035$). No associations were observed between volume asymmetry or shape and spatial displacement.

This study shows that features often associated with CMI—peg shaped, descent below the obex, and right-sided dominance—can occur in anatomically normal brains. Without compression or CSF flow impairment, these findings may not justify tonsillar reduction, and surgery should be guided by clinical, imaging, and intraoperative assessment.

Keywords: Cadaveric anatomy, Cerebellar tonsils, Chiari malformation type I, Cerebellar Morphology, Peg-shaped tonsil, Tonsillar volume

Introduction

The cerebellar tonsils form the inferomedial lobules of the cerebellar hemispheres and are positioned adjacent to critical posterior fossa structures, including the medulla, obex, and inferior cerebellar peduncles (ICPs). Under normal anatomical conditions, the tonsils lie just superior to or partially overlapping the foramen magnum, with notable individual variation in shape, volume, and spatial orientation (1-7). Due to their proximity to the fourth ventricle floor, posterior medullary velum, and vascular loops of the posterior inferior cerebellar artery, the tonsils have clear surgical relevance in Chiari decompression. In such cases, manipulation, coagulation, or partial resection may be necessary to restore cerebrospinal fluid flow (1, 2, 6, 8-10).

Cerebellar tonsillar descent is the hallmark radiologic feature of Chiari malformation type I (CMI), historically defined as $\geq 5 \text{ mm}$ extension of the tonsils

below the foramen magnum on midsagittal imaging (7, 9-13). However, the diagnostic utility of this cutoff has been questioned, as modest descent may be observed in asymptomatic individuals, particularly in the setting of age-related or postural variation (1-4, 14-16). Recent studies have proposed that obex position may be a more reliable marker of hindbrain descent and symptom burden than tonsillar displacement alone, particularly in cases of "borderline" tonsillar ectopia (8, 11, 15, 17).

The pathophysiology of CMI is multifactorial, involving theories of congenitally small posterior fossa volume, impaired cerebrospinal fluid (CSF) dynamics, craniospinal pressure gradients, and altered tissue compliance (16, 18). Herniated tonsils may obstruct CSF flow across the craniocervical junction, contributing to clinical symptoms such as occipital headache, vertigo, paresthesias, gait instability, dysphagia, and syringomyelia (9, 18). Surgical intervention often includes posterior fossa

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Fig. 1. Gross anatomical view of all 30 formalin-fixed adult human brain specimens used in this study. Each specimen includes an intact cerebellum, brainstem, and associated posterior fossa structures, with all cranial bones removed to enable direct visualization and morphometric analysis of the cerebellar tonsils

decompression, with or without duraplasty or direct tonsillar manipulation, depending on the degree of crowding and the presence of syrinx (19-21).

Despite the centrality of the cerebellar tonsils in the diagnosis and surgical management of CMI, few anatomical studies have systematically quantified their three-dimensional morphology. Most prior work has relied on imaging or cadaveric midline measurements without assessing bilateral volume, asymmetry, or shape classification. While radiological literature often distinguishes between "round" and "peg-shaped" tonsils, these shape types have rarely been validated in anatomical studies or correlated with volumetric or spatial parameters (1-6, 8, 10).

Asymmetry in tonsillar descent is frequently observed on imaging, with the right tonsil often appearing lower than the left. Whether this reflects true anatomical volume asymmetry or lateralized descent remains unclear, as few studies have measured bilateral volumes and spatial distances to fixed landmarks such as the obex, vermis midline, or ICP (1, 2, 4).

