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An International Journal of Experimental and Clinical Anatomy

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Anatomy, an international journal of experimental and clinical anatomy, is a peer-reviewed journal published three times a year with an objective to publish manuscripts with high scientific quality from all areas of anatomy. The journal offers a forum for anatomical investigations involving gross, histologic, developmental, neurological, radiological and clinical anatomy, and anatomy teaching methods and techniques. The journal is open to original papers covering a link between gross anatomy and areas related with clinical anatomy such as experimental and functional anatomy, neuroanatomy, comparative anatomy, modern imaging techniques, molecular biology, cell biology, embryology, morphological studies of veterinary discipline, and teaching anatomy. The journal is currently indexing and abstracting in TUBITAK ULAKBIM Turkish Medical Index, Proquest, EBSCO Host, Index Copernicus and Google Scholar.

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Letter from new Editor-in Chief

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Anatomy 2020;14(1):iii–iv

Dear Colleagues,

It was a great pleasure and honor for me when the position of Editor-in-Chief of *Anatomy* was offered to me. *Anatomy*; the official journal of the Turkish Society of Anatomy and Clinical Anatomy was founded by Professors Salih Murat Akkın and Hakan Hamdi Çelik. Professor Salih Murat Akkın took part as the first Editor-in-Chief at the toddler period of the journal. After that, the journal than has risen to new heights under the leadership and meticulous eye of former Editor-in-Chief Professor Gülgün Şengül. With her rigorous efforts, the journal was started to be published three issues per year with a rich content. *Anatomy*; as an international journal of experimental and clinical anatomy, is currently indexing and abstracting in TUBITAK ULAKBIM Turkish Medical Index, Index Copernicus, Proquest, EBSCO Academic Search Complete and Google Scholar. I would like to take this opportunity to ask each of you to submit your best work to our journal for consideration. With your help, my goal is to continue this successful path and make our journal indexed in other databases such as Web of Science (Clarivate Analytics), MEDLINE/PubMed (NLM), and Science Citation Index (Clarivate Analytics). I would also ask you to contact your colleagues who might not be familiar with "*Anatomy*" and suggest that they consider our journal for any original papers covering a link between gross anatomy and areas related with other disciplines such as experimental and functional anatomy, neuroanatomy, comparative anatomy, modern imaging techniques, molecular biology, cell biology, embryology, morphological studies of veterinary discipline, and teaching anatomy. Please note that our journal is open to submissions from all areas of anatomy, offering a forum for anatomical investigations involving gross, histologic, developmental, neurological, radiological and clinical anatomy, and anatomy teaching methods and techniques. High quality submissions relevant to these fields will continue to move us forward. The future of our journal *Anatomy* is promising and I look forward to sharing exceptional scientific works with you. This journal is all ours and I believe that it will have its well-deserved ranking among other journals with your efforts. I am very willing to hear your suggestions on ways that you believe we can further improve our journal.

The first issue of this year is dedicated to the memory of Professor Dr. Med. Dr. H.C. Andreas H. Weiglein, former Head of the Institute of Clinical Gross Anatomy at the Medical University Graz, Austria; one of the greatest clinical anatomist many of you are familiar with. It was not only my personal, but all Turkish Anatomists' sadness to learn the decease of Andreas Weiglein on February 7, 2020 at such a young and productive age. His contributions to Clinical Anatomy and personal supports to development of academic career of many Turkish anatomists, including myself will never be forgotten. He was a good and a sincere friend, a very knowledgeable person and an irreplaceable figure in Anatomy world-wide. He was also one of the honorary members of the Turkish Society of Anatomy and Clinical Anatomy. That's one of the several reasons why I wanted to dedicate this issue to his memory. You will have chance to read and learn about more him in the

memorandum articles written by his close friends and colleagues.

Lastly, I once more invite you all to submit your best works to our journal and help in the reviewing process of submitted articles to increase the level of excellence of our journal. And please remember that citing the relevant articles published by our journal in any of your works will increase the visibility and impact factor of our journal in the long run.

With my deepest regards.

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Andreas Weiglein: exceptional teacher and scientist not only for Graz

Georg Feigl

Department of Macroscopic and Clinical Anatomy, Medical University of Graz, Graz, Austria

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Andreas Weiglein - Anatomists all over the world know this name very much. His death in February 2020 was a shock and tragedy, although many of the anatomical community knew about his illness and his suffer. Despite the tragic end, let´s highlight this person and honor him respectfully in a different way. Not about numbers of publications, not about the regularly known stories, I want to present some personal key-moment with Andreas.

Andreas Weiglein studied at the Karl Franzens University in Graz and became Studying Assistant at the Institute of Anatomy. At that time, the head of Department was Professor Thiel, who is also well known due to his developed embalming procedure. Under his "mentor" Professor Anderhuber, he became assistant and was assisted and supervised in his early career. When he received the "Venia docendi", he already was known in the English-speaking countries. He attended the meetings of the AACA and AAA frequently, also won prizes for "Best lectures". Memorable as his style of lectures, presenting with an easiness and high standard. When myself saw him as a presenter for the first time at a meeting of the International Society of Plastination (ISP) in Knoxville, TN, in 1997 and at a AACA meeting in Lexington, KY, in 1998, I was deeply moved and impressed about the way of his presentations, the standard and the clinical background of his scientific work. He became an idol, to work hard and to try the best in presenting our scientific work on an international platform. What is more, he was a respected person with high reputation at that time. In addition, we always highlighted the affiliation to the University of Graz and was proud to be part of the Institute. All the upcoming years, he surprised with new investigations and never rested to support young colleagues not only from the own Institute, such as myself, but especially encouraged young scientists to come to Graz. Many visits were enforced by Andreas´ support, many of our, nowadays experienced scientists still remember unforgettable moments in Graz and worldwide at meetings and during the gala dinners or spouse programs.

Figure 1. Andreas Weiglein (1961–2020), Professor of Anatomy and Vice Chairman, Institufe of Anatomy, Medical University Graz, Austria.

Science is one part of the anatomist´s work. Teaching is the other also important part. I was lucky to be able to assist his lectures many years. He was one of the professors, who was able to present almost any topic of the human body without any prior preparation. I always have kept in mind one moment: he landed in Graz, returning from a conference which was held in the United States, took a taxi and went straight to…. not home but to University to do a lecture about the inner ear. When arriving, about five minutes were left and he asked for water and entered the lecture hall. In there, he asked us as assistants: "Please give me a keyword, where we stopped last lecture!" started an anatomical firework.

All his work, his love to dissect and to teach he kept until the very end. Although he suffered a lot because of his illness, he never gave up. When I ruled the Department of Macroscopical and Clinical Anatomy as an interims HoD, I often took his advice due to his experience and passion on Anatomy. The passion and his spirit, which infiltrated so many of us and encourage us in becoming a better teacher, better scientist and better anatomist daily.

Andreas, thank you for all moments; thank you for the time we could share; thank you for being a personal highlight and unforgettable professor of our anatomical community.

Requiescat in pace!

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Professor Andreas H. Weiglein (1961–2020): a life dedicated to teach and promote clinical anatomy

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The world-wide clinical anatomy and plastination communities received the terrible news on February. We lost Univ. Prof. Dr. med. Andreas H. Weiglein, the university lecturer and academic member of the Department of Macroscopic and Clinical Anatomy at Medical University of Graz, in his most productive years, on February 7, 2020 in Graz. As a very good clinical anatomist, Andreas Weiglein had his medical education at the Faculty of Medicine, University of Graz (Karl-Franzens-Universität) between 1979 and 1988, graduated with MD degree, and later worked with his renowned masters Prof. Thiel and Prof. Anderhuber at the Institute of Anatomy of the same university. From then on, he was committed to clinical anatomy and trained generations of medical students. The importance of the clinical aspects of anatomy and teaching anatomy in medicine and dentistry always remained at the forefront in his scientific and academic career.

Andreas was one of the honorary members of our society, the Turkish Society of Anatomy & Clinical Anatomy (TSACA) since 2009 and the member of the scientific advisory board of our journal "*Anatomy*" since its start in 2007.

I first met with Andreas at the Joint Meeting of the British Association of Clinical Anatomists and the Spanish Anatomical Society organized by Prof. Sanudo at Barcelona in 2002 summer. He assumed the organization duties of EACA congress to be held at Graz one year later. As an academician, who had his heart set on clinical anatomy, he wanted to realize a planning which would be a first in the world. His excitement could be told from his eyes when he was sharing his great enthusiasm. He would draw two great clinical anatomy societies from Europe and the USA together in a congress for the first time. He had the knowledge and experience to achieve his goal, because he had many international contacts in both AACA and EACA thanks to his strenuousness and friendly personality. He also wished many

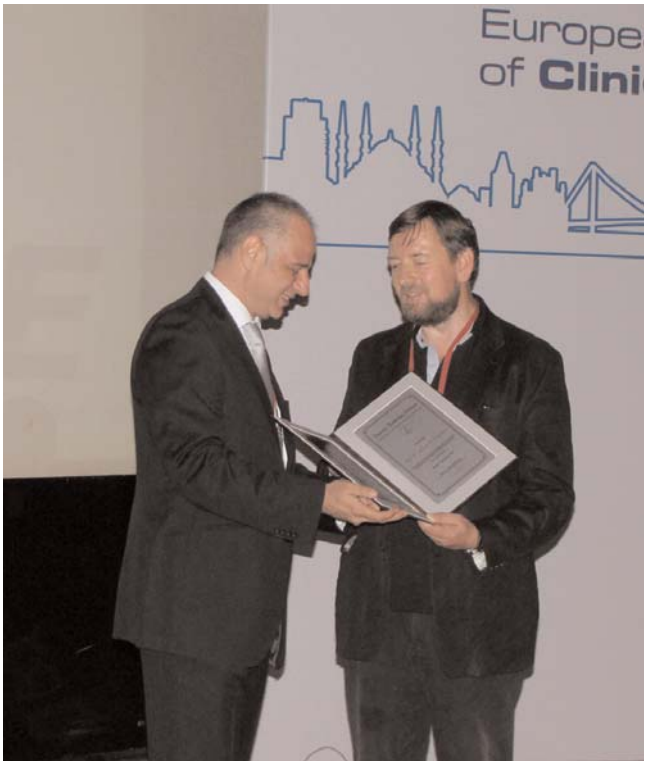

Figure 1. Presenting the honorary membership of TSACA to Andreas H. Weiglein during the opening ceremony at the 10th Congress of EACA held on July 2, 2019 in Istanbul.

Figure 2. A great moment from the 10th Congress of EACA, 2009, Istanbul. From left to right: Cristian Stefan (USA), Subramaniam Krishnan (Malaysia), Fabrice Duparc (France), Andreas H. Weiglein (Austria) and Salih Murat Akkın (Turkey).

national societies to participate in the congress. In this regard, he offered our society (TSACA), which is known for its potential in the clinical anatomy, to be among the invited societies. We gladly accepted this kind offer.

The 1st Joint Meeting of EACA & AACA held in Graz on July 2003 was completed successfully in terms of clinical anatomists. Andreas was a great host with all Graz anatomy team as the organizer of the congress, and all participants left Graz with quite positive impressions.

We invited Andreas as one of the keynote speakers to our seventh National Congress held in Diyarbakır in September of the same year. He gladly accepted our invitation. The congress hosted locally by Prof. Hatipoğlu was organized meticulously also to promote the rich history and cultural background of the Southeastern Anatolia. Andreas was amazed at many local characteristics of this region in which he had been for the first time, and made a representation created with the photographs he shot to his colleagues and students when he got back to Graz. Our scientific communication continued in the following years. He participated in our national congresses and made inspiring presentations. With Prof. Anderhuber, he helped young anatomists and students from Turkey to have an opportunity to do researches at the Institute of Anatomy in Graz. At the 10th Congress of EACA that we, as TSACA, assumed and held in Istanbul in 2009, he was the International Congress Coordinator together with Prof. Stephen W. Carmichael from Mayo Clinic, Rochester, MI, USA. Andreas had very substantial contributions to hold the congress successfully with over 400 participants and more than 500 presentations. He was presented the honorary membership of TSACA at this congress.

Andreas was an academician with humanitarian perspectives who believed that there would never be any boundaries in the cooperation among scientists and that all clinical anatomists in the world are the members of a great family. He had a great scientific friendship network from Japan and Malaysia to Brazil and Argentina. He also had close relationship with AACA, and he was the board member of the society. Andreas was a colleague with organizing capabilities. In addition to his position as the vice-chairman of the Institute of Anatomy at Medical University Graz since 1996, he had been the councilor and president of EACA for long years. He was one of the founders and honorary chairman of the International Academy of Clinical Anatomy (IACA). Moreover, he was the chairman of the International Society for Plastination (ISP) between 1997 and 2004, and he made great efforts to increase the scientific quality of the international meetings and the journal of the society. He was awarded with the honorary membership of ISP in 2012 in Beijing.

Figure 3. Together with the other participants, Andreas Weiglein in the local cultural atmosphere of Southeastern Anatolia during the social program of the seventh National Congress of TSACA, 2003, Diyarbakır.

Besides our journal "*Anatomy*", Andreas was a member of the editorial board of several journals such as Anatomical Record, Argentine Journal of Clinical Anatomy, Ars Medica Tomitana, Cells-Tissues-Organs, Clinical Anatomy, Journal of the ISP, and associate editor of Surgical & Radiologic Anatomy. In addition to the publication of more than 60 papers and 35 textbook chapters, videos and DVDs, he translated and edited the 13th English Edition of the Sobotta Atlas (2005), edited the chapter on the trapezius flaps in Wei/Mardini: Flaps

Figure 4. A picture from the General Meeting of IACA, 2009, Istanbul. From left to right: Andreas H. Weiglein (Austria), David Kachlik (former Czech Republic), Christian Fontaine (France), Vaclav Baca (former Czech Republic), Subramaniam Krishnan (Malaysia), Cristian Stefan (USA), Tatsuo Sato (Japan), Deniz Demiryürek (Turkey), Stephen W. Carmichael (USA), Fabrice Duparc (France), a colleague from Egypt, Mustafa Sargon (Turkey), Salih Murat Akkın (Turkey) and Friedrich Anderhuber (Austria).

(1st ed., 2010), edited the chapter on head and neck in Waldeyer's Anatomie des Menschen (24th ed., 2012) and he was a member of the international advisory board of Netter's Atlas of Anatomy (6th ed., 2012). His research was covering the wide field of clinically applied and radiologic anatomy with special emphasis on the musculoskeletal system, which reflects his clinical training in orthopedic trauma surgery and radiology, and the head and neck regions were of his major interest, as proved by several papers on the temporal bone, the paranasal sinuses, and dental implantology.

Andreas, whom I know as a friend enjoying the life as well as being a good scientist and educator, will always be remembered with his cheerful personality, warm-hearted friendship and great efforts to promote clinical anatomy worldwide.

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Andreas Weiglein (1961–2020): exemplary clinical anatomist and respected colleague

Cristian Stefan

Department of Molecular Pathobiology, New York University College of Dentistry, New York, USA

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During a time when faculty members, departments and societies related to the field of anatomy have strived to align themselves with the clinical dimensions and applications of this discipline, Andreas H. Weiglein was, and will always be, remembered as a highly respected academic and a personification of what a Clinical Anatomist truly represents. He brought the symbiotic relationship between anatomy and its clinical relevance to the highest possible level, not only through commitment, diligence, perseverance and creativity, but also through his natural ability to interconnect the dots of multiple fields. Andreas was able to see the essence of the living body in the context and perspective of the entire medical and dental curriculum and across all health care professions.

Born, raised and educated in the charming historical city of Graz, Austria, Andreas received the MD degree from the Karl-Franzens University Medical School in 1988. He started his academic career in 1988 as an Assistant Professor in the Anatomical Institute at his alma mater. In 1996 he was promoted to Associate Professor and Vice Chair at the same institution. Andreas assumed essential administrative tasks in the numerous courses, programs, projects and initiatives in which he was involved, often with a leadership role.

Throughout his career, Andreas was very active in many local, national and international professional associations and venues. Meeting Andreas at one of these occasions was a great opportunity to listen to his exqui-

Figure 1. Gala dinner picture from the 4th International Symposium of Clinical and Applied Anatomy, 28 June–1 July 2012, Ankara, Turkey. We celebrated Andreas' birthday that night. From left to right: Andreas H. Weiglein (Austria), Antonio Gonçalves-Ferreira (Portugal), Salih Murat Akkın (Turkey), Cristian Stefan (USA) and Fabrice Duparc (France).

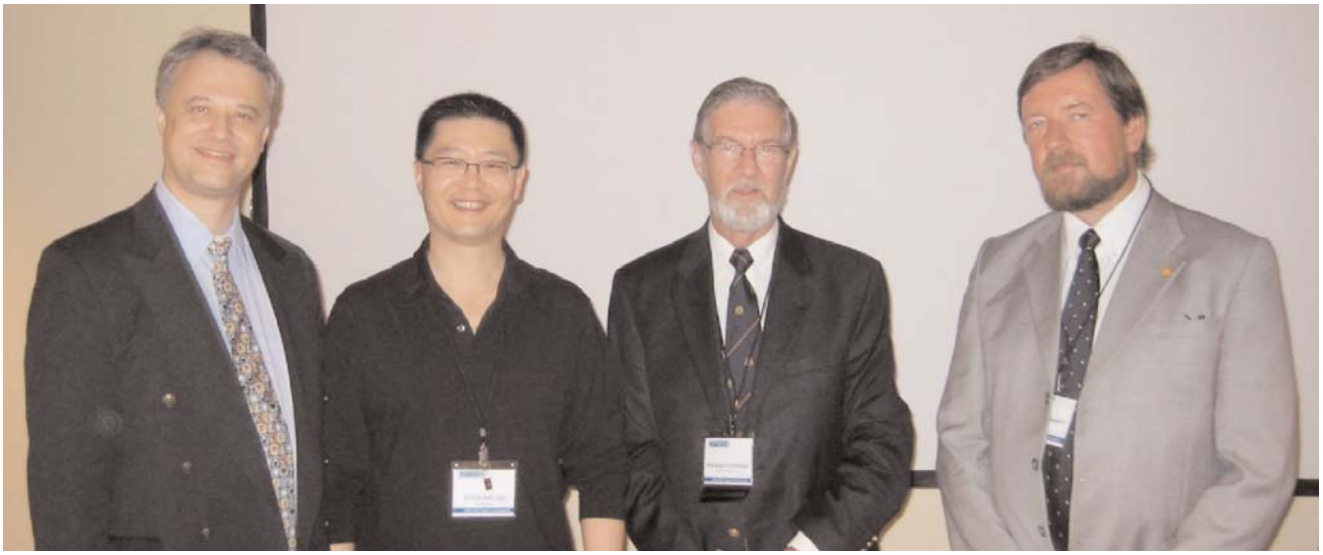

Figure 2. Panelists on a symposium at the Association for Medical Education in Europe Annual Conference in Prague 2008. From left to right: Cristian Stefan (USA), Goh-Poh Sun (Singapore), Allan Carmichael (Australia) and Andreas Weiglein (Austria).

site presentations, learn from his rich experience, explore new possibilities and approaches, and be inspired for further projects. It was also a real pleasure to exchange ideas with a wonderful colleague and establish a long-lasting friendship with him. Frequently listening with an enigmatic smile, Andreas did not rush into speaking, but when he spoke, each sentence conveyed a deep understanding often with a unique perspective. No matter if he were talking to a large audience or to a small group, he easily held the attention of everybody due to his erudition, clarity of thought, accuracy and precision in expression. Moreover, he had a great and very appropriate sense of humor.

Therefore, it is not surprising that Andreas was well known in academic circles and was invited around the world as a speaker, presenter, moderator and contributor to panels, workshops and symposia. His leadership qualities extended to the international level. He was President

Figure 3. Another great moment with Andreas at the American Association of Clinical Anatomists Annual Meeting, Gainesville, FL, USA, 2002. From left to right: Cristian Stefan (USA), Thomas Quinn (USA), Andreas Weiglein (Austria), Neil Norton (USA).

or Councilor of the European Association of Clinical Anatomy; President, Vice-President or Secretary for the International Society for Plastination; Councilor of the American Association of Clinical Anatomists; Honored Member of the Turkish Society of Anatomy and Clinical Anatomy, Honored Member of the Argentine Association of Clinical Anatomists, to name a few. He also had a central role in organizing several important meetings, including the 7th International Conference on Plastination; the First Joint Meeting of the American Association of Clinical Anatomists and European Association of Clinical Anatomy; and the 5th International Symposium on Clinical and Applied Anatomy.

In addition to an impressive list of publications, abstracts, presentations and contributions to books and his activity as editor, co-editor or reviewer for several journals, one of the most important aspects of Andreas' impact on the academic environment was his dedication to undergraduate and postgraduate education. He was a role model for students and young physicians alike in the many and diverse programs he conducted or participated in.

Beyond and above the transmission of knowledge and skills, Andreas' strongest legacy was his enthusiastic and relentless effort to encourage active and life-long learning, facilitate critical thinking and instill professionalism in all of those who had the privilege to be in his presence for a longer or shorter period of time. He was always interested in finding innovative, creative and effective instructional formats in addition to traditional methods to accomplish short, and especially long-term, educational goals.

Because the true clinical dimension of anatomy was so clear and meaningful to Andreas as a way to enrich the study and practice of medicine seen in its complexity as both art and science, his vision and multifaceted work will persist not only through a rich and valuable collection of articles, books and methodology but will remain alive in all of us who knew him, to inspire us and therefore extend its light to so many generations to come.

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Professor Andreas Weiglein, MD

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Prof. Dr. Andreas Weiglein was a great scientist and a very good friend. He was a perfect teacher not only in classical gross anatomy but also a perfect promoter in developing alternative methodologies for preservation of bodies such as Thiel's embalmment and plastination. He served as the President of European Association of Clinical Anatomy for many years and also as the President of the International Society of Plastination for a long time. He was always involved in building bridges between cultures and increasing communication among colleagues from different countries. In 2002 he organized an unforgettable joint meeting of the European and American Associations of Clinical Anatomy in Graz. That meeting was an excellent platform for planning a lot of future projects among anatomists all over the world. The last meeting, he attended was the International Meeting of Clinical Anatomy held in 2018 in Madrid. Although he was very ill, he previously promised me to attend the meeting and he was there. I attached the photo with his students below who learned a lot from him until the last minute.

Good bye my friend!

Figure 1. Andreas Weiglein with his students, 2018, Madrid.

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Occipital emissary foramina in human skulls: review of literature and proposal of a classification scheme of the occipital venous anastomoses in the posterior cranial fossa

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Abstract

Objectives: The present study aims to explain the interesting discrepancy between the occipital emissary foramina and the respective emissary veins in the literature. Majority of the studies report that the foramina have a low and variable frequency, but the emissary veins are reported to be disproportionately present in quite large number of patients in some diagnostic imaging studies.

Methods: Seventy-five adult skulls were examined for the presence of occipital foramina.

Results: A complete occipital emissary foramen was found only in one skull (1.33%), but a number of other skulls also showed some foramina on the external and internal surfaces of squamous part of the occipital bone.

Conclusion: It can be concluded that foramina of another vein which is related to the squamous part of occipital bone, the occipital diploic vein, might be the main reason for the discrepancies present in the literature. The suggested classification scheme of venous anastomoses in the posterior cranial fossa can explain the variable bony foramina observed in skull series.

Keywords: human; occipital emissary foramen; occipital emissary vein; skull; vein anastomoses

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Introduction

In the textbooks of human anatomy there is an interesting discrepancy between one of the skull foramina and the respective structures contained within. According to Terminologia Anatomica,[1] the occipital emissary vein (OEV) is one of the four emissary veins, but the respective occipital emissary foramen (OEF) is not even mentioned in the textbook descriptions of occipital bone and posterior cranial fossa.[2–4] Reviewing the pertinent literature, it seems that this bony foramen in skull series shows low and quite variable frequency.[5–13] Additionally, it is demonstrated with much higher incidence in diagnostic imaging studies.[14,15] With the present study, based on examination of human skulls, and after reviewing the literature, we aimed to explain the discrepancies between the reported incidence of the OEF and OEV, which might help radiologists in diagnosing specific pathologies in the dural sinus system[14,15] and also neurosurgeons performing approaches to the posterior cranial fossa.[16]

Materials and Methods

A total of 75 adult skulls from the bony collection available at the Department of Anatomy, Histology and Embryology of the Medical University of Sofia, Bulgaria were examined. We used, when necessary, the wire probe method for estimation of size of bony foramina as described by Boyd.[5] Most of the skulls belonged to elderly individuals (60–80-year-old). Forty four belonged to females and 31 to males. For this study, all the foramina on both inner and outer surfaces of squamous part of occipital bone and especially around the midline were recorded and analyzed. A descriptive statistical approach was used to represent the data in terms of frequency (%).

Results

A complete OEF was found only in 1 skull belonging to a female, that makes the incidence of OEF as 2.27% for female skulls and 1.33% for the total skulls in our series. The foramen (**Figures 1a** and **b**) allowed a wire probe of 1.5 mm to pass completely through. Externally, its opening was located just on the left side of the external occipital crest at a distance of 9 mm from the border of foramen magnum. The inner aperture was in the posterior cranial fossa, slightly to the left of the midline and within the splitting formed by the lower end of the internal occipital crest. In a number of other skulls, the description of occipital foramina was more complicated (**Figures 2a–d**). In some cases, there were only visible openings from outside (6 skulls, 8%) or inside (12 skulls, 16%) of the squamous part of occipital bone, or both inner and outer openings were presented (10 skulls, 13.3%), but not connected and probably belonging to different vessels but the OEV. Passing through all of these aforementioned openings was not possible even with the thinnest wire probe. In most of the cases, the external occipital foramina (EOF) were grouped around the external occipital crest below the level of inferior nuchal line (**Figure 2a**). They were rarely found around the external occipital protuberance and even once found much higher in the midline of the upper part of the squamous part of the occipital bone (**Figure 2b**). The internal occipital foramina (IOF) (**Figures 2c** and **d**) were identified most commonly on the internal occipital protuberance or on the triangular extension of the internal occipital crest. In 42 of the skulls of our series (15 male and 27 female skulls) no foramina were identified on either the inner or outer surface of the squamous part of occipital bone. Some bony lytic defects were observed in 4 of the skulls (5.33%). The data collected from our skull series are summarized in **Table 1**.

