Original Article

Morphometric Evaluation of Sacrum Volume in Healthy Women

Emrah Özcan, Ömür Karaca, Mine İslimye Taşkın[1], Ramazan Çetin, Aycan Büyükmert, Alper Vatansever, İlter Kuş

Departments of Anatomy and [1]Obstetrics and Gynecology, Faculty of Medicine, Balikesir University, Balikesir, Turkey

Abstract

Introduction: The aim of this study was to calculate volume of the sacrum, sacral canal, caudal part of the epidural space, and dural sac volumes using stereological methods on magnetic resonance images (MRIs). **Material and Methods:** We used MRI series of 50 healthy women (the mean age; 44.0) in the study, retrospectively. Point counting and planimetry methods were used to calculate the volumetric parameters on MRIs. Volume calculation was performed by placing the dotted field ruler on MRI sections for point counting method, whereas ImageJ software was used for planimetry method. **Results:** Sacrum volume was measured as 135.38 ± 24.12 cm^3 using point counting method, whereas it was 136.87 ± 24.76 cm^3 in planimetry method. The mean volume of sacral canal was determined as 10.11 ± 2.64 cm^3 and 10.30 ± 2.73 cm^3 using point counting and planimetry methods, respectively. The mean volume of the caudal portion of the epidural space was 6.54 ± 2.04 cm^3 in point counting method, whereas it was 6.53 ± 1.89 cm^3 in planimetry method. **Discussion and Conclusion:** Knowing the volume of sacrum would contribute to minimization of complications during surgical approaches and anesthesia procedures in that region. Our results showed that sacrum volume can be calculated accurately using stereological methods such as point counting and planimetry.

Keywords: *Anatomy, caudal epidural block, sacrum, stereology*

Introduction

In degenerative diseases, lumbosacral instabilities and during surgical approaches targeting sacral region, preservation of anatomical structures are crucial. Therefore, a good knowledge of anatomic organization and morphometric values of the sacrum would be useful to prevent unexpected complications during surgical procedures in this region.[1]

Dural and arachnoid sheaths of spinal cord terminate at the level of S2 vertebra. Adipose tissue, venous plexus, filum terminale, and coccygeal nerve are located in caudal part of the epidural space under dural sheath of S2 vertebra. Caudal part of epidural space is commonly used for caudal epidural block (CEB) and epidural analgesia.[2] CEB is performed by administering local anesthetic into caudal part of epidural space. CEB is frequently used for treating lumbar spinal disorders and prevention of chronic low back pain, as well.[1]

Epidural analgesia or commonly known as "painless delivery," is a special form of local anesthesia used to eliminate pain during labor or cesarean section. The difference of epidural analgesia from general anesthesia is that the expectant mother is awake during the procedure and completely perceives what is going on around her. It is a very safe method in terms of undesirable effects compared to general anesthesia.[3,4]

If volume of caudal portion of the sacrum and epidural space is not known, it does not only increase the risk of perforation of the dural sac but also increases the probability of cardiac arrest due to overdosing of anesthetic or analgesic drug during CEB and epidural analgesia applications.[3-7] Therefore, to prevent unexpected complications, volume of caudal part of the sacrum and epidural space should be carefully evaluated before surgical approaches.[6]

The recent studies about epidural analgesia and CEB approaches demonstrated the importance of knowing anatomical organization of sacral region. Therefore, the main aim of this study was to morphometric evaluation of the sacrum, sacral canal, caudal part of the epidural space, and

How to cite this article: Özcan E, Karaca Ö, Taşkın Mİ, Çetin R, Büyükmert A, Vatansever A, *et al.* Morphometric evaluation of sacrum volume in healthy women. J Anat Soc India 2022;71:119-22.

Article Info

Received: 22 February 2021
Revised: 10 July 2021
Accepted: 31 October 2021
Available online: 30 June 2022

Address for correspondence:
Dr. Emrah Özcan, Department of Anatomy, Faculty of Medicine, Balikesir University, Balıkesir, Turkey.
E-mail: emrahozcan@balikesir.edu.tr

Access this article online

Website: www.jasi.org.in
DOI: 10.4103/jasi.jasi_33_21
Quick Response Code:

dural sac volume using stereological methods on magnetic resonance image (MRI) series of healthy women.

Material and Methods

Ethical approval

Our study was begun after received ethical approval by Balikesir University's NonInterventional Clinical Research Ethics Committee (2018/108).