To address this anatomical gap, we conducted a detailed study of cerebellar tonsil morphology in 30 adult human brain specimens. Using ellipsoid modeling, we calculated bilateral tonsil volumes, classified their shape (Round vs. peg-shaped), and recorded their spatial relationships to the obex, cerebellar vermis, and ICPs. Asymmetry metrics were also examined. To our knowledge, this is the first cadaveric study to integrate bilateral volumetric modeling, shape classification, and multi-point spatial

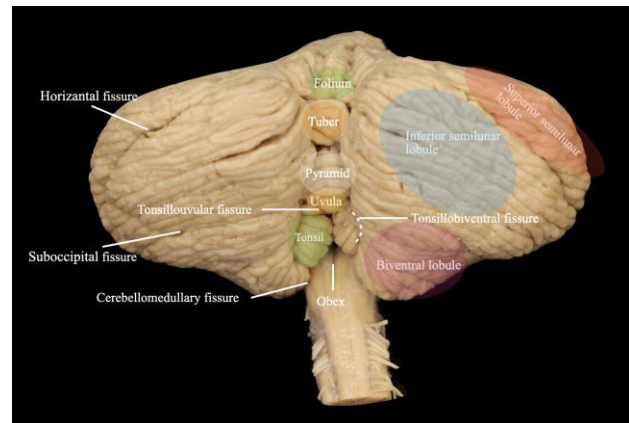


Fig. 2. Annotated dissection of the cerebellum and brainstem illustrating key anatomical landmarks. Labeled structures include the folium, tuber, pyramid, uvula, and cerebellar tonsils, as well as the biventral, inferior semilunar, and superior semilunar lobules. Identified fissures include the horizontal, suboccipital, tonsillouvar, tonsillobiventral, and cerebello-medullary fissures. The obex is also indicated at the lower margin of the fourth ventricle

correlation of the cerebellar tonsils. Our goal is to provide normative anatomical reference values and clarify how tonsillar volume, shape, and position interrelate, offering insights for both diagnosis and surgical treatment of Chiari malformation.

Materials and Methods

This anatomical study was conducted on 30 formaldehyde-fixed adult human brain specimens, which contained intact cerebellum, brainstem, and posterior fossa structures, excluding all cranial bones (Figure 1). The removal of bony elements enabled unobstructed bilateral access to the cerebellar tonsils and adjacent posterior fossa structures. While this approach did not permit direct measurement of the foramen magnum–tonsil relationship, it allowed high-precision assessment of intrinsic tonsillar morphology and its spatial relationship to key brainstem landmarks.

The specimens were obtained from the Department of Neurosurgery at the University of Wisconsin–Madison, USA. According to institutional policy, the use of cadaveric material for anatomical research does not require separate ethics committee approval. Cadavers with prior posterior fossa surgery, congenital anomalies, or distortion of the cerebellar anatomy were excluded.

After relevant neuroanatomical landmarks were exposed bilaterally, each tonsil was measured along three orthogonal axes: length (from the inferior tip to the superior pole), width (maximum mediolateral dimension), and depth (anteroposterior thickness).

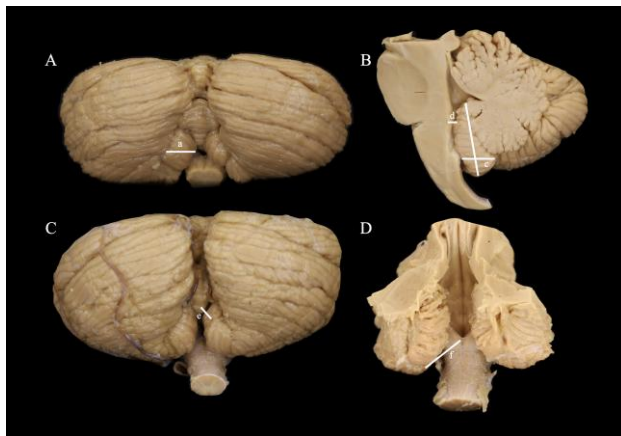


Fig. 3. Morphometric landmarks used for linear measurements and volumetric modeling. (A) a: mediolateral width; (B) b: vertical length (inferior tip to superior pole); c: anteroposterior depth; d: shortest distance to the inferior cerebellar peduncle (ICP); (C) e: horizontal distance from the medial tonsillar border to the cerebellar vermis midline; (D) f: vertical distance from the inferior tonsillar tip to the obex

Measurements were obtained using high-precision digital calipers under magnification (Figures 2 and 3).