Discussion

Some of the skull bones contain small perforating foramina especially for the emissary veins, which connect the dural venous sinuses with the extracranial veins.[2–4] Four main emissary veins are usually described in Terminologia Anatomica,[1] including parietal emissary, mastoid emissary, condylar emissary and occipital emissary veins.

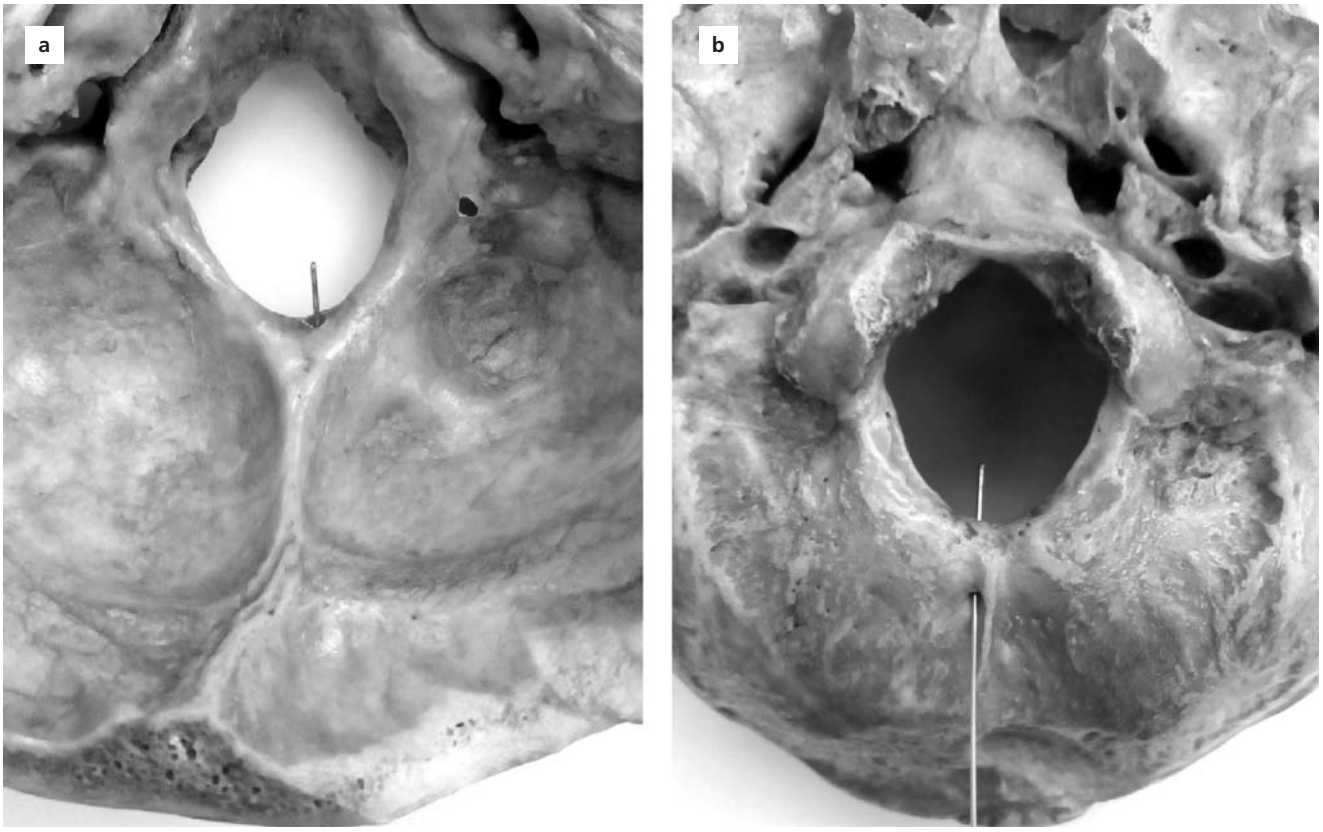

Figure 1. Photographs of a complete OEF with the wire probe showing the inner (**a**) and outer (**b**) openings. **OEF:** occipital emissary foramen.

Bearing in mind the morphology of the common (despite not always present) parietal and mastoid foramina and condylar emissary canal, the "emissary foramen" (or canal) should be a complete passage through the skull bone that contains a short anastomosing (emissary) vein between a dural venous sinus and an extracranial vein.

Our examinations revealed that the OEF showed a low incidence and had specific morphology. We observed that OEF is usually a single direct bony passage around the midline and close to the border of foramen magnum. One of the studies describing the lowest frequency of OEF also in a series of Bulgarian skulls was published by Kadanoff and Mutafov.[6] In this extensive study on 5000 skulls, the foramen was found only twice (0.04%) and it was called "foramen occipitale accessorium". In some other studies, the incidence of OEF was reported as 0.46% (1/214),[7] 1.6% (24/1500),[5] 2% (7/338),[8] 2.6% (8/300).[9] There are also papers describing higher incidence of complete OEF in skull series – 9.5% (21/221),[13] 14% (21/150),[10] and 14.1% (11/78).[12] If we consider higher incidence of this foramen in Indian and Bangladeshi populations,[10,12,13] then a very low frequency (0.46%) in the Indian population was also reported by Sharma et al.[7]

In a study of 100 dry skulls and 100 dissected cadaveric heads, Louis et al.[11] reported OEF in 11% (22/200), as the number of emissary foramina varied between one and three. However,the study revealed some limitations. The authors didn't demonstrate a complete emissary foramen by passing of a wire probe through the occipital bone, as reported in other skull studies.[8,9,12,13] Probably, in this study, the percentage of complete emissary foramina was increased by counting all identifiable foramina on the external surface of the occipital bone (in dry skulls) and the foramina through which a vein passes to join the occipital vein (in cadaveric heads).

The location and the route of these bony foramina were explained in some earlier studies. In a corrosion cast study describing the craniocervical venous system and the venous anastomoses in the posterior cranial fossa, OEV was found in 8.3%.[17] It was observed that the OEV was connecting confluence of sinuses (torcula) with an occipi-

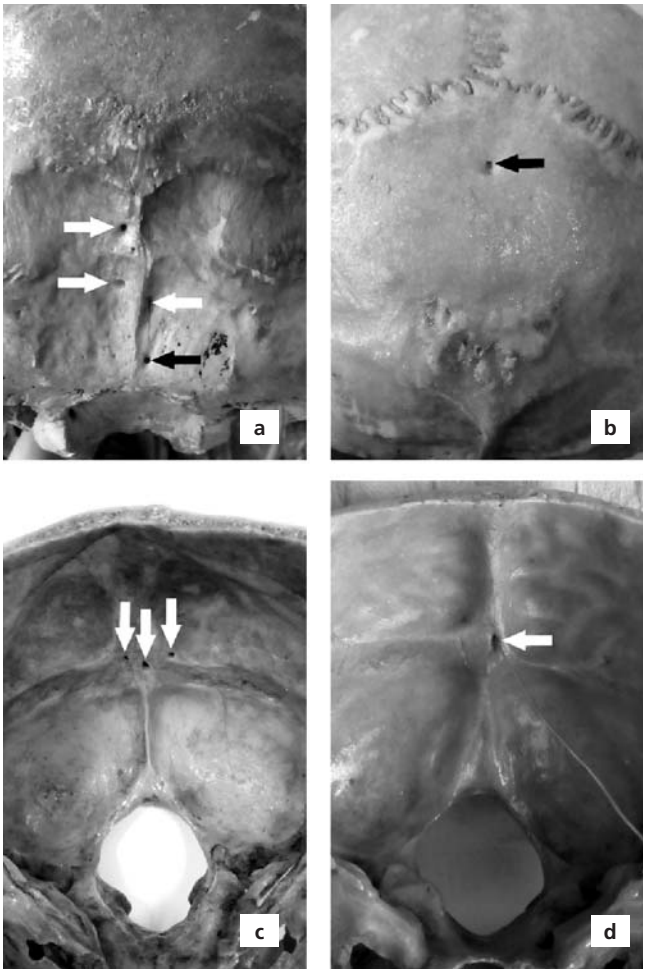

Figure 2. Photographs of the external (**a**,**b**) and internal (**c**,**d**) occipital foramina. (**a**) The foramina were grouped around the external occipital crest; (**b**) an external foramen in the midline in the upper squamous part of occipital bone is shown; (**c**) three foramina on the internal occipital protuberance are demonstrated; (**d**) single internal foramen.

Table 1
Data on 75 human skulls.

	Male skulls		Female skulls		Total skulls	
Bony findings	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
Complete OEF	0	0	1	2.27%	1	1.33%
EOF	3	9.68%	3	6.82%	6	8.00%
IOF	5	16.13%	7	15.91%	12	16.00%
EOF+IOF	6	19.35%	4	9.09%	10	13.33%
Bony lytic defects	2	6.45%	2	4.55%	4	5.33%
None	15	48.39%	27	61.36%	42	56.00%

EOF: external occipital foramen; **IOF:** internal occipital foramen; **OEF:** occipital emissary foramen.

tal vein, but the precise passage through the squamous part of occipital bone was not described because all the soft tissues and bones were already dissolved.

In a MRI study on axial images, Cakmak et al.[14] reported the OEV in 28% of the cases examined. In another imaging study on subtracted CT venography and contrast enhanced MRI, Hedjoudje et al.[15] examined the OEV and reported its presence in 65.2% of the patients with increased pressure in the transverse sinus system versus 31.5% of the patients without pressure signs. Interestingly, however, the whole study is based on an identifiable occipital anastomosing vein connecting the confluence of sinuses or distal part of the superior sagittal sinus with the occipital vein. This anastomosing vein was descending intraosseously for several centimeters within the squamous part of occipital bone. The exit point of the OEV was described between the external occipital protuberance and the foramen magnum, as multiple foramina were also found in 3.2%.

The development of the OEV in human embryos was mentioned in a study by Okudera et al.,[18] and it was noted that this vein appeared occasionally from the confluence of sinuses and penetrating the occipital bone as it passes below the external occipital protuberance to join the suboccipital veins.

One of the main reasons for the discrepancies in the reported incidence of the OEF and OEV might be simply the descriptions of some bony openings for another venous systems but the emissary vein system. Basically, the OEV should connect a dural venous sinus with an extracranial vein, however, another vein is also drained here, and that is the occipital diploic vein.[2–4] In anatomy textbooks, the occipital diploic vein is described as the largest one that drains internally to the transverse sinus or confluence of sinuses or externally to the occipital vein.[2–4] Bearing in mind the great variability of the veins in the human body and lack of valves in the emissary veins,[2,3] we can speculate that actually we have three venous systems anastomosing here, including dural venous sinuses, occipital diploic vein and the extracranial occipital vein, that makes possible several variant venous patterns to exist among individuals (**Figures 3a–d**). Most importantly, the variant venous patterns will be reflecting the variable patterns of the occipital foramina on the surface of the occipital bone and will explain the direct (through the emissary vein) and indirect (through the diploic vein) connections between the dural venous sinuses and the occipital vein.

Conclusion

In conclusion, we can identify some kind of misunderstanding between the anatomical and clinical descriptions of the OEF and OEV. From anatomical point of view, if we refer to the proposed classification system (**Figure 3d**), an OEV should rarely found having a short course andmaking a direct anastomosis through a complete OEF, which connects a dural sinus with an extracranial vein. In the imaging studies, however, even a longer intraosseous anastomosis is called as OEV,[15] although it should be

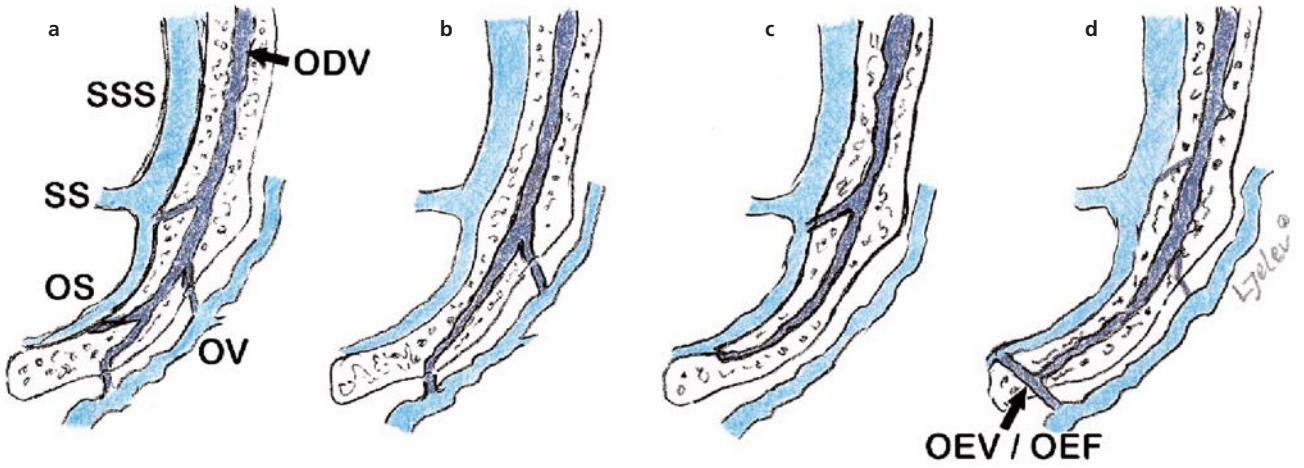

Figure 3. Classification scheme of the variable anastomoses between the dural venous sinuses, occipital diploic vein and extracranial occipital vein. In (**a**) the diploic vein is drained to both dural sinus and occipital vein; in our series corresponding IOF+EOF were found in 13.3% of the skulls. In (**b**) the occipital diploic vein drains only to the occipital vein through EOF (8%). In (**c**) the draining of the occipital diploic vein is only toward dural sinuses through IOF (16%). The short direct anastomosis in (**d**) is the OEV passing through OEF (1.3%). **ODV:** occipital diploic vein; **OEV:** occipital emissary vein; **OS:** occipital sinus; **OV:** occipital vein; **SS:** straight sinus; **SSS:** superior sagittal sinus.

described as an anastomosing venous channel along the occipital diploic vein. Any incomplete foramina on the midline of the inner or outer surfaces of the squamous part of occipital bone (**Figures 3a–c**) are most probably for the occipital diploic veins draining to the dural sinuses or extracranial occipital vein.

Author Contributions

All authors equally contributed.

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Morphologic and morphometric analysis of mandibular lingula

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Abstract

Objectives: The aim of this study was to determine the morphology and location of mandibular lingula in relation to the surrounding structures in adult mandibles to provide data that can be used during oral and maxillofacial procedures.

Methods: This study was performed on 50 dry adult mandibles of Turkish population. The shape of the lingula was examined bilaterally and classified into four types. Osteometric measurements were performed on both sides using a digital caliper. Statistical analysis was performed to determine the differences between right and left side measurements.

Results: The most frequently encountered shape of lingula was triangular type (42%). The assimilated type was not observed among the mandibles studied. The mean distance between the lingula and the anterior border of the ramus of the mandible and between the lingula and the posterior border of the ramus of the mandible was measured as 16.86±2.73 mm and 14.7±1.6 mm, respectively. The mean height of the lingula was measured as 11.92±2.03 mm. No statistically significant differences were observed between the right and left side measurements for any parameters.

Conclusion: The findings of present study may be used for various oral and maxillofacial surgical procedures and help surgeons in avoiding inferior alveolar nerve injury during mandibular osteotomies.

Keywords: inferior alveolar nerve; injury; lingula of the mandible; mandibular foramen; sagittal split ramus osteotomy

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Introduction

Mandibular lingula (lingula of the mandible) is a remarkable, sharp bony projection located on the medial aspect of the ramus of the mandible to which the sphenomandibular ligament is attached.[1] The lingula forms the orifice of mandibular foramen (MF), also known as inferior alveolar foramen. MF transmits the inferior alveolar neurovascular bundle to the mandibular canal. The inferior alveolar nerve (IAN) provides the sensory innervation of pulps of all mandibular teeth, the lower lip and skin over the chin.

IAN is prone to injury during various surgical interventions of the mandible such as sagittal split ramus osteotomy, post-traumatic reconstruction, tumor resection. These complications may cause psychological and social impairment leading a significant decrease in patients' quality of life.[2] In this regard, the lingula serves as a reliable anatomical landmark for identifying the location of MF to prevent complications related with IAN damage when performing above-mentioned surgeries (**Figure 1**). Furthermore, precise determination of MF is obligatory for surgical treatment of IAN-related neuralgia and inferior alveolar nerve block anesthesia which is essential for most dental procedures in mandible.[3]

This study was presented as an oral presentation at 20th National Anatomy Congress, 27th-31st August 2019, Istanbul, Turkey.

Considering the fact that metric characteristics of mandible vary among ethnic groups, several studies have been performed to better understand the morphology and anthropometric location of lingula on different population.[4–6] Although two studies have attempted to investigate the morphology of lingula using cone beam computed tomography (CBCT) data, there is scant information regarding Turkish population.[7,8]

The aim of this research was to determine the morphology and location of mandibular lingula in relation to surrounding structures in dry adult mandibles of Turkish population for to provide data that can be used during oral and maxillofacial procedures.

Materials and Methods

This study has been performed on 50 dry adult mandibles belonging to Anatolian people of unknown sex and age obtained from the bone collection of Department of Anatomy, Faculty of Medicine, Akdeniz University to determine the different shapes and positions of the lingula. This study was conducted with the permission taken from the local ethics committee of the University (Approval number: 70904504/287).

The shape of the lingula was examined bilaterally and classified into four types including triangular, truncated, nodular and assimilated lingula, as previously reported by Tuli et al.[6] (**Figure 2**).

Osteometric measurements were performed on both sides using a digital caliper with following parameters (**Figure 3**):

- Horizontal distance between the anterior border of ramus of mandible and the anterior rim of mandibular foramen (A),

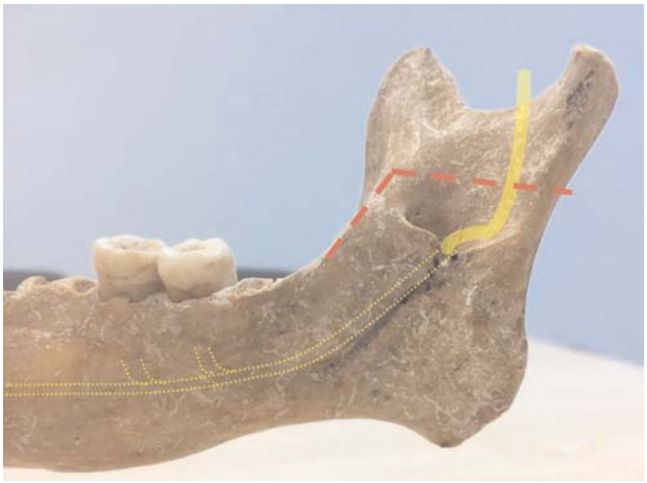

Figure 1. Schematic illustration of the formation of mandibular foramen by lingula and transmission of the inferior alveolar neurovascular bundle (yellow line). Red lines represent the borders of bone cut in sagittal split ramus osteotomy.

- Horizontal distance between the posterior rim of mandibular foramen and the posterior border of ramus of mandible (P),
- Vertical distance between the alveolar socket of second mandibular molar tooth and the superior rim of mandibular foramen (H).

The horizontal distances were measured parallel to the occlusal plane of the molars, whereas the vertical distances were measured perpendicular to the occlusal plane of the molars.

Statistical Analysis

The classification of the lingula shapes was described in numbers and percentages. The data regarding all distances

Figure 2. Different types of lingula; (**a**) triangular, (**b**) nodular, (**c**) truncated.

studied was organized with descriptive statistics such as means, standard deviation (SD) and percentage distributions. The normality of the data was assessed using the Shapiro-Wilk test. The mean values of the right and left sides were compared using t-test (differences were considered significant at $p<0.05$) with the statistics software IBM SPSS Statistics for Windows (Version 22.0,IBM Corp. Armonk, NY, USA, released 2013).

Results

The most frequently encountered shape of lingula was triangular type. The triangular lingula was present totally in 42 sides (42%) and in 14 mandibles (28 sides) it was present bilaterally. The unilateral assessment showed that 9 of triangular lingula occurred on the right side and 5 on the left. The truncated type was found totally in 28 sides (28%) and in 9 mandibles (18 sides) it was present bilaterally. Four of the unilateral truncated lingula were on the right side and 6 on left. The nodular lingula were noticed totally on 30 sides (30%). In 10 mandibles (20 sides) it was bilaterally present. Four of the unilateral nodular lingula were on the right side and 6 the on left. The assimilated type was not observed among the mandibles studied (**Table 1**).

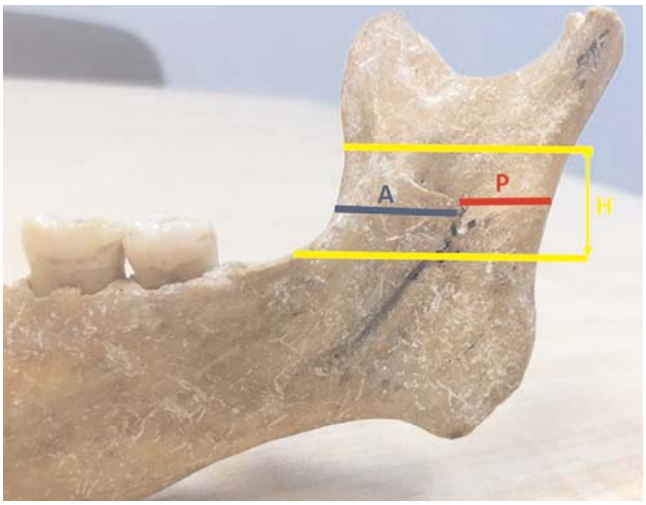

Figure 3. Outline of the points and distances measured on the mandibles.

The height and distance of lingula from anterior and posterior borders of ramus of mandible is shown in **Table 2**. The mean distance between the lingula and the anterior border of ramus of mandible (A) was 16.86±2.73 mm, and it was 16.72±2.57 mm on the right side and 16.99±2.9 mm on the left side. No statistically significant difference was

Table 1

Distribution lingula by shapes and sides.

Shape of lingula	Bilateral	Right side	Left side	Total
Triangular	14 (42.42%)	5 (14.7%)	9 (26.47%)	42 (42%)
Truncated	9 (27.27%)	6 (17.64%)	4 (11.76%)	28 (28%)
Nodular	10 (30.3%)	6 (17.64%)	4 (11.76%)	30 (30%)
Assimilated	0	0	0	0

Table 2

Descriptive data regarding the measurements of the height (H) and distances between anterior (A) and posterior (P) borders of ramus of mandible to lingua.

	n	Min. (mm)	Max. (mm)	Mean±SD (mm)	Shapiro-Wilk test
A-right side	50	11.54	23.8	16.72±2.57	.573
A-left side	50	11.25	25.58	16.99±2.9	.705
A-total	100	11.25	25.58	16.86±2.73	.248
P-right side	50	11.35	17.74	14.85±1.53	.167
P-left side	50	11.35	17.3	14.55±1.67	.073
P-total	100	11.35	17.74	14.7±1.6	.098
H-right side	50	9.89	13.61	11.75±1.86	.31
H-left side	50	10.03	13.95	11.99±1.96	.122
H-total	100	9.89	13.95	11.92±2.03	.271

found between the right and left side measurements regarding A values (p=0.623) (**Table 3**). The mean distance between the lingula and the posterior border of ramus of mandible (P) was 14.7±1.6 mm, and it was 14.85±1.53 mm on the right side and 14.55±1.67 mm on the left side. Similarly, B values did not show significant difference between the right and left sides (p=0.387) (**Table 3**).

The mean height of the lingula (H) was 11.92±2.03 mm and it was 11.75±1.86 mm on the right side and 11.99±1.96 mm on the left side (p=0.542).

Discussion

Lingula is a critical clinical landmark for identification of mandibular foramen from which inferior alveolar neurovascular bundle enters to mandibular canal. It serves as a main reference point for determining osteotomy lines in various orthognathic procedures especially in sagittal split ramus osteotomy to preserve the inferior alveolar nerve.[9,10] A thorough knowledge on the shape and morphometry of the lingula is of great importance for success and safety of the mandibular surgeries and also for inducing inferior alveolar nerve block in various dental treatments involving mandibular teeth.[11] Although a considerable amount of studies have been conducted on lingula anatomy, studies on different populations are still necessary due to the variation of morphological and morphometric properties of lingula among different ethnic groups.

Morphological types of the lingula was first described by Tuli et al. as triangular, nodular, truncated and assimilated.[6] According to their classification, triangular type had a wide base and a narrow rounded or pointed apex, while nodular type was of nodular shape and of variable size. Truncated type had a quadrangular top and assimilated type was completely incorporated into the ramus.

To date, several studies have been performed reporting various distribution and frequency of shapes of lingula across different population and ethnic groups. In a study on 165 dry adult mandibles of Indian origin, Tuli et al.,[6] reported that the most common type was triangular (68.5%), followed by truncated (15.8%) and nodular (10.9%) types and the least was assimilated (4.8%). Similarly, Gupta and Pandey[12] reported that the incidence of triangular lingula was 50% and truncated type was 33.82%, while nodular type lingula was 11.76% and assimilated type was 2.9% in an Indian population. In another study on Indian population, it was reported that 47.67% of lingula had triangular shape, 27.97% were nodular, 13.69% were assimilated and 10.71% were truncated.[13] In a study on a Brazilian population, Lopes et al.[14] found that the triangular shape was the most common and assimilated type the least common variety of shape of the lingula. Another study by Kositbowornchai et al.[5] examined 72 dry adult mandibles of Thai origin and found that the truncated shape was observed as the most common shape (47.2%), followed by the nodular (22.9%), triangular (16.7%) and assimilated shapes (13.2%).

Regarding Turkish population, we were able to find two studies evaluating morphology of lingula using CBCT images. One of these studies included 63 patients and the authors reported that the most frequently encountered shape was the nodular type (32.5%) and the second was the assimilated (26.2%), followed by triangular (22.2%) and truncated (19%) types.[8] They also reported that bilateral shape (76%) was found more often than the unilateral shape (24%).[8] The other study by Sekerci and Sisman,[7] it was reported that the most common shape was the nodular type (51.2%) and the least common was the assimilated type (2.7%) while truncated and triangular varieties were present in 32% and 14.1% of the mandibles, respectively.[7] In accordance with Senel et al.,[8] they found that the bilateral shape (79.4%) was more often than the unilateral one (20.6%). In contrast to Senel et al.[8] and Sekerci and Sisman,[7] the current study revealed that the most common type was triangular type (42%), followed by nodular (30%) and trunculated (28%), while assimilated type was not observed in the mandibles examined.

