International Journal of Biomedicine 13(1) (2023) 101-105
http://dx.doi.org/10.21103/Article13(1)_OA13

INTERNATIONAL JOURNAL OF BIOMEDICINE

ORIGINAL ARTICLE

Radiology

Stereological Measurement of the Volume of Medulla Oblongata in Young Adults from Magnetic Resonance Images using ImageJ Software

Abdalrahim Y. Mohamed[1], Zuhal Y. Hamd[2*], Amal I. Alorainy[2], Awadia Gareeballah[3,10], Basim Abdullah Alhomida[4], Nagwan Elhussein[5], Haya Abdulrahman Alshegri[6], Sahar A. Mustafa[7], Sara S. Albadri[8], Wegdan Ahmed[9]

[1]*Anatomy Department, Faculty of Medicine, El Imam El Mahdi University, Sudan*
[2]*Department of Radiological Sciences, College of Health and Rehabilitation Sciences, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia*
[3]*Department of Diagnostic Radiology, College of Applied Medical Sciences, Taibah University, Medina, KSA*
[4]*College of Medicine Almaarefa University, Riyadh, Saudi Arabia*
[5]*Department of Diagnostic Radiology, College of Applied Medical Sciences, University of Ha'il, Ha'il, Saudi Arabia*
[6]*Medical Imaging Department, King Abdullah bin Abdul-Aziz University Hospital, Riyadh, Saudi Arabia*
[7]*Department of Radiological Sciences Alghad International Colleges for Applied Medical Sciences, Riyadh, Saudi Arabia*
[8]*Department of Radiological Sciences, Alghad International Colleges for Applied Medical Sciences, Alqassim, Saudi Arabia*
[9]*Anatomy Department, Faculty of Medicine, National University, Sudan*
[10]*Faculty of Radiological Sciences and Medical Imaging, Alzaiem Alazhari University, Khartoum Sudan*

Abstract

Background: The aim of this study was to measure the volume of the medulla oblongata (MO) in young adult Sudanese from magnetic resonance images using ImageJ software.

Methods and Results: The study included 36 (18 males and 18 females) young adult Sudanese with normal brain MRI. The MO volume was measured from a T1-weighted MRI in healthy young adult Sudanese using ImageJ software to determine the effect of age, sex, and body mass index (BMI) on the MO volume. The study found that the stereological volume of MO was 717.39±82.31 mm^3 with significant differences between genders. The mean MO volume was greater in males than in females (769.2±54.2 mm^3 and 665.7±73 mm^3, respectively. $P<0.001$). There was an inverse, positive, moderately significant correlation between the age and MO volume (r=-0.341, $P<0.05$). In contrast, there was no significant correlation between BMI and MO volume ($P>0.05$)

Conclusion: Our study detected a significant difference between genders in MO volume, which was greater in males than in females. There is no significant correlation between MO volume and BMI. The size of the MO in individuals with normal brain MRI decreased gradually, by increasing age, from 20 to 40 years.(**International Journal of Biomedicine. 2023;13(1):101-105.**)

Keywords: medulla oblongata • magnetic resonance imaging • ImageJ software

For citation: Mohamed AY, Hamd ZY, Alorainy AI, Gareeballah A, Alhomida BA, Elhussein N, Alshegri HA, Mustafa SA, Albadri SS, Ahmed W. Stereological Measurement of the Volume of Medulla Oblongata in Young Adults from Magnetic Resonance Images using ImageJ Software. International Journal of Biomedicine. 2023;13(1):101-105. doi:10.21103/Article13(1)_OA13

Abbreviations

BMI, body mass index; **MRI**, magnetic resonance imaging; **MO**, medulla oblongata.

Introduction

The medulla oblongata (MO) is the lower part of the brainstem, a cone-shaped neuronal mass. It lies anterior to the cerebellum; the midbrain lies at the upper part, where the pons sits in between. The MO joins the spinal cord inferiorly with the pons superiorly. The MO contains not only many cranial nerve nuclei[1] but also contains autonomic centers such as the cardiac, respiratory, and vasomotor centers, which regulate heart rate, breathing, and blood pressure, respectively.[2]

Generally, the size depends on several factors, such as age, gender, body size, and shape.[3] Growing older begins with fertilization and continues throughout the life of individuals, with increasing cell numbers and sizes, which is demonstrated by some permanent physiological and structural changes.[4] Numerous studies have been conducted to determine the volume of brain areas and their sex differences.[5-8] Some studies show no gender phenotypic variation in the volume of brain structures,[9,10] although, other studies have demonstrated that men have greater brain structure volumes than women.[11-13] This sexual dimorphism is explained by the fact that males have larger body sizes than females. There are few studies about the MO measurement. From available literature and published studies, there has yet to be any documentation of normal values of the MO. As a result, sex and time-of-life volumetric disparities in the MO have been interesting subjects for researchers. Thus, a thorough understanding of the asymmetrical construction of MO variations due to age and gender would be critical for an accurate diagnosis and neurosurgery procedure.