Tonsillar volume (mm^3) was estimated using the ellipsoid formula: $\text{Volume} = (4/3) \times \pi \times (\text{Length}/2) \times (\text{Width}/2) \times (\text{Depth}/2)$. In addition to morphometric data, each tonsil was categorized as either round-shaped or peg-shaped based on the morphology of its inferior tip. Shape classification was performed independently by two observers and finalized by consensus (Figure 4).

Three anatomical distances were recorded for each tonsil: the vertical distance from the inferior tip to the obex; the horizontal distance from the medial border of the tonsil to the midline of the cerebellar vermis; and the shortest linear distance to the visible portion of the ICP. All distances were measured in millimeters using calibrated dissection rulers and confirmed with digital caliper tools (Figure 3).

To assess laterality, all measurements were taken for both right and left tonsils (a total of 60 tonsils). Volume and distance asymmetries were calculated as absolute differences between sides, and the larger tonsil was defined as the dominant side. Asymmetry metrics were also examined concerning descent and spatial orientation.

Statistical Analysis: All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were reported as mean $\pm$ standard deviation (SD) and range. The Shapiro–Wilk test was used to assess the normality of continuous variables. The assumption of homogeneity of variances was verified using Levene’s test before

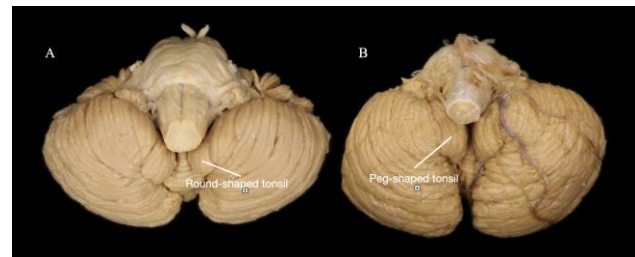


Fig. 4. Morphological variants of cerebellar tonsil shape. (A) Example of a round-shaped tonsil, characterized by a smooth, globular inferior pole. (B) Example of a peg-shaped tonsil, distinguished by a tapered and elongated inferior extension

applying parametric analyses. Paired two-tailed t-tests were used to compare right and left cerebellar tonsil measurements, including length, width, depth, volume, and distances to the obex, ICP, and vermis midline. Unpaired t-tests were used to compare tonsil volumes between the Peg-shaped and the Round-shaped groups. The distribution of tonsillar shapes between sides was evaluated using the chi-square test.

Pearson correlation coefficients (r) were calculated to examine associations between tonsillar dimensions (volume, length, and asymmetry) and anatomical distances (Obex, ICP, and vermis), including both side-specific and asymmetry-based measures. For comparisons of anatomical distances between shape groups (Peg vs Round), the non-parametric Mann–Whitney U test was applied due to the ordinal nature of the grouping variable. A p-value less than 0.05 was considered statistically significant. All statistical tests were two-tailed.

Results

Tonsillar Volume and Side Differences: In the 30 cadaveric specimens (60 cerebellar tonsils), the mean volume of the right tonsil was significantly greater than that of the left ($1199.8 \pm 463.1 \text{ mm}^3$ vs $1060.5 \pm 400.7 \text{ mm}^3$; $p = 0.023$), indicating a mild but statistically significant right-sided dominance in tonsillar volume (Figures 1 and 3). No significant differences were observed in length ($p = 0.914$) or depth ($p = 0.520$) between sides. However, the right tonsil was significantly wider than the left ($11.2 \pm 2.3 \text{ mm}$ vs $9.8 \pm 2.7 \text{ mm}$; $p < 0.001$), and this increased width likely contributed to the larger calculated volume on the right (Table 1).

