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Volumetric Assessment of the Medulla Oblongata According to Sex Using 1.5T Magnetic Resonances Imaging

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ABSTRACT
Background: The medulla oblongata, a critical brainstem structure, governs essential autonomic functions such as respiration, heart rate, and blood pressure. Understanding its anatomical and volumetric characteristics is vital for diagnosing neurological and neurodegenerative disorders, forensic investigations, and neurosurgical planning. Despite advancements in neuroimaging, normative data—especially population-specific information related to age and gender—remain limited, particularly in the western region of Gujarat. This study aims to establish normative volumetric data for the medulla oblongata using 1.5 Tesla MRI in the Western Gujarat population.
Method: This retrospective observational study was conducted on 50 subjects (26 males and 24 females) aged 20 to 66 years who underwent MRI brain scans at a tertiary care hospital from March 2023 to February 2024. Only scans with normal brain findings were included. MRI images were analyzed using Radiant DICOM Viewer 2023, and volumetric parameters such as length (MOL), width (MOW), height (MOH), and volume (MOV) of the medulla oblongata were measured.
Results: The study found significant differences in MOH and MOV between males and females ($p < 0.001$). Males had a higher average MOV (2274 mm³) than females (1752 mm³). Age-wise comparisons showed significant differences in MOL and MOW across age groups ($p <0.024$ and $p < 0.020$, respectively). Post-hoc analysis revealed that MOL significantly differed between the 20–29 and 30–39 age groups ($p < 0.035$), and MOW differed between the 50–59 and 60–69 groups ($p < 0.036$). Within-gender analysis found that MOV significantly varied among males across age groups ($p < 0.022$), while MOW varied among females ($p < 0.048$). Strong positive correlations were observed between MOV and individual medullary dimensions ($p < 0.001$).
Conclusion: This study establishes foundational normative data on the volumetric parameters of the medulla oblongata for the Western Gujarat population. Significant gender and age-related differences were observed, emphasizing the importance of demographic specificity in clinical assessments. These findings have potential applications in forensic science for gender identification, neurosurgical planning, and early detection of neurodegenerative diseases.

Keywords: *MOV: Medulla Oblongata Volume, MOL: Medulla Oblongata Length, MOH: Medulla Oblongata Height, MOW: Medulla Oblongata Width, MRI: Magnetic Resonance Imaging, MP-RAGE: Magnetization Prepared Rapid Gradient Echo*

1. Introduction

The medulla oblongata, a crucial component of the brainstem, plays a vital role in regulating autonomic functions such as respiration, heart rate, and blood pressure. Its anatomical and volumetric assessment is essential not only for understanding normal physiological function but also for diagnosing and managing a wide range of neurological and neurodegenerative conditions[1]. Accurate volumetric evaluation of the medulla oblongata holds particular significance in clinical neurology, forensic science, and neurosurgical planning.
Magnetic Resonance Imaging (MRI) has emerged as a non-invasive and highly reliable imaging modality for studying brain structures in vivo. Despite advancements in neuroimaging, there is a scarcity of normative data regarding the volume of the medulla oblongata, especially when considering age- and gender-related variations[2].

Furthermore, regional studies focusing on specific populations, such as the western population of Gujarat, are

limited. Establishing baseline volumetric values specific to this demographic is crucial, given that anatomical variations may exist across different ethnic and geographic groups.
Although several studies have examined brain volume changes with age and gender, the medulla oblongata has received comparatively less attention. Current literature lacks comprehensive normative data on the volume of the medulla oblongata in the western Gujarat population, MRI a widely accessible and clinically relevant imaging tool[3-4]. Additionally, the potential applications of this data in forensic science, neurosurgery, and the early detection of neurodegenerative diseases have not been fully explored or documented in existing studies[5-6]. The study aims to determine the volume of the medulla oblongata in the Western population of Gujarat, based on age and gender, to assess its overall volume. This tool aids in gender identification in the forensic science department, establishes accurate normative data on medulla oblongata volume, provides a foundation for anatomical planning in surgeries, and aids in neurological and neurodegenerative disorder assessment.