In our study, the MO volume was measured from a T1-weighted MRI in healthy young adult Sudanese using ImageJ software to determine the effect of age, sex, and BMI on the MO volume.

Materials and Methods

This cross-sectional descriptive study was conducted in the MRI department from February to October 2018. The study included 36 (18 males and 18 females) young adult Sudanese with normal brain MRI. The age of the participants ranged between 20 and 40 years. The participants were from different Sudanese tribes, and all of them were right-handed. The participants had no history of neurological or psychiatric diseases or congenital anomalies. Verbal consent from the department where the study was performed and from each participant included in the study sample was obtained after explaining the objectives of the study.

MRI protocol

The structured MRI was performed at the radiology department of Doctor's Hospital. Magnetic resonance procedure was carried out using 1.5 Tesla Philips scanners. T1-weighted images were acquired in 3D, utilizing Magnetization Prepared Rapid Acquisition (MP-RAGE), which results in excellent distinction between gray and white matter in the coronal slice. The acquisition time is 5 minutes and 18 seconds; the slice distance is 1.0 mm; the FOV is 250 reading, 192-millimeter phase, TR=1657 msec, TE=2.95 msec; the bandwidth is 180 Hz/pixel, the flip angle is 15°, the ECHO spacing is 7 msec, the phase resolution is 100%, and the slice resolution is 50%. ImageJ (version 1.8.0_112) software was used to analyze MR images. ImageJ is available and free to download from the NIH website (http://rsb.info.nih.gov/ij).

Protocol for measuring the MO using ImageJ software

The planimetry technique, which includes manually identifying the boundaries of the area of interest, was used to measure the cross-sectional area on ImageJ software.

The the images were processed according to the protocol prepared to analyze the MR images. Figure 1 shows step sequences for measurements of medulla oblongata volume using ImageJ software processing. The software automatically measures the medulla's sectional cut surface. The medulla volumes were calculated by multiplying the total sectional surface area by the section interval, as is shown in the formula: $V=\Sigma a \times t$, where V denotes the volume, t is the space between the studied sections, and Σa is the overall sectional area of the construction.

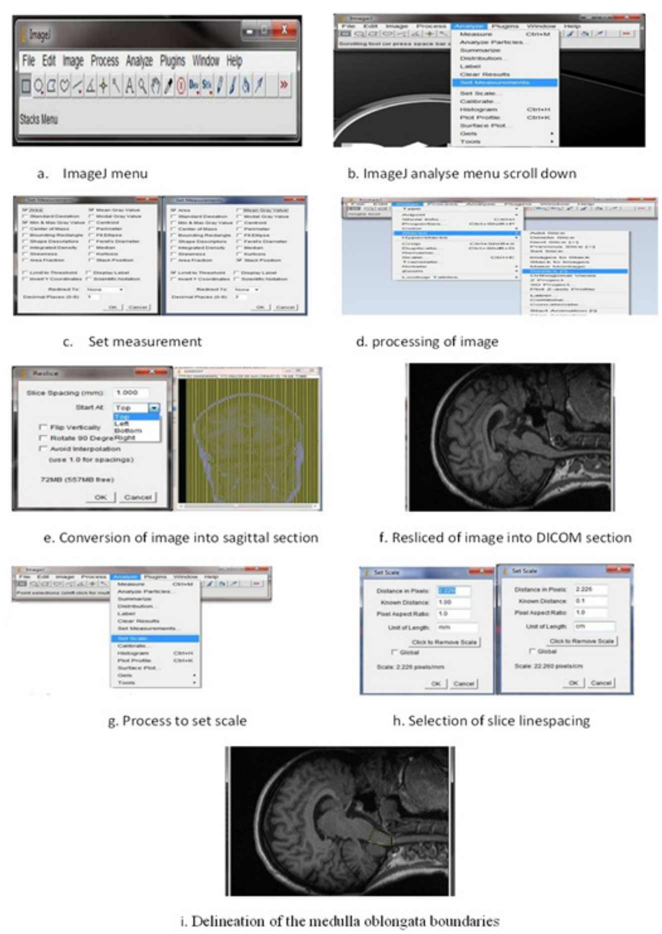

Fig. 1. *Step sequences for measurements of medulla oblongata volume using ImageJ software processing.*

Microsoft Excel was used to do the calculations and calculate the coefficient of error. The surface area data were transferred from ImageJ to an Excel spreadsheet. All the calculations were automated.