Anatomical Position Relative to the Obex, Vermis, and ICP: The vertical distance from the inferior tip of the tonsil to the obex was similar between sides (right: $3.9 \pm 1.8 \text{ mm}$; left: $3.8 \pm 1.6 \text{ mm}$; $p = 0.703$), suggesting symmetrical descent

Table 1: Descriptive Statistics and Paired Comparisons of Right and Left Cerebellar Tonsils

Measurement	Right Side		Left Side		p-value
	Mean $\pm$ SD	Min–Max	Mean $\pm$ SD	Min–Max	
Tonsil Length (mm)	20.1 $\pm$ 3.1	14.0–26.0	20.1 $\pm$ 2.6	15.0–24.0	0.914
Tonsil Width (mm)	11.2 $\pm$ 2.3	7.0–15.0	9.8 $\pm$ 2.7	4.0–14.0	< 0.001
Tonsil Depth (mm)	10.0 $\pm$ 2.0	7.0–14.0	10.3 $\pm$ 2.0	6.0–13.3	0.520
Tonsil Volume (mm ³)	1199.8 $\pm$ 463.1	469.1– 2450.4	1060.5 $\pm$ 400.7	529.3– 2096.5	0.023
Distance to Obex (mm)	3.9 $\pm$ 1.8	1.0–8.0	3.8 $\pm$ 1.6	2.0–7.0	0.703
Distance to Vermis Midline (mm)	1.0 $\pm$ 0.8	0.0–2.5	1.1 $\pm$ 0.7	0.0–2.0	0.446
Distance to ICP (mm)	1.4 $\pm$ 0.4	1.0–2.0	1.3 $\pm$ 0.4	1.0–2.0	0.706
Tonsil Shape	Round-Shaped	Peg-Shaped	Round-Shaped	Peg-Shaped	
Numbers	19	11	20	10	1.000
Volumes (mm ³)	1310.4 $\pm$ 515.8	1008.8 $\pm$ 282.5	1152.4 $\pm$ 406.9	876.9 $\pm$ 333.8	0.048a 0.061b

Abbreviations: SD = standard deviation; mm = millimeter; mm³ = cubic millimeter; ICP = inferior cerebellar peduncle.

Note: Paired two-tailed *t*-tests were used to compare right and left tonsillar dimensions. Unpaired *t*-tests were applied for volume comparisons between Peg- and Round-shaped tonsils. Chi-square tests assessed shape distribution frequencies. Statistical significance was set at *p* < 0.05. Superscripts indicate side: ^a = right tonsil; ^b = left tonsil

Table 2: Correlation Analyses of Tonsillar Volume, Length, Asymmetry, and Anatomical Distances

Comparison	Right Side		Left Side	
	Correlation (r)	p-value	Correlation (r)	p-value
Volume vs Obex Distance	-0.118	0.534	-0.385	0.035*
Volume vs ICP Distance	-0.149	0.431	0.089	0.639
Length vs Obex Distance	0.31	0.095	-0.061	0.75
Volume vs Vermis Distance	0.274	0.143	0.325	0.079
	Correlation (r)		p-value	
Volume Asymmetry vs Mean Obex Distance	0.28		0.135	
Volume Asymmetry vs ICP Distance Asymmetry	0.029		0.877	
Volume Asymmetry vs Vermis Distance Asymmetry	-0.148		0.434	
Volume Asymmetry vs Obex Distance (Larger Tonsil)	0.256		0.171	

Abbreviations: ICP = inferior cerebellar peduncle.

Note: Pearson correlation coefficients (*r*) were calculated to assess associations between tonsillar dimensions and anatomical distances. Statistical significance was defined as *p* < 0.05. Significant correlations are marked with an asterisk (*)

below the obex. The horizontal distance from the medial edge of the tonsil to the cerebellar vermis midline also showed no significant difference between sides (*p* = 0.446). Similarly, the shortest distance from each tonsil to the visible portion of the ICP did not differ significantly (*p* = 0.706), indicating bilateral spatial symmetry across these anatomical landmarks (Table 1).

