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Original Article

Variations of Tentorial Notch Anatomy in Autopsy and NCCT of Head Injury Patients to Correlate Its Impact over Brainstem—An Observational Study

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Abstract

Background Tentorium cerebelli divide cranial cavity into supratentorial and infratentorial compartment. Tentorial notch is a gap in tentorium cerebelli located centrally and anteriorly, related to upper brainstem, first six cranial nerves, cerebrum, and cerebellum. The aim of this study was to analyze morphometric variation in tentorial notch anatomy in autopsy and computed tomography (CT) of head injury patients and to find out correlation between tentorial notch anatomy and uncal herniation and changes over brainstem surface in case of uncal herniation.

Materials and Methods Autopsy examination of head injury patients was done between July 1, 2021, and Jan 31, 2023. Skull was opened in a standard manner and midbrain sectioned at the level of tentorial edge. Tentorial notch parameters (anterior notch width, maximum notch width, notch length, posterior tentorial length, apicotectal distance, interpedunculoclival distance) were measured using geometry compass and vernier caliper. These parameters were also measured on noncontrast computed tomography (NCCT) head of same patients. Evidence of uncal herniation was sought for in both NCCT head and autopsy examination. Impact of uncal herniation over brainstem in form of indentation over lateral surface of midbrain and macroscopic brainstem hemorrhage was noted.

Results In 65 autopsy cases, there were 56 male and 9 female specimens; their mean age was 40.63 ± 16.78 years (range: 7–86 years). The most frequent type of tentorial notch observed in our study was typical type (32.30%). Relative frequency of uncal herniation was present predominantly (75%) in large type of tentorial notch and least (20%) in small type of tentorial notch. A significant correlation (p-value < 0.01) was found between uncal herniation and indentation over lateral surface of midbrain, while no significant correlation (p-value > 0.05) was found between uncal herniation and macroscopic brainstem hemorrhage in autopsy specimens.

Conclusion The results of our study provide a baseline data about tentorial notch anatomy and it may facilitate neurosurgical decision making as well as help in deciding the best trajectory for lesions approaching in the vicinity of the tentorial notch

Keywords
- neuroimaging
- postmortem examination
- tentorial notch classification
- traumatic brain injury
- uncal herniation

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Introduction

Tentorium cerebelli is a crescent-shaped second-largest dural reflection cover cerebellum that divides the cranial cavity into supratentorial and infratentorial compartment.[1] Communication between above two compartments is only via tentorial notch or incisura and gap in tentorium cerebelli located centrally and anteriorly. Tentorial notch is related to upper brainstem, first six cranial nerves, cerebrum, and cerebellum.[2,3]

Size of the tentorial notch varies from person to person even in same-age groups, which influences brainstem distortion in head injury.[3] Meyer was the first to recognize and outline the fatal effects of brainstem compression by transtentorial coning.[4] Tentorial notch was found difficult to quantify until certain landmark studies done.[5,6] The studies are still lacking in detailed findings on the morphometric analysis of the tentorial notch.[6]

In order to understand and predict the course and clinical effects of transtentorial herniation and brainstem distortion in head injuries, a thorough study of anatomical variability in tentorial hiatus was required. There were very few studies done for analyzing the tentorial hiatus size of Indian population and its clinical implication.[2,3,6,7] Therefore, the objective of this study was to elaborate morphometric variations in the tentorial notch anatomy in autopsies of head injury patients. Emphasis was placed on careful dissection in order to determine the size of the tentorial notch and correlate these anatomical findings with computed tomography (CT) head of same patients.

This study will provide a baseline anatomical data of Indian population for determination of notch types on CT that may influence the criteria to determine the anticipated early deterioration or impending herniation in case of traumatic brain injury and it will be helpful in prognostication too. This knowledge will help us in various neurosurgical procedures.

Methodology

Study Design and Setting

A prospective observational study was conducted for morphometric analysis of tentorial notch variations on fresh (< 48 hours after death) cranium specimens during autopsy examination of 71 head injury patients from July 2021 to Jan 2023 (19 months). The autopsy examinations were done in mortuary, in collaboration with the Department of Forensic Medicine and Toxicology and Department of Anatomy, at KGMU, Lucknow, a tertiary care center.