2. Method & Material

The Present observational Retrospective study was performed on subjects randomly selected from the attendees coming for MRI scans of 50 subjects [24 males and 26 females] aged 20 to 66 years referred to the Department of Radiology, from March 2023 to February 2024.
The study included patients from both inpatient and outpatient departments who underwent MRI examination of the head, aged between 20 to 66 years, of both sexes (male and female), with only normal brain MRI findings considered Patients were excluded from the study if they had a history of trauma, were below 20 years of age, and had congenital abnormalities, cerebrovascular disease, dementia, or any contraindications for undergoing MRI.
MRI scans were performed using a GE Signa 1.5 tesla scanner. The patients came to the Department of Radiology for MRI scans of the brain, which enfold the region of the medulla oblongata. Through OSIRIX, the patient data was transferred to Radiant Dicom viewer software for measurements. RADIANT DICOM Viewer version 2023.

Statistical analysis:
The collected data were summarized by using the Independent sample "t" test was used to compare the medulla oblongata volume according to gender. One-way ANOVA was used to compare medulla oblongata volume equivalent to age groups. The Post hoc analysis, Tukey test was used for the multiple comparisons of MOL and MOW according to age groups. To find the relation between the various parameters of medulla oblongata volume, the Pearson correlation coefficient ("r") was used. The p-value < 0.05 was considered significant. Data were analysed by using the SPSS software (SPSS Inc.; Chicago, IL) version 29.0.10.

3. Results

A sum of 50 (24 male and 26 female) individuals were included in which five age groups in this cross-sectional Retrospective study who were referred to the Department of Radio diagnosis.

Table 1: Descriptive Statistics for age and medulla oblongata volume

(n = 50)	Range	Mean	S.D.
Age	20 to 66	37.82	12.75
MOL	1.04 to 1.64	1.28	0.15
MOW	1.44 to 2.05	1.76	0.15
MOH	0.73 to 2.19	1.78	0.24
MOV	726 to 29.29	2023	437

Table 2: Representation of age and gender distribution where 48% of males and 52 % were females.

(n = 50)		Frequency	%
Age groups	20-29	16	32
	30-39	15	30
	40-49	10	20

	50-59	4	8
	60-69	5	10
Gender	Male	26	52
	Female	24	48

Age groups 20-29 and 30-39 years have the highest and equal number of patients 9 in males (34.6%) whereas in females the number of patients is 7 (29.2%) out of 50. The age groups 50-59 and 60-69 years have the lowest and equal number of patients 2 in males (7.7%), whereas in females the lowest number of patients 2 in the age group 50- 59(8.3%) out of 50.

Table 3: Represents Comparison of medulla oblongata volume according to gender

		Mean	S.D.	"t"	p-value
MOL (Cm)	Male	1.32	0.14	1.64	0.107
	Female	1.25	0.15		
MOW (Cm)	Male	1.82	0.13	3.30	0.002
	Female	1.70	0.14		
MOH (Cm)	Male	1.89	0.14	4.27	< 0.001*
	Female	1.65	0.25		
MOV (MM^3)	Male	2274	338	5.22	< 0.001*
	Female	1752	368		

("t" = Independent sample "t" test; * Significant)

The Independent sample "t" test was used to compare the medulla oblongata volume according to gender. There was a difference ($p < 0.05$) in MOH as well as MOV between males and females. [Table – 3]

The results show that the parameter (MOH) medulla oblongata height is considered a significant change ($p< 0.05$). One more parameter (MOV) medulla oblongata volumes is considered a significant change ($p<0.05$)

Fig 1 Demonstrate a Comparison between MOL, MOW, & MOH shows that there is a difference between the parameters which is compared to medulla oblongata (length, width, height) among gender.