Morphometric characteristics of lingula have been studied by many researchers by measuring the height and distance of lingula from various mandibular landmarks.

Table 3

Comparison of height of lingula and distance of lingula from anterior and posterior border of the ramus between right and left sides.

Groups	Mean±SD (mm)	SE mean	t	df	Sig. (2-tailed)
A-right & A-left	-.2706±1.65271	.23373	-1.158	49	.253
P-right & P-left	.2924±1.49032	.21076	1.387	49	.172
H-right & H-left	.23512±1.47893	.22745	1.219	49	.311

Jansisyanont et al.[15] examined 92 dried Thai mandibles and reported mean the height of lingula as 8.2±2.3 mm. Another study by Woo et al.[16] on Korean population, the height of the lingula was found to be 10.51±3.84 mm. Furthermore, in one other study on 80 dried adult human mandibles of Indian population, Nicholson et al. reported the height of lingula on right side, 8.6±4.7 mm and left side, 9.1±5.7 mm.[17] In a CBCT study by Sekerci and Sisman on a Turkish population, height of the lingula was measured as 8.03±1.73 mm on the right side and 7.82±1.79 mm on the left side.[7] The height of the lingula in the present study was consistent with previous findings, which was 11.75±1.86 mm on the right side and 11.99±1.96 mm on the left side.

In a study by Samanta et al.,[3] the mean distance of lingula from the anterior border of ramus of mandible was measured as 20±2.4 mm on Indian population. Likewise, Jansisyanont et al.[15] reported the anterior distance of lingula as 20.6±3.5 mm in a Thai population. In another study on Korean population, Woo et al.[16] found the mean anterior distance of lingula as 18.6±2.5 mm, which was similar to Sekerci and Sisman's[7] findings indicating a mean distance of 16.77±2.74 mm in a Turkish population. In the current study, the mean distance from lingula to the anterior border of ramus of mandible was measured as 16.71±1.88 mm on the right side and 16.99±1.94 mm on the left side.

When it comes to posterior localization, Woo et al.[16] reported the mean distance of lingula from the posterior border of ramus of mandible as 16.1±3.5 mm on 20 dry mandibles from a Korean population. In a study on a Thai population, Kositbowornchai et al.[5] found the mean posterior distance of lingula as 15.4±1.9 mm on 72 dry mandibles. In another study on Thai population, Jausisyanont et al.[15] examined 92 dry mandibles and reported that the posterior distance of lingula as 18±2.6 mm. On the Turkish population, Sekerci and Sisman[7] found a distance of 13.02±2.31 mm from the posterior border of the ramus of mandible to the lingula. The distance of lingula from posterior border of ramus of mandible in the present study was consistent with previous findings, which was found to be 14.85±1.25 mm on the right side and 14.55±1.43 mm on the left side.

Conclusion

The present study contributes to current knowledge on morphologic and morphometric characteristics of the mandibular lingula in a Turkish population. The most common shape encountered in this study was triangular lingula. The mean height of the lingula was 11.9 mm. The lingula was located at a mean of 16.9 mm from the anterior border of the ramus of the mandible, and 14.7 mm from the posterior border of the ramus of thebmandible. The findings of present study may be useful for various oral and maxillofacial surgical procedures and help surgeons in avoiding inferior alveolar nerve injury during mandibular osteotomies.

Author Contributions

ÖÖ, EÇ, MS and AS: project planning. HS, BB, SÖ, MSD and MBG: data collection. ÖÖ, HS, BB and AS: data analysis. ÖÖ, EÇ, MS and AS: interpretation of the results. ÖÖ, HS, BB, SÖ, MSD and MBG: writing manuscript. EÇ, MS and AS: final check of the manuscript.

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Pulmonary trunk to ascending aorta ratio and reference values for diameters of pulmonary arteries and main bronchi in healthy adults

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Abstract

Objectives: The ratio of the diameter of pulmonary trunk (PT) to the diameter of the ascending aorta (AA) is used to evaluate cardiopulmonary diseases. Different values have been reported for the normal value of PT:AA ratio (to be less than 0.9, 1 or 1.4). In this study, we aimed to investigate the diameters of the PT, right (RPA) and left pulmonary artery (LPA), AA, right (RMB) and left main bronchus LMB) using multidetector computed tomography (MDCT) and to determine reference values for PT:AA according to age and sex in normal healthy adults.

Methods: Thoracic CT images of 200 individuals, (103 males, 97 females; age 18–89 years), without cardiopulmonary pathology and surgery, were retrospectively evaluated using MDCT. Diameters of PT, RPA, LPA, AA were measured at the level of the pulmonary artery bifurcationand PT:AA ratio was calculated.

Results: The mean diameters of PT, AA, RPA, LPA, RMB, LMB were found as 2.7±0.51 cm, 3.25±0.63 cm, 1.98±0.46 cm, 1.81±0.43 cm, 1.73±0.35 cm, and 1.66±0.55 cm, respectively. The mean value of PT:AA ratio was 0.84±0.18 cm in males and 0.86±0.13 cm in females. .

Conclusion: Determining the normal values of related measurements will contribute to diagnosis and treatment of cardiopulmonary diseases.

Keywords: ascending aorta; MDCT; pulmonary trunk

Anatomy 2020;14(1):22–28

Introduction

The aorta is the main artery in the human body. Originating from the left ventricle of the heart, it is divided into the ascending aorta (AA), aortic arch, and descending aorta.[1]

Pulmonary trunk (PT) carries venous blood from the right ventricle of the heart to the lungs.[2] PT runs upwards on the left side of the AA and bifurcates into the right and left pulmonary artery (RPA, LPA) beneath the aortic arch and anterior to the left main bronchus (LMB).[1] The RPA passes horizontally to the right being posterior to the AA and superior vena cava and inferior to the carina. The LPA runs inferiorly and posteriorly before leaving the pericardium under the aortic arch.[3] At the hilum, the RPA is located superior and posterior to the right main bronchus (RMB) and superior pulmonary vein. When the LPA enters the hilum, the superior pulmonary vein is at its anterior and the LMB at its posterior side.[1]

The ratio of the diameter of the PT to the diameter of the AA, referred as PT:AA ratio, is used to evaluate cardiopulmonary diseases. It is a useful indicator for to determine diseases with pulmonary artery enlargement; espe-

This study was presented as an oral presentation at the IV International Academic Research Congress, October 30 – November 3, 2018, Antalya, Turkey.

cially for diagnosis of pulmonary arterial hypertension (PAH) and estimation of frequent exacerbations of chronic obstructive pulmonary disease (COPD).[4,5] In addition, PT:AA ratio can be a predictive of underlying diseases, as well as may serve as an indicator for prognosis of the patient.[6] The normal value of PT:AA ratio have been reported in a wide range in recent studies (as less than 0.9, 1 or 1.4).[4,5,7–10]

The trachea bifurcates into RMB and LMB at the level of the fourth thoracic vertebra.[2] Knowing the exact localization of this bifurcation is important for anesthesiologists and thoracic surgeons.[11] Detailed knowledge of the morphology of the tracheobronchial tree, particularly knowing the diameters of the bronchi, helps to optimize surgical procedures such as intubation, reconstruction of the airway tree, and improving medical equipments such as double-lumen endobronchial tube.[12] The normal reference value of morphometric variables differ among various population groups and sometimes even among various ethnic groups within the same population.[11]

In this study, we aimed to investigate the diameters of PT, RPA, LPA, AA, RPB, LPB using multidetector computed tomography (MDCT) and additionally to determine normal reference values for PT:AA ratio in healthy adults according to age and sex. We believe that these measurements will be used as decisive data for possible lung diseases.

Materials and Methods

Thoracic CT images of 200 adults (103 males, 97 females, min age: 18, max age: 89) without any cardiopulmonary pathologies and recent surgeries at thoracic region were retrospectively evaluated with MDCT. The past medical history revealed that MDCT was requested from these patients with a preliminary diagnosis of pulmonary nodule. Patients were divided into three groups according to age by taking the most-frequently-seen/onset age of lung diseases into account as 40[13] and geriatric age as 60 (we consider people over 60 years as older adults, as advocated by the World Health Organization) Accordingly those between the ages of 18–39 were determined as Group 1, 20–40 as Group 2, more than 61 as Group 3 (**Table 1**).

Scans were performed with a 256-slice multidetector computed tomographic scanner (Siemens Somatom Flash, Erlangen, Germany). Imaging parameters were as follows: Kv = 120; mA = 160; rotation time = 0.5 s; collimation = 64 × 0.625; FOV = 220 mm. Images were analyzed retrospectively on a workstation by the same radiologist (Snygo Via, Siemens, Munich, Germany). This single-center retrospective study was approved by the local institutional review board with a waiver of the requirement for written, informed consent. Ethical approval was obtained from the Non-Intervention Clinical Research Ethics Committee of Medical Faculty (approval number 2018/128).

Table 1
Distribution of individuals by age and gender.

	Age groups			
	Group 1 (18–39)	Group 2 (40–60)	Group 3 (≥61)	Total
Females	30	26	41	97
Males	26	38	39	103

The PT and AA were evaluated on axial sections at the level of the bifurcation point of pulmonary arteries (ideally where both the RPA and LPA appear). Diameters of PT and AA were measured where they have the widest diameter (**Figures 1** and **2**). They usually had their widest diameter on the axial section which was close to the bifurcation of PT.[5,6,14–17] PT:AA ratio was calculated relying on these measurements.

The diameters of RPA and LPA were evaluated on axial sections taken at the level of the bifurcation of pulmonary arteries (**Figure 3**).[18]

The maximum distance between the lateral and medial walls of the RMB and LMB was measured on the coronal sections obtained close to carina (**Figure 4**).[11]

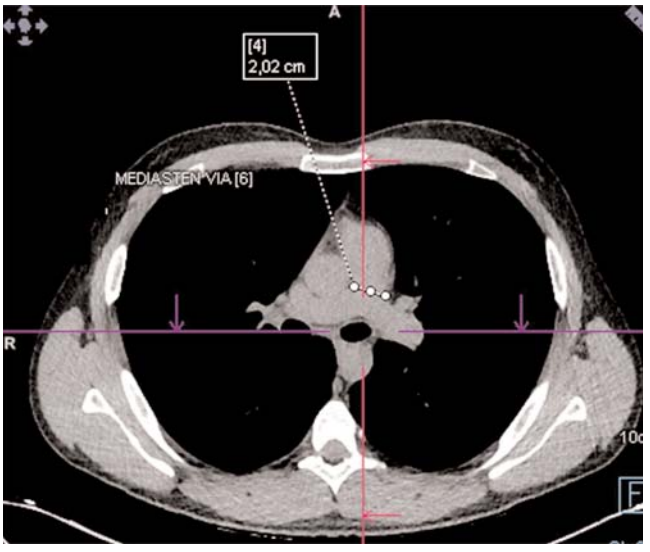

Figure 1. Measurement of PT diameter (axial section).

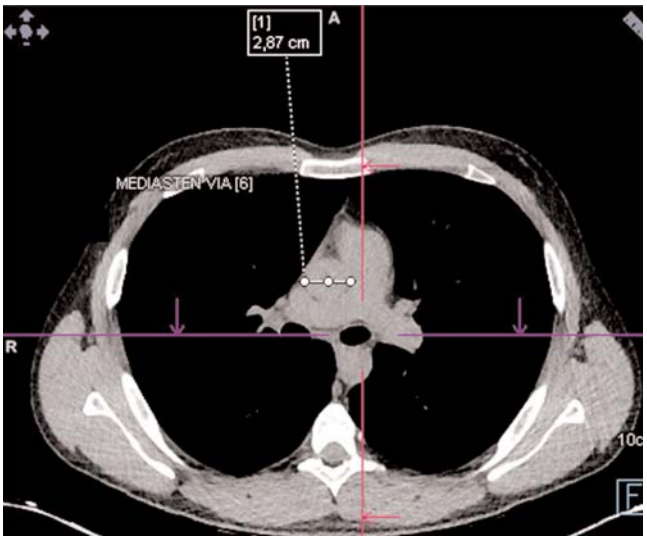

Figure 2. Measurement of AA diameter (axial section).

Figure 3. Diameters of RPA and LPA (axial section).

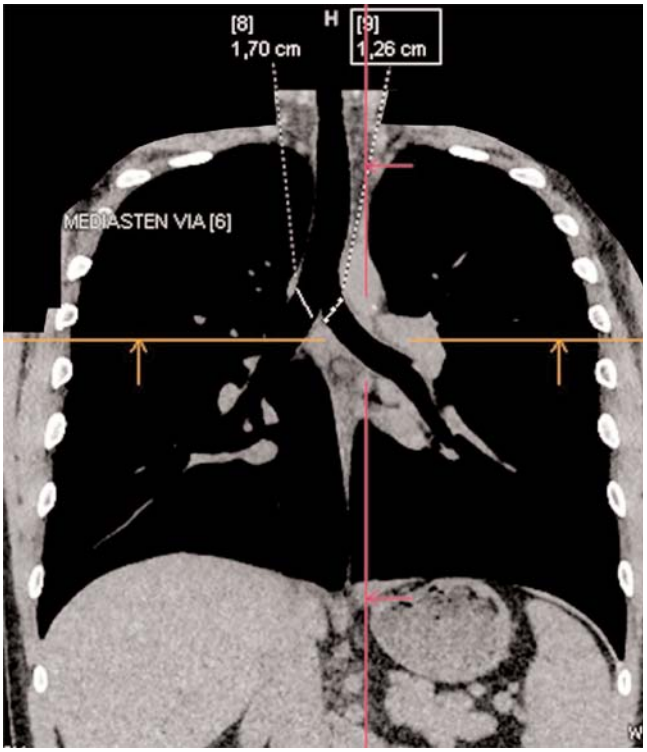

Figure 4. Diameters of RMB and LMB (coronal section).

All statistics were carried out using SPSS Statistics for Windows (Version 22, Chicago, IL, USA). Normality and homogeneity of variances were checked from the parametric test assumptions before applying the one-way ANOVA and independent samples t-test. The data were expressed as mean±standard deviation (SD), minimum and maximum values. One-way ANOVA was used to compare the significance between different groups; $p<0.05$ was considered statistically significant.

Results

The diameters of PT, AA and LPA were significantly larger in Group 3 compared to the other two groups ($p<0.05$). There was no statistically significant difference between Group 1 and 2 ($p>0.05$). The PT:AA ratio was higher in Group 1 compared to Group 2 ($p<0.05$).

The mean value of PT:AA ratio was 0.84±0.18 cm in males and 0.86±0.13 cm in females. This value was minimum 0.44 cm, maximum 1.41 cm among all individuals. The mean PT:AA ratio was significantly higher in Group 1 when compared to Group 2 ($p<0.05$). The mean PT:AA ratio of Group 3 was not statistically significant when compared to the other two groups ($p>0.05$).

The diameter of RPA was significantly larger in Group 3 than Group 1 ($p<0.05$). The mean diameter of RPA in Group 2 showed no statistically significant difference compared to the other two groups ($p>0.05$).

When RMB and LMB diameters were compared according to age groups, the mean differences between groups were not statistically significant ($p>0.05$) (**Table 2**).

The PT:AA ratio was found to be 0.84±0.18 cm and 0.86±0.13 cm in males and females, respectively. When PT, AA, LPA diameters and PT:AA ratio were compared according to gender, the mean differences between groups were not statistically significant ($p>0.05$). However, RPA,

Table 2

The minimum, maximum and mean diameters of PT, AA, RPA, LPA, RMB, LMB and PT:AA ratio in healthy adults according to age.

Diameters	Min-Max (cm)			Mean±SD (cm)		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
PT	1.32–4.07	1.56–3.74	1.87–4.2	2.58±0.52	2.53±0.46	2.92±0.47
AA	1.52–4.25	1.89–4.45	2.39–4.85	2.93±0.64	3.15± 0.49	3.4 ±0.46
PT:AA	0.57–1.41	0.44–1.24	0.6–1.4	0.9±0.18	0.81±0.15	0.85±0.14
RPA	0.71–2.62	1.35–2.7	1.16–3.56	1.8±0.44	1.92±0.34	2.15±0.48
LPA	0.83–2.54	0.91–2.61	1.15–3.1	1.7±0.4	1.67±0.37	1.99±0.43
RMB	0.87–2.37	1.17–2.27	1.01–2.57	1.73±0.29	1.68±0.28	1.73±0.3
LMB	0.77–2.49	1.11–2.4	0.91–2.3	1.55±0.34	1.63±0.28	1.65±0.26

AA: ascending aorta; **LMB:** left main bronchus; **LPA:** left pulmonary artery; **PT:** pulmonary trunk; **RMB:** right main bronchus; **RPA:** right pulmonary artery.

RMB and LMB diameters were significantly higher in males than females ($p<0.05$) (**Table 3**).

Discussion

Pulmonary arterial hypertension is characterized with increased pulmonary vascular resistance and may lead to right heart failure and eventually to death. Increase in pulmonary vascular resistance resulting in higher pulmonary artery pressure and vessel wall tension causes enlargement of the PT.[19]

Enlargement of the PT is frequently recognized in patients with severe PAH. It has also been reported that there is an association between defective pulmonary activity and arterial diameter, especially with respect to the PT rather than the aorta.[6] A dilated PT may be seen on radiography or echocardiography; however, a CT or magnetic resonance imaging of the chest enables more correct measurements.[20] CT is a non-invasive method which can be employed for assessing both intrinsic pulmonary and intrathoracic vascular diseases.[21,22] Chest and cardiac CT have become more widely accessible and they are frequently ordered for diagnosing pulmonary, cardiac and vascular diseases in clinical practice.[23]

COPD is a highly prevalent dysfunction and an important cause of mortality worldwide. It is characterized by progressive, permanent airway obstruction which is associated with a chronic inflammatory course in the airways and pulmonary parenchyma. PAH occurs in serious COPD cases due to various reasons, such as hypoxic vasoconstriction, pulmonary hyperinflation with increased intrathoracic pressure, or loss of pulmonary vascular capacity due to parenchymal devastating.[21]

The PT enlargement is simply measured noninvasively and is due to a variety of conditions, including PAH.[20] The PT:AA ratio is used as a tool to evaluate the dilatation of the pulmonary arterial segments since dilation is not

Table 3

The minimum, maximum and mean diameters of PT, AA, RPA, LPA, RMB, LMB and PT:AA ratio in healthy adult according to gender.

Diameters	Min-Max (cm)		Mean±SD (cm)	
	Females	Males	Females	Males
PT	1.32–4.2	1.56–4.19	2.68±0.53	2.72±0.5
AA	1.52–4.85	1.91–4.75	3.16±0.61	3.28±0.53
PT:AA	0.62–1.16	0.44–1.41	0.86±0.13	0.84±0.18
RPA	0.71–3.2	1.06–3.56	1.91±0.46	2.04±0.44
LPA	0.83–3.1	0.91–2.87	1.81±0.46	1.8±0.39
RMB	0.87–2.57	1.18–2.55	1.61±0.28	1.81±0.26
LMB	0.77–2.27	1.03–2.49	1.49±0.25	1.74±0.28

AA: ascending aorta; **LMB:** left main bronchus; **LPA:** left pulmonary artery; **PT:** pulmonary trunk; **RMB:** right main bronchus; **RPA:** right pulmonary artery.

Table 4
Comparison of PT and AA diameters and PT:AA ratio with previously published studies.

Method		Population	Age range (year)	PT			AA			PT:AA		
MRI	Pellicori et al.[14]			Range: 2.51–2.88 cm			Range: 3.39–3.43 cm			Mean: 0.9		
				Females (cm)	Males (cm)	Mean (cm)	Females (cm)	Males (cm)	Mean (cm)	Females	Males	Mean
CT	Edwards et al.[15]		11–90	2.64	2.77	2.72						
	Truong et al.[23]	American	≥18			2.63			3.17			0.84
MDCT	Compton et al.[16]	Canadian	0–18									1.09
	Lee et al.[6]	Korean	>20	2.58	2.65	2.59	2.96	3.16	–	0.88	0.85	0.87
	Caro-Dominguez et al.[17]	Canadian	1–17	1.71	1.72	1.71	–	–	–	1.1	1.13	1.11
	Present study	Turkish	18–89	2.68±0.53	2.70±0.5	2.7±0.51	3.16±0.61	3.31±0.63	3.23±0.57	0.86±0.13	0.84±0.18	0.85±0.16

AA: ascending aorta; CT: computed tomography; MDCT: multidetector computed tomography study; MRI: magnetic resonance imaging; PT: pulmonary trunk.

seen in AA although PAH causes selective dilation of the PT and its main branches.[17] Different values have been reported regarding the normal range of PT:AA ratio in various studies (to be less than 0.9, 1 or 1.4).[4,5,7–10] An elevated PT:AA ratio was important since it was associated with an increased risk of all-cause mortality (>0.9).[4] The mean PT:AA ratio was found higher in females than in males for all age groups, but this ratio found to decrease with increasing age in both genders.[6] Our study revelaed the PT:AA ratio in a range of 0.44–1.41 cm, showing significant differences according to age.

In adults, the maximum limit of the PT:AA ratio is assumed to be 1 and if this ratio is more than 1, it is considered to be an indicator of PAH. But this ratio shows differences in the pediatric cases. In a study performed on healthy children under 18 years of age, it was reported that the PT:AA was not affected by sex.[16]

The diameters of PT, AA, LMB, RMB and PT:AA ratio in different populations have been investigated by using different methods (**Tables 4** and **5**). PT diameter found in our study was similar with previous studies.[6,14,15,23] The diameter of PT was significantly higher in male than in female as reported by some previous studies,[6,15] but the results of Caro-Dominguez et al.,[17] and our study showed no statistically significant difference between males and females. When compared with the results of the previous studies,[6,23] the diameter of AA found in our study was found similar. Lee et al.,[6] reported the diameter of AA as significantly higher in males than in females but our study showed no significant difference.[6,14,23] The results of our study revealed that diameters of RMB and LMB were higher than in previous studies.[11,24] These diameters were found higher in male, in both our study and in earlier studies.[11,24] The body mass index, body surface area and lifestyle differences may be the reason of these differences.[6]

Tracheal and bronchial diseases are rare and have a sneaky progress. Serious obstruction findings occur when 75% of trachea or bronchial lumen is blocked. Symptoms

Table 5
Comparison of RMB and LMB diameters with previously published studies.

Method		Population	Age range (year)	RMB			LMB		
				Females (cm)	Males (cm)	Mean (cm)	Females (cm)	Males (cm)	Mean (cm)
Multi-slice spiral CT	Mi et al.[11]	Chinese	18–90	1.23	1.41	1.33	1.13	1.31	1.23
Spiral CT	Kim et al.[24]	Asian	19–80	AP 1.32 TR 1.18	AP 1.53 TR 1.51		AP 1.03 TR 9.9	AP 1.27 TR 1.31	
MDCT	Present study	Turkish	18–89	1.65±0.39	1.71±0.29	1.71±0.2	1.56±0.72	1.74±0.27	1.62±0.3

AP: anteroposterior; CT: computed tomography; LMB: left main bronchus; MDCT: multidetector computed tomography; RMB: right main bronchus; TR: transverse.

may be nonspecific and it may be difficult to diagnose because the findings may be misinterpreted. For this reason, MDCT which is a non-invasive method is often preferred for routine screening and management of the patients.[25,26] Studies on morphometric evaluation of airways are limited. The accumulation of medical or environmental inhalation materials in the lungs makes it necessary to know the normal range of diameters of major airways.[27,28]

We defined a set of normal range of age and gender specific PT, AA, RPA, LPA, LMB, RMB diameters and PT:AA ratio by MDCT in 200 healthy adults with no predisposing factors for cardiopulmonary diseases, such as PAH, COPD. We suggest that knowing these parameters can provide physicians to assess current cardiopulmonary status of patients. Reference values of RMB and LMB diameters can especially be valuable to radiologists, anesthesiologists, otolaryngologists and thoracic surgeons. Knowledge of diameters of LMB and RMB is important for interpreting situations such as recurrent infections, hemoptysis and malignancy and for applying procedures such as bronchoscopy.

Conclusion

Due to the anatomically complicated shape and axis of the PT and its branches, measurements of the PT at various positions may be dissonant and misleading to accurately predict PAH or COPD exacerbation. Therefore, knowing the diameters of the PT and its branches may be useful for following-up the patients with PAH and COPD.

Author Contributions

BP: project development, data collection, data analysis, writing text, ZF: project development, data analysis, final check of the manuscript, MK: data collection, data analysis, AKK: final check of the manuscript, NUD: final check of the manuscript.

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Evaluation of sternal morphology according to age and sex with multidetector computerized tomography

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Abstract

Objectives: The sternum is located in the middle of the anterior wall of the thoracic cage. It consists of three parts; manubrium, body (corpus) and xiphoid process. Since it is an easy bone to scan, it can be used for age and sex determination in forensic medicine. The aim of the study was to investigate the characteristics of the sternum according to age and gender.

Methods: This study was performed retrospectively on 700 CT images. 3D volume rendering images of sternum were created from the axial CT images at a 1 mm slice thickness.

Results: There were significant differences in sternum measurements according to age and sex. The xiphoid process was identified under three different types. Ossification between the manubrium and sternum body showed significant differences according to age and sex.

Conclusion: Data collected from a single bone is important for age and sex prediction especially in forensic medicine. These data taken from a large series may also contribute to evaluation of variations in sternal morphology.