Ethical clearance from institutional ethical committee was obtained.

Study Participants

Only those expired head injury patients of Department of Neurosurgery, King George's Medical University (KGMU), who had a good quality noncontrast CT (NCCT) head prior to death and underwent postmortem examination within 48 hours of death were included in this study to avoid any alteration in the tentorial notch because of decomposition or putrefaction.[8] Those who underwent postmortem examination after 48 hours of death and had findings of distorted tentorial notch anatomy either due to trauma, iatrogenic, or intracranial pathology at the time of autopsy or poor-quality NCCT head were excluded from the study.

Data Collection

Total 65 expired head injury patients fulfilling above inclusion and exclusion criteria were enrolled in the study. The following measurements were taken in autopsy with the help of vernier's calipers and geometry compass to analyze the morphometric variations in tentorial notch in Indian population (►Fig. 1).[2,9]

1. Anterior notch width (ANW): The width of the tentorial notch in the axial plane through the posterior aspect of the dorsum sellae.
2. Maximum notch width (MNW): The maximum width of the tentorial notch in the axial plane.
3. Notch length (NL): The distance between the superoposterior edge of the dorsum sellae in the median plane and the apex of the notch.
4. Posterior tentorial length (PTL): The shortest distance between the apex of the notch and the most anterior part of the confluence of sinuses.
5. Apicotectal distance (AT): The distance from the tectum in the median plane to a perpendicular line dropped from the notch apex to the cerebellum.
6. Interpedunculoclival (IC) distance: The distance from the interpeduncular fossa to the superoposterior edge of the dorsum sellae.

These tentorial notch parameters were also measured on NCCT head of same patients (►Fig. 2). Evidence of uncal herniation was sought for in both NCCT head and autopsy

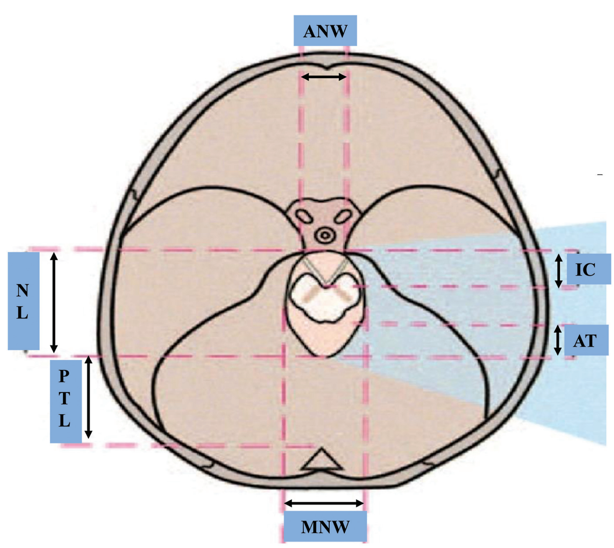

Fig. 1 Tentorial Notch parameters.