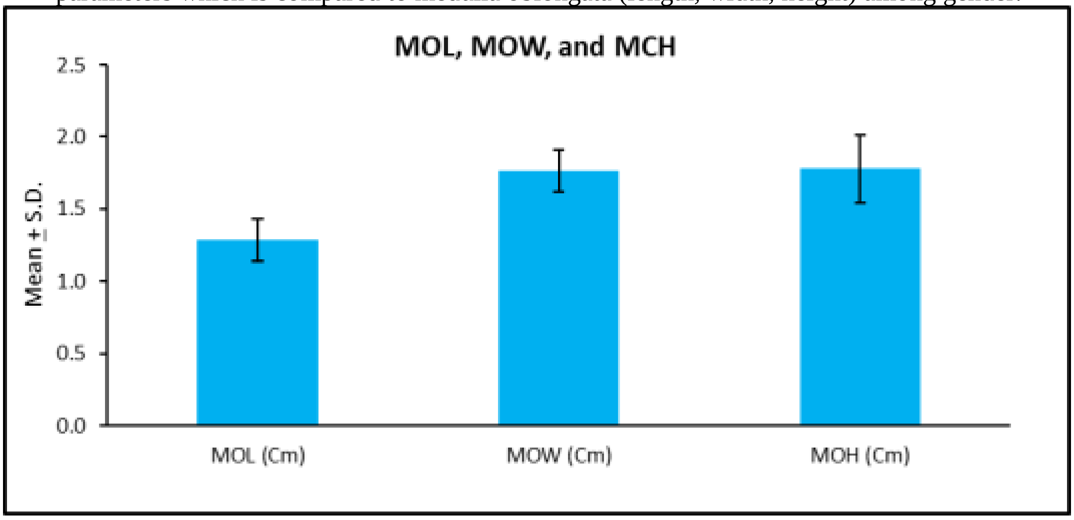

Fig 2 Represents MOL, MOW, and MOH according to gender

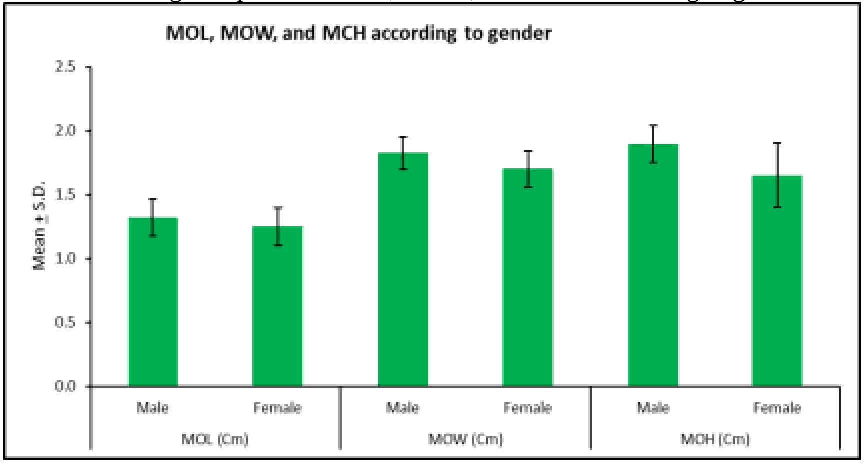

Table 4: Represents Comparison of medulla oblongata volume according to age groups

		Mean	S.D.	"F"	p value
MOL (Cm)	20-29	1.21	0.11	3.12	0.024*
	30-39	1.36	0.16		
	40-49	1.31	0.17		
	50-59	1.35	0.11		
	60-69	1.19	0.05		
MOW (Cm)	20-29	1.72	0.15	3.24	0.020*
	30-39	1.82	0.10		
	40-49	1.77	0.14		
	50-59	1.89	0.11		
	60-69	1.62	0.16		
MOH (Cm)	20-29	1.78	0.18	0.59	0.669
	30-39	1.81	0.21		
	40-49	1.68	0.37		
	50-59	1.80	0.22		
	60-69	1.86	0.11		
MOV (MM^3)	20-29	1859	330	2.44	0.060
	30-39	2239	439		
	40-49	1973	571		
	50-59	2280	277		
	60-69	1799	218		

(“F” = One way ANOVA; * Significant)

One-way ANOVA was used to compare medulla oblongata volume according to age groups. There was a difference ($p < 0.05$) in MOL as well as MOW according to age groups. [Table- 4]

Fig 3: Represents the MOV according to gender shows there is a difference in males and females when comparing the parameter (MOV) which is medulla oblongata volume in mm^3