Tonsil Shape and Volume Comparison:

Tonsillar shapes were classified as Round or Peg-shaped based on the morphology of the inferior pole. Shape distribution was similar between sides, with 19 Round and 11 Peg-shaped tonsils on the right and 20 Round and 10 Peg-shaped on the left (*p* = 1.000). Round-shaped tonsils tended to have greater volume than Peg-shaped ones. On the

Table 3: Group Comparisons of Tonsillar Shape (Peg vs Round) with Anatomical Distances and Asymmetries

Comparison	Right	Left
	p-value	
Tonsil Shape vs Obex Distance	0.176	0.982
Tonsil Shape vs ICP Distance	0.079	0.591
Tonsil Shape vs Vermis Distance	0.544	0.323
Tonsil Shape vs Mean Obex Distance	0.249	
Tonsil Shape vs ICP Distance Asymmetry	0.137	
Tonsil Shape vs Vermis Distance Asymmetry	0.911	
Tonsil Shape vs Obex Distance (Larger Tonsil)	0.653	

Abbreviations: ICP = inferior cerebellar peduncle.

Note: Mann–Whitney U tests were used to compare anatomical distances and asymmetry measures between Peg- and Round-shaped tonsils. The use of non-parametric testing was guided by a normality assessment using the Shapiro–Wilk test. Statistical significance was defined as $p < 0.05$

right, this difference was statistically significant ($1310.4 \pm 515.8 \text{ mm}^3$ vs $1008.8 \pm 282.5 \text{ mm}^3$; $p = 0.048$). On the left, a similar trend was observed ($1152.4 \pm 406.9 \text{ mm}^3$ for round vs $876.9 \pm 333.8 \text{ mm}^3$ for Peg-shaped), although this difference did not reach statistical significance ($p = 0.061$) (Table 1).

Correlation Between Tonsillar Dimensions and Obex Depth: A significant negative correlation was found between left tonsillar volume and vertical distance from the tonsil to the obex ($r = -0.385$, $p = 0.035$), indicating that larger left tonsils tend to descend further below the obex. No such correlation was observed on the right ($r = -0.118$, $p = 0.534$). Tonsillar length showed a positive, though non-significant, correlation with obex distance on the right ($r = 0.31$, $p = 0.095$), while no association was found on the left ($p = 0.75$) (Table 2).

Relationship Between Volume and Vermis or ICP Distance: Tonsillar volume was not significantly correlated with distance to either the vermis midline or the ICP on either side. A near-significant positive correlation was observed between left tonsillar volume and distance to the vermis midline ($r = 0.325$, $p = 0.079$), suggesting that larger left tonsils may be positioned slightly farther from the midline, although this association did not reach statistical significance (Table 2).

Volume Asymmetry and Spatial Correlates: Volume asymmetry, defined as the absolute difference in volume between the right and left sides, showed a weak, non-significant positive

correlation with the mean obex distance ($r = 0.28$, $p = 0.135$). This suggests that when volume asymmetry is greater, the average vertical distance of both tonsils to the obex tends to be slightly longer—that is, both tonsils may lie slightly higher (more rostrally) overall, rather than descending more deeply. No significant correlation was found between volume asymmetry and the obex distance of the larger tonsil ($r = 0.256$, $p = 0.171$), indicating that the more voluminous tonsil does not necessarily descend further (Table 2).

Volume asymmetry also did not correlate with asymmetry in ICP distance ($r = 0.029$, $p = 0.877$) or vermis distance ($r = -0.148$, $p = 0.434$), suggesting that size differences between tonsils are not associated with lateral displacement relative to midline or brainstem landmarks (Table 2).