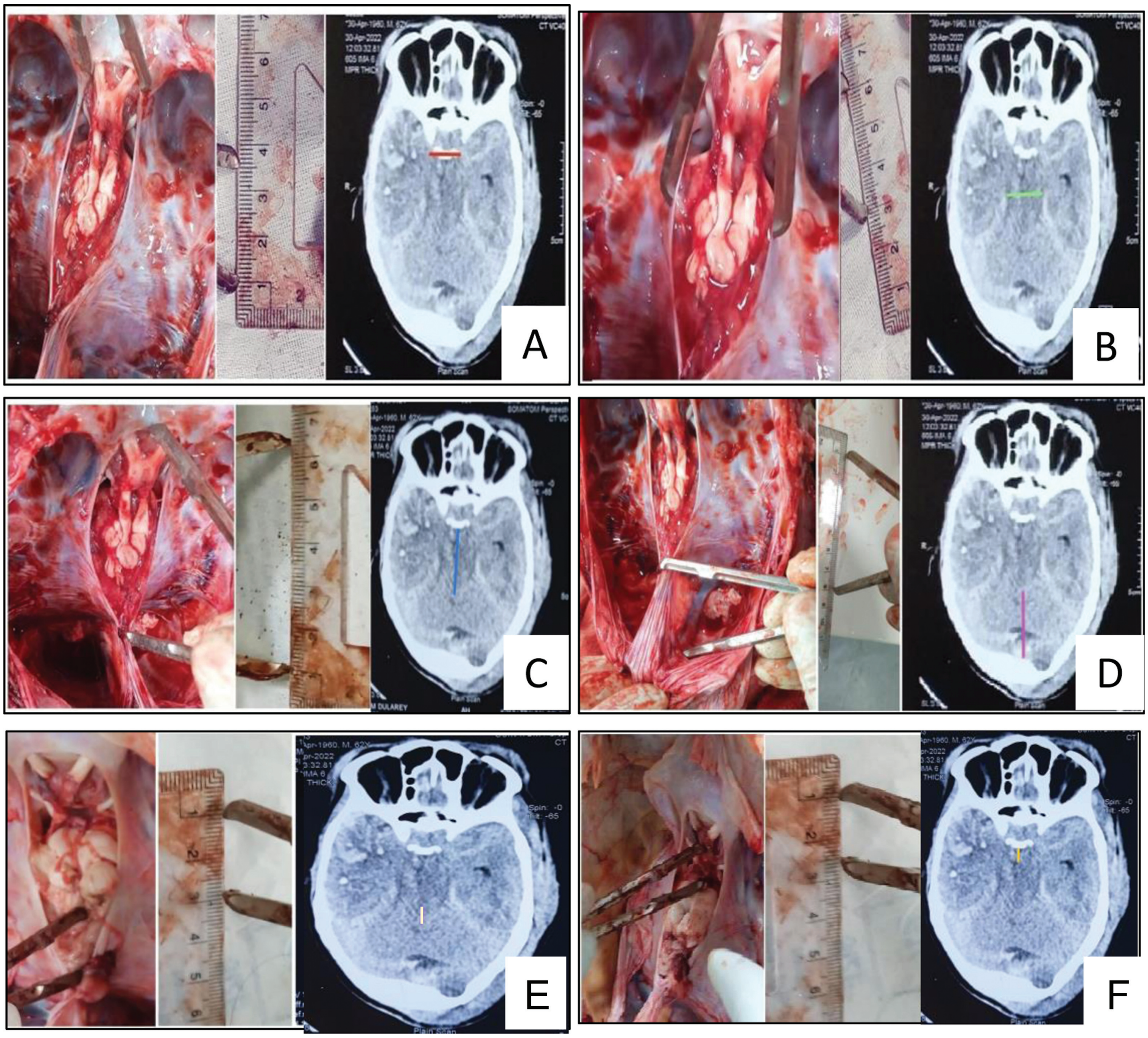

Fig. 2 Measurement of tentorial notch parameters—(**A**) Anterior notch width, (**B**) Maximum notch width, (**C**) Notch length, (**D**) Posterior tentorial length, (**E**) Apicotectal distance, (**F**) Interpedunculoclival distance.

examination. Impact of uncal herniation over brainstem in form of indentation over lateral surface of midbrain and macroscopic brainstem hemorrhage was noted.

Steps of Dissection

In this study, human cadavers were opened in a standard manner within 48 hours after death. Unfixed head of the cadaver was placed on a wooden block at an angle of 45 to 60 degrees above the horizontal plane. An incision across the vertex was made from mastoid to mastoid in the coronal plane and the scalp was reflected anteriorly up to orbit and posteriorly below the occipital protuberance. Periosteum was denuded and temporal muscles were dissected off. Skull cap was opened in circular manner little above the eye brow ridges and little above the inion.[9]

The dura mater was cut at the level of removal of skull cap. The dura mater over the vertex and the posterior falx was kept intact. The frontal lobes were lifted and falx cerebri was cut from its attachment on crista galli. The diencephalon was cut axially above the level of the optic chiasm, through the third ventricle to the apex of the tentorial notch. The cerebral hemispheres were removed, leaving intact a small portion of diencephalon, the posterior portion of the falx, and the tentorium cerebelli.