Participants

Fifty healthy women's (the mean age; 44.0, range; 16–71) MRI series were evaluated, retrospectively. MRI series of participants admitted to Obstetrics and Gynecology Department of Balikesir University Hospital for an another reasons than sacral region disorders between 2015 and 2018 and underwent lower abdominal MRI were retrospectively obtained from picture archiving and communication system. MRI series was evaluated by an obstetrics and gynecology and anatomy specialists.

Women that did not have any pathology or disorder in the sacrum and sacral region were included in the study. Women who had a sacral tumor history, sacrum anomaly, spina bifida, spinal surgery, osteoporosis, or related disorders were excluded.

Magnetic resonance image protocol

Pelvic MRI series was obtained from a 1.5 Tesla MRI unit (Philips, Ingenia, 2013). T1-weighted repetition time for volume measurements: 4500 ms, echo time: 80 ms, field of view: 170 × 170, matrix size: 172 × 119, voxel size: 1 × 1 × 1, flip angle: 90, and the images in the sagittal plane with a section thickness of 3 mm were used.

Morphometric measurements

The volume of sacrum, sacral canal, caudal epidural space and dural sac and termination of the dural sac were calculated using stereological methods such as Cavalieri and planimetry methods on MRI series.

Point counting method (Cavalieri method)

The point counting method used in our study is based on Cavalieri principle. Transverse-sectional images with 3 mm thickness were used to calculate the volume of the region of interest (ROI). First, MRIs in digital imaging and communications in medicine (DICOM) format imported to the RadiAnt DICOM viewer, and then sagittal sections were opened. Principally, preliminary study was needed to be performed with different point area measurement scales to calculate the coefficient of error for selecting an accurate scale. As a result of our preliminary study, 0.3 cm point area measurement scale was used, with the lowest error coefficient (0.05 and less). The dotted area measurement chart was randomly plotted onto the MRI and this procedure was repeated for each section [Figure 1]. The number of points on the ROI was noted. In the

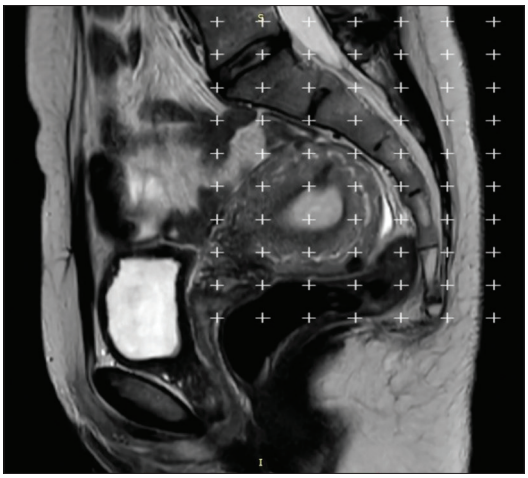

Figure 1: Disposal of the dotted area measurement ruler on the magnetic resonance image

MRIs of participants, sacrum's volume was calculated on 59 sections, sacral canal's volume in 13 sections, volume of caudal part of epidural space in 11 sections, and dural sac volume in 10 sections. The mean number of points was 578 for the sacrum, 99 for the sacral canal, 81 for the caudal part of the epidural space, and 64 for the dural sac. Once point counting process was completed, the volume was calculated according to the previously stated formula.[8]

Planimetry method

For volumetric calculations using the planimetry method, Image J (Image Processing and Analysis in Java, Version 1.53), National Institutes of Health, Maryland, USA. which was developed by the American National Institute of Health and obtained free of charge[9] was used. Images were displayed using a standard image and display levels on a monitor with constant contrast settings. In the ImageJ software, boundaries of the ROI were manually drawn on each MRI section [Figure 2]. The software automatically calculated the number of pixels covered within the ROI boundaries, and this process was repeated for each section. The ROI volume was calculated based on the pixel size and section thickness using the following formula:

Volume = Sum of areas (cm^2) × Section thickness (cm)

Statistical analysis

Statistical analysis was completed using the SPSS (Statistical Package for the Social Sciences, Version 22), IBM Incorporated, New York, USA. The suitability of the variables to normal distribution was evaluated by applying Shapiro-Wilk test. Descriptive tests were performed to determine the volume of sacrum, sacral canal, caudal portion of epidural space, and dural sac. To determine statistically significant differences between Cavalieri and planimetry methods, intraclass correlation analysis was performed. Summary of data were stated as mean ± standard deviation. "Pearson correlation" test was used to evaluate the relationship between volumetric data

and normal distribution age. The cases where the $P < 0.05$ were evaluated as statistically significant.