The study was approved by the Ethics Committee at Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia.

Statistical analysis was performed using statistical software package SPSS version 23.0 (Armonk, NY: IBM Corp.). Baseline characteristics were summarized as frequencies and percentages for categorical variables. Continuous variables with normal distribution were presented as mean (standard deviation [SD]). Means of 2 continuous normally distributed variables were compared by independent samples Student's t-test. Pearson's correlation coefficient (r) was used to determine the strength of the relationship between the two continuous variables. A probability value of $P<0.05$ was considered statistically significant.

Results

The study found that the stereological volume of MO was 717.39±82.31 mm^3 with significant differences between genders. The mean MO volume was greater in males than in females (769.2±54.2 and 665.7±73mm^3, respectively, $P<0.001$) (Figure 2). No significant differences in MO volume were found among the 2 age groups (20-30 years and 31-40 years) ($P>0.05$) (Table 1). There was an inverse, positive, moderately significant correlation between the age and MO volume (r=-0.341, $P<0.05$). In contrast, there was no significant correlation between BMI and MO volume ($P>0.05$) (Table 2). On linear regression analysis, a weak linear relationship was found between the age and MO volume (Figure 3).

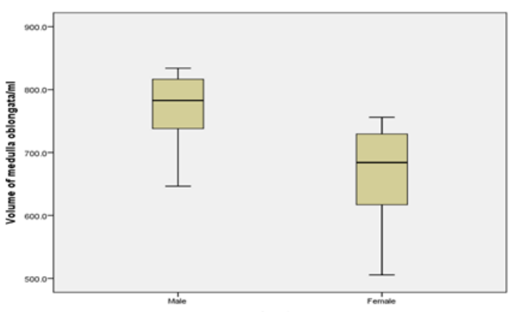

Fig. 2. *The mean MO volume in males and females.*

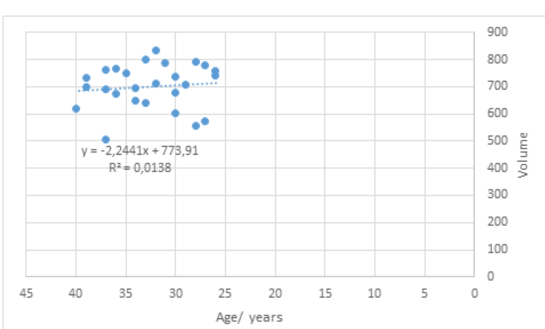

***Fig. 3**. Linear regression analysis: A weak linear relationship between the age and MO volume.*

Table. 1.

The mean MO volume in the age and gender groups.

Variable		n	The MO volume, mm^3	P-value
Gender	Male	18	769.16±54.17	<0.0001
	Female	18	665.61±73.06	
Age group	20-30 years	20	726.20±84.61	0.481
	31-40 years	16	706.38±80.67	
Total		36	717.39±82.31	

Table 2.

Correlation between the age, BMI, and the MO volume.

Correlation		Age	BMI	MO
Age	Pearson Correlation	1	-0.123	-0.341
	Sig. (2-tailed)		0.473	0.042
	N	36	36	36
BMI	Pearson Correlation	-0.123	1	-0.069
	Sig. (2-tailed)	0.473		0.688
	N	36	36	36

Discussion

The brainstem is the control center of the human brain and connects the spinal cord to the cerebrum. Studying the effects of aging on the brainstem is important not only for understanding normal aging but also for comparing the pathophysiology of degenerative brain diseases and significant differences in brainstem size between males and females. Several studies have concluded that age-related changes in brainstem diameter are insignificant, while other studies have demonstrated a significant decrease in brainstem size with age. Studies describe specific brainstem growth patterns in different age groups.[14-17]