The optic nerves were cut rostral to the sella turcica. The optic chiasm was lifted and the mesencephalon cut at the level of the interpeduncular fossa in the axial plane, extending posteriorly. The vein of Galen was cut, the pineal gland removed, and the arachnoid dissected, allowing for a clear view of cerebellar anatomy within the tentorial notch. The field was irrigated to remove any blood and debris.

Statistical Analysis

Statistical analysis was performed using SPSS version 23.0. Quartile distribution, frequency distribution, and parametric correlation of data were analyzed.

Results

Sixty-five statistical data were obtained for all variables. Correlation coefficient(r) greater than 0.4 and less than −0.4 were worthy of mention. Correlation was considered significant when the *p*-value less than 0.05 and if it was less than 0.01, it was considered more significant.

In 65 autopsies of head injury patients, majority of the patients (23; 35.4%) were aged between 21 and 30 years. The mean age of subjects was 40.63 ± 16.78 years. There was a male predominance with 86.2% males and only 13.8% females. The most frequent mechanism of head injury was road traffic accident 51 (78.5%) followed by 9 (13.8%) due to fall from height and 4 (6.2%) due to assault (►**Table 1**).

Table 1 Baseline characteristics of study participants

Variables		Frequency	Percent
Age	Upto 10 years	1	1.5
	11–20 years	3	4.6
	21–30 years	23	35.4
	31–40 years	9	13.8
	41–50 years	13	20.0
	51–60 years	7	10.8
	61–70 years	6	9.2
	Above 70 years	3	4.6
Gender	Male	56	86.2
	Female	9	13.8
Mechanism of Injury	RTA	51	78.5
	FFH	9	13.8
	Assault	4	6.2
	Fall of tree on head	1	1.5
Mean age (years)		40.63 ± 16.78	

Abbreviations: FFH, fall from height; RTA, road traffic accident.

In autopsy and on NCCT head both, age positively correlates with the AT, while ANW positively correlates with the MNW and NL positively correlates with the AT. NL positively correlates with IC in autopsy only (►**Tables 2** and **3**).

On comparing the mean values of tentorial notch parameters on autopsy and on NCCT head, there was no statistically significant difference (*p*-value > 0.05) (►**Table 4**). Uncal herniation was seen in 29 (44.6%) patients on autopsy and 18 (27.7%) patients on NCCT head. There was no significant difference (*p*-value = 0.097) of uncal herniation distribution in autopsy and on NCCT head in same patients (►**Table 5**).

There was no statistically significant difference of tentorial notch parameters on autopsy and NCCT head with presence and absence of uncal herniation (*p*-value > 0.05; ►**Table 6**).

Tentorial notch was categorized from matrix into nine types by applying quartile distribution to NL and MNW and data were interposed into matrix. The most common type of tentorial notch encountered in overall autopsy and uncal herniation group was classical (typical) type (32.30 and 34.5%, respectively). The relative frequency of uncal herniation was maximum (75%) in large type and minimum (20%) in small type of tentorial notch (►**Table 7**).

The impact of uncal herniation in form of indentation on lateral surface of midbrain was observed in 20 (68.97%) cases, while cases without uncal herniation had no indentation. This distribution was statistically significant (*p*-value < 0.001). However, no significant correlation (*p*-value > 0.05) was observed between uncal herniation and macroscopic brainstem hemorrhage (►**Table 8**).

Discussion

Morphometric variations in tentorial notch anatomy had explained the wide spectrum clinical presentation of transtentorial herniation to some extent.[6] Transtentorial herniation rapidly escalates to severe disability or death if there is delay in its detection.[4,10]

Table 2 Correlations between age and tentorial notch parameters in autopsy

		Age (y)	ANW (mm)	MNW (mm)	NL (mm)	PTL (mm)	AT (mm)	IC (mm)
Age (y) Pearson correlation		1	−0.023	0.056	0.173	0.177	0.340[a]	0.027
Sig. (2-tailed)			0.857	0.659	0.168	0.157	0.006	0.832
N		65	65	65	65	65	65	65
ANW (mm)	Pearson correlation	−0.023	1	0.469[a]	−0.089	0.125	−0.133	0.006
	Sig. (2-tailed)	0.857		0.000	0.483	0.322	0.290	0.965
	N	65	65	65	65	65	65	65
MNW (mm)	Pearson correlation	0.056	0.469[a]	1	0.292[b]	0.308[b]	0.235	0.286[b]
	Sig. (2-tailed)	0.659	0.000		0.018	0.012	0.059	0.021
	N	65	65	65	65	65	65	65
NL (mm)	Pearson correlation	0.173	−0.089	0.292[b]	1	0.185	0.784[a]	0.332[a]
	Sig. (2-tailed)	0.168	0.483	0.018		0.141	0.000	0.007
	N	65	65	65	65	65	65	65