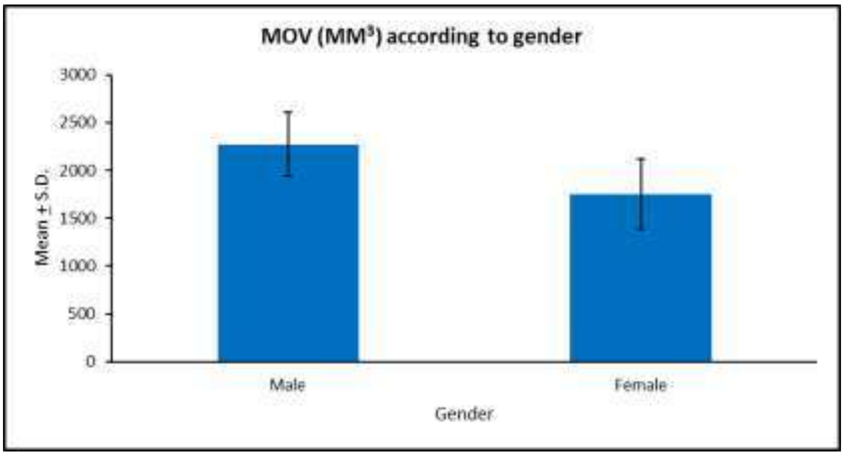

Fig 4: Represents MOL, MOW, and MOH according to age groups shows the comparison of parameters MOL, MOW, and MOH according to age group in which shows that, there are significant variations between the parameters.

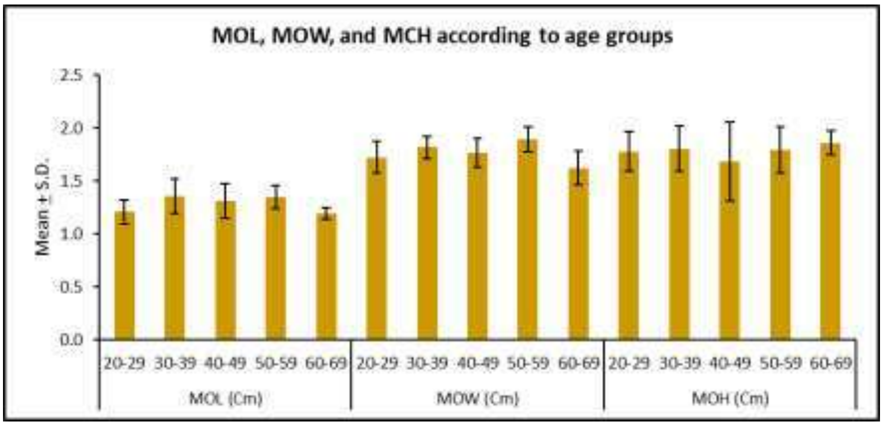

Fig 5: Representing MOV (MM^3) according to age group shows that the parameter (MOV) medulla oblongata volume is highest in age groups 50-59 and 30-39 and lowest in age groups 60-69 among males and females.

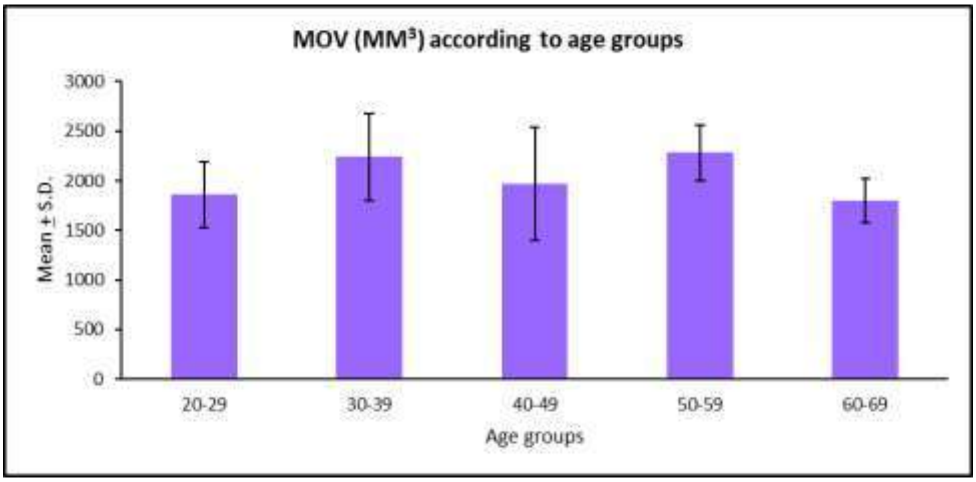

Table 5: Represents Comparison of medulla oblongata volume between males and females within the age group