Shape-Based Comparisons of Anatomical Positioning: There were no statistically significant differences between Peg- and Round-shaped tonsils in terms of their distance to the obex, vermis midline, or ICP on either side. However, a near-significant trend was noted on the right, where Peg-shaped tonsils tended to lie closer to the ICP ($p = 0.079$). Although not conclusive, this trend may have clinical relevance in cases where space is limited in the posterior fossa (Table 3).

Discussion

This cadaveric study provides detailed anatomical data on cerebellar tonsil morphology, volume,

shape, and spatial orientation in adult human brain specimens selected for normal posterior fossa anatomy. By establishing baseline reference values, our findings offer a framework for distinguishing normal anatomical variation from features often associated with CMI. To our knowledge, this is the first anatomical study to integrate bilateral volumetric modeling, shape classification, and multi-point spatial correlation of the cerebellar tonsils.

Right-sided Volume Dominance and Its Implications: We observed a statistically significant volume asymmetry, with the right cerebellar tonsil being larger than the left ($1199.8 \pm 463.1 \text{ mm}^3$ vs. $1060.5 \pm 400.7 \text{ mm}^3$; $p = 0.023$), primarily due to increased width ($p < 0.001$) (Table 1). Right-sided descent has been frequently described in Chiari imaging studies and often assumed to reflect pathological herniation (1, 6, 22). However, since this asymmetry was present in cadaveric specimens without posterior fossa malformation or prior surgery, our data suggest that right-sided dominance may represent a normal anatomical variant rather than a Chiari-specific trait. This raises the possibility that tonsillar laterality, by itself, may not reliably indicate pathology and should be interpreted cautiously. The consistent right dominance we observed may reflect underlying embryologic or vascular asymmetries in posterior fossa development, as previously suggested by Shekhawat et al. and Tubbs et al. (1, 2, 4).

Peg-shaped Morphology in the Context of Normal Anatomy: Tonsillar shape classification revealed 11 right-sided and 10 left-sided peg-shaped tonsils in our sample. Peg-shaped tonsils have been commonly associated with symptomatic CMI and are thought to reflect more severe descent or CSF pathway obstruction (1, 2, 4, 6, 9, 10). However, in our study, peg-shaped tonsils were significantly smaller in volume than round-shaped tonsils on the right ($p = 0.048$), and trended smaller on the left ($p = 0.061$). These results suggest that peg morphology does not necessarily indicate increased tonsillar mass (Tables 1 and 3).

Our findings support previous anatomical studies reporting the presence of peg-shaped tonsils in anatomically normal adult specimens (1, 5, 6). While these findings do not refute the clinical relevance of peg-shaped tonsils in Chiari patients, they raise the possibility that this morphology may also occur as part of normal anatomical variation. In symptomatic CMI, peg-shaped tonsils may contribute to obstruction through motion,

descent, or crowding, but static shape alone does not imply such behavior. Therefore, shape alone should not be used to define pathology and must be interpreted in a clinical and radiologic context. Our data further suggests that shape may correspond to volume; round-shaped tonsils tend to be larger, which supports previous radiological impressions but now grounds them in anatomical evidence.

In addition to volume, spatial metrics also failed to distinguish between the two shapes. There was no significant relationship between tonsillar configuration and asymmetry in position relative to the obex, ICP, or cerebellar vermis. These findings suggest that shape alone does not predict coronal or sagittal displacement within the posterior fossa, nor does it consistently correlate with anatomical asymmetry. Collectively, the data imply that static morphological appearance—whether peg-shaped or round—should not be overinterpreted as a marker of pathological descent or obstruction in isolation. (Table 3).

Side-specific Correlation Between Volume and Obex Distance: Only the left tonsillar volume was significantly correlated with the vertical distance to the obex ($r = -0.385$, $p = 0.035$); no correlation was found on the right side (Tables 1 and 2). The obex position has been proposed as a more reliable marker of symptom burden and syringomyelia risk than tonsillar descent alone (8, 15, 17). Our findings offer partial anatomical support for this view but also reveal variability by side. Importantly, we found that all tonsils in our specimens were located below the obex, despite the absence of any gross pathology. This challenges the assumption that descent below the obex is inherently pathological and supports proposals that obex-based measurements—though useful—must be interpreted relative to population norms.