Keywords: anatomy; multidetector computerized tomography; morphology; sternum

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Introduction

The sternum originates from a pair of vertical mesenchymal bands that develop ventrolaterally on the anterior wall of the body. These mesenchymal bands are called as sternal bands in which cartilage development occurs in the craniocaudal direction. Then, the cartilage gets ossified to form sternum. The manubrium and the xiphoid process ossifies from a single center whereas the body (mesosternum) from four centers. The ossification centers begin to form in the sixth intrauterine month and the ossification process continues during the first postnatal life. The development of xiphoid process is generally completed between 5–18 years of age.[1] The ossification centers of manubrium and body of sternum grow in the cephalocaudal direction and develop till 12 years of age. The ossification centers in the body of sternum develop in caudocephalic direction and complete between puberty and 25 years of age.[1] Manubriosternal and sternoxiphoid ossification continues in adulthood.[2]

A variety of bones have been explored for gender prediction.[3–5] The sternum is a strong bone that does't deform easily for a long time, therefore it can be used for age and gender prediction.[6] Multidetector computerized tomography (MDCT) imaging method is gold standart to evaluate bone tissue hat easily provides a detailed imaging of the sternum.[7] A through knowledge of the

This study was presented as an oral presentation at 1st International Congress on Sports, Anthropology, Nutrition, Anatomy and Radiology/SANAR2018, 3-5 May 2018, Cappadocia, Nevşehir, Turkey.

Table 1
Distribution of cases by age and gender.

Age	0–9	10–19	20–29	30–39	40–49	50–59	≥60	Total
Female	9	22	32	45	56	46	127	337
Male	16	25	41	53	41	45	142	363

ossification, variations and morphological anatomy of the sternum is not only important for age and sex determination in forensic medicine but also for planning thoracic surgeries and decreasing postoperative complications.[8] The aim of this study, therefore, was to evaluate the sternal morphology according to age and gender using MDCT on a large series to provide substantial data for forensic scientists and thoracic surgeons.

Materials and Methods

This study was conducted with the permission taken from the Selçuk University School of Medicine Non-Interventional Clinical Research Ethics Committee (Approval number: 2017/69).

Thin section MDCT thoracal images of 897 patients were examined between January 2016 and May 2017. These patients had undergone CT imaging because of various reasons but none of them had any previous history of thoracic trauma or surgery. Images of 78 cases were excluded from the study due to interference in the region, and images of 119 cases due to low resolution. Thus, 700 images were included in the study. CT images obtained in an axial plane at a thickness of 1 mm. In addition to axial images, sagittal and coronal reformat images were obtained at the workstation.

The images were grouped according to the gender and age. Accordingly, 7 different age groups were determined as: 0–9 years, 10–19 years, 20–29 years, 30–39 years, 40–49 years, 50–60 years, and ≥60 years (**Table 1**).

The width and length of manubrium and body of sternum and the angle between the manubrium and the body (angle of Louis) were measured on sagittal and coronal images. Variations of the sternum were also examined in all sections.

The measurements were done as follows; Manubrium width (MW): the distance between the midpoint of the right and left first costal notches on coronal images (**Figure 1**); Manubrium length (ML): the distance between the jugular notch and the midpoint of the manubriosternal joint on coronal images (**Figure 1**); Corpus length (CL): the distance between the midpoint of the manubriosternal joint and the midpoint of the symphysis xiphosternal joint on coronal images (**Figure 1**); Corpus width (CW1): the horizontal distance measured between 2nd and 3rd costal notches on the coronal images (**Figure 1**); Corpus width (CW2): the horizontal distance measured between 4th and 5th costal notches on the coronal images (**Figure 1**); Angle of Louis (LA): the angle between the manubrium and the body measured on sagittal images (**Figure 2**).

Xiphoid process was examined under three types according to its shape; Type 1: having two extensions; Type 2: in the form of a single extension; Type 3: having three extensions (**Figure 3**).

The sternum was examined under two types according to the direction of the xiphoid process; Type 1: xiphoid process having the same direction with the body of sternum; Type 2: xiphoid process having a slope towards the ventral direction (**Figure 4**).[7,9]

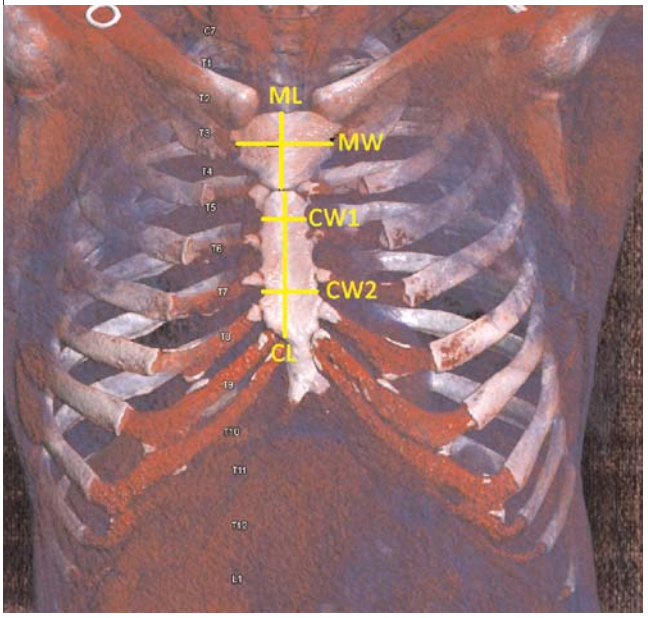

Figure 1. Measurements of the sternum done with multidetector computerized tomography. **CL:** corpus length; **CW1:** corpus width between 2nd and 3rd costal cartilages; **CW2:** corpus width between 3rd and 4th costal cartilages; **ML:** manubrium length; **MW:** manubrium width.

The presence and number of foramen on the xiphoid process and corpus were also determined (**Figure 5**).

The ossification of the sternum was also examined and it is further classified under three types according to the amount of ossification; Type 1: no ossification; Type 2: partial ossification; and Type 3: complete of ossification (Type 3) (**Figure 6**).

The data obtained in the study were analyzed using SPSS (Statistical Package for Social Sciences) for Windows (version 22, Chicago, IL, USA). The data were expressed as number, percentage, mean±standard deviation (SD). The relationship between grouped variables was analyzed by chi-square analysis. The t-test and one-way ANOVA were used to compare the significance between different groups. Scheffe test was used as a complementary post-hoc analysis to determine the differences after the ANOVA test. Pearson correlation analysis was used for determining significant correlations. For all analyses, $p<0.05$ was considered as statistically significant.

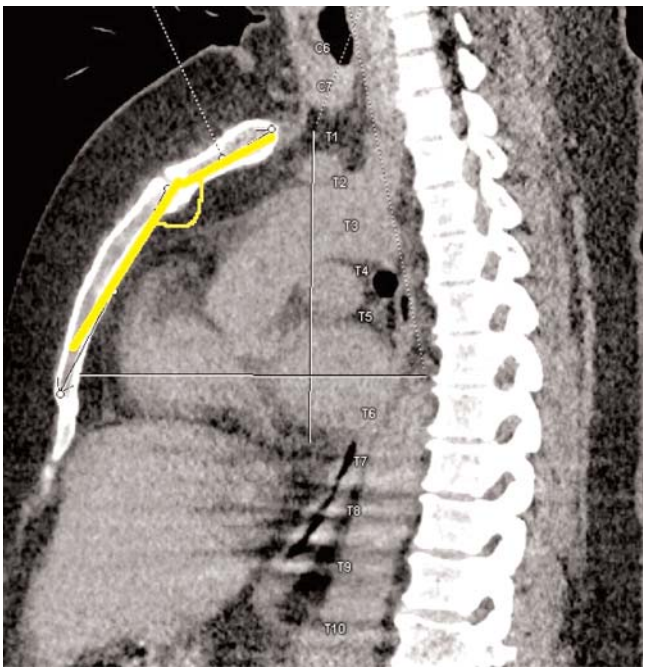

Figure 2. Measurement of angle of Louis with MDCT.

Results

The mean width of the manubrium (MW) was 5.13±0.93 cm. The MW was significantly higher in males (5.32 cm) compared to females (4.92 cm) ($p<0.05$). MW showed significant differences among age groups and genders ($p\leq0.05$). The MW was significantly higher in ≥60 and lower in the 0–9 age group for both genders. The MW was significantly lower in the 0–9 and 10–19 age groups compared to other age groups (**Table 2**).

The mean length of the manubrium (ML) was 4.54±0.73 cm. The ML was significantly higher in males (4.66 cm) than females (4.42 cm) ($p<0.05$). The ML showed significant differences among age group and gender ($p<0.05$). The ML was significantly higher in ≥60 and lower in the 0–9 age group for both genders. The ML was significantly higher in 10–19 age group than the 0–9 age group. The ML values of other age groups were significantly higher than 0–9 and 10–19 age groups (**Table 3**).

The mean length of body of sternum (CL) was found to be 8.91±0.69 cm in males and 8.23 cm in females. The CL was significantly higher in males than females

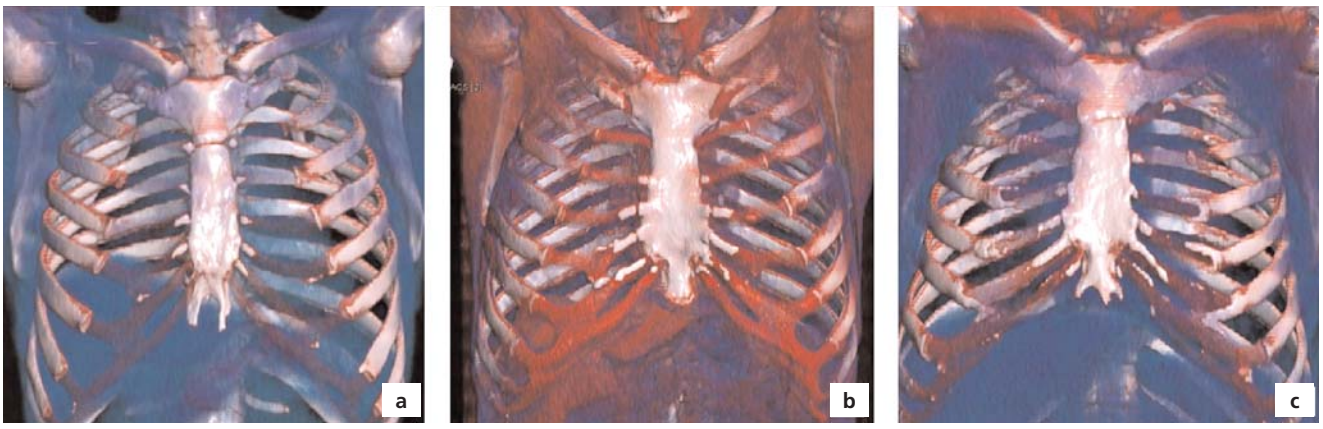

Figure 3. Types of the xiphoid process according to its shape. (**a**) Xiphoid process with 2 extensions (Type 1); (**b**) xiphoid process in the form of a single extension (Type 2); (**c**) xiphoid process with 3 extensions (Type 3).

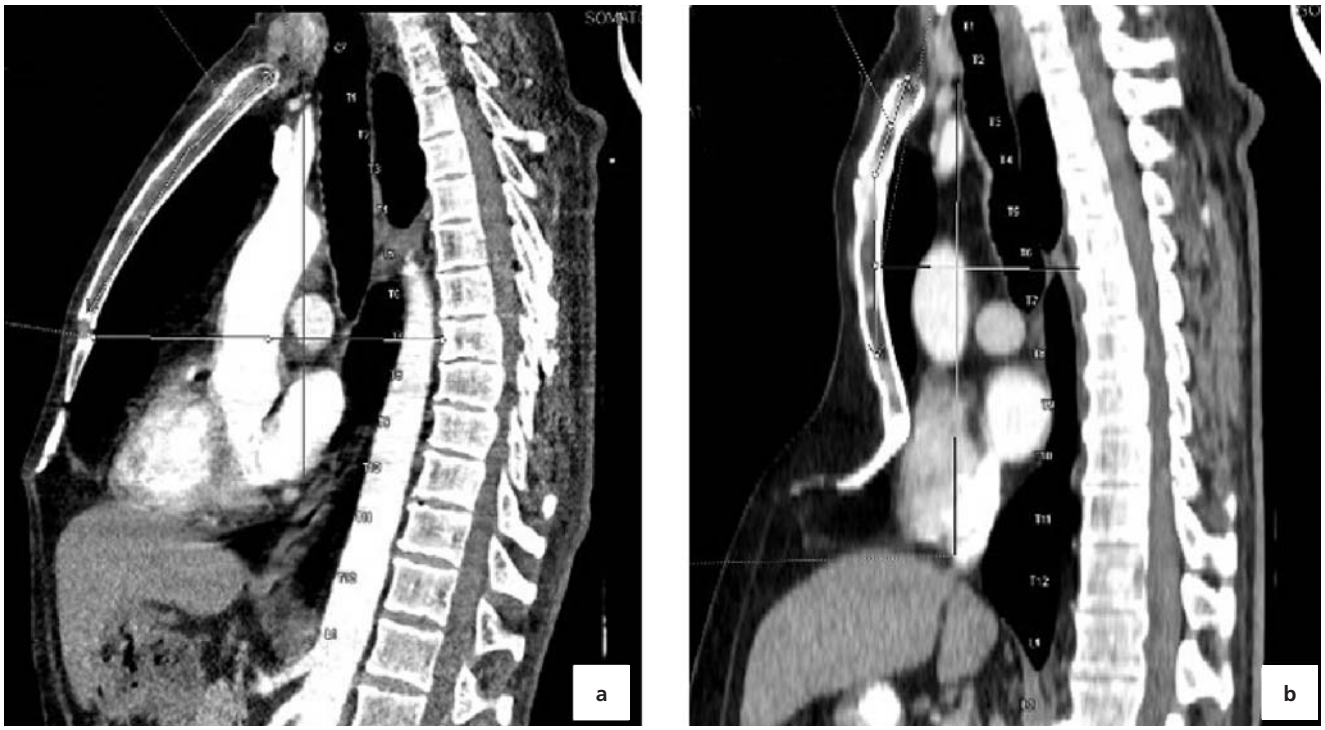

Figure 4. Types of xiphoid process according to its direction. (**a**) Xiphoid process in line with the body of sternum corpus; (**b**) xiphoid process having a slope towards the ventral direction.

(p<0.05). The CL was also significantly higher in ≥60 and lower in the 0–9 age group for both genders (**Table 4**).

The width of the corpus was measured by using two reference lines (CW1 and CW2). The mean CW1 was 2.72±0.58 cm, where as CW2 3.23±0,76 cm. The mean CW1 was significantly higher in males (2.83 cm) than females (2.59 cm) (p<0.05) likewise the CW2 that is 3.47 cm in males and 3.1 in females (p<0.05). The CW1 and

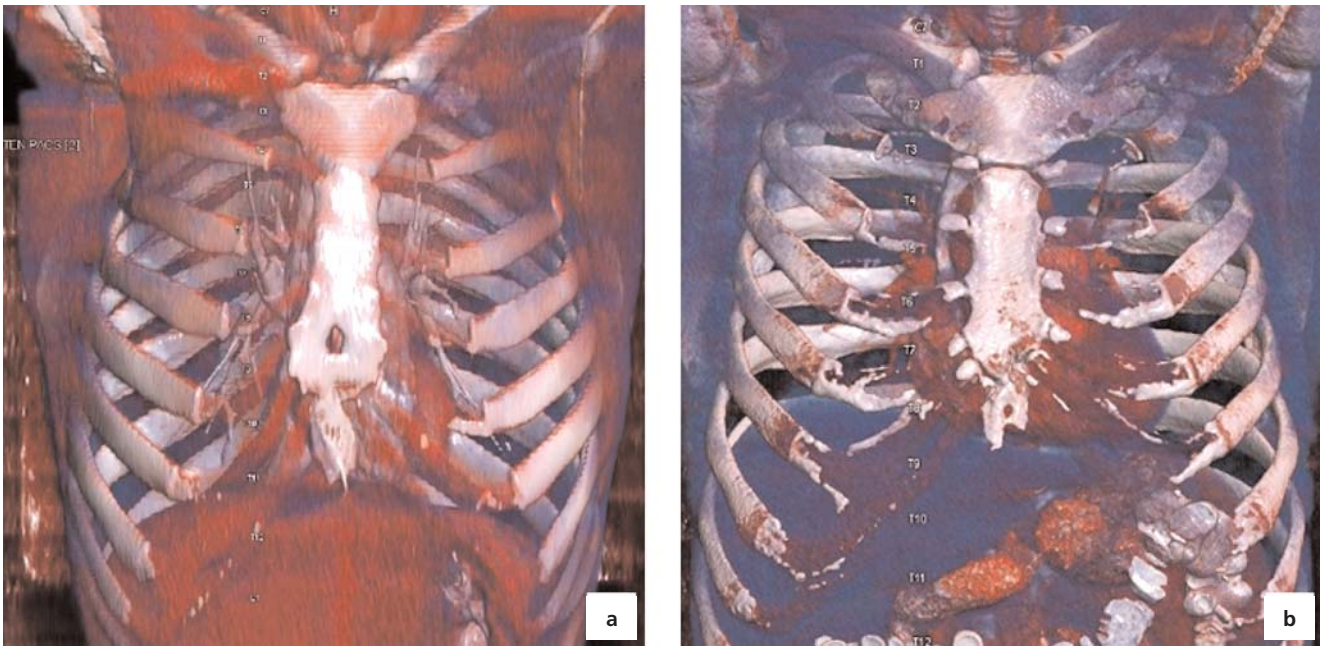

Figure 5. Foramina detected with MDCT (**a**) foramen on body of sternum; (**b**) foramen on the xiphoid process.

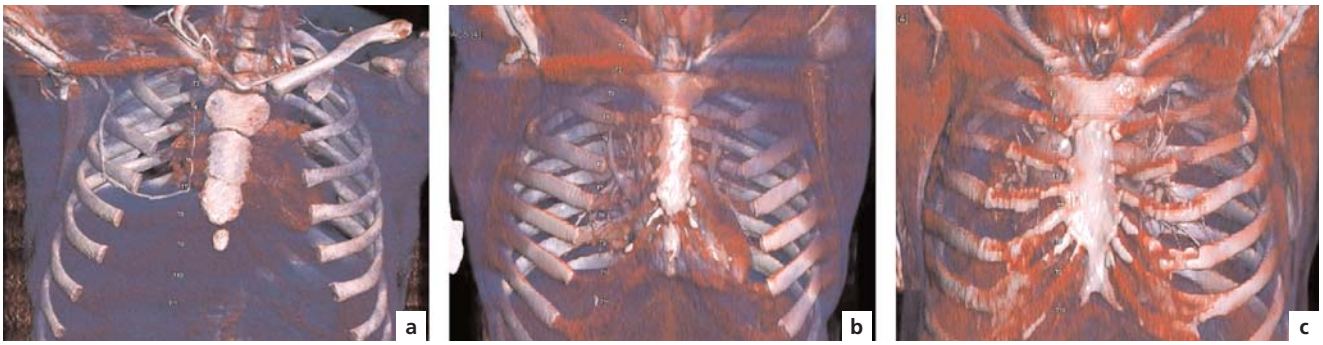

Figure 6. Degree of ossification between the parts of the sternum as detected with MDCT. (**a**) No ossification (Type1); (**b**) partial ossification (Type2); (**c**) complete ossification (Type 3).

Table 2
MW measurements according to age groups.

	Group	Mean±SD	p	Differences according to p-value
MW	0–9	2.68±0.8 cm	0.000	2>1
	10–19	4.78±0.75 cm		3>1
	20–29	5.06±0.74 cm		4>1
	30–39	5.24±0.78 cm		5>1
	40–49	5.19±0.69 cm		6>1
	50–59	5.18±0.82 cm		7>1
	≥60	5.35±0.84 cm		5>2 7>2 7>3

Table 3
ML measurements according to age groups.

	Group	Mean±SD	p	Differences according to p-value
ML	0–9	2.49±0.55 cm	0.000	2>1
	10–19	4.22±0.59 cm		3>1
	20–29	4.6±0.5 cm		4>1
	30–39	4.6±0.6 cm		5>1
	40–49	4.69±0.65 cm		6>1
	50–59	4.56±0.52 cm		7>1
	≥60	4.70±0.65 cm		3>2 4>2 5>2 7>2 5>6

CW2 was significantly higher in ≥60 and lower in the 0–9 age group for both genders. Those in the 10–19 age group had significantly higher CW2 values than the 0–9 age group. CW2 of other age groups was significantly higher than 0–9 and 10–19 age groups ($p<0.05$) (**Tables 5** and **6**).

The angle of Louis (LA) was 158.820. LA showed no statistically significant difference among genders ($p>0.05$). LA was significantly higher in ≥60 and lower in the 0–9

Table 4
CL measurements according to age groups.

	Group	Mean±SD	p	Differences according to p-value
CL	0–9	4.48±1.29 cm	0.000	2>1
	10–19	8.32±1.3 cm		3>1
	20–29	9.12±1.6 cm		4>1
	30–39	9.36±1.28 cm		5>1
	40–49	8.8±1.43 cm		6>1
	50–59	9.13±1.5 cm		7>1
	≥60	9.16±1.47 cm		4>2 7>2

Table 5
CW1 measurements according to age groups.

	Group	Mean±SD	p	Differences according to p-value
CW1	0–9	1.48±0.42 cm	0.000	2>1
	10–19	2.5±0.46 cm		3>1
	20–29	2.6±0.5 cm		4>1
	30–39	2.75±0.5 cm		5>1
	40–49	2.73±0.57 cm		6>1
	50–59	2.75±0.49 cm		7>1
	≥60	2.87±0.54 cm		5>2 7>2 7>3 7>4

Table 6
CW2 measurements according to age groups.

	Group	Mean±SD	p	Differences according to p-value
CW2	0–9	1.59±0.52 cm	0.000	2>1
	10–19	3.03±0.67 cm		3>1
	20–29	3.34±0.59 cm		4>1
	30–39	3.34±0.69 cm		5>1
	40–49	3.39±0.87 cm		6>1
	50–59	3.35±0.65 cm		7>1
	≥60	41±0.65 cm		5>2 7>2 5>4

Table 7
LA measurements according to age groups.

	Group	Mean±SD	p (Females)	p (Males)	Differences according to p-value
LA	0–9	162.49±8.0 cm	0.131	0.000	2>1
	10–19	160.77±5.851 cm			3>1
	20–29	158.7±6.983 cm			4>1
	30–39	158.49±6.736 cm			5>1
	40–49	157.78±7.425 cm			6>1
	50–59	157.43±7.464 cm			7>1
	≥60	156.49±8.0 cm			3>2 5>2 6>2 7>2 5>4

age group for both genders ($p<0.05$). LA of other age groups was significantly higher than 0–9 and 10–19 age groups ($p<0.05$) (Table 7).

Examination of the xiphoid process according to its shape revelaed 335 (48%) cases as Type 1, 316 (43%) as Type 2 and 49 (7%) as the Type 3. The direction of the xiphoid process was in line with the body in 536 (77%) cases and having a slope towards the ventral direction in 164 (24%) cases. At least 1 foramen was observed in xiphoid process in 81 (12%) cases, and in the body of sternum in 36 (5%) cases. Considering the xiphoid process variations, the number of xiphoid processes with a single foramen was 61 (75%), the number of xiphoid processes with two foramina was 15 (18%), and the number of xiphoid processes with more than two foramina was 6 (7%). The number of corpus containing a single foramen was 34, and the number of corpus containing two foramina was 2.

The ossification rates among different groups showed that the highest ossification was present in 30–39 age group, partial ossification was highest in 20–29 age group, and no ossification in 0–9 age group as expected (Figures 7–9).

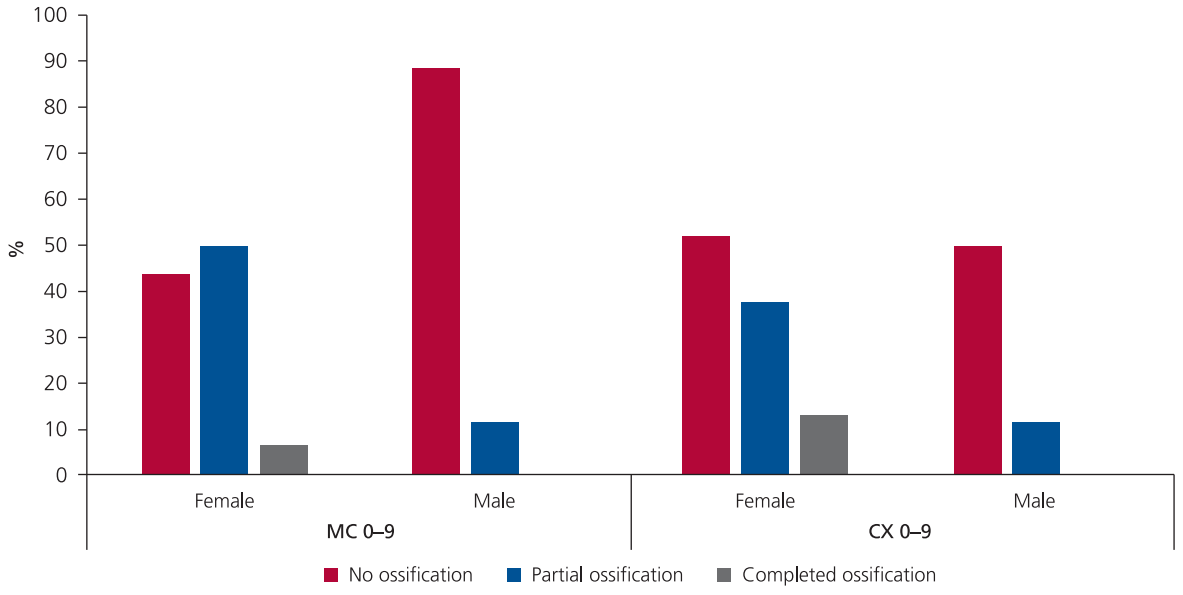

Figure 7. Degree of ossification in the 0–9 age group. **CX:** ossification between body of the sternum and the xiphoid process; **MC:** ossification between manubrium and body of the sternum.