Results

Volume of sacrum was 135.38 ± 24.12 cm^3 in Cavalieri method, whereas it was 136.87 ± 24.76 cm^3 in planimetry method. The mean volume of sacral canal was 10.11 ± 2.64 cm^3 and 10.30 ± 2.73 cm^3 in Cavalieri and planimetry methods, respectively. The mean volume of caudal portion of epidural space was 6.54 ± 2.04 cm^3 by Cavalieri method and 6.53 ± 1.89 cm^3 by planimetry method. Volume of the dural sac was measured as 3.57 ± 1.85 cm^3 with Cavalieri method and 3.78 ± 1.96 cm^3 with planimetry method. Intraclass correlation analysis showed no difference between the two methods [Table 1]. The closure site of the dural sac was found to be S2 vertebrae level in 82.0% (n = 41), S1 vertebrae level in 16.0% (n = 8), and S3 vertebrae level in 2.0% (n = 1) of participants. As a result of Pearson correlation analysis, there was a negative weak correlation between sacral canal volume and caudal part of epidural space with age, but no statistically significant correlation was found between other parameters and age [Table 2].

Discussion

Epidural analgesia and CEB have recently been performed by physicians in female patients. Thus, it is crucial to know the sacrum morphometry to prevent unexpected injuries during epidural analgesia and CEB. Therefore, in this study, we aimed to determine termination of the dural sac by calculating volumetric values of sacrum, sacral canal, caudal portion of the epidural space, and sacral sac using the Cavalieri and planimetry methods on MRIs of healthy women.

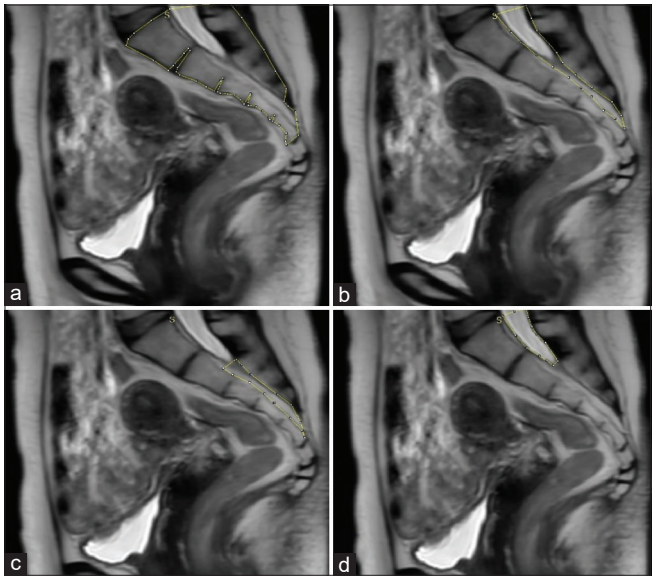

Figure 2: Volume calculation using the planimetry method. (a) sacrum volume, (b) sacral canal volume, (c) caudal portion of epidural space volume, and (d) dural sac volume

The advantage of Cavalieri method is that it is easy to apply and economical and this method does not require extra accessories. This method can be applied on the MRI printed sections, and it is also a suitable method for prospective and retrospective studies. The advantages of the planimetry method are that it gives more accurate results and ImageJ software is free of charge and easy to use. Although this method requires a high degree of hand-eye coordination and skill in defining boundaries of the structure of interest, higher sensitivity, and higher standard deviation are among the advantages.[8-10]

In the literature review, it is observed that morphometric studies of sacrum are generally performed on dry bones and radiographs directly, but there was not any study about the sacrum morphometry using MRIs of healthy individuals.[6,11,12] These studies were completed using dry bones; thus, gender discrimination and individual's medical history were not known. Therefore, the results of recent studies remain insufficient to determine the sacrum morphometry.

The studies indicated that decreased volume of caudal part of the epidural space with age.[6,13] Similarly, in our study, a negative correlation was found between age and volume of caudal portion of the sacral canal and epidural space. Our findings showed that volume of the sacral canal and caudal portion of the epidural space located in the canal decreased with age.

The mean volume of sacral canal was 10.11 ± 2.64 cm^3 with Cavalieri method and 10.30 ± 2.73 cm^3 with planimetry method in healthy women. On the other hand, Crighton *et al*.[14] performed a study on MRIs of 22 female and 13 male patients who suffering from low back pain. They found that the mean volume of sacral canal in women was 13.2 ± 2.68 cm^3 that was different from our results. This difference may be caused due to their study was completed with patients with low back pain.[11]

In a study conducted by Asghar and Naaz[4] on 77 dry sacrum (42 females and 30 males), volume of the sacral canal was measured as 34.86 ± 6.86 cm^3 in women, and