Table 2 (*Continued*)

		Age (y)	ANW (mm)	MNW (mm)	NL (mm)	PTL (mm)	AT (mm)	IC (mm)
PTL (mm)	Pearson correlation	0.177	0.125	00.308[b]	0.185	1	0.066	0.033
	Sig. (2-tailed)	0.157	0.322	0.012	0.141		0.604	0.792
	N	65	65	65	65	65	65	65
AT (mm)	Pearson correlation	0.340[a]	−0.133	0.235	0.784[a]	0.066	1	0.057
	Sig. (2-tailed)	0.006	0.290	0.059	0.000	0.604		0.653
	N	65	65	65	65	65	65	65
IC (mm)	Pearson correlation	0.027	0.006	0.286[b]	0.332[a]	0.033	0.057	1
	Sig. (2-tailed)	0.832	0.965	0.021	0.007	0.792	0.653	
	N	65	65	65	65	65	65	65

Abbreviations: ANW, anterior notch width; AT, apicotectal distance; IC, interpedunculoclival; MNW, maximum notch width; NL, notch length; PTL, posterior tentorial length.
[a]Correlation is significant at the 0.01 level (2-tailed).
[b]Correlation is significant at the 0.05 level (2-tailed).

Table 3 Correlations between age and tentorial notch parameters in NCCT head

		Age (y)	ANW (mm)	MNW (mm)	NL (mm)	PTL (mm)	AT (mm)	IC (mm)
Age (y) Pearson correlation		1	−0.032	0.052	0.188	0.161	0.281[a]	−0.025
Sig. (2-tailed)			0.800	0.681	0.133	0.201	0.023	0.846
NN		65	65	65	65	65	65	65
ANW (mm)	Pearson correlation	−0.032	1	0.442[b]	−0.065	0.131	−0.178	0.013
	Sig. (2-tailed)	0.800		0.000	0.606	0.297	0.155	0.920
	N	65	65	65	65	65	65	65
MNW (mm)	Pearson correlation	0.052	0.442[b]	1	0.317[a]	0.292[a]	0.237	0.292[a]
	Sig. (2-tailed)	0.681	0.000		0.010	0.018	0.057	0.018
	N	65	65	65	65	65	65	65
NL (mm)	Pearson correlation	0.188	− 0.065	0.317[a]	1	0.202	0.759[b]	0.293[a]
	Sig. (2-tailed)	0.133	0.606	0.010		0.107	0.000	0.018
	N	65	65	65	65	65	65	65
PTL (mm)	Pearson correlation	0.161	0.131	0.292[a]	0.202	1	0.006	0.015
	Sig. (2-tailed)	0.201	0.297	0.018	0.107		0.964	0.908
	N	65	65	65	65	65	65	65
AT (mm)	Pearson correlation	0.281[a]	−0.178	0.237	0.759[b]	0.006	1	0.056
	Sig. (2-tailed)	0.023	0.155	0.057	0.000	0.964		0.656
	N	65	65	65	65	65	65	65
IC (mm)	Pearson correlation	−0.025	0.013	0.292[a]	0.293[a]	0.015	0.056	1
	Sig. (2-tailed)	0.846	0.920	0.018	0.018	0.908	0.656	
	N	65	65	65	65	65	65	65

Abbreviations: ANW, anterior notch width; AT, apicotectal distance; IC, interpedunculoclival; MNW, maximum notch width; NCCT, noncontrast computed tomography; NL, notch length; PTL, posterior tentorial length.
[a]Correlation is significant at the 0.05 level (2-tailed).
[b]Correlation is significant at the 0.01 level (2-tailed).