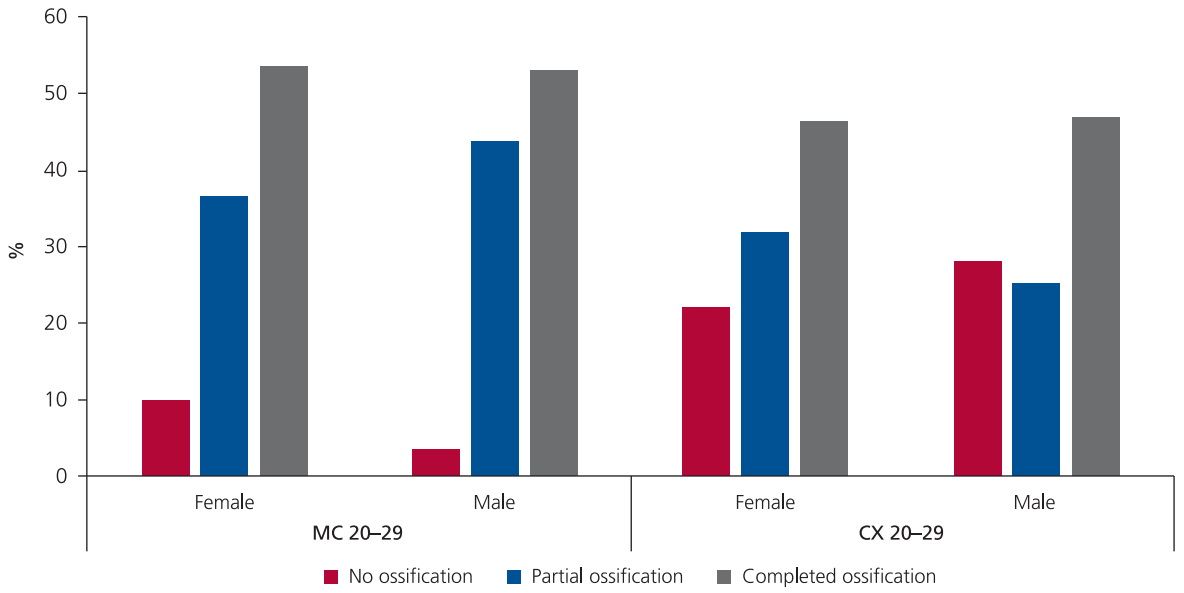

Figure 8. Degree of ossification in the 10–19 age group. **CX:** ossification between body of the sternum and the xiphoid process; **MC:** ossification between manubrium and body of the sternum.

Discussion

Three-dimensional radiological studies are gold standart to understand the anatomy and relations of the bony tissue such as sternum. The MDCT images cover larger anatomical regions and it makes bone measurements very close to real values.[2,10] There are limited number of studies examining the morphology and the variations of sternum with MDCT.[11] So this study relied on measurements taken with MDCT.

Determination of gender from skeleton is of utmost importance in forensic medicine and anthropology.[12] It is challenging to estimate sex and age from bones that have been disintegrated for various reasons. Data collected from a single bone is therefore important for gender predic-

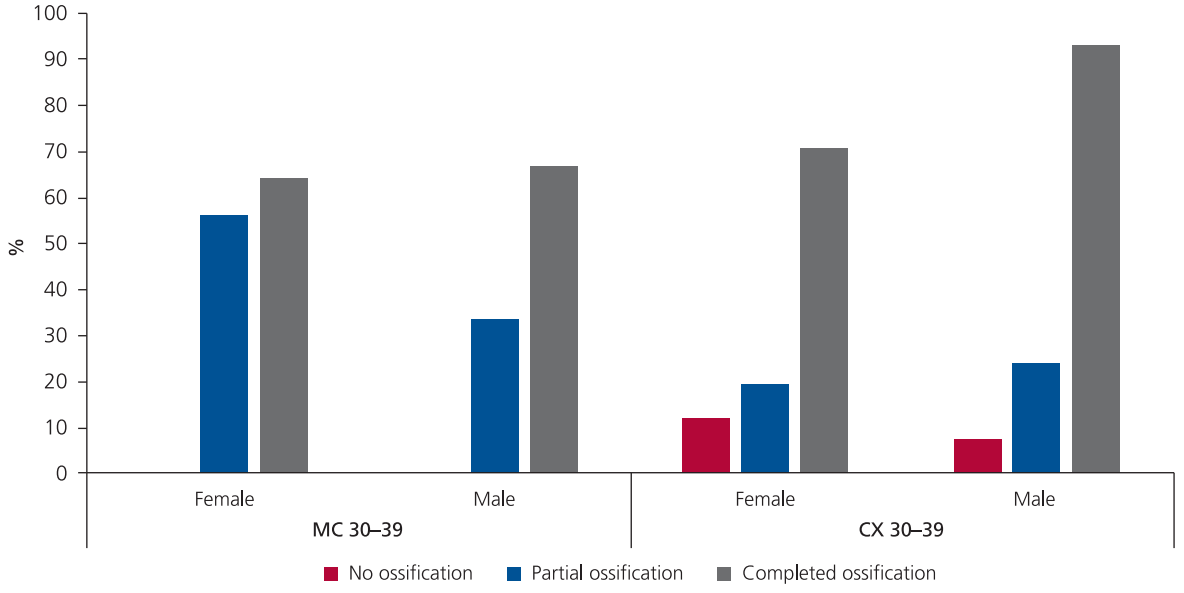

Figure 9. Degree of ossification in the 20–29 age group. **CX:** ossification between body of the sternum and the xiphoid process; **MC:** ossification between manubrium and body of the sternum.

Table 8
Typing the xiphoid process according to its shape and direction in previously published studies.

		Xiphoid process shape			Xiphoid process direction	
		Type 1	Type 2	Type 3	Type1	Type2
Kirum et al.[29] (2017)	Dry bone	42.9%	57.1%			
Yekeler et al.[7] (2006)	MDCT	27.2%	71%	0.7%		
Akın et al.[9] (2011)	MDCT	32.8%	62.6%	4.6%	65.4%	33.2%
Present study	MDCT	47.9%	45.1%	7%	77%	24%

tion.[13,14] Owing to its big size, sternum is not destroyed very quickly and can be scanned easily, thus it can be used in gender and age determinations.[14,15]

The studies on sternum measurements generally reports gender difference.[11,16,17] But there are differences of opinion about whether to determine gender or not.[15,18–20] Recent studies have shown that the sternum is longer, wider and thicker in the males.[16,17,21] The results of our study showed that the width and the length of the manubrium was significantly higher in males than that of females, so that gender determination can be made by using sternum.

The width (MW) and the length (ML) of manubrium was reported to be significantly higher in males than females[14,18,19,21–26] as our results. MW and ML was not examined according to age groups previously. Our results showed the MW and ML as increasing rapidly and significantly until the age of 10–19 and then increasing gradually at later ages without making a significant difference. Thus, together with other measurements, MW and ML can be used for age estimation as well.

The size of the body of sternum was also found larger in males than that of females[11,20,21,25,26] as in our study. It is known that gender can be determined by using the length and the width of manubrium and body of sternum as landmarks.[21,25,27,28] However, no data is available regarding the size of the body of sternum in different age groups. As MW and ML, the results of our study showed that the size of the sternum (CL, CW1, CW2) increased rapidly until the age of 10–19. Thus, we suggest that age determination can be made in addition to gender by using the CL, CW1, CW2 as references.

The angle of Louis (LA) has previously not recommended for gender discrimination.[29,30] According to the results of this study, LA showed no statistically significant difference among genders as well.

Previous studies done on typing the xiphoid process according to its shape showed that the incidence changes in a wide range as; Type 1 varying between 27.2% and 42.9%, Type 2 between 45.1% and 71%, and Type 3 between 0.7% and 4.6% (**Table 8**).[7,9,29] The most frequent type was as detected as Type 1 (47.9%), followed by Type 2 (45.1%) and least common Type 3 (7%).

Sternal fractures account for about 5–10% of all thoracic injuries. It is an injury that occurs directly with the steering wheel or seat belt. It can also occur during cardiopulmonary resuscitation. Differences in xiphoid direction can also be misidentified as a fracture. So, it is important to know the variations in the shape and direction of the xiphoid process.[17,27] In a study on determining the direction of the xiphoid process, it had a ventrally directed slope in 65.4% (Type 1) and in line with the body in 33.2% (Type 2) (**Table 8**).[9] 77% of our cases was Type 1, and 24% was Type 2.

The frequency of foramina on the sternum have been investigated in various studies. The presence of any foramen on the xiphoid process was reported in a great range between 9.5% to 36.1% (**Table 9**).[7,9,29,31] A foramen on the xiphoid process was observed in 11.7% of our cases, 75% of which were in the form of a single foramen. In 18% of our cases there were two foramina and 7% more than two foramina. The body of sternum was reported to have fewer foramina, the incidence being 4.3% to 16.6% (**Table 9**).[7,9,29,31–34] Our series showed a single foramen in the body

Table 9
Foramen ratios on xiphoid process in previously published studies.

		Presence of foramen on the xiphoid process	Presence of foramen on the sternum body
Yekeler et al.[7] (2006)	MDCT	27.4%	4.5%
Kirum et al.[29] (2017)	Dry bone	9.5%	12.9%
Babinski et al.[31] (2015)	MDCT	17.5%	16.6%
Akin et al.[9] (2011)	MDCT	36.1%	
Singh et al.[32] (2013)	Cadaver		11.9%
Stark at al.[1] (1986)	CT		4.3%
Moore et al.[34] (2015)	CT		6.6%
Present study	MDCT	11.7%	%5.1

of sternum in 5.1% of the cases. The presence of foramina on the sternum was associated with some fatal complications in early infancy.[35–37] During sternal puncture or sternal bone marrow aspiration, a sternal foramen may pose a great danger due to unwanted cardiac or major vascular damage.[7,36,38] Therefore, knowing the presence and the frequency of foramina is clinically important.

The ossification of the sternum had been reported to complete in various ages. Pekcan[39] stated that ossification between the manubrium and corpus was completed at the age of 31 in men and 26 in women, Garg et al.[40] found that full ossification between the manubrium and the corpus was still not completed in 60% of cases in the 60–65 age group. In the study of Kaneriye et al.,[41] no ossification was observed under the age of 40. In another study, the ossification between the manubrium and the corpus started at the age of 40 was completed at the age of 55, and the ossification between the xiphoid process and corpus was completed at 50.[22] It is known that manubrium and corpus can remain united and amount of union increases with advancing age.[42] Since the manubriosternal joint has a fibrocartilage, even if the ossification gets completed, the cartilage structure is preserved inside the joint. In our study, there were no significant gender differences for ossification between the manubrium and corpus, which started at the ages of 0–9 and completed between the ages of 30–39. The ossification between the xiphoid process and the corpus started at the ages of 0–9, completed at the ages of 50–59 and there was no significant gender difference.

There are some limitations in our study. This is a retrospective study and since all images were obtained in the supine position, personal characteristics such as height, weight, presence of anatomical deformities or postural disorders could not be identified. For this reason, we think that it would be beneficial to support it with prospective studies taking into consideration of other parameters such as height, weight, thoracic diameter, BMI of the cases in different positions (standing *vs* sitting).

Conclusion

Data collected from a single bone is important for age and sex prediction especially in forensic medicine. These data taken from a large series containing 700 images may also contribute to evaluation of variations in sternal morphology by age and gender. We suggest that the results obtained from our study may contribute basic anatomy knowledge and be used by thoracic surgeons and radiologists.

Author Contributions

GB: data collection and data analysis, writing text. NUD: Project development, data analysis, final check of the manuscript. MK: data collection and analysis. ZF: project development, final check of the manuscript. AKK: project development, final check of the manuscript

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Bibliometric analysis of articles published in *Anatomy*, the official publication of the Turkish Society of Anatomy and Clinical Anatomy between 2007–2018

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Abstract

Objectives: Bibliometry is a research approach to measure and analyze the productivity of the literature in a specific area or journal. Therefore, bibliometric analysis is significant in the evaluation of the journals. In this study, we aimed to examine the articles published in *Anatomy* (ISSN: 1307–8798), the official publication of the Turkish Society of Anatomy and Clinical Anatomy (TSACA) between 2007–2018.

Methods: The affiliations of the authors, identity, type, content and number of citations of articles published in the journal *Anatomy* between 2007–2018 were recorded. Descriptive statistics of the data were made.

Results: Between 2007 and 2018, 214 articles were published in 12 volumes and 19 issues, the number of published articles varying by years. 101 (47.6%) of 214 articles were cited. Forty four articles (20.56%) were prepared by a single author, and 170 (79.44%) articles by multiple authors.

Conclusion: The findings obtained in this study are thought to be important for understanding the place of the journal *Anatomy* and its contribution to the scientific literature in the field of anatomy.

Keywords: anatomy; article; bibliometric analysis; citation

Anatomy 2020;14(1):39–43

Introduction

The journal of *Anatomy* (ISSN: 1307-8798), the official publication of the Turkish Society of Anatomy and Clinical Anatomy (TSACA), is an international refereed journal published three times a year. In the journal, anatomical studies including histological, developmental, neurological, radiological, clinical and anatomy teaching methods and techniques are published. The journal, the first issue of which was published in 2007, is indexed and abstracted in TUBITAK ULAKBIM TR Index, Index Copernicus, Proquest, EBSCO Academic Search Complete and Google Scholar.[1] On the other hand, *Anatomy* is one of the 18 official journals in the Federative International Committee for Scientific Publications (FICSP) of International Federation of Associations of Anatomists (IFAA).[2]

Bibliometry (βιβλιο: *book*, μετρηση: *measurement*) is a Greek origin word, and entered the literature for the first time in 1969 by Alan Pritchard (1935–2010) with his work titled *Statistical Bibliography or Bibliometrics*. But it became popular in the 1980s.[3,4] Bibliometry is defined as a kind of research approach used to measure and analyze the productivity of the literature in a specific area or journal.[5–7] Bibliometric analyses include the characteristics of published articles, citations, and the number of authors.[8] Therefore, it is an important method to evaluate the scientific features of a journal. It also provides information for understanding scientific productivity and researchers' publication preferences.[6,7] Many disciplines use bibliometric analysis to determine the impact of their field, the impact of a number of researchers, or the impact of a spe-

This study was presented as an oral presentation at 8th Anatomy Winter Meeting, 22-24 January 2020, Trabzon, Turkey.

cific article.[6] Scientific journals are considered as the most up-to-date tool of scientific communication.[9] For this reason, it is considered important to evaluate the journals as bibliometric.

Although there are many studies[4–15] using bibliometric method in different areas, it has been seen in the detailed literature review that the number of bibliometric studies in the field of anatomy is very few.[16,17] In this study, we aimed to examine the articles published in *Anatomy* (ISSN: 1307–8798), the official publication of the Turkish Society of Anatomy and Clinical Anatomy (TSACA) between 2007–2018, bibliometrically.

Materials and Methods

All articles published in the *Anatomy* (ISSN: 1307–8798) between 2007 and 2018 were reviewed on the journal's website. The full text of the articles in all issues, excluding the special issues published between these years, was evaluated and the name of each article, the year it published, the volume, issue and page numbers, the authors, the institutions to which the authors were affiliated, the type of the article and the study design were recorded. On 29 November 2019, each article was accessed from the Google Scholar database and the number of citations was recorded.

Statistical Analysis

Descriptive statistics are given as mean±standard deviation for numerical variables and number and percentage values for categorical variables. SPSS for Windows version 22.0 (SPSS Inc., Chicago, IL, USA) package software was used for statistical analysis and $p<0.05$ was considered statistically significant.

Results

Twelve volumes, 19 issues and 214 articles were published in *Anatomy* between 2007–2018 (**Table 1**).The number of published articles varied by years and the highest number of peer-reviewed articles were published in 2016. The categories of published articles are shown in **Table 2**. The majority of published articles were original articles (45.3%). The study design of original articles and case reports are shown in **Table 3**. The vast majority of original articles were experimental animal (29.9%) and radiological (22.7%) studies. 65.2% of case reports were cadaveric studies.

Fourty-four (20.56%) of 214 articles were found to be single author, and 170 (79.44%) articles were found to be more than one author. There were 190 articles with authors from the same country and 24 articles with authors from more than one country. One hundred ten (57.89%) articles of 190 were from Turkey, followed by Nigeria (7.36%), India (5.78%) and USA (4.68%). Thirty three different countries made contributions to the journal.

When the citations to the articles were analyzed, 101 (47.6%) of 214 articles were cited (**Figures 1** and **2**). The most cited article with 44 citations was an original article and a clinical study. The total number of citations

Table 1
Distribution of published articles by years.

Year	Volume number	Issue number	Number of articles
2007	1	1	1
2008	2	1	14
2009	3	1	15
2010	4	1	9
2011	5	1	8
2013	7	1	16
2014	8	1	12
2015	9	1	11
		2	14
		3	14
2016	10	1	15
		2	13
		3	12
2017	11	1	9
		2	9
		3	11
2018	12	1	11
		2	10
		3	10
Total			214

Table 2
Article types and citations by article types.

Article type	n (%)	Citation (Mean±SD)
Original article	97 (45.3)	2.97±6.41
Case report	46 (21.5)	3.43±5.47
Teaching anatomy	20 (9.3)	4.5±9.44
Review	15 (7)	2.46±3.39
Book review	10 (4.7)	-
Editorial	6 (2.8)	-
Historical view	6 (2.8)	-
Obituary	4 (1.9)	-
Terminology zone	4 (1.9)	0.25±0.5
Viewpoint	2 (0.9)	-
Letter to the editor	2 (0.9)	-
Announcement	1 (0.5)	-
Invited review	1 (0.5)	13*

*It was determined that there is only one article invited review and it has 13 citations.
n: total number of articles; **SD:** standard deviation.

to the articles in the journal was 588 and the average value was 2.74±5.97. The highest number of citations was 97 and in 2016 (**Figure 1**). In addition, it has been observed that the number of citations to articles published in 2008 is more than the other years (**Figure 2**).

When the citation numbers were examined according to article types, the highest number of citations was 13 for the invited articles. In other article types, the article type with the highest citation average was teaching anatomy (**Table 2**). When the original articles were evaluated according to the study design, it was found that the clinical and cadaveric studies had the highest citation average. Similarly, in case reports, it was determined that the studies with the highest citation average were cadaveric studies.

Table 3
Distribution of original article and case report articles by study design.

Study design	Original article	Case report
Experimental animal study	29 (29.9%)	-
Radiologic study	22 (22.7%)	10 (21.7%)
Clinical study	13 (13.4%)	2 (4.3%)
Cadaveric study	12 (12.4%)	30 (65.2%)
Dry bone study	8 (8.2%)	3 (6.5%)
Histologic study	4 (4.1%)	-
Fetus study	4 (4.1%)	-
Dry bone and radiologic study	3 (3.1%)	-
Cadaveric and radiologic study	1 (1%)	-
Autopsy study	-	1 (2.2%)
Other	1 (1%)	-

Discussion

Bibliometric studies are important in evaluating the development and productivity of a scientific area or journal in the literature. In addition, bibliometric researches provide an idea about the future vision of a journal. Although there are studies using bibliometric method in various fields in the literature, there are very few bibliometric studies in the field of anatomy,[16,17] and there are no bibliometric studies on anatomy journals.

Citation analysis is the most commonly used form of bibliometry, allowing to measure the impact factor of journals.[8] Petekkaya[16] examined the 100 most cited articles in the field of anatomy from the Web of Science database and found that the average citation for the articles was 634.83 accordingly. Also, it was stated that the most cited article had 4471 citations.[16] Wing and Massoud[17] examined the neuroimaging studies conducted in the field of anatomy in two different neuroradiology journals, and determined that there were 244,119 articles and 6419 citations to these articles between 1970–2009. It has been reported that the probability of citing articles decreases in a certain time after publication of the article.[18] In the present study, the total number of citations to articles com-

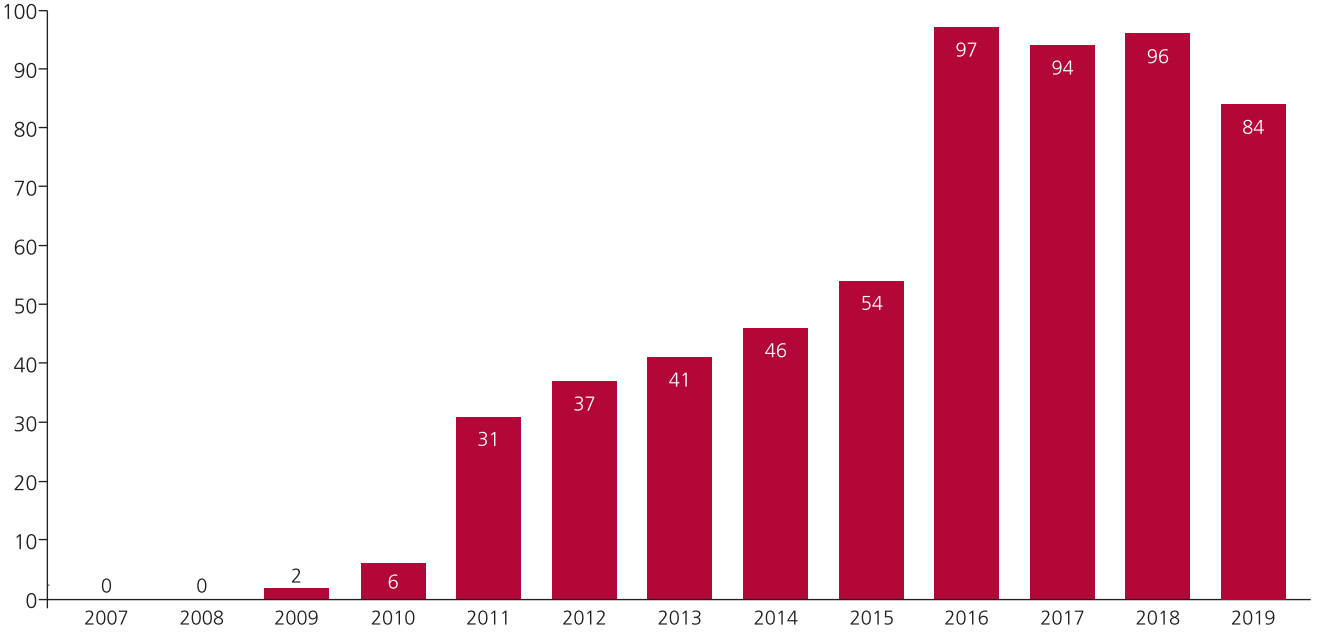

Figure 1. The number of citations to *Anatomy* varies by the years.

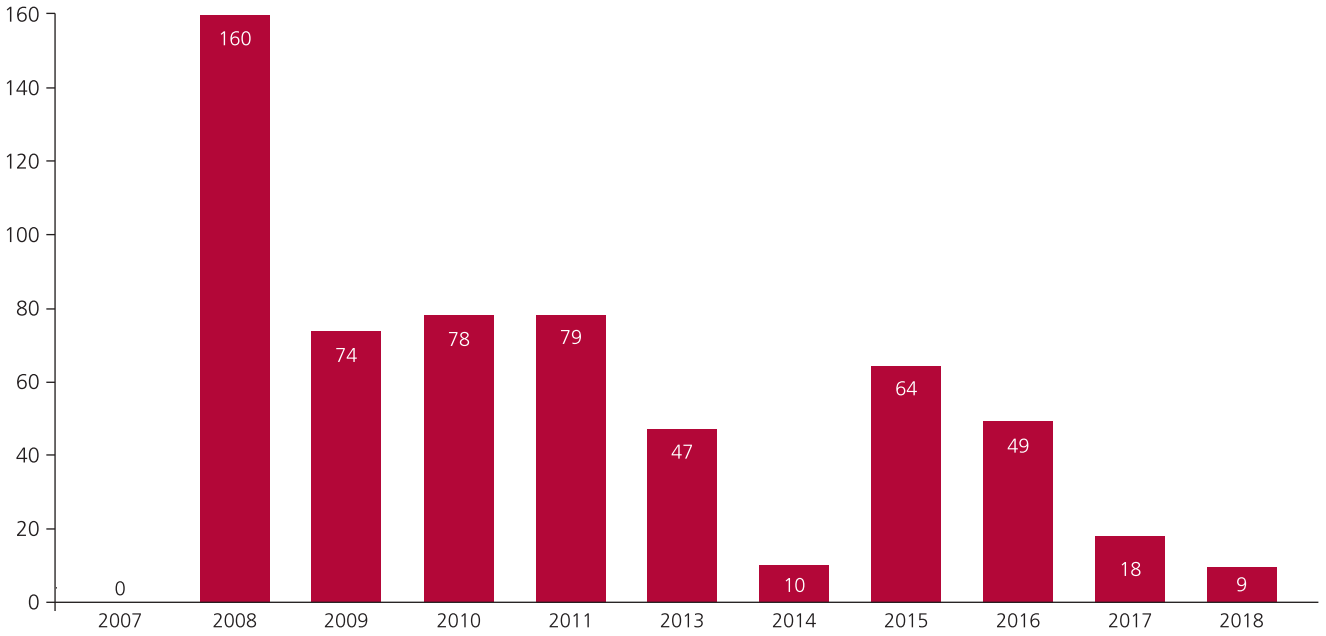

Figure 2. The number of citations and year of publication of articles in the journal *Anatomy*.

pared to the years they were published was close to each other, but the total number of citations to articles published in 2008 was higher than other years, possibly because the most cited article was published in 2008.

Weale et al.[19] reported that the number of citations varied according to the article type and study design in the study which they evaluated the citation analysis of all original articles and reviews in the field of immunology in the Web of Science database. Similarly, in the present study, the number of citations to articles in *Anatomy* varied according to years, article type and study design. The fact that the number of citations of clinical and cadaveric studies is higher than others suggest that the interest in the studies in this field and the publication rate of the studies is higher than the others.

Another factor that affects the number of citations is the open access policy of the journals. Eysenbach[20] reported that the citation average of the articles with open access published in the same journal is significantly higher than those without open access. The acceptance of open access policy of *Anatomy* can be seen as an advantage in terms of the number of citations to published articles in *Anatomy*. On the other hand, despite the fact that all articles are open access, the journal does not demand any fees from the authors during the article evaluation or acceptance stage, and this is an indication that they are selective about the articles accepted in the journal.

Yang et al.[21] reported that many researchers needed collaboration in medical publications. Ullah et al.[5] found that there was more than one author in 91.21% of the articles in a medical journal they examined bibliometrically. In another study conducted by Ullah et al.,[22] the rate of single author articles was found to be 4.64%. In this study, more than one author was found in 79.43% of the articles. The high number of articles with more than one author suggests that co-authorship is important in the emergence of publications in the field of medicine.

Nasir et al.[14] reported that international cooperation is important for the emergence of quality publications. In 24 (11.2%) of 214 articles evaluated in the present study, it was determined that there were authors from more than one country. In these articles, it is seen that authors from Turkey are mainly working with authors from countries such as USA, Switzerland, and Germany.