	Age groups	Male		Female		"t"	p value
		Mean	S.D.	Mean	S.D.		
MOL (Cm)	20-29	1.26	0.12	1.14	0.07	2.33	0.035*
	30-39	1.40	0.16	1.29	0.16	1.26	0.229
	40-49	1.32	0.15	1.31	0.19	0.07	0.949
	50-59	1.32	0.11	1.38	0.14	-0.52	0.655
	60-69	1.20	0.09	1.19	0.03	0.09	0.933
MOW (Cm)	20-29	1.78	0.14	1.66	0.15	1.65	0.121
	30-39	1.86	0.10	1.76	0.09	1.86	0.086
	40-49	1.85	0.11	1.71	0.13	1.76	0.116
	50-59	1.92	0.19	1.87	0.03	0.33	0.773
	60-69	1.75	0.18	1.54	0.09	1.77	0.175
MOH (Cm)	20-29	1.83	0.18	1.71	0.18	1.34	0.203
	30-39	1.92	0.12	1.63	0.20	3.63	0.003*
	40-49	1.94	0.10	1.51	0.39	2.09	0.070
	50-59	1.94	0.23	1.65	0.07	1.73	0.226
	60-69	1.91	0.11	1.83	0.12	0.69	0.539
MOV (MM^3)	20-29	2040	251	1627	276	3.13	0.007*
	30-39	2490	269	1863	374	3.79	0.002*
	40-49	2374	380	1705	533	2.15	0.064
	50-59	2436	330	2125	159	1.20	0.354
	60-69	1990	251	1673	59	2.28	0.107

("t" = Independent sample "t" test; * Significant)

The Independent sample "t" test was used to differentiate the medulla oblongata volume according to gender within the age groups. There was a difference ($p < 0.05$) in MOL and MOV between males and females among the age groups: 20-29 years. The MOH and MOV between males and females were found to be different among the age groups: 30-39 years. [Table – 5]

Table 6: Represents multiple comparisons of MOL and MOW according to age group

Multiple comparisons			Mean Difference	p value
MOL (Cm)	20-29	30-39	-0.148	0.035*
		40-49	-0.104	0.344
		50-59	-0.139	0.385
		60-69	0.017	0.999
	30-39	40-49	0.044	0.936
		50-59	0.009	1.000
		60-69	0.165	0.159
	40-49	50-59	-0.035	0.993
		60-69	0.121	0.503
	50-59	60-69	0.156	0.454
MOW (Cm)	20-29	30-39	-0.095	0.301
		40-49	-0.044	0.927

		50-59	-0.169	0.180
		60-69	0.099	0.608
	30-39	40-49	0.051	0.885
		50-59	-0.075	0.861
		60-69	0.194	0.056
	40-49	50-59	-0.126	0.520
		60-69	0.143	0.312
	50-59	60-69	0.269	0.036*

(* Significant)

The Post hoc analysis, Tukey test was used for the multiple comparisons of MOL and MOW according to age groups. There was a difference ($p < 0.05$) in MOL between the age groups: 20-29 and 30-39 years. Also, a difference ($p < 0.05$) in the MOW was found between the age groups: 50-59 and 60-69 years [Table – 6]

Fig 5: Representing MOL, MOW, and MOH according to age and gender

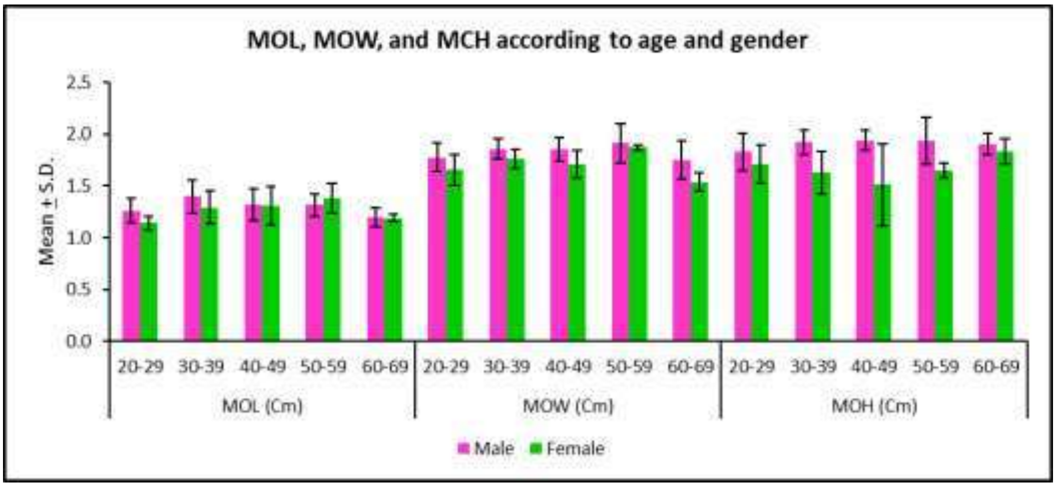

Table 7: Represents Comparison of medulla oblongata volume according to age group within gender