ImageJ is a software program that provides a variety of image processing procedures for two-dimensional (2D) and three-dimensional (3D) images. ImageJ includes various high-level image analysis methods in addition to basic image processing (filtering, edge detection, and resampling). ImageJ was created in Java. ImageJ can open a wide range of typical 2D image files and medical image data, such as MRI in DICOM format. The present study provided the normal value of the MO in the young adult Sudanese population from an MRI T1 image using the ImageJ software technique. The study demonstrated that males have a larger volume of MO than females. Our result is consistent with a study by Lee et al.,[18] which explained the gender-related differences in the

MO volume by evolution and features of the male physique. Our study demonstrated an insignificant difference in the MO volume in the third and fourth decades of life. Lee et al. found no significant difference in MO volume between younger and older age groups, emphasizing that during these age periods, there is no synaptic loss. A study by Oguro[19] clarified that supratentorial brain atrophy progressed by decades, with significant age-related atrophy in the tegmentum and pretectum of the midbrain and the base of the pons in men. In our study, there was significant age-related atrophy in the MO volume (by 2.2441mm^3/year). Our results were inconsistent with Liptak,[20] who found no significant linear relationship with age in healthy subjects, but in multiple sclerosis patients, MO was reduced by 0.008 cm^3/year.

A few studies assessed the MO volume using MRI. Most of the studies were conducted to evaluate the sagittal and AP measurement of the medulla. A study performed by Debnath et al.[21] found that the cerebral peduncle, middle cerebellar peduncle, ventral midbrain thickness, midbrain height, pons, medulla, and spinal cord diameter, showed a steady and sharp increase in values from infancy and reached maximum values during the third decade, followed by a variable degree of decline in values. A study conducted in Sudan by Elameen et al.[22] found the diameter of MO decreased significantly and gradually after age 20. Singh et al.[23] found that the sagittal diameter of the MO and patient genders had no statistically significant association. The study also found that beyond age 50, the MO sagittal diameter reduced slightly, but after age 70, it decreased significantly. Ranganath et al.[24] found no significant differences in the AP diameter of the MO between genders; the AP diameter of the MO after 40 years of age at the cervical-medullary junction was significantly reduced. Our study reported that the MO volume was not significantly correlated with BMI.

Conclusion

Our study detected a significant difference between genders in MO volume, which was greater in males than in females. There is no significant correlation between MO volume and BMI. The size of the MO in individuals with normal brain MRI decreased gradually, by increasing age, from 20 to 40 years.

Competing Interests

The authors declare that they have no competing interests.

References

1. Snell RS. Clinical Neuroanatomy. 7th Edition. Philadelphia: Lippincott Williams & Wilkins: 2010.
2. Scanlon VC, Sanders T. Essentials of Anatomy and Physiology. 8th Edition, FA Davis; 2018 Oct 24.
3. Castell DO, Frank BB. Abdominal examination: role of percussion and auscultation. Postgrad Med. 1977 Dec;62(6):131-4. doi: 10.1080/00325481.1977.11714708.
4. Gocmen-Mas N, Pelin C, Canan S, Yazici AC, Zagyapan R, Senan S, Karabekir HS, Sahin B. Stereological evaluation of volumetric asymmetry in healthy human cerebellum. Surg Radiol Anat. 2009 Mar;31(3):177-81. doi: 10.1007/s00276-008-0424-4.
5. Allen JS, Damasio H, Grabowski TJ. Normal neuroanatomical variation in the human brain: an MRI-volumetric study. Am J Phys Anthropol. 2002 Aug;118(4):341-58. doi: 10.1002/ajpa.10092.
6. Allen JS, Damasio H, Grabowski TJ, Bruss J, Zhang W. Sexual dimorphism and asymmetries in the gray-white composition of the human cerebrum. Neuroimage. 2003 Apr;18(4):880-94. doi: 10.1016/s1053-8119(03)00034-x.
7. Blatter DD, Bigler ED, Gale SD, Johnson SC, Anderson CV, Burnett BM, Parker N, Kurth S, Horn SD. Quantitative volumetric analysis of brain MR: normative database spanning 5 decades of life. AJNR Am J Neuroradiol. 1995 Feb;16(2):241-51.
8. Filipek PA, Richelme C, Kennedy DN, Caviness VS Jr. The young adult human brain: an MRI-based morphometric analysis. Cereb Cortex. 1994 Jul-Aug;4(4):344-60. doi: 10.1093/cercor/4.4.344.
9. Barta P, Dazzan P. Hemispheric surface area: sex, laterality and age effects. Cereb Cortex. 2003 Apr;13(4):364-70. doi: 10.1093/cercor/13.4.364.
10. Nopoulos P, Flaum M, O'Leary D, Andreasen NC. Sexual dimorphism in the human brain: evaluation of tissue volume, tissue composition and surface anatomy using magnetic resonance imaging. Psychiatry Res. 2000 Feb 28;98(1):1-13. doi: 10.1016/s0925-4927(99)00044-x.
11. Acer N, Sahin B, Baş O, Ertekin T, Usanmaz M. Comparison of three methods for the estimation of total intracranial volume: stereologic, planimetric, and anthropometric approaches. Ann Plast Surg. 2007 Jan;58(1):48-53. doi: 10.1097/01.sap.0000250653.77090.97.
12. Kruggel F. MRI-based volumetry of head compartments: normative values of healthy adults. Neuroimage. 2006 Mar;30(1):1-11. doi: 10.1016/j.neuroimage.2005.09.063.
13. Mayhew TM, Olsen DR. Magnetic resonance imaging (MRI) and model-free estimates of brain volume determined using the Cavalieri principle. J Anat. 1991 Oct;178:133-44.
14. Elhussein N, Alkhathami AH, Ayad CE. Norms for Brain Stem: A morphometric MRI Based Study. IOSR Journal of Dental and Medical Sciences (IOSR-JDMS). 2017;16(6):74-79.
15. Suh JO, Joo YG, Suh SJ. MR measurement of normal brainstem diameter in Korean adults. Journal of the Korean Radiological Society. 1990 Aug 1;26(4):653-7. doi: 10.3348/jkrs.1990.26.4.653
16. Murshed KA, Ziylan T, Seker M, Cicekcibasi AE, Acikgozoglu S. Morphometric assessment of brain stem und cerebellar vermis with midsagittal MRI: the gender differences and effects of age. Neuroanatomy. 2003;2:35-8.
17. Raininko R, Autti T, Vanhanen SL, Ylikoski A, Erkinjuntti T, Santavuori P. The normal brain stem from infancy to old