In the study that examined the Journal of Pakistan Medical Association as bibliometrics, it is found 78% of the articles are from the same country (Pakistan), followedby Iran and Turkey.[23] Similarly, in the present study, the maximum contribution to the *Anatomy* was made by the authors from Turkey. On the other hand, the contribution of the journal from 33 different countries is an indication that the journal is also respected internationally.

The increase in the number of issues and articles published in *Anatomy* every year since 2007 shows that the

journal has a tendency to grow. The majority of the published articleas type are original articles. This is also important for the future demanding of the journal. On the other hand, the fact that the journal's most cited article type is on anatomy education (Teaching Anatomy) shows that the contribution of such articles to the journal is remarkable.

Conclusion

Examining scientific journals bibliometrically provides understanding of the place of journals in the literature and having an idea about its future vision. The findings obtained in this study are important for understanding the place of *Anatomy* in the literature and its contribution to the literature.

Author Contributions

SSA: data collection, literature review, writing text. İB: literature review, writing text, final check of the manuscript. PK: writing text, final check of the manuscript, MO: writing text, final check of the manuscript, ÖFC: writing text, final check of the manuscript.

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Do anthropometric characteristics of head and neck affect the craniocorpographic balance measurement?

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Abstract

Objectives: The present work aimed to study the relationship of some head and neck anthropometric characteristics with the data obtained from balance analysis.

Methods: Thirty healthy male volunteers participated in the study. The measurements obtained at the same time of day (10:00–12:00). Craniocorpography section of the CMS20P-2 (Zebris© Medical GmbH, Isny im Allgäu, Germany) was used for measurements. The head length, head circumference, head width, neck circumference and neck width and length anterior-posterior diameter were measured. As the balance values, the longitudinal deviation, lateral sway width, angular deviation, self-spin, longitudinal sway, lateral sway, angle of torticollis were evaluated. The relationships between data were compared statistically.

Results: The head length showed moderate correlation with lateral sway width (r=-0.29), self-spin (r=-0.35) and lateral sway (r=0.28). A moderate positive relationship was found between the head length and longitudinal deviation. The correlation was also moderate between neck circumference, neck width and longitudinal sway. Neck circumference and neck width values showed a moderate correlation with longitudinal sway (r=0.46 and r=0.36).

Conclusion: The results of this showed that there is a moderate correlation between the balance and the head-neck characteristics.

Keywords: anthropometry; balance; head; neck

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Introduction

Body balance is maintained by a network composed of the brainstem, cerebellum, brain and sensory organs.[1–6] Stimuli received from the proprioceptive receptors and also vestibular and visual stimuli are analysed with this network to maintain balance of our body. Any disturbances in this network may lead to symptoms such as vertigo and tinnitus.[2,3,7–9]

Balance measurement was first performed by Unterberger for the diagnosis of vertigo using the closed-eye stepping test.[2,3,7] Fukuda[5] developed this test and added numerical data to it. In 1968, photographic techniques were added to these tests by Claussen.[1,3,6,10,11] This technique developed by Claussen called craniocorpography (CCG) helped to obtain the data of quantitative and objective balance analysis on patients. The CCG technique relies on recording patients' movements digitally by means of an apparatus with sensors attached to head and shoulder. A computer records the results and prints them into a polar coordinate system.

Previous studies investigated the correlation between balance and body movements in pathological conditions such as vestibular, whiplash, and abnormal psychomotor activity.[1,2,7,10,12] The studies reported that CCG might be useful in the follow-up of pathological conditions.[1,12,13] However, there is no study on the effects of head and neck

posture and anthropometric characteristics on CCG data. The aim of the present study, therefore, was to study the relationship of some head-neck anthropometric characteristics with the data obtained from balance analysis by using CCG.

Materials and Methods

Ethical approval was obtained from the Scientific Research Ethics Committee (Decision number: 12/03 Date: 02.05.2012). Thirty healthy volunteer male subjects participated; mean age was 20.27±1.31 years, mean height was 1.77±0.06 m and mean weight 78.67±14.46 kg. Subjects with previous movement system dysfunctions, head and neck injury, vestibular disease and psychomotor activity disorders were not included in the study. The subjects did not have any physical activity on an ongoing basis.

CCG section of the CMS20P-2 device (Zebris© Medical GmbH, Isny im Allgäu Germany) and the WinBalance database were used for balance measurements. The system consists of a main unit, a measuring sensor, a helmet marker, a shoulder marker which transfers the data into the computer software and a computer. The anthropometric data were collected using thr Harpenden anthropometer set (Holtain Ltd., Crymych, Dyfed, Wales, UK)

The measurements of all subjects were carried out at the same time of day (10:00 am–12:00 am). The experimental protocol was explained to each subject before measurement. The head and neck apparatus were then placed. The sensor was placed behind the subject. The subjects were positioned standing upright with their back facing the device, eyes closed and hands parallel to the ground. First, the Romberg test was performed to measure the balance. The balance of the subjects was evaluated by the device for 60 seconds and recorded in the computer environment. After the first measurement, the subjects rested for 5 minutes and then, the Unterberger test was performed. The subjects stepped in situ eyes closed and hands parallel to the ground. The balance of the subjects was evaluated with the device for 60 seconds and recorded in the computer environment. The same examiner measured the head-neck anthropometric data of the subjects three times and the data were recorded by taking the mean of these measurements. For the CCG technique, the following seven parameters were measured in each subject:

- **Longitudinal sway (LONS) (cm):** indicates the shifting distance of head and shoulders frontward and backward during the test period.
- **Lateral sway (LATS) (cm):** indicates the lateral displacement distance of the helmet marker.
- **Torticollis angle (TA) (º):** the degree of the angle between the end positions of head and shoulder at the end of the posture test.
- **Longitudinal deviation (LDEV) (cm):** the measurement of the distance between the starting point and the end point during stepping.
- **Lateral sway width (LATSW) (cm):** the distance of maximal lateral left and right swing movements of head and shoulder during stepping.
- **Angular deviation (ADEV) (º):** the deviation angle of the line combining the starting point and the end point from the midline during stepping.
- **Self-spin (SS) (º):** the angle when the body rotates around its own axis during stepping. It shows the angles between the start and end points of the shoulder marker. Right turn is used as negative direction, and left turn is used as positive direction by the software.

The parameters measured as anthropometric data were:

- **Head length:** the distance between opisthocranion and glabella in an anatomical position.
- **Head circumference:** circumference of the head measured from the line passing over the inion and supraorbital crest.
- **Head width:** it is the distance between the left and right eurion, the most lateral point of the parietal tuberosity.
- **Neck circumference:** circumference of the neck measured just below the laryngeal prominence, perpendicular to the long axis of the neck.
- **Neck width:** the diameter of the neck circumference measured on coronal plane.
- **Neck antero-posterior diameter:** the diameter of the neck circumference measured on sagittal plane.

The SPSS version 20.0 software for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The correlation between the data was compared using the Spearman's correlation test. Correlation coefficients (r) of 0–0.24, 0.25–0.49, 0.5–0.74, 0.75–1 were considered as weak, moderate, strong and very strong correlation, respectively.

Results

The demographic and CCG data obtained from our study is shown in **Table 1**. There was a significant moderate negative correlation between head length and SS (r=-0.389; p=0.033) (**Figure 1**). There was a moderate positive correlation with no statistically significant differ-

Table 1
Anthropometric and CCG parameters.

Parameters (n=30)	Mean±SD
Age (year)	20.27±1.31
Height (cm)	1.77±0.06
Weight (kg)	78.67±14.46
BMI	25.04±4.12
ADEV (°)	15.67±15.74
HC (cm)	58.41±1.79
HL (cm)	20.3±0.7
HW (cm)	16.29±1.13
LATS (cm)	3.08±1.6
LATSW (cm)	15.06±9.06
LDEV (cm)	93.05±33.79
LONS (cm)	5.78±1.89
NAP (cm)	11.63±0.64
NC (cm)	38.22±2.44
NW (cm)	11.98±0.6
SS (°)	34.40±30.59
TA (°)	9.90±5.91

ADEV: angular deviation; **BMI:** body mass index; **HC:** head circumference; **HL:** head length; **HW:** head width; **LATS:** lateral sway; **LATSW:** lateral sway width; **LDEV:** longitudinal deviation; **LONS:** longitudinal sway; **NAP:** neck antero-posterior diameter; **NC:** neck circumference; **NW:** neck width; **SS:** self-spin; **TA:** torticollis angle.

ence between head length and LATS (r=0.260; p=0.166). Although there was a moderate negative correlation between head circumference and LATS (r=-0.327; p=0.078) and SS (r=-0.262; p=0.161), it was not significant. There was a moderate positive correlation with no statistically significant difference between head width and LDEV (r=0.308; p=0.098) and LATSW (r=0.313; p=0.092) while there was a moderate negative correlation between it and ADEV (r=-0.318; p=0.086). There was a significant moderate negative correlation between neck circumference and LDEV (r=-0.408; p=0.025) (**Figure 2**). The moderate correlations between LONS, TA and SS and neck circumference were not significant (**Table 2**).

Discussion

It is important to use anthropometric data to design an optimal product in the field of ergonomics. While designing a product, it must be considered that there are number of differences among the individuals.[14] These differences come from the gender, body mass index (BMI), age and ethnic characteristics.[15] The anthropometric methods have been used as a guide in a wide range of areas from the diagnosis of numerous diseases to the suitability of living and working environments. It has been reported that BMI, waist circumference and waist/hip ratio are used to predict the increased risk in

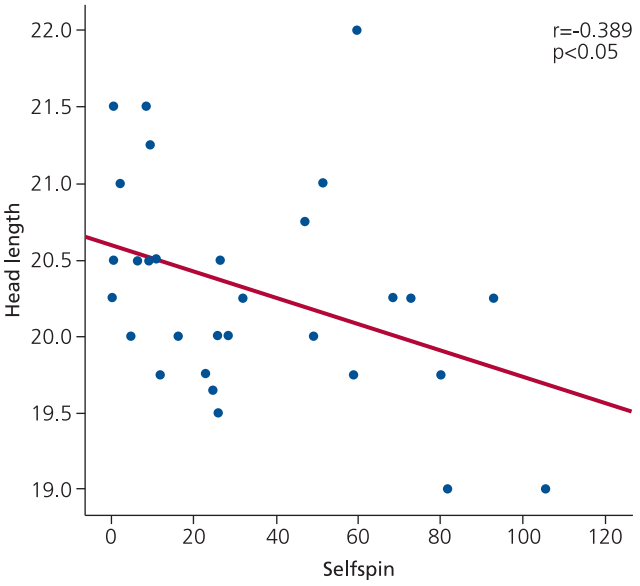

Figure 1. Correlation curve between head length and self-spin.

chronic diseases such as hypertension and diabetes.[16] Although the anthropometric measurements have been used in such conditions, the correlation between CCG and anthropometric measurements is lacking. CCG is a medical investigation and measurement procedure developed in 1968 by Claus-Frenz Claussen for to document and evaluate disorders of the equilibrium.[1,3,6,10,11] The studies on CCG indicated that this device was most use-

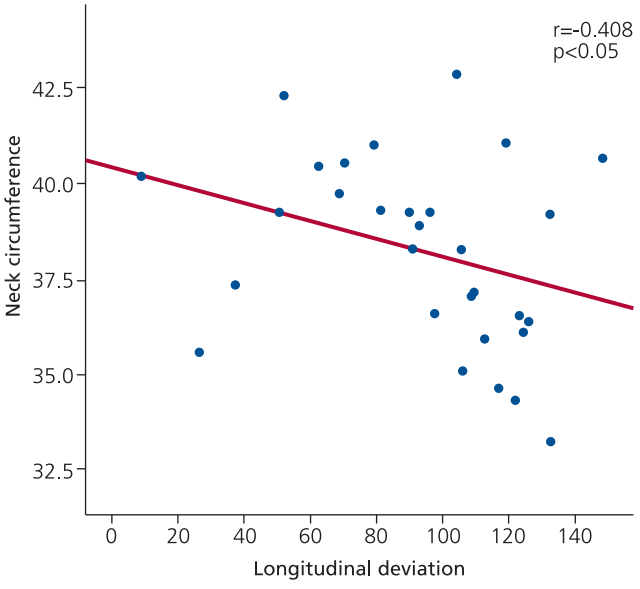

Figure 2. Correlation curve between neck circumference and longitudinal deviation.

Table 2
Spearman correlation analysis for anthropometric and CCG data.

		LONS	LATS	TA	LDEV	LATSW	ADEV	SS
Head length	r	0.170	**0.260**	-0.138	-0.043	-0.118	0.027	**-0.389***
	p	0.368	**0.166**	0.466	0.822	0.536	0.885	**0.033**
Head circumference	r	0.029	-0.020	-0.190	**-0.327**	-0.057	0.045	**-0.262**
	p	0.881	0.918	0.313	**0.078**	0.766	0.814	**0.161**
Head width	r	-0.011	0.130	0.039	**0.308**	**0.313**	**-0.318**	-0.148
	p	0.953	0.493	0.839	**0.098**	**0.092**	**0.086**	0.436
Neck circumference	r	**0.289**	0.185	**-0.256**	**-0.408***	-0.164	0.043	**-0.290**
	p	**0.122**	0.327	**0.173**	**0.025**	0.386	0.822	**0.120**
Neck width	r	**0.314**	-0.007	0.019	-0.076	-0.235	0.003	-0.115
	p	**0.092**	0.969	0.923	0.688	0.212	0.988	0.546
Neck antero-posterior diameter	r	0.237	0.088	**-0.290**	-0.024	0-.188	0.141	-0.086
	p	0.207	0.645	**0.120**	0.900	0.320	0.459	0.653
BMI	r	0.237	0.127	-0.226	-0.272	0.079	-0.013	-0.135
	p	0.208	0.503	0.230	0.146	0.680	0.947	0.478

r: Spearman's correlation coefficient; 0-0.24 poor, 0.25–0.49 moderate, 0.5–0.74 well, 0.75–1 high correlation; **p:** correlation is significant at the 0.05 level; **ADEV:** angular deviation; **LATS:** lateral sway; **LATSW:** lateral sway width; **LDEV:** longitudinal deviation; **LONS:** longitudinal sway; **SS:** self-spin; **TA:** torticollis angle.

ful in the diagnosis and treatment follow-up of peripheral vestibular diseases. Alpini et al.[1] indicated the normal values of the parameters evaluated in the standing test as LONS in the range of 1.75–10.53 cm and LATS in the range of 1.74–7.06 cm. In the stepping test, the normal range of LDEV was defined as 30.03–113.35 cm, LATS as 5.17–16.15 cm, the mean ADEV was defined as 55.13° to the right and 48.37° to the left, and SS as 82.21° to the right, 82.89° to the left. The data obtained from our study was fitting to normal range values. Szirmai et al.[13] found that the longitudinal deviation increased in patients with vestibular system pathology. In our study, we determined a significantly moderate negative correlation between this parameter and neck circumference, and showed that the self-spin value was not affected by vestibular system pathology. However, in another study, it increased in patients with peripheral system disease.[13] Our study revealed that this value was affected by anthropometric data. There was a statistically significant negative correlation between self-spin value and head length.

Serafini et al.[3] showed that angular deviation increased, but lateral sway did not change in patients with peripheral labyrinthine disease. We did not find any correlation between these parameters and anthropometric measurements.

Anthropometry is one of the important factors in the design of ergonomic devices to be used on people. Lacko et al.[17,18] designed easier-to-use EEG headsets by performing anthropometric measurements. With this study, they showed that 3D anthropometry is a suitable tool for ergonomic design. Silva et al.[19] performed 39 different body measurements on Brazilian pilots for the design of aircraft cockpit and hardware. Hsiao[15] made four different anthropometric designs for respiratory device test panel, fire extinguishing mask size, fire truck cabin, fall protection safety belt.

Our results showed that CCG may also be affected by anthropometric data as it is affected by pathological conditions. Therefore, we suggest it is necessary to consider the anthropometric characteristics of the patients while using CCG in clinical diagnosis and follow-up.

Author Contributions

SÇ: design and writing of the study, EU: statistical analysis, AY: interpretation of anthropometric measurements, MP: interpretation of balance measurement, MK: conducting balance measurements, DDA: conducting anthropometric measurements, AZYK: conducting balance measurements.

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Morphometry of the internal capsule on MR images in adult healthy individuals

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Abstract

Objectives: There is substantial information on the morphometric differences of the pathways passing through the internal capsule according to the dominant extremity; however, the diameters of the internal capsule in the horizontal plane have not been previously evaluated. The aim of this study was to evaluate the diameters of parts of the internal capsule (anterior limb, posterior limb and genu) and angle in between these parts in healthy subjects.

Methods: MRI images of 80 females and 37 males (age: 18–65) with no obvious intracranial pathology were evaluated. The diameters of the anterior and posterior limb and the genu of the internal capsule and the angle between the anterior and posterior limbs were measured.

Results: There was no statistically significant difference in measurements of internal capsule when compared bilaterally in all individuals ($p>0.05$). The right and left genu angles were significantly wider in females. This angle in the present study was found as 122°, while the classical knowledge reveals it as around 90°.

Conclusion: Understanding the normal morphometry of this region may help clinicians in the diagnosis and follow-up of some neurological diseases. Some morphometric characteristics of this region have shown differences from the classical knowledge. Further studies in larger samples should be done for re-evaluating the normal ranges of these morphometric values.

Keywords: internal capsule; morphometry; MRI

Anatomy 2020;14(1):49–52

Introduction

Internal capsule is a white matter consisting of efferent and afferent fibers in the shape of a fan extending vertically to connect some of the cortical centers with the spinal cord. Internal capsule is divided into anterior limb, genu, posterior limb, retrolentiform limb (retrolenticular part) and sublentiform limb (sublenticular part). It is located in the inferomedial part of each cerebral hemisphere and separates the caudate nucleus and thalamus from the lentiform nucleus. The descending and ascending pathways passing through the internal capsule connect the brain hemispheres and subcortical structures to brain stem and spinal cord.[1,2]

The parts of the internal capsule carry different descending and ascending axonal pathways which have critical functions.[1] The anterior limb extends between the head of caudate nucleus and the lentiform nucleus. The posterior limb is between the thalamus and the lentiform nucleus.[3]

The anterior limb of the internal capsule carries thalamic and brain stem fibers from prefrontal cortical regions that are associated with different aspects of emotion, moti-

This study was a poster presentation at the 20th National Anatomy Congress & 1st International Mediterranean Anatomy Congress, 6th–9th September 2018, Konya, Turkey.

vation, cognitive processing and decision-making.[4] The genu portion of the internal capsule contains the corticobulbar tract fibers, which begin from the lower part of the primary motor area and extend to the motor nuclei of the cranial nerves with superior thalamic radiations.[2] The posterior limb of the internal capsule contains posterior thalamic radiations, corticospinal tract, corticorubral tract and corticopontine tract.[1]

A decrease in anterior limb volume is associated with psychiatric disorders such as major depressive disorder, bipolar disorder, obsessive-compulsive disorder and schizophrenia.[4] Therefore, knowing the normal morphometry of this region may help clinicians in the diagnosis and follow-up of diseases. In this study, we aimed to evaluate the width of the parts (anterior, posterior and genu) and genu angle of the internal capsule on MR images of healthy individuals.

Materials and Methods

Our study was performed in Departments of Anatomy and Radiology of Faculty of Medicine at Afyonkarahisar Health Sciences University. This retrospective clinical study was performed after approval of the Clinical Research Ethics Committee of the Afyon Kocatepe University (2018/2-47). MRI images of 80 females and 37 males (age: 18–65) admitted to the Afyon Kocatepe University Hospital with no obvious intracranial pathology were evaluated in this study. Those with pathological findings in white matter (tumors, cysts, bleeding, etc.) and those with head trauma or stroke were not included in the study.

Measurements were made at the level where caudate nucleus, lentiform nucleus and thalamus were seen in the same transverse plane on MRI. Measurements were performed bilaterally from the widest parts of genu, anterior limb, posterior limb of the internal capsule. The angle at the intersection of the line passing through the middle of the anterior and posterior limbs was also measured (**Figure 1**).

Statistical analysis was performed using SPSS for Windows version 20.0 (SPSS Inc., Chicago, IL, USA). All values were presented as mean±standard deviation (SD). The distribution of the data was evaluated by Kolmogorov-Smirnov test. Mann–Whitney U test was used to determine the difference between two groups. Correlation analysis between groups was done using Pearson's correlation test. The results were evaluated at a 95% confidence interval and $p<0.05$ was considered statistically significant.

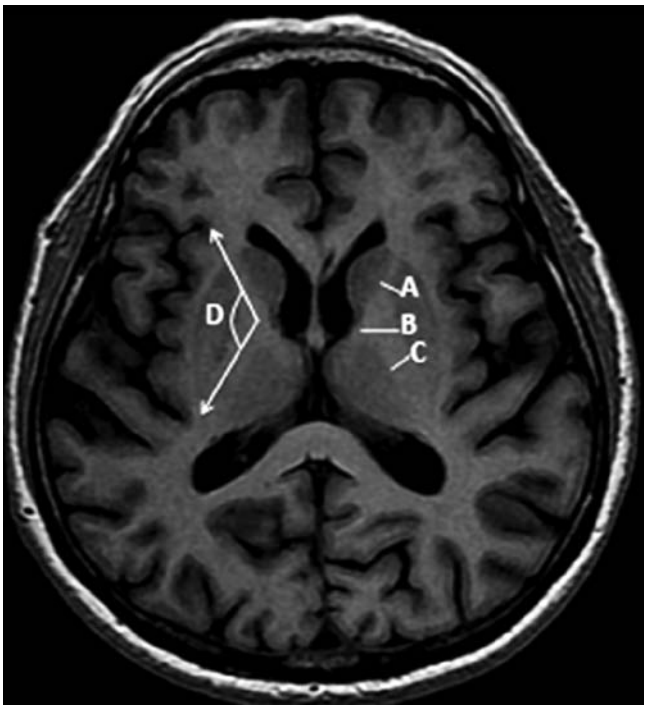

Figure 1. Measurements made in transverse sections. A: width of the anterior limb of internal capsule; B: width of the genu of internal capsule; C: width of the posterior limb of internal capsule; D: genu angle (measured between the lines passing through the middle of the anterior and posterior limbs).

Results

The mean widths of the anterior limb, genu and posterior limb were measured as 3.05±0.55 mm, 6±0.62 mm and 4.23±0.86 mm on the left side and 3.12±0.54 mm, 6.05±0.6 mm and 4.04±0.86 mm on the right side, respectively. The widths of anterior limb, genu and posterior limb showed no statistically significant difference when compared bilaterally in all individuals ($p>0.05$) (**Table 1**). There was no statistically significant difference between anterior limb, genu, posterior limb measurements among genders as well ($p>0.05$). However, the right and left genu angles were significantly wider in females than males ($p<0.05$). The mean genu angle was measured as 120.58°±4.79° on the left side and 120.53°±3.86° on the right side in males, while it was 123.01°±7.69° on the left side and 123.43°±5.12° on the right side in females (**Table 2**).

Discussion

Internal capsule is affected by a variety of pathologies. It is clinically important to know the morphological structure of such a vulnerable site affected by so many diseases (degenerative and demyelinating diseases, vitamin defi-

Table 1
Comparison of right and left measurements in all subjects (p<0.05).

	Left		Right		p-value
	min-max	mean±SD	min-max	mean±SD	
Anterior limb (mm)	1.42–4.36	3.05±0.55	1.96–4.75	3.12±0.54	.273
Genu (mm)	4.37–7.69	6±0.62	4.72–7.63	6.05±0.6	.835
Posterior limb (mm)	2.25–7.12	4.23±0.86	1.96–6.76	4.04±0.86	.086
Genu angle (x/180)	73–137	122.24±6.98	105.0–135.5	122.51±4.93	.862

ciency, infarction, hemorrhage, arteriovenous malformation, vascular pathologies such as angioma, hypoxia, glioma, oligodendroglioma, ganglioglioma, neoplastic conditions such as neuroectodermal tumor, metastatic lesions, tuberculosis, pyrocystic neurosis, neurogenic cystosis, parasitic diseases such as hydatid cysts, trauma, iatrogenic, epilepsy, psychiatric diseases).[2] There is also need for easily applicable techniques for clinical evaluation and follow-up. It is of great importance to know the morphological features of this anatomical area, which has important functional and clinical features. However, the number of studies evaluating internal capsule morphometry using imaging methods is quite few. Previous studies examining the characteristics of internal capsule relies on findings on cadavers or imaging techniques such as diffusion tensor tractography (DTT) and imaging (DTI), MR and functional MR imaging (fMRI).[4–13]

DTT provides useful data on localization of the parts of the internal capsule as well as the length or vertical angle of fiber tracts composing the internal capsule. DTT can be used to assess white mater tracts both in healthy individuals and in individuals with pathology (stroke, glioblastoma, multiple sclerosis, amyotrophic lateral sclerosis, etc.).[4–7,12,13] MRI and FMRI also provides assessment of detecting pathologies affecting the internal capsule.[9,14] In a recent study by Dos Santos et al.[15] brain specimens taken from cadavers stained by a special technique and relationships of the basal nuclei and the internal capsule was described with anatomical coordinates. When all the findings using different imaging techniques compared, it can be seen that the results do not always match.

The genu angle was expressed as 90° in one of the well-known national anatomy textbook.[16] However, our measurements revealed this angle to be approximately 120°. Considering the difference, we think that this information should be re-evaluated. However, studies with more samples are more likely to yield results that are more accurate.

In conclusion, we suggest that this study on internal capsule morphometry in normal subjects will provide a basis for future studies relying on data regarding internal capsule.

Table 2
Comparison of measurements between genders (p<0.05).

		Males		Females		p-value
		min-max	mean±SD	min-max	mean±SD	
Left	Anterior limb	2.14–4.36	3.11±0.54	1.42–4.19	3.01±0.55	.372
	Genu	4.48–7.03	5.88±0.56	4.37–7.69	6.06±0.64	.159
	Posterior limb	2.71–5.64	4.27±0.79	2.25–7.12	4.21±0.89	.761
	Genu angle	111.5–129	120.58±4.79	73–137	123.01±7.69	.003*
Right	Anterior limb	2.34–4.28	3.14±0.47	1.96–4.75	3.12±0.58	.813
	Genu	4.94–7.52	5.91±0.6	4.72–7.63	6.11±0.59	.086
	Posterior limb	2.2–5.74	4.06±0.71	1.96–6.76	4.02±0.93	.831
	Genu angle	109–126.5	120.53±3.86	105–135.5	123.43±5.12	.003*

Author Contributions

Concept: OT, AB, EH, TE, ÇÖG; design: OT, AB, EH, TE, ÇÖG; supervision: OT, ÇÖG, TE; data collection &/or processing: OT, AB, ÇÖG, HE; analysis &/or interpretation: OT, AB, EH, TE, ÇÖG, HE; literature search: OT, AB, EH; writing: OT, AB, EH; critical review: OT, TE, ÇÖG.