	Age groups	Male				Female			
		Mean	S.D.	"F"	p value	Mean	S.D.	"F"	p value
MOL (Cm)	20-29	1.26	0.12	1.56	0.223	1.14	0.07	2.13	0.117
	30-39	1.40	0.16			1.29	0.16		
	40-49	1.32	0.15			1.31	0.19		
	50-59	1.32	0.11			1.38	0.14		
	60-69	1.20	0.09			1.19	0.03		
MOW (Cm)	20-29	1.78	0.14	0.93	0.468	1.66	0.15	2.93	0.048*
	30-39	1.86	0.10			1.76	0.09		
	40-49	1.85	0.11			1.71	0.13		
	50-59	1.92	0.19			1.87	0.03		
	60-69	1.75	0.18			1.54	0.09		
MOH (Cm)	20-29	1.83	0.18	0.65	0.630	1.71	0.18	0.94	0.463
	30-39	1.92	0.12			1.63	0.20		
	40-49	1.94	0.10			1.51	0.39		

	50-59	1.94	0.23			1.65	0.07		
	60-69	1.91	0.11			1.83	0.12		
MOV (MM^3)	20-29	2040	251	3.62	0.022*	1627	276	0.90	0.484
	30-39	2490	269			1863	374		
	40-49	2374	380			1705	533		
	50-59	2436	330			2125	159		
	60-69	1990	251			1673	59		

("F" = One way ANOVA; * Significant)

The One-way ANOVA was used to compare medulla oblongata volume according to age group within gender. There was a difference ($p < 0.05$) in MOV, according to age groups among males. The MOW was found to be different ($p < 0.05$) of the age groups among females. [Table –7].

Fig 6: Representing MOV (MM^3) according to age and gender

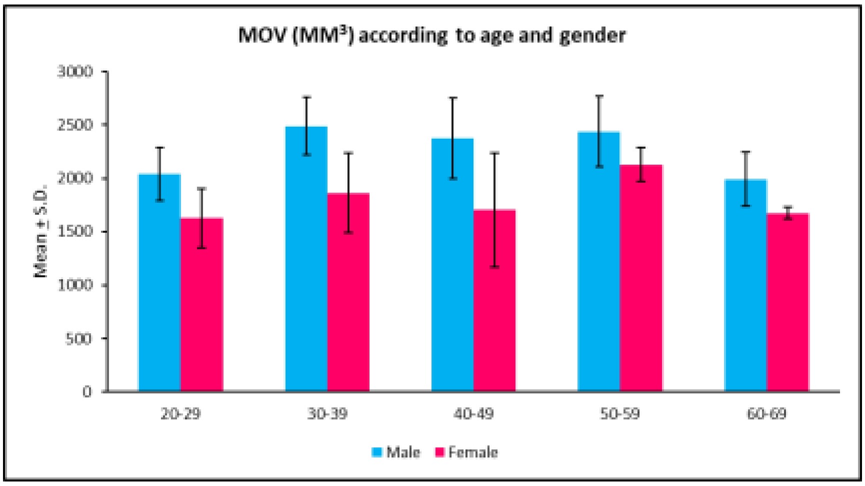

Table 9: Representing Relation between the various parameters of medulla oblongata volume

		MOL (Cm)	MOW (Cm)	MOH (Cm)	MOV (MM^3)
MOL (Cm)	"r"	1	0.412	-0.037	0.654
	p value	--	0.003*	0.800	< 0.001*
MOW (Cm)	"r"		1	0.258	0.753
	p value		--	0.070	< 0.001*
MOH (Cm)	"r"			1	0.640
	p value			--	< 0.001*
MOV (MM^3)	"r"				1
	p value				--

("r" = Pearson correlation coefficient; * Significant)

The Pearson correlation coefficient ("r") was used to find the relation between the various parameters of medulla oblongata volume. The MOL was positively correlated ($p < 0.05$) with MOW and MOV. Also, the MOV was positively correlated ($p < 0.05$) with MOW as well as MOH. [Table –9].