*Corresponding author: Assistant Professor, Dr. Zuhal Y. Hamd, PhD. Department of Radiological Sciencest, College of Health and Rehabilitation Sciences, Princess Nourah Bint Abdulrahman University, P.0. Box .84428, Riyadh 11671, Saudi Arabia. E-mail: zuhalhamd2019@gmail.com

age. A morphometric MRI study. Neuroradiology. 1994 Jul;36(5):364-8. doi: 10.1007/BF00612119.
18. Lee NJ, Park IS, Koh I, Jung TW, Rhyu IJ. No volume difference of medulla oblongata between young and old Korean people. Brain Res. 2009 Jun 18;1276:77-82. doi: 10.1016/j.brainres.2009.04.027.
19. Oguro H, Okada K, Yamaguchi S, Kobayashi S. Sex differences in morphology of the brain stem and cerebellum with normal ageing. Neuroradiology. 1998 Dec;40(12):788-92. doi: 10.1007/s002340050685.
20. Liptak Z, Berger AM, Sampat MP, Charil A, Felsovalyi O, Healy BC, Hildenbrand P, Khoury SJ, Weiner HL, Bakshi R, Guttmann CR. Medulla oblongata volume: a biomarker of spinal cord damage and disability in multiple sclerosis. AJNR Am J Neuroradiol. 2008 Sep;29(8):1465-70. doi: 10.3174/ajnr.A1162.
21. Debnath J, Sharma V, Patrikar S, Krishna S, Shijith KP, Keshav RR. Normal measurements of brainstem and related structures for all ages: An MRI-based morphometric study. Medical Journal Armed Forces India. 2022. doi:10.1016/j.mjafi.2022.06.002
22. Elameen RAAE. Measurement of Normal Brainstem Diameter in Sudanese Population using MRI (Master dissertation, Sudan University of Science and Technology). 2016. Available from: http://repository.sustech.edu/handle/123456789/15708
23. Singh S, Sharma BR, Bhatta M, Poudel N. Measurement of anteroposterior diameters of normal brainstem by magnetic resonance imaging. Journal of Gandaki Medical College-Nepal. 2019:12(2):53-58. doi:10.3126/jgmcn.v12i2.27210
24. Ranganath A, Saklecha AK, Singh A, Vineela E. Age and gender differences in morphometric measurements of brain stem using magnetic resonance imaging in healthy Indian adults. Journal of Datta Meghe Institute of Medical Sciences University. 2022:*17*(1):21-24. doi:10.4103/jdmimsu.jdmimsu_238_22.