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Relationship between the shape of the obturator foramen and the shape of the pelvic cavity in adult women

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Abstract

Objectives: There is variable information on the efficiency of surgical treatment of urinary incontinence (SUI). To date, there is no common understanding of the role of variations in the pelvic anatomy for the success of surgical treatment of SUI. The aim of the present study was to investigate the relationship between the morphometric characteristics of the pelvis, and particularly the shape of the obturator foramen with the shape of pelvic cavity, in adult women.

Methods: Sixty-one articulated specimens of female pelvis from the bone collection of the Museum of the St. Petersburg Military Medical Academy named after S.M. Kirov were studied. A pelviometric form was developed, according to the linear and angular parameters of the pelvis and the obturator foramen, and indices of the pelvic cavity and the obturator foramen were evaluated. The discriminant analysis was used to determine the parameters that have the greatest effect on the shape of the obturator foramen.

Results: Based on the calculated indices of the pelvic cavity, the form of the pelvic cavity was determined as: narrowing downwards, cylindrical, and expanding downwards. For pelviometric parameters, for each form of the pelvic cavity, significant differences were defined, and a wide range of anatomical variations anatomy were also demonstrated. A mathematical model for predicting the shape of the obturator foramen was developed with the help of the discriminant analysis. At the same time, two main forms of the obturator foramen were marked out as triangular and ellipsoid. The triangular form was predominantly found in cylindrical and narrowing downwards pelvis groups, and the ellipsoid form dominated in the expanding downwards group.

Conclusion: Longitudinal and transverse indices of the pelvic cavity may allow us to determine its shape as narrowing downwards, cylindrical or expanding downwards. The obturator foramen has a typical shape in each particular configuration of the pelvis.

Keywords: discriminant analysis; lesser pelvic cavity; morphometry; obturator foramen; pelvic anatomy; pelvimetry; stress urinary incontinence

Anatomy 2020;14(1):53–60

Introduction

The human pelvis has been of interest for many years. There are a large number of studies on the development, functional role and morphological variations of pelvic bones.[1,3] However, even today the detection of new anatomical relationship does not lose its relevance for surgical correction of the pelvic floor dysfunction. One of the most popular and studied methods of treatment of stress urinary incontinence in women is the implantation of synthetic suburethral sling installed in structures located in the area of the obturator foramen. However, information about its efficiency varies greatly, from 50 to 100%. According to a meta-analysis study conducted in 2017 by Maggiore et al.,[4] the objective effectiveness of

transobturator sling is 67%. Today, there is a problem with the installation of the sling, which consists in the absence of a personalized approach based on the variations in pelvis anatomy.[4,5] These data together with the results of the studies of anatomical variability of the pelvis imply the possibility of improving the surgical technique, taking into account the individual anatomical features of the obturator foramen and neighboring area.[6,7] The impact of pelviometric parameters as well as the variability of the shape of the pelvis on the development of pelvic floor dysfunction are of interest for obstetric and gynecological practice.[8–10] Nevertheless, there are no studies evaluating the relationship of morphometric characteristics of some pelvic structures involved in surgical interventions with the shape of pelvic cavity. Thus, the aim of the present study was to investigate the relationship between the morphometric characteristics of the pelvis, particularly the shape of the obturator foramen and the shape of pelvic cavity in adult women.

Materials and Methods

Sixty-one articulated pelvises selected from the Gruber collection were studied. The collection which consists of 1200 human skeletons is located in the museum of the Department of General Anatomy, Military Medical Academy named after S.M. Kirov. For each skeleton, the ethnic group, age, height, weight and other anthropometric characteristics were documented. The pelvises of Caucasian women aging from 35 to 65 were randomly selected for the study. Damaged samples were excluded from the study.

A pelviometric form was developed for the study, on the basis of which the linear and angular parameters of the pelvis were evaluated. Additionally, the lumbosacral angle was measured. A total of 21 parameters were studied. These parameters were:

- Direct size of pelvic inlet: the distance in the median plane between the upper inner edge of the pubic symphysis and the mid-point of sacral promontory (A);
- Direct size of pelvic outlet: the distance between the lower internal edge of the pubic symphysis and the apex of the coccyx (B);
- Longitudinal size of the pelvic cavity: the distance between the lower edge of the pubic symphysis and the apex of the sacrum (Spc);
- Transverse size of the pelvic inlet: the distance between the furthest points of the arched lines in the frontal plane (C);
- Transverse size of the pelvic outlet: the distance between the inner surfaces of the ischial tuberosities (D);
- Symphysis-tuberosity distance: the distance between the lower edge of the symphysis and the most distant points of the lower inner edges of the ischial tuberosities (Std);
- Pelvic height: the distance between the highest point of the iliac crest and the lowest point of the ischial tuberosity (right, left) (Ph);
- Height of pubic symphysis: the distance between upper and lower edges of pubic symphysis (Hps);
- Thickness of pubic symphysis: the largest distance between the anterior and posterior surfaces of the symphysis in the median plane (Tps);
- Interspinal distance: the distance between the anterior superior iliac spines (Is);
- Width of pubic symphysis: the distance between symphysis surfaces in the middle third (Wps);
- Interobturator foramina distance: the smallest distance between the obturator foramina (Ifd);
- Subpubic angle: the angle which formed at pubic arch by the convergence of the inferior rami of the ischium and pubis on either side ° (Sa);
- Length of sacrospinous ligament: the distance from sacrum to spina ischiadica (Lssl);
- Length of sacrotuberous ligament: the distance from sacral apex to ischial tuberosities (Lstl);
- Lower angle of the obturator foramen: the angle formed by the branches of pubic and ischial bones, forming the lower boundary of the obturator foramen ° (Laof);
- The medial angle of the obturator foramen: the angle formed by the pubic bone branches, forming the medial boundary of the obturator foramen ° (Maof);
- The width of the obturator foramen: the distance between the furthest points on the side edges of the obturator foramen (Wof);
- The length of the obturator foramen: the distance between the highest point on the top edge of the obturator foramen and the lowest point on its lower edge (Lof);
- The depth of the obturator foramen: the distance from the lateral edge of the acetabulum, perpendicular to the point on the inner surface of the pubic bone (Dof);
- Lumbosacral angle: the angle formed between a line across the plane of the superior margin of the sacrum and a horizontal line ° (Lsa).

The pelvic indices (longitudinal-longitudinal and transverse-transverse) were used to determine the shape of the pelvic cavityas narrowing downwards, expanding downwards and cylindrical (**Figure 1**). Longitudinal-longitudinal (LL) index represents the ratio of the direct size of the pelvic inlet (**Figure 2a**) to the direct size of the outlet (**Figure 2b**). The transverse-transverse (TT) index, respectively represents the ratio of the transverse size of the pelvic inlet to the transverse size of the outlet (**Figure 2**). The obturator foramen index (OFI) was determined as the ratio of the width of the obturator foramen (Wof) to the length of the obturator foramen (Lof). On the basis of visual assessment three forms of obturator foramen were identified: triangular, ellipsoid and quadrangular (**Figure 3**) which were subsequently subjected to discriminant analysis. A discriminant analysis was applied to classify the forms of the obturator foramen, which has a number of advantages over similar mathematical methods, namely: takes into account the variability of the parameter and considers a set of available indicators, which reflect the specific weight of the influence of each measured parameter to determine the shape of the obturator foramen.

The measurements of pelviometric parameters have been made with the use of Martin pelvimeter, measuring ruler, protractor. Because there were no significant differences between right and left sides, the mean measure-

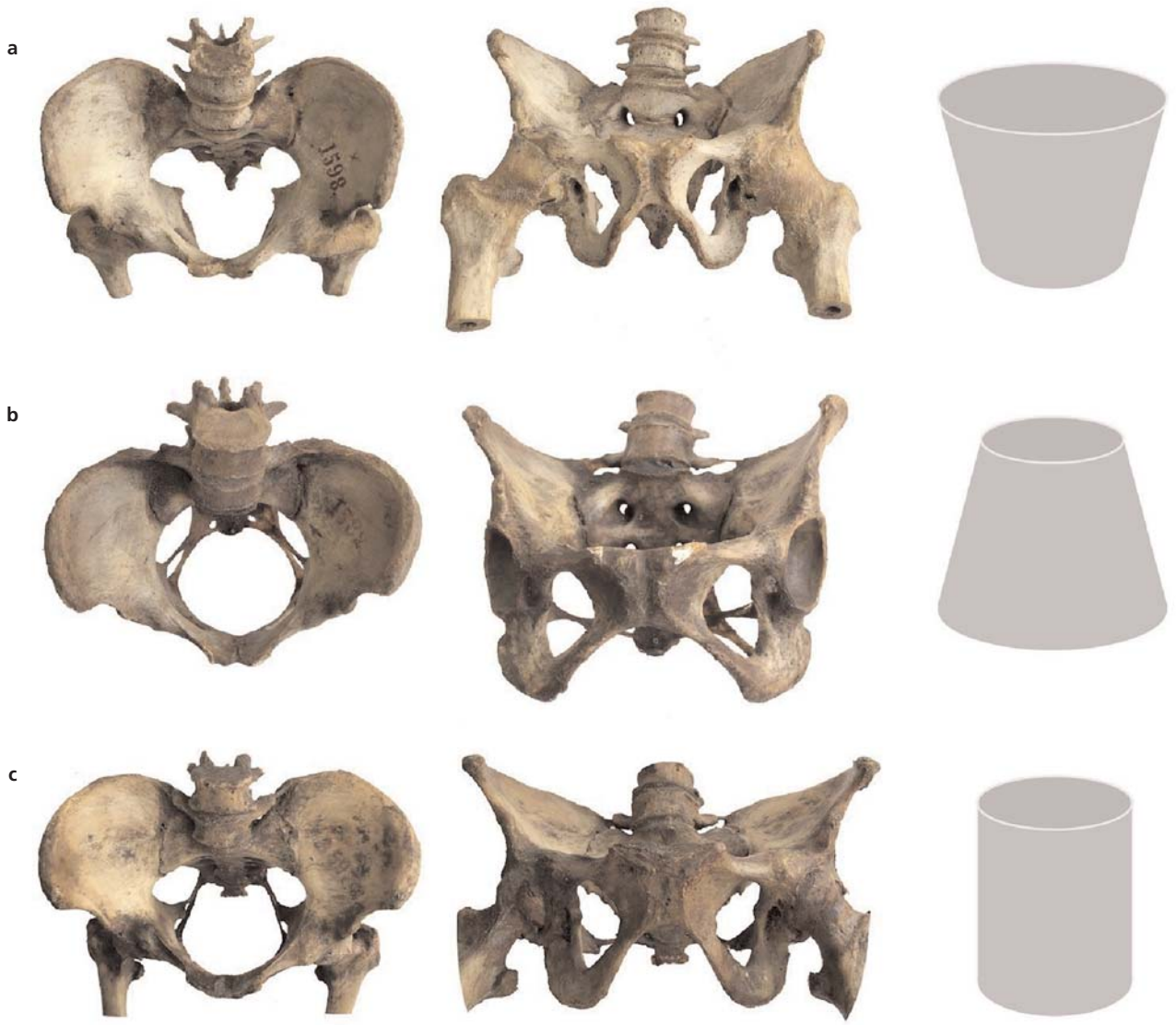

Figure 1. Variation of lesser pelvic cavity (**a**) narrowing downwards; (**b**) expanding downwards; (**c**) cylindrical.

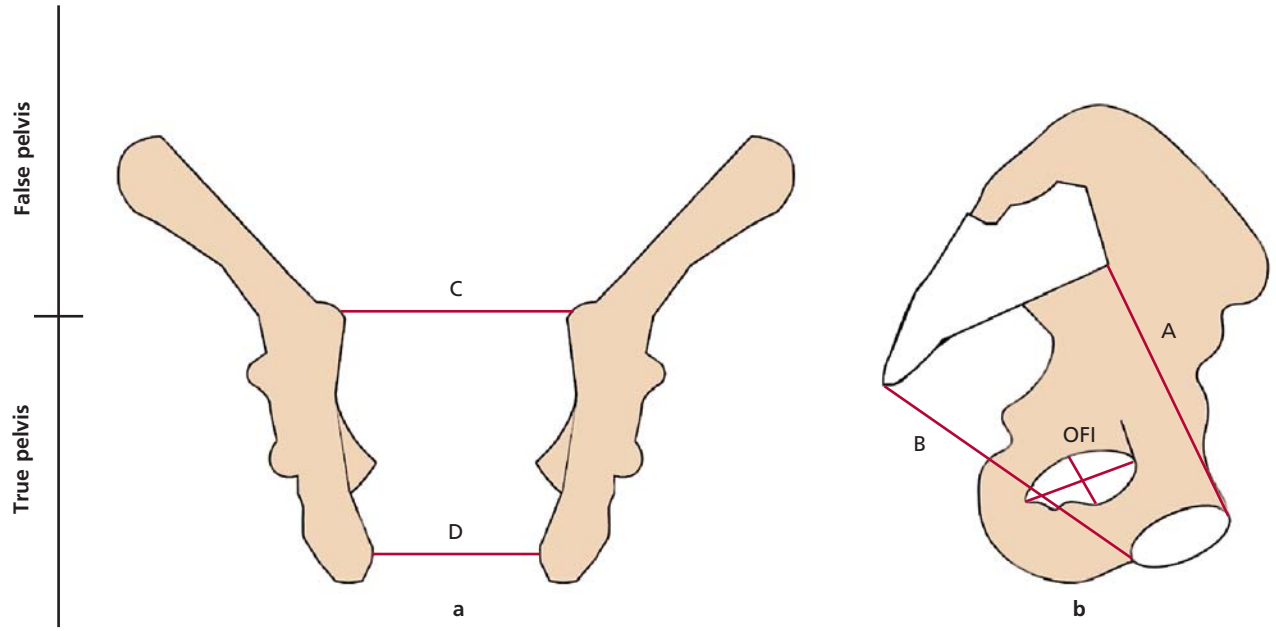

Figure 2. (**a**) Coronal section of the pelvis and (**b**) medial view of the left hip bone articulated with the sacrum. **A:** direct size of the pelvic inlet; **B:** direct size of the pelvic outlet; **C:** transverse size of the pelvic inlet; **D:** transverse size of pelvic outlet; **OFI:** width of the obturator foramen to the length of the obturator foramen.

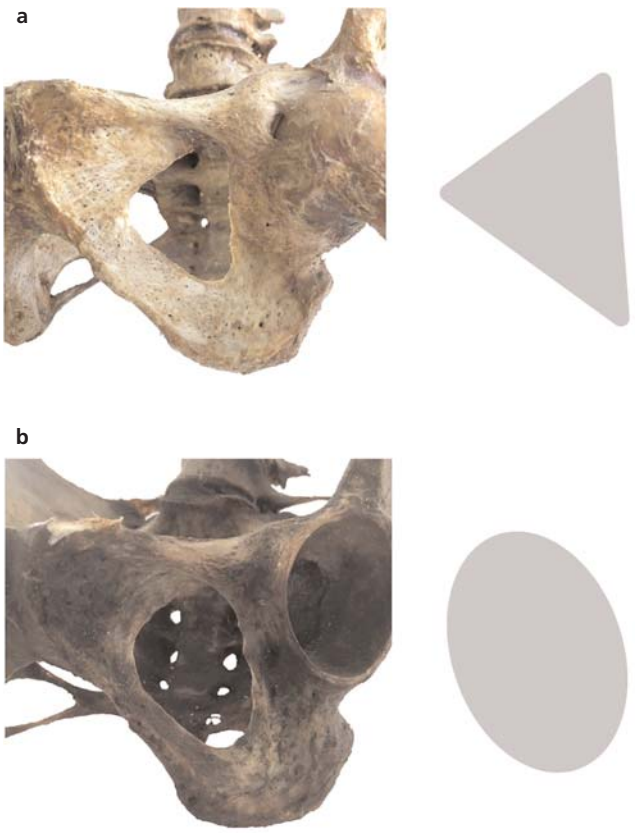

Figure 3. Shapes of obturator foramen of female pelvis. (**a**) triangular; (**b**) ellipsoid.

ments were considered. Statistical analysis of the obtained data was evaluated using STATISTICA v10 (Dell Statistica, Tulsa, OK, USA) software. The criterion of statistical significance of the tested hypotheses was the value $p<0.05$. To analyze the qualitative parameters defined with frequencies and percentages, the chi-square criterion and Fisher's exact test were used. Normalities were tested using the Shapiro-Wilk criterion. The values were defined with the mean value and standard error of the mean (in case of normal distribution) or by the median and quantile otherwise. The non-parametric Kruskal-Wallis criterion was used to check the differences between the groups.

This study was approved by the local research ethics committee of Military Medical Academy named after S. M. Kirov meeting dated 22.03.2019 (No:199).

Results

The values of linear dimensions in centimeters (cm) and angular characteristics in degrees (°) were are presented in **Table 1**. Parameters A, B, Spc, C, D, Std, Tps, Sa, Laof, Maof, Lsa (Parameter no: 1,2,3,4,5,6,9,13,16,17 and 21 in **Table 1**) differed significantly with the coefficient of variation more than 20%. Considering the high variability of these parameters, they were selected as the most important parameters for classification of the pelvises.

Table 1
Pelviometric form: parameters of the true pelvis and the obturator foramen.

Pelviometric parameters (cm)/(°)	Values			Coefficient of variation (%)
	Min	Max	Mean±SD	
Direct size of pelvic (A)	8.5	12.8	11.1±1.4	22.76
Direct size of pelvic outlet (B)	7.1	12	8.8±1.1	25.27
Longitudinal size of the pelvic cavity (Spc)	8.8	13.4	11.9±0.8	20.32
Transverse size of the true pelvic inlet (C)	11.5	14.5	13.1±0.8	24.43
Transverse size of the pelvic outlet (D)	7.5	12.5	10.3±1.1	23.29
Symphysis-tuberosity distance (Std)	8.2	10.6	9.4±0.5	22.46
Pelvic height (right, left) (Ph)	17.4 (R) 17.6 (L)	22.4 22.5	19.4±1.1 18.9±1.9	5.62 6.11
Height of pubic symphysis (Hps)	2.9	4.4	3.5±0.3	8.96
The pubic symphysis thickness (Tps)	1.0	2.1	1.5±0.3	22.79
Interspinal distance (Is)	19.0	25.8	23.6±1.5	17.71
Width of pubic symphysis (Wps)	0.7	1.3	1.0±0.2	5.84
Interobturator foramina distance (Ifd)	3.9	6.3	5.2±0.6	9.6
Subpubic angle ° (Sa)	48	117	78.3±9.1	21.76
Length of sacrospinous ligament (Lssl)	4.5	6.1	5.2±0.3	13.94
Length of sacrotuberous ligament (Lstl)	5.6	8.7	7.1±1.2	11.27
Lower angle of the obturator foramen ° (Laof)	49.0	80.0	59.2±11.1	24.34
The medial angle of the obturator foramen ° (Maof)	71.0	95.5	80.4±9.8	20.55
The width of the obturator foramen (Wof)	2.6	4.3	3.4±0.5	12.94
The length of the obturator foramen (Lof)	4.0	5.9	4.9±0.6	7.96
The depth of the obturator foramen (Dof)	1.3	2.4	1.8±0.3	9.12
Lumbosacral angle ° (Lsa)	119.7	143.2	136.4±7.1	21.19

The TT index was 1.32 cm on average (min: 0.95 cm, max: 1.5 cm). Similarly, the LL index was 1.12 cm on average (min: 0.88 cm, max: 1.39 cm). With these findings on the frontal and sagittal planes of the pelvis in the given specimens, it was possible to distinguish three pelvis shapes as "narrowing downwards", "cylindrical" and "expanding downwards" (**Figure 1**). The TT index was more than 1 and averaged from 1.06 to 1.5 in the narrowing downwards group (33.4%), equal to 1 and ranged from 1 to 1.05 in the cylindrical group (50%), and less than 1 (0.95–0.99) in the expanding downwards group (16.6%). The LL index ranged between 1.06 to 1.39 in the narrowing downwards (12%), 1 to 1.05 in the cylindrical (63%) and 0.88 to 0.99 in the expanding downwards (25%) groups.

The parameters were analyzed by distributing into groups according to the TT index to determine the shape of the pelvic cavity using the nonparametric Kruskal-Wallis test. This test allowed us to determine the dependent variables among the parameters (**Table 2**). Accordingly, the shape of the pelvic cavity was dependent on the linear and angular parameters such as straight and transverse dimensions of the pelvic inlet and outlet, longitudinal size of the pelvic cavity, symphysis-tuberosity distance, subpubic angle, length of sacrospinous ligament, lumbosacral angle, and lower and medial angles of the obturator foramen.

To identify the morphometric parameters that have the maximum effect on the shape of the obturator foramen and to construct the predictive function, a discriminant analysis was carried out. A qualitative variable, the index of the obturator foramen, was used for grouping variables. The following variables were used as discriminant variables capable of influencing the shape of the obturator foramen: lower angle (Laof) of the obturator foramen, medial angle (Maof) of the obturator foramen, and the index of the obturator foramen. When planning the study, one of the objectives was to conduct a discriminant analysis for three assumed forms of the obturator foramen: triangular, ellipsoid and quadrangular. However,

Table 2

Comparative characteristics of the morphometric parameters of the true pelvis and the obturator foramen in various forms of its cavity.

Pelviometric parameters (cm)/(°)	Parameter values for various forms of lesser pelvis (Mean±SD)			p-value
	Narrowing downwards (n=20)	Cylindrical (n=30)	Expanding downwards (n=11)	
Direct size of pelvic inlet	9.1±0.8*	10.3±0.5	11.5±0.4*	p=0.002 $p_{1,3}$=0.018
Direct size of pelvic outlet	7.8±0.4*	8.6±0.2	11.6±0.5*	p=0.004 $p_{1,3}$=0.021
Longitudinal size of the pelvic cavity	8.6±0.3*	9.2±0.5	11.9±0.4*	p=0.001 $p_{1,3}$=0.011
Transverse size of the pelvic inlet	11±0.5*,†	12.7±0.3†,‡	13.1±0.3*,‡	p=0.018 $p_{1,2}$=0.12 $p_{1,3}$=0.016 $p_{2,3}$=0.01
Transverse size of the pelvic outlet	7.9±0.4*,†	10.2±0.7†	10.4±0.8*	p=0.0024 $p_{1,2}$=0.011 $p_{1,3}$=0.016
Symphysis-tuberosity distance	8.2±0.3*	9±0.4	10.3±0.3*	p=0.003 $p_{1,3}$=0.01
Pelvic height	21.5±0.6	19.4±0.4	17.1±0.2	p=0.081
Height of pubic symphysis	3.1±0.3	3.9±0.1	4.1±0.5	p=0.75
The pubic symphysis thickness	1.2±0.3	1.9±0.2	2.1±0.2	p=0.57
Interspinal distance	20.8±0.5	22.6±0.4	24.6±0.3	p=0.21
Width of pubic symphysis	0.7±0.1	0.9±0.2	1.1±0.1	p=0.15
Interobturator foramina distance	4.1±0.2	5.1±0.4	5.7±0.5	p=0.20
Subpubic angle °	93±2.2*,†	98±6.3†,‡	106±3.1*,‡	p=0.001 $p_{1,2}$=0.022 $p_{1,3}$=0.009 $p_{2,3}$=0.027
Length of sacrospinous ligament	4.9±0.4*,†	5.3±0.4†,‡	5.8±0.3*,‡	p=0.02 $p_{1,2}$=0.02 $p_{1,3}$=0.003 $p_{2,3}$=0.001
Length of sacrotuberous ligament	7.8±0.8	8.2±0.4	8.4±0.3	p=0.35
Lower angle of the obturator foramen °	59.3±6.1*,†	66.8±8.2†,‡	75.3±5.1*,‡	p=0.002 $p_{1,2}$=0.04 $p_{1,3}$=0.05 $p_{2,3}$=0.012
The medial angle of the obturator foramen°	77.4±3.4*,†	85±4.1†,‡	90.1±4.9*,‡	p=0.0013 $p_{1,2}$=0.031 $p_{1,3}$=0.011 $p_{2,3}$=0.04
Obturator foramen index	0.55±0.3*,†	0.61±0.5†,‡	0.79±0.2*,‡	p=0.043 $p_{1,2}$=0.028 $p_{1,3}$=0.016 $p_{2,3}$=0.03
The depth of the obturator foramen	2±0.1	2.2±0.1	2.3±0.1	p=0.32
Lumbosacral angle °	131±4.3*	136±2.1	141±2*	p=0.0051 $p_{1,3}$=0.003

*Relationship between narrowing downwards and expanding downwards; †relationship between narrowing downwards to cylindrical; ‡relationship between cylindrical to expanding downwards.

the quadrangular form was found to be 3.3% (less than 5% of the total number of specimens), which was the criterion for its exclusion from the discriminant analysis. Thus, the samples the distributed into two main groups as triangular (1) and ellipsoidal (0) forms of the obturator foramen (**Table 3**).

The greatest influence on the shape of the obturator foramen was its lower angle. This angle is formed by the inferior pubic ramus and the ischial ramus. With the help of the data obtained, a discriminant function to calculate the shape of the obturator foramen was determined:

D0 = 0.416*Laof+0.267*Maof+22.97*OFI-66.562

LA - low angle of the obturator foramen; MA - medial angle of the obturator foramen; OFI - index of the obturator foramen. If D0>0, the shape is considered as "1" (triangular), otherwise "0" (ellipsoid). With this formulation it was possible to assess the shape of the obturator foramen with above parameters with 96% sensitivity, 100% specificity and 97.1% accuracy.

While the correlational analysis of obturator foramen shape with the LL and TT index revealed a significant correlation with TT (p=0.053), there was no significant correlation with LL index (p=0.12).