Fig 7: Demonstration of Correlation between parameters

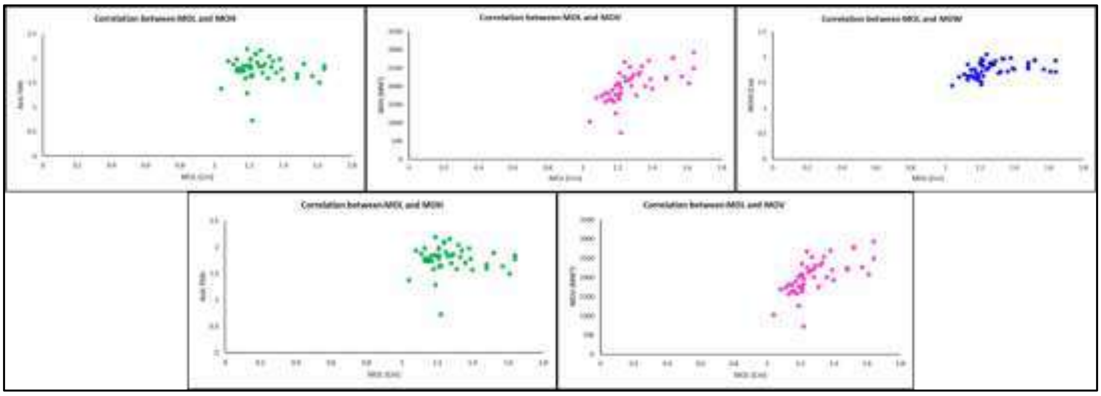

Table 10: Representing the Relation between the various parameters of medulla oblongata volume according to gender

			MOL (Cm)	MOW (Cm)	MOH (Cm)	MOV (MM^3)
Male	MOL (Cm)	"r"	1	0.299	-0.315	0.705
		p value	--	0.138	0.117	< 0.001*
	MOW (Cm)	"r"		1	0.051	0.729
		p value		--	0.805	< 0.001*
	MOH (Cm)	"r"			1	0.284
		p value			--	0.160
	MOV (MM^3)	"r"				1
		p value				--
Female	MOL (Cm)	"r"	1	0.412	-0.126	0.623
		p value	--	0.046*	0.558	0.001*
	MOW (Cm)	"r"		1	0.040	0.644
		p value		--	0.854	0.001*
	MOH (Cm)	"r"			1	0.608
		p value			--	0.002*
	MOV (MM^3)	"r"				1
		p value				--

("r" = Pearson correlation coefficient; * Significant)

Table 11: Relation between the various parameters of medulla oblongata volume according to age group.

			MOL (Cm)	MOW (Cm)	MOH (Cm)	MOV (MM^3)
20-29	MOL (Cm)	"r"	1	0.482	-0.077	0.677
		p value	--	0.059	0.776	0.004*
	MOW (Cm)	"r"		1	0.140	0.802
		p value		--	0.605	< 0.001*
	MOH (Cm)	"r"			1	0.533
		p value			--	0.034*
	MOV (MM^3)	"r"				1
		p value				--
30-39	MOL (Cm)	"r"	1	0.177	0.074	0.671
		p value	--	0.528	0.794	0.006*
	MOW (Cm)	"r"		1	0.590	0.719
		p value		--	0.021*	0.003*
	MOH (Cm)	"r"			1	0.740
		p value			--	0.002*
	MOV (MM^3)	"r"				1
		p value				--
40-49	MOL (Cm)	"r"	1	0.365	0.023	0.541
		p value	--	0.299	0.949	0.106
		"r"		1	0.409	0.737

	MOW (Cm)	p value		--	0.241	0.015*
	MOH (Cm)	"r"			1	0.807
		p value			--	0.005*
	MOV (MM^3)	"r"				1
		p value				--
50-59	MOL (Cm)	"r"	1	-0.514	-0.749	-0.362
		p value	--	0.486	0.251	0.638
	MOW (Cm)	"r"		1	0.731	0.856
		p value		--	0.269	0.144
	MOH (Cm)	"r"			1	0.853
		p value			--	0.147
	MOV (MM^3)	"r"				1
		p value				--
60-69	MOL (Cm)	"r"	1	0.362	-0.143	0.603
		p value	--	0.549	0.819	0.282
	MOW (Cm)	"r"		1	-0.294	0.833
		p value		--	0.631	0.080
	MOH (Cm)	"r"			1	0.171
		p value			--	0.784
	MOV (MM^3)	"r"				1
		p value				--