Table 1: Intraclass correlation coefficient

	Intraclass correlation	95% CI (lower bound–upper bound)	*F* test with true value 0			
			Value	df1	df2	Significance
Single measures	0.993	0.987-0.996	273.287	49	49	0.000
Average measures	0.996	0.994-0.998	273.287	49	49	0.000

CI: Confidence interval

Table 2: Pearson correlation analysis

Volume (cm^3)	Age			
	Cavalieri method		Planimetri method	
	P	*r*	*P*	*r*
Sacrum	0.219	−0.177	0.169	−0.197
Caudal portion of epidural space	0.079	−0.251	0.023	−0.321
Dural sac	0.342	−0.137	0.272	−0.158
Sacral canal	0.041	−0.289	0.017	−0.335

caudal volume of the epidural space was measured as 12.46 ± 3.52 cm^3. They found that volumes of the caudal portion of the sacral canal and epidural space were very high compared with the results of our study. The fact that the study was carried out on dry bone, and the disease resumes belonging to the owners of the measured bones explain the difference between the results obtained and our findings.

Senoglu *et al*.[7] completed a study using MRIs of 641 women to determine the termination level of the dural sac. According to their results, this level was found at the S2 vertebra in 72.0% of women (n = 460). Furthermore, the termination level of dural sac was found at S3 vertebra in only one participant in our study.

Many previous studies mainly used dry bones and radiographic images for morphometric evaluation of sacrum and its contents in patients suffering from any clinical history. Meanwhile, our study especially focused on anatomical properties of these structures in healthy individuals. Our results may be useful as a preoperative guide for physicians. Therefore, postoperative quality of life of patients suffering from any pathology may be increased.

Conclusion

Knowing the sacrum morphometry well is very important for surgical approaches and anesthesia procedures to this region. Each patient should be evaluated individually to select a proper surgical method with regard to anatomical properties. Knowing volume of the sacrum may reduce risks of unexpected complications by preserving the anatomical structures (especially dural sac) in this region.

Limitations of the study

Due to the retrospective nature of our study, the limitations were the fact that the cross-sectional thickness of the MRIs was 3 mm and the number of participants was low.

Acknowledgments

Authors would like to thank to staff of the Radiology Department for their support.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 41st ed. New York: Elsevier Limited; 2019.
2. Moore KL, Dalley AF, Agur AM. Clinically Oriented Anatomy. 7th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2014.
3. Park GY, Kwon DR, Cho HK. Anatomic differences in the sacral hiatus during caudal epidural injection using ultrasound guidance. J Ultras Med 2015;34:2143-8.
4. Asghar A, Naaz S. The volume of the caudal space and sacral canal in human sacrum. J Clin Diagn Res 2013;7:2659-60.
5. Moralar GD, Turkmens UA, Altan A. Dogum aneljezisi. Okmeydani Tip Derg 2011;27:5-11.
6. Cheng JS, Song JK. Anatomy of the sacrum. Neurosurg Focus 2003;15:E3.
7. Senoglu N, Senoglu M, Ozkan F, Kesilmez C, Kızıldag B, Celik M. The level of termination of the dural sac by MRI and its clinical relevance in caudal epidural block in adults. Surg Radiol Anat 2013;35:579-84.
8. Başaloğlu H, Turgut M, Taşer FA, Ceylan T, Başaloğlu HK, Ceylan AA. Morphometry of the sacrum for clinical use. Surg Radiol Anat 2005;27:467-71.
9. Aggarwal A, Aggarwal A, Harjeet, Sahni D. Morphometry of sacral hiatus and its clinical relevance in caudal epidural block. Surg Radiol Anat 2009;31:793-800.
10. Gundersen HJ, Bendtsen TF, Korbo L, Marcussen N, Moller A, Nielsen K, *et al*. Some new, simple and efficient stereological methods and their use in pathological research and diagnosis – Review article. APMIS 1988;96:379-94.
11. Abramoff M, Magalhães P, Ram SJ. Image processing with ImageJ. Biophotonics Int 2004;11:36-42.
12. Acer N, Sahin B, Usanmaz M, Tatoğlu H, Irmak Z. Comparison of point counting and planimetry methods for the assessment of cerebellar volume in human using magnetic resonance imaging: A stereological study. Surg Radiol Anat 2008;30:335-9.
13. Polat KT, Ertekin T, Acer N, Cınar S. Sakrum kemiginin morfometrik degerlendirilmesi ve eklem yuzey alanlarinin hesaplanmasi. Erciyes Univ Saglik Bilimleri Derg 2014;26:67-73.
14. Crighton IM, Barry BP, Hobbs GJ. A study of the anatomy of the caudal space using magnetic resonance imaging. Br J Anaesth 1997;78:391-5.