Variations in Tentorial Notch Parameters

Studies in the literature mostly analyzed tentorial notch in cadavers and very few studies have been done on fresh autopsy specimens.[2,6,7,9] Large number of fresh autopsy specimens of head injury patients were included in our study for first time.[3]

Unexpected variations in the size and form of the tentorial notch were documented by Corsellis in 1958.[11] Sunderland

Table 4 Correlation of tentorial notch parameters between autopsy and NCCT head

Tentorial notch parameters	Autopsy examination (mean ± SD)	NCCT head (mean ± SD)	*p*-Value
ANW (mm)	17.26 ± 4.03	17.07 ± 4.02	0.786
MNW (mm)	28.82 ± 3.53	28.43 ± 3.64	0.542
NL (mm)	51.52 ± 4.72	51.87 ± 4.79	0.679
PTL (mm)	53.54 ± 7.40	53.85 ± 7.64	0.811
AT (mm)	17.60 ± 4.25	17.92 ± 4.19	0.663
IC (mm)	15.74 ± 3.12	16.17 ± 3.30	0.446

Abbreviations: ANW, anterior notch width; AT, apicotectal distance; IC, interpedunculoclival; MNW, maximum notch width; NCCT, noncontrast computed tomography; NL, notch length; PTL, posterior tentorial length; SD, standard deviation.

Table 5 Distribution of uncal herniation in autopsy and NCCT head

Uncal herniation	Autopsy examination, *n* (%)	NCCT, *n* (%)
Yes	29 (44.6%)	18 (27.7%)
No	36 (55.4%)	47 (72.3%)

Abbreviation: NCCT, noncontrast computed tomography.
*p-Value = 0.097.

elaborated the relationship between this free space and the brainstem, nerves, and arteries in the same year.[5]

Controversial tentorial notch parameter estimations had been discovered in research even from the studies of the same nation. Results of our study were comparable to studies from southern India[6,7] but quite less than other studies from the same country.[2,3] Variable interval between death and autopsy might be the cause of difference, but it could not be compared statistically due to unavailability of complete data.

Tentorial Notch Type and Transtentorial Herniation

The most typical type of brain herniations is called a tentorial herniation. Brain edema, tumors, and hemorrhages are just a few clinical condition that can cause the transtentorial herniation syndrome.[12,13] Uncal herniation via tentorial incisura as a result of remote effect of supratentorial enlarging lesion was originally identified as a pathological entity by Meyer.[4] In rare cases of transtentorial herniation, Kernohan and Woltman documented grooving of the cerebral peduncle on the side opposite the tumor due to indentation of the midbrain against free tentorial edge.[14]

According to cutting-edge studies by Corsellis and Sunderland, the size and form of the notch through which the brain herniated must in some way affect the pattern of transtentorial herniation.[5,11]

The first tentorial notch categorization system was developed by Adler and Milhorat, who also put out a theory to explain why different people experience transtentorial herniations differently.[9] It has been demonstrated that compared to tiny notches, big notches

Table 6 Correlation of tentorial notch parameters with uncal herniation

Tentorial notch parameters		Uncal herniation		*p*-Value
		Yes	No	
		Mean ± SD	Mean ± SD	
Autopsy examination	ANW (mm)	17.34 ± 4.49	17.15 ± 3.73	0.850
	MNW (mm)	28.87 ± 3.45	28.74 ± 3.63	0.887
	NL (mm)	51.56 ± 4.53	51.50 ± 4.91	0.963
	PTL (mm)	53.85 ± 6.59	53.32 ± 8.00	0.776
	AT (mm)	17.85 ± 4.21	17.42 ± 4.33	0.691
	IC (mm)	16.37 ± 2.78	15.29 ± 3.30	0.170
NCCT head	ANW (mm)	17.33 ± 4.37	16.39 ± 3.89	0.402
	MNW (mm)	28.80 ± 3.09	27.47 ± 3.80	0.191
	NL (mm)	52.38 ± 4.56	50.53 ± 4.82	0.164
	PTL (mm)	54.72 ± 7.23	53.52 ± 7.85	0.575
	AT (mm)	17.94 ± 4.61	17.91 ± 4.07	0.980
	IC (mm)	16.06 ± 3.46	16.21 ± 3.28	0.865

Abbreviations: ANW, anterior notch width; AT, apicotectal distance; IC, interpedunculoclival; MNW, maximum notch width; NCCT, noncontrast computed tomography; NL, notch length; PTL, posterior tentorial length; SD, standard deviation.