(“r” = Pearson correlation coefficient; * Significant)

4. Discussion

The brainstem, which connects the spinal cord to the cerebrum, serves as a central control hub of the brain. Studying the effects of aging on the brainstem is essential not only for understanding normal aging processes but also for comparing the pathophysiology of degenerative neurological disorders and assessing the impact of gender differences on brainstem size. While several studies have reported minimal age-related changes in brainstem dimensions, others have shown a significant reduction in brainstem size with advancing age. Research highlights distinct patterns of brainstem development across different age groups. This study contributes by comparing the volume of the medulla oblongata between males and females.

This study highlights significant findings regarding the volume of the medulla oblongata (MO), which ranged from 726 ± 2929 mm³, with notable gender differences. The mean MO volume was significantly higher in males (2274 ± 1752 mm³) compared to females ($P < 0.001$). Gender distribution is illustrated in the pie chart, showing 48% males and 52% females. Significant differences in MO volume measurements were observed across different age groups. Specifically, MOL and MOW showed statistically significant differences in the 40–49 age group ($P < 0.05$). In the 20–29 age group, gender-based differences were found in MOL and MOV, while in the 30–39 age group, significant differences in MOH and MOV were noted between males and females. Additionally, MOW differed significantly between the 50–59 and 60–69 age groups ($P < 0.05$). Among males aged 30–39, a significant difference ($P < 0.05$) in MO volume was also observed across age groups. The study identified inverse, positive, and moderately significant correlations between age, gender, and various MO volume parameters. MOL showed a positive correlation with both MOW and MOV ($P < 0.05$), and MOV was also positively correlated with MOW and MOH ($P < 0.05$).

Previous studies have demonstrated significant correlations related to gender; however, the combined manual assessment of all three parameters in a single study had not been undertaken. Individually, each parameter has shown notable correlations with both age and gender. In a study conducted by Abdalrahim Y. Mohamed et al. in 2023, a significant gender-based difference in medulla oblongata (MO) volume was identified, with males having a greater volume than females. This research involved 36 young adult participants (18 males and 18 females), and MO measurements were obtained from MRI images using ImageJ software. The study found no clear association between MO volume and body mass index (BMI). Additionally, a gradual decrease in MO size was observed among individuals aged 20 to 40, even in those with otherwise normal brain anatomy. MRIs.[13]
In 2009, Naam Joon Lee et al. conducted a study using 3D MRI volumetric to compare the sizes of various brain regions in 115 patients, analysing the data based on age and gender. The study found no significant difference in the volume of the medulla oblongata (MO) between older and younger age groups, suggesting that synaptic loss

does not occur in this region during the studied age range[11]. In a 2019 study by Singh S et al., it was found that gender differences did not significantly correlate with the sagittal diameter of the medulla oblongata (MO). The study included data from 103 patients who underwent brain MRI. The sagittal diameter of the brainstem increased until around age 20, after which growth plateaued. A slight reduction in the size of the medulla oblongata was observed after age 50, with a more pronounced shrinkage occurring beyond age 70[12]

5. Conclusion

Although the approach of this study differed from previous research, the findings remained consistent. The study revealed a significant gender difference in medulla oblongata (MO) volume, with males exhibiting a higher MO volume than females. Among males, variations in MO volume were observed in the 40–49 age group. Additionally, differences in medulla oblongata length (MOL) and width (MOW) were noted within the same age group. In the 20–29 age group, significant gender differences were found in both MOL and MO volume (MOV). Similarly, in the 30–39 age group, both MO height (MOH) and MOV differed between males and females. Furthermore, MOV showed a positive correlation with both MOW and MOH.

Limitation

Due to the limited sample size, a larger study is recommended for further evaluation, and repeating the study using a 3 Tesla MRI—with its higher sensitivity—may improve the visibility of the medulla oblongata, making the results more reliable, given the potential inaccuracies at this anatomical location.

Scope for the future study

The evaluation of the medulla oblongata plays a crucial role in gender identification for forensic science, provides accurate volumetric assessment, serves as a foundational reference for surgical approaches, and aids in the diagnosis of neurological and neurodegenerative diseases.

6. References

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