Volume Asymmetry and Spatial Symmetry: We found no significant correlation between volume asymmetry and obex distance ($r = 0.256$, $p = 0.171$), vermis midline distance ($r = -0.148$, $p = 0.434$), or ICP proximity ($r = 0.029$, $p = 0.877$) (Table 2). These findings suggest that volume differences between tonsils do not result in consistent spatial displacement within the posterior fossa. This supports prior anatomical observations indicating that the cerebellar tonsils are generally symmetric in their coronal alignment (2, 7, 15, 20).

In contrast, a recent radiologic study by Chuang et al. found that CM-I patients had significantly larger tonsillar volumes and longer total tonsillar length

compared to controls, and that greater neural tissue at the foramen magnum correlated with syrinx formation and the need for surgical intervention (7). Our cadaveric data showed right-sided volume dominance in normal anatomy, but no difference in tonsillar length and no correlation with asymmetry in brainstem relationships. This discrepancy highlights the importance of interpreting tonsillar volume in the context of overall craniospinal dynamics and symptomatology.

Clinical and Surgical Implications: Several features commonly associated with Chiari malformation—including right-sided dominance, peg-shaped morphology, and mild descent—were also observed in cadaveric specimens with no gross cerebellar abnormality. This suggests that such features may represent anatomical variants rather than inherently pathological findings. However, this does not diminish their possible relevance in CMI when present alongside symptomatology, crowding, or CSF flow obstruction (5-8, 12, 16, 22).

In Chiari decompression surgery, partial tonsillar resection or coagulation has traditionally been performed to enlarge the cisterna magna and improve CSF flow, particularly in the presence of peg-shaped tonsils or tight foramen magnum spaces (19, 20, 23). However, our findings raise the possibility that these morphologic features—especially in the absence of crowding—may not be sufficient to justify tonsillar reduction alone. Recent clinical series have shown that bony decompression and release of fibrotic bands alone may restore CSF dynamics in selected patients, while others recommend combining dural opening with targeted arachnoid lysis to relieve obstruction without requiring tonsillar reduction in many cases (13, 16, 17, 19, 21).

Therefore, we propose that tonsillar resection or coagulation should be guided not by shape, descent, or asymmetry alone, but by intraoperative evidence of CSF obstruction, presence of arachnoid bands, and symptom correlation. Our anatomical data underscore the importance of individualized surgical decision-making that incorporates patient-specific morphology, clinical characteristics, and dynamic imaging.

Limitations: This study was conducted on formalin-fixed adult cadaveric specimens selected for intact cerebellar and brainstem anatomy, with exclusion of cases showing gross malformation or prior posterior fossa surgery. However, pre-mortem imaging and clinical history were not available, so we could not confirm the presence or absence of Chiari-related symptoms or radiologic features. While ellipsoid modeling offers a

consistent method for estimating volume, it does not capture irregular surfaces as precisely as 3D reconstruction. Shape classification, though performed by two observers and resolved by consensus, introduces some subjectivity. Additionally, the study was not powered to assess sex-based or age-dependent anatomical variations.

This study provides normative anatomical values for cerebellar tonsillar morphology, including volume, shape, and spatial relationships to the obex and surrounding structures. Features frequently associated with Chiari malformation type I, such as peg-shaped tonsils, descent below the obex, and right-sided volume dominance, were also identified in adult specimens with no evidence of anatomical deformity. **These findings suggest that such features alone are not inherently pathological.** In particular, when there is no brainstem compression or cerebrospinal fluid flow obstruction, characteristics such as tonsillar shape, asymmetry, or mild descent may not justify reduction during decompression. Surgical decisions should instead be guided by symptom correlation, radiologic findings, and intraoperative assessment, underscoring the importance of individualized, context-specific management.

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