Table 7 Frequency of distribution of tentorial notch and relative frequency of uncal herniation in different type of tentorial notch

Type of tentorial notch	Frequency distribution of tentorial notch, *n* (%)	Frequency distribution of tentorial notch in uncal herniation, *n* (%)	Relative frequency of uncal herniation (%)
Long and wide (large)	4 (6.15)	3 (10.34)	75
Long and medium	10 (15.38)	5 (17.24)	50
Medium and wide	6 (9.23)	3 (10.34)	50
Short and wide	2 (3.07)	1 (3.44)	50
Classical (typical)	21 (32.30)	10 (34.4)	47.6
Short and medium	8 (12.30)	3 (10.34)	37.5
Medium and narrow	6 (9.23)	2 (6.89)	33.3
Long and narrow	3 (4.61)	1 (3.44)	33.3
Short and narrow (small)	5 (7.69)	1 (3.44)	20

Table 8 Impact of uncal herniation on brainstem

Impact on brainstem		Uncal herniation		*p*-Value
		Yes	No	
Lateral surface of midbrain	Indentation	20 (68.97%)	0 (0%)	< 0.001
	No	9 (31.03%)	36 (100.0%)	
Macroscopic brainstem hemorrhage	Present	7 (24.1%)	3 (8.33%)	0.198
	Absent	22 (75.9%)	33 (91.67%)	

include higher volumes of cerebellum tissue exposed through posterior incisural space that corresponds to apicotectal distance.[5,9,12] This study also concluded that the morphometry of the tentorial notch affects the herniation.

In this study, it was also observed that the uncal herniation was most frequent in long and wide notches. Wide notches allow for the herniation of uncal tissue and the hippocampal gyrus through the aperture of same side during supratentorial expanding lesions, which may directly press on the oculomotor nerve and cause pupillary dilation. This is made possible by the space between the cerebral peduncles and the tentorial edges.[15]

Variations in the IC distance may influence the risk of brainstem damage during acceleration–deceleration episodes. The clinical sequelae that are developed following concussive and inertial brain injuries that result in herniation, according to Adler and Milhorat and the current study, may be influenced by anatomical changes in tentorial aperture.[9]

This study has some limitations too which are follows: This study was conducted during medico-egal autopsies, which may have unavoidably altered the tentorium morphology; (2) large-scale study will be needed for more stronger external validity; (3) age-wise distribution of patients was unequal; (4) contrast-enhanced CT could be better than NCCT head for accurate measurement of tentorial notch; (5) effect of tentorial slope/angle for tentorial herniation was not considered; and (6) there was inherent tentorium distortion in dead brain.

However, this distortion may be avoided by using neuroimaging methods to measure tentorial notch morphometry in living people.

Conclusion

We could not find any statistically significant difference in tentorial notch parameters in autopsy and on NCCT head as well as in uncal herniation and nonuncal herniation group. There was no significant difference of evidence of uncal herniation in autopsy and on NCCT head also.

The most frequent type of tentorial notch was typical type (32.30% overall and 34.5% in uncal herniation group, respectively). Relative chance of uncal herniation was maximum (75%) in large type of tentorial notch and least (20%) in small type of tentorial notch. Indentation over lateral surface of midbrain was found to be significantly correlating with uncal herniation, while macroscopic brainstem hemorrhage was not found to be significantly correlating with uncal herniation.

The results of our study provide a baseline data about tentorial notch anatomy and it may facilitate neurosurgical decision making as well as help in deciding the best trajectory for lesions approaching in the vicinity of the tentorial notch. Further study will be needed to redefine threshold of surgical intervention for traumatic brain injury that may lead to less than 5 mm of midline shift in large type of tentorial notch.[3]

The relationship of tentorial notch type with other transtentorial herniations and type of head injury should also be investigated in future study as relatively large number of subjects are required.

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Conflict of Interest
None declared.

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