To determine the dependence of the shape of obturator foramen on the shape of pelvis, a statistical analysis was carried out according to the Pearson's criterion by creating a contingency table (**Table 4**). The results indicated that the triangular form was predominantly found in cylindrical and narrowing downwards group. In turn, the ellipsoid form dominated in the expanding downwards group. Due to the small sample number with a quadrangular shape of the obturator foramen, it was not possible to draw a certain conclusion about its relationship with the pelvic shape.

We also carried out a statistical analysis of standard parameters obtained in the course of a complex morphometric study in order to determine the correlation between linear and angular parameters of these pelvic bone forms according to the TT index. As a result, moderate direct correlational relations (p≤0.05) of the form narrowing downwards with the subpubic angle (r=74.9) were revealed, as well as its strong negative correlation (p≤0.05) with the lumbosacral angle (r=-0.86).

Discussion

Three forms of the obturator foramen were revealed: triangular, ellipsoid and quadrangular. The triangular shape of the obturator foramen was typically found in cylindrical or narrowing downwards configurations of the pelvis. At the same time, the ellipsoidal shape of the obturator foramen dominated in the expanding downwards configuration. On the basis of the direct correlation between the shape of the pelvis and the subpubic angle, it can be concluded that the pelvic cavity narrows downwards more when the subpubic angle gets smaller and *vice versa*.

Table 3
Discriminatory variables and corresponding coefficients arranged in order of importance.

Discriminatory variables	Discriminatory coefficient	p-value
Lower angle of the obturator foramen	0. 416	0. 002
Medial angle of the obturator foramen	0. 267	0. 001
Obturator foramen index	22. 972	0. 003
Constant	-66. 562	

A comprehensive analysis of the morphometric characteristics of the bone pelvis in adult women indicates a wide range of variant anatomy of linear and angular parameters and the size of the obturator foramen, which correlates with the results of former studies.[6,7] Taking into account that the bone component of the obturator complex plays the role of a framework for fascial and muscular structures of the pelvis, its variability in shape can affect the position of implanted prostheses in tissues.[7] Also, a significant role in understanding the distribution of the intra-abdominal pressure in the pelvis was played by the interconnection of the pelvic shape with the value of the lumbosacral angle, which increased significantly with the expansion of the pelvic cavity. Under such conditions, the pressure vector shifts from the spine to the pelvic diaphragm region, which can lead to anatomical and functional disorders of the pelvic floor. Our assumptions regarding the significance of the lumbosacral angle in the development of pelvic floor dysfunction are confirmed in the study of Stav et al.[11] and Amonoo-Kuofi.[12]

The strong point of this study was the large number of samples used for determining pelviometric parameters and the use of discriminant analysis which turned out to be a sensitive statistical method and allowed to create a mathe-

Table 4
Occurrence of the obturator foramen forms depending on the shape of the pelvic cavity.

Shape of the obturator foramen	Pelvic shape according to transverse-transverse index			Total
	Cylindrical	Narrowing downwards	Expanding downwards	
Triangular	23 (59%)	16 (41%)	0	39
Ellipsoid	5 (25%)	4 (20%)	11 (55%)	20
Quadrangular	2 (100%)	0	0	2
Total	30	20	11	61

matical model to predict the shape of the obturator foramen. We evaluated only the bone component of the obturator complex which was a limitation of our study. In order to confirm the given interrelations, it is necessary to find out the role of the obturator muscles and the obturator membrane, as well as to study the morphology of the paraurethral area. This collection did not have medical history data or information on parity or pelvic floor disorders, therefore, we could not comment on the relationship between these findings and clinical outcomes. Furthermore, some of these bony pelvises had mild degeneration that could potentially affect the measurements.

Conclusion

There is a need to study individual pelvic anatomy in the surgical treatment of SUI. The obturator foramen and angle of the pubic arch are highly variable in females. It is important to take into account that the bone component of the obturator complex is a framework for fascial and muscular structures of the pelvis, and the role of individual anatomy of muscles and ligaments in the studied area for the successful surgical treatment of stress urinary incontinence in women and should be evaluated in further studies. The results of this study did not answer the questions for improving the objective efficacy of suburethral sling, but suggested further studies using imaging techniques and cadaver dissections.

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Research concept and design: GIV, SDD; collection and processing of material: KGV, LIA, NGI; data analysis and interpretation: KGV, KND; writing and editing text: KGV, LIA.

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Enteric nervous system, gut-brain connection and related neurodevelopmental disorders

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Abstract

The vagus nerve is the primary neural medium which enables gastrointestinal tract and brain communication. Hippocampus, a region of the brain commonly linked to memory function, is activated by vagus nerve-mediated gastrointestinal signals. Vagal afferent information is received by the medial solitary nucleus and is then transmitted via ascending neural pathways to different regions of the forebrain and hindbrain. Explanation of the exact mechanisms of microbiota and amygdala communication requires further research. By linking microbial activities to progressive structural and functional events in the brain in mice models and in humans, we can suggest that intestinal microbiota is an important contributor to neurodevelopment and neurodegeneration. Further researches revealing these relations may provide new approaches for understanding neurodegenerative, psychiatric and behavioral diseases.

Keywords: enteric nervous system; gut-brain connection; neurodegenerative diseases; vagus nerve

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Enteric Nervous System and Its Internal Structure

When compared to other peripheral organs of the body, the gastrointestinal tract (GIT) differs from all of them. GIT has a comprehensive internal nervous system called enteric nervous system (ENS), which can control intestinal function, even if it is totally cut off from the central nervous system (CNS).[1] The ENS provides unique innervation of the intestine and is the most neurochemically diverse part of the peripheral nervous system (PNS).[2] The ENS was described by British physiologist John Newport Langley as one of the three autonomic nervous system parts: parasympathetic nervous system, enteric nervous system and sympathetic nervous system.[3] More than 100 million efferent neurons that reach the intestines through the vagus nerve are present in human ENS.[4] Unlike the rest of the PNS, the complexity of managing bowel behavior is a privilege that evolution provides to the ENS, which has led to the ability to manifest complementary neuronal activity and to control gastrointestinal behavior independently of the brain or spinal cord.[5–7] The ENS has at least as many neurons as in the spinal cord but has more neurons than any other group of peripheral ganglia. Unique to PNS, the ENS is regulated in microcircuits with intrinsic primary afferent neurons (IPANs) and interneurons that are capable of initiating reflexes. The phenotypic diversity of enteric neurons is very wide and almost every class of neurotransmitters found in the CNS has been identified in the ENS.[6] Although the ENS can work independently from the CNS, it normally does not; CNS affects the enteric system and the intestine also sends information to the brain. Indeed, 90% of the vagal fibers between the intestine and the brain are afferent, suggesting that the brain is more recipient than a giver in brain-intestinal communication.[6,8]

ENS is located within the tubular digestive system walls, biliary system and pancreas. ENS has myenteric and submucosal plexuses, two ganglioned plexuses in the intestine, where almost all intrinsic nerve cells are present.[9] The myenteric plexus is located between the outer longi-

tudinal and circular muscle layers and runs from the esophagus to the rectum along the full length of the digestive tract. The submucosal plexus is found only in the large and small intestines.[10]

The enteric motor neuron has five broad types and many subtypes; excitatory neurons that excite intestinal muscles, inhibitory neurons that inhibit intestinal muscles, vasodilator/secretomotor neurons, non-vasodilator secretomotor neurons, and neurons that innervate the enteroendocrine cells.[11] In the guinea pig's small intestine, one type of ascending as well as three types of descending interneurons have been identified. Neurons that ascend, which have enkephalin/calretinin/ChAT (ENK/calretinin/ChAT) chemical code, are cholinergic and form chains extending across the intestine, such as descending neurons.[12] The three descending interneuron species that the intestines have are called by the following names and chemical codes: nitric oxide synthase/choline acetyltransferase/vasoactive intestinal peptide ± gamma-aminobutyric acid ± bombesin ± neuropeptide Y (NOS/ChAT/VIP±GABA±BN±NPY), choline acetyltransferase/5-hydroxytryptamine (ChAT/5-HT) and choline acetyltransferase/somatostatin (ChAT/SOM). With the investigation of all these neurons' connections, the hypothesis that ChAT/NOS/VIP neurons involved in local mobility reflexes were related to the transmission of migrating myoelectric complexes (MMCs) of ChAT/SOM neurons. It was found that neurons were directly involved in secretomotor reflexes but indirectly in mobility reflexes in the small intestine and ChAT/5-HT.[11,13] ChAT/SOM neurons have distinctive morphology with branching filament dendritic cell bodies. In the distal colon, filamentous neurons with anal axons are not present but they are present in the colon.[14–16]

Many studies have noted that reflexes occur in the isolated intestine, even after the cut-off of the extrinsic nerves feeding the intestines and after a certain period of time for the ends to degenerate. This indicates the presence of IPANs (sensory neurons) in the intestine.[17,18]

Intestinal secretomotor neurons of two types have been identified that are cholinergic and non-cholinergic, and also the release of IPANs in the mucosa from the ends of these neurons, indicates that these cells may have secretomotor effects.[11] It has been shown that non-cholinergic neurons use VIP or a related peptide as their main transmitter and mediate the majority of the local reflex response. The point of innervation of ACh/calretin neurons and the secretory glands is the mucosal base where the former have collaterals against submucosal arterioles but ACh/NPY neurons don't supply innervation to the arterioles.[11]

Gut-Brain and Vagus Nerve

The vagus nerve serves as the first neural communication mediator between the brain and the gastrointestinal (GI) system. The vagus nerve transmits energy state signals through the vagal afferent (sensory) nerves from the intestine to the brain. There are separate afferent fibers innervating GI organs to determine intestinal nutrient content or stomach volume.[19–21] Afferent fibers mentioned include cell bodies inside the nodose ganglia synapsing with the CNS. The medial nucleus of the solitary tract (mNTS) in the caudal brain stem acquires vagal afferent/sensory information in the brain and the information is then transmitted via ascending neural pathways to the various hindbrain and forebrain regions.[22] Vagal-mediated signaling from the GI organs is first received in the mNTS area of the brain.[23] GI-mediated signals, such as direct vagus nerve stimulation, mechanical tension in the stomach, and intestinal infusion, activate neurons in a region of the brain that is classically affiliated with memory control, feeding behavior, and learning; the hippocampus (HPC).[22,24–27] Studies of Clark et al.[28–30] have shown that unilateral cervical vagus nerve stimulation and stimulated vagal afferents by inactivation of the vagal efferents, improve inhibition-avoidance retention memory in rats, while in humans, vagus nerve stimulation increases retention in recognition memory as stimulation occurs upon learning.

The vagus nerve promotes neurotrophic and neurogenic signaling. The endogenous relevance of vagal signaling, particularly the vagal afferent pathways of the innervated intestines, abnormal and cognitive control is not well understood. The neural pathways that enable transmission of vagal mediated energy-state signals between hippocampal neurons and the GI pathway have not totally clarified. Furthermore, the neural pathways which cater for the transmission of vagal mediated energy-state signals between the GI pathway and hippocampal neurons are not completely understood. MNTS, where sensory inputs from the digestive system synapse here, sends projections to several brainstem and forebrain regions, but not directly to the HPC.[31–33] This shows that communication between mNTS and HPC is made through multiple nerve projection pathways. The potential brain region reserve location that binds mNTS to the ventral CA1 HPC (one of the subregions of the HPC) was defined as the locus coeruleus (LC) and the medial septum (MS).[31] In the world of gut-brain connection, HPC is a new player. GI signal with in-meal saturation signals (eg, gastric bloating, intestinal food infusion) activates cerebral blood flow (CBF) in hippocampal neurons in rodents.[24,34]

In addition, HPC blood flow is strongly actuated after gastric vagal nerve stimulation in people suffering from obesity.[27]

Suarez et al.[22] noted that the gastrointestinal derived vagal sensory signaling supports hippocampus-dependent memory function by way of brainstem–septal nerve pathway, in this way initializing a previously unbeknown act for the axis of the brain-gut in memory control. Other studies have shown that vagal nerve stimulation, mimicking afferent signaling from the intestine, has been successfully used to treat depression, and also increases memory as well as learning in both humans and animals.[35,36] Potentially, luminal microbiota can affect behavior, mood, and brain development via signals transmitting by the vagus nerve.[6,37–39]

The amygdala is a small, almond-like structure and is considered one of the most important parts in the limbic system and has a vast record of scientific research in emotion processing with its role in behavior modulation.[40,41] Because it is located centrally in the temporal lobe, the amygdala complex is highly joined to multiple brain regions. Amygdala receives sensory input from thalamus and cortical regions, as well as various other sites in the limbic system, including hippocampus and the prefrontal cortex.[42]

There are noradrenergic projections extending directly and indirectly from NTS to amygdala.[43] Thus, visceral information received by the vagus nerve may ultimately affect amygdala activity. In fact, vagus nerve stimulation has been shown to stimulate norepinephrine release in the amygdala,[44] increasing behavioral outcomes in preclinical fear extinction models and clinical trials of major depressive disorder, and regulating connections to the amygdala prefrontal cortex.[45,46] In contrast, the interruption of vagal communication in the subdiaphragmatic disruption of the vagus nerve has been shown to reduce fear depletion but to reduce anxiety-like behavior in rats.[47]

Numerous neurodevelopmental complications are also linked to abnormalities in the amygdala. Changes in amygdala efficacy, volume (properties affected by the intestinal microbiota)[48–51] and/or connectivity have been reported in individuals diagnosed with attention deficit hyperactivity disorder,[52] schizophrenia,[53,54] and autism spectrum disorders (ASD).[55,56]

Link between the Gut Microbiota-Brain and Neurodevelopmental Disorders

In humans, the gastrointestinal tract is collectively colonized by trillions of microorganisms called intestinal microbiota. This gut microbiota regulate host physiology in many aspects, including the maturation and function of the immune system.[57–59] Furthermore, increasing evidence suggests that intestinal microbiota have effects on brain development, function and regulation of behavior.[37,60,61]

Brain development in mammals is a complex process that lasts until adolescence and in humans lasts until early adulthood. In addition, the brain development process involves the passage of cells over longer distances to create specific circuits underlying behavior, as well as the migration of cells to extraordinary, large-scale long distances during certain fetal development.[62,63] The biggest portal in the molecular universe is the intestine hence it has been shown that various dietary ingredients interact directly with the brain development and trigger functional changes in the grown-up brain.[64,65] Recent research has found evidence that the intestinal microbiota has long-term effects on health, such as leading and easing developmental processes in the brain.

The mammalian microbiome consists of a unique combination of many different microorganisms (i.e. bacteria, fungi, archaea, and viruses) in the body. There are many pieces of research showing the effect of the intestinal microbiome on CNS function, but most of these researches are preclinic, rather than human investigations.[61,66] These include diet management, interventions that bolster the growth of beneficial bacteria (like prebiotics), administration of specific bacterial strains (like probiotics), antibiotic treatments, germ-free mice (microbiota deficient), fecal microbiota transplantation and C-section.[67] Recent reports of studies on mice models show that disruption of the microbiome will contribute to the understanding of the pathology of various neurological diseases. According to evidence from rodent models, there is a direct link between intestinal microbiota, stress and anxiety.[68] Research on human and animal models has linked intestinal bacteria with the function and development of the immune system. Microbiota includes all types of immune cells, and specific microbes that increase or ameliorate immunological disorders like asthma, inflammatory bowel disease and type 1 diabetes.[69] There are many animal models research based on the potential role of the microbiome in neuropsychiatric disorders like depression, anxiety,[68] autism spectrum disorder,[70] schizophrenia,[71] Parkinson's disease, and Alzheimer's disease.[72]

Increasing evidence indicates bi-directional nature of communication between intestinal microbial populations and brain.[73–76] De Palma et al.[77] used a maternal separation model in mice and showed deep differences in intes-

tinal microbiota in response to early life stress resulting in an anxiety-like phenotype. It has also been reported that intestinal bacteria have a reciprocal effect where certain bacteria or whole microbial populations have an effect on host stress and depression-like behavior.[78–80] It is not yet clear whether these examples are directly driven by an intestinal-brain interaction or mediated by other physiological factors caused by the disease state. But these reports and others illustrate potential interactive relations between the gastrointestinal tract microbiome and the brain.

Evidences from studies in rodent animal models show that intestinal microbiome plays a role in depressive behavior.[81–83] Approximately 20% of patients with gastrointestinal symptoms have been reported to be associated with depression.[84] According to a hypothesis, depression or subsets of this disorder are the result of a microglial disorder, since the presence of depression commonly leads to either intense inflammatory episodes in the brain or a descend in microglial function.[85] According to latest findings on the role of the microbiota in microglia maturation and activation, it is not difficult to predict that microbiota can trigger depression by affecting microglial maturation and activation.[86,87] In a study on depression, reduced bacterial richness and diversity were addressed and it was reported that depression-like phenotypes could be transmitted to rats by fecal transplantation.[88] More recently, studies on mice and humans have indicated that microbiota has an active role in guiding depression-like behavior and suggests potential new ways of therapeutic development.

In this review, in the light of general information about the enteric nervous system and its internal structure, we evaluate the relationship between microbiota and brain in human as well as animal models through many studies with gut and vagus nerve connections. The vagus nerve is the primary neuron that enables the gastrointestinal tract–brain communication. Vagus nerve mediated gastrointestinal signals activate the hippocampus. Explanation of the exact mechanism concerning microbiota and amygdala communication requires further research. By linking microbial activities to progressive structural and functional events in the brain in mice models and in humans, we can suggest that intestinal microbiota is an important contributor to neurodevelopment and neurodegeneration. Further researches revealing these relations may provide new approaches for understanding neurodegenerative, psychiatric and behavioral diseases.

Author Contributions

EA: designing the review and writing text, EA and KA: literature search, EA, KA, MB and ING: writing text, final check of the manuscript.

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Rhomboid muscle variations: notes on their naming and classification principles

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Abstract

In this report we present two cases of rhomboid muscle variations observed during routine anatomical dissections. In the first case, on the left side of an adult male cadaver, a long and slender aberrant muscle was identified starting from the lateral part of the superior nuchal line and inserting to the scapula between the rhomboid minor and levator scapulae. The muscle was identified as the rare rhomboid capitis. In the second case, in an adult female cadaver, a bilateral variation in the origin of the rhomboid major fibers was described. On the left side, the rhomboid major fibers started from spinous processes of C1–C6, while on the right side it was narrower and originating from spinous processes of C1–C3. Reviewing the literature about the rhomboid muscles variations, we conclude that one and the same aberrant structure might be named differently. We also discuss the presentation of the known variations of the rhomboids in a common scheme instead of classification.

Keywords: human; rhomboid muscle; variation

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Introduction

The superficial muscles of the back connect the upper limb to the axial skeleton. In the upper back region, the rhomboids (minor and major) and levator scapulae muscles can be identified inserting on the medial scapular border under the trapezius.[1,2] The rhomboids fix the medial border of the scapula to the thoracic wall and also retract this bone superiorly and medially and rotate it to depress the glenoid cavity.[1,3] Variations of the rhomboids have been described in different names depending on the authors' understanding of the nature of variant muscles.[4–12]

In this report, we present two cases of variations of the rhomboids and also provide a critical review of the present literature on this topic. Additionally, we aimed to discuss the controversies with the naming of these muscle variations and their proper grouping.

Case Report

In the first case (**Figure 1**), during routine anatomical dissection of a 70-year-old Caucasian male cadaver, after cutting and retracting the trapezius muscle, a small aberrant muscle bundle was identified between the rhomboid minor and levator scapulae on the left side. The complete dissection revealed that the variant muscle bundle originated form the lateral part of the superior nuchal line next to the base of the mastoid process. As it passed downwards, it crossed the fibers of the splenius capitis near its cranial insertion. Finally, the aberrant slip inserted to the superior scapular angle, between the scapular attachments of rhomboid minor and levator scapulae. Based on its origin and insertion, the variant muscle slip was identified as rhomboid capitis muscle.[13,14] It had a length of 21 cm and a width of 6–7 mm.

In the second case (**Figure 2**), routine anatomical dissection of a 67 year-old Caucasian female cadaver revealed quite asymmetrical rhomboids. On the left side, rhomboid major had an extended origin from T1 to T6 spinous processes, as the lowest part of the muscle was mostly aponeurotic. On the right side, the rhomboid major seemed much narrower and originated from T1 to T3 spinous processes.

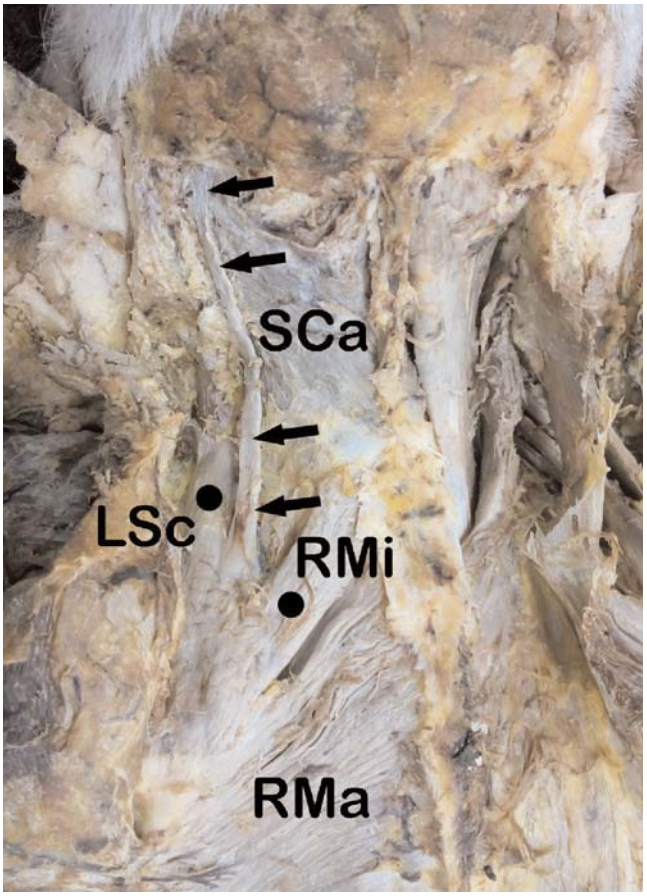

Figure 1. Photograph of the rhomboid capitis muscle (**arrows**), observed on the left side and described in Case 1. **LSc:** levator scapulae; **RMa:** rhomboid major; **RMi:** rhomboid minor; **SCa:** splenius capitis.

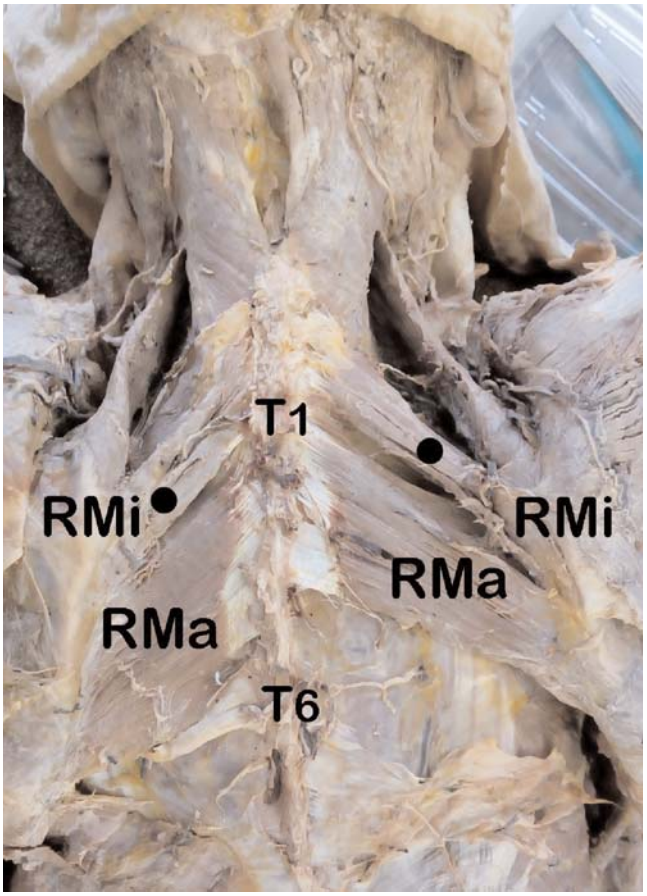

Figure 2. Photograph of the asymmetrical rhomboid muscles layer described in Case 2. **RMa:** rhomboid major; **RMi:** rhomboid minor.

Discussion

The rhomboids are composed usually of six flat slips that originate from the spinous processes of either C7–T5 vertebrae[1,3] or C6–T4 vertebrae.[2,15] The fibers of the muscles run downwards and laterally to insert on to the medial border of scapula. The upper two slips of the rhomboids belong to the rhomboid minor muscle, while the lower four slips to the rhomboid major muscle. The rhomboids are mainly supplied by the dorsal scapular nerve of the brachial plexus made up of C4 and C5 spinal nerve fibers.[3] Additional fibers contributing from C3 and C6 spinal nerves were also reported in some studies.[16]

Variations of the rhomboids were previously reported as case reports,[9,14,17] or in large series.[4–8,10] One and the same aberrant muscle is named and grouped differently in majority of these reports. A common problem is the description of this variant muscle with different names, depending on its complete separation or fusion with the usual muscle (**Figures 3a** and **b**). Such examples might be the rhomboid minimus (or minus)[10,12,18] and rhomboid tertius muscles.[11,19] When these aberrant muscles are fused with or being a part of the rhomboids they are described as extended attachments or increased number of the slips; however, when well separated from the usual muscles, they are called by their own names (**Figures 3a** and **b**). Rhomboideus minimus is a small, nearly horizontal variant muscle below the rhomboid major, which was described by von Haffner.[18] A muscle with the same morphology was named as rhomboideus minus by Mori,[10] who also mentioned that this muscle is common in Japanese. Interestingly, a muscle also called rhomboid minimus was described in quite a different location; just superior to the rhomboid minor.[12] Another interesting variation reported is the rhomboid capitis (rhomboid occipitalis),[13,14] also named as occipitoscapular muscle.[4,5] Basically, the rhomboid capitis is a common neck muscle in many lower mammals.[14] But it is quite a rare finding in humans and great apes.[13] Some authors still named the same muscle based on its origin and insertion simply as occipitoscapular muscle.[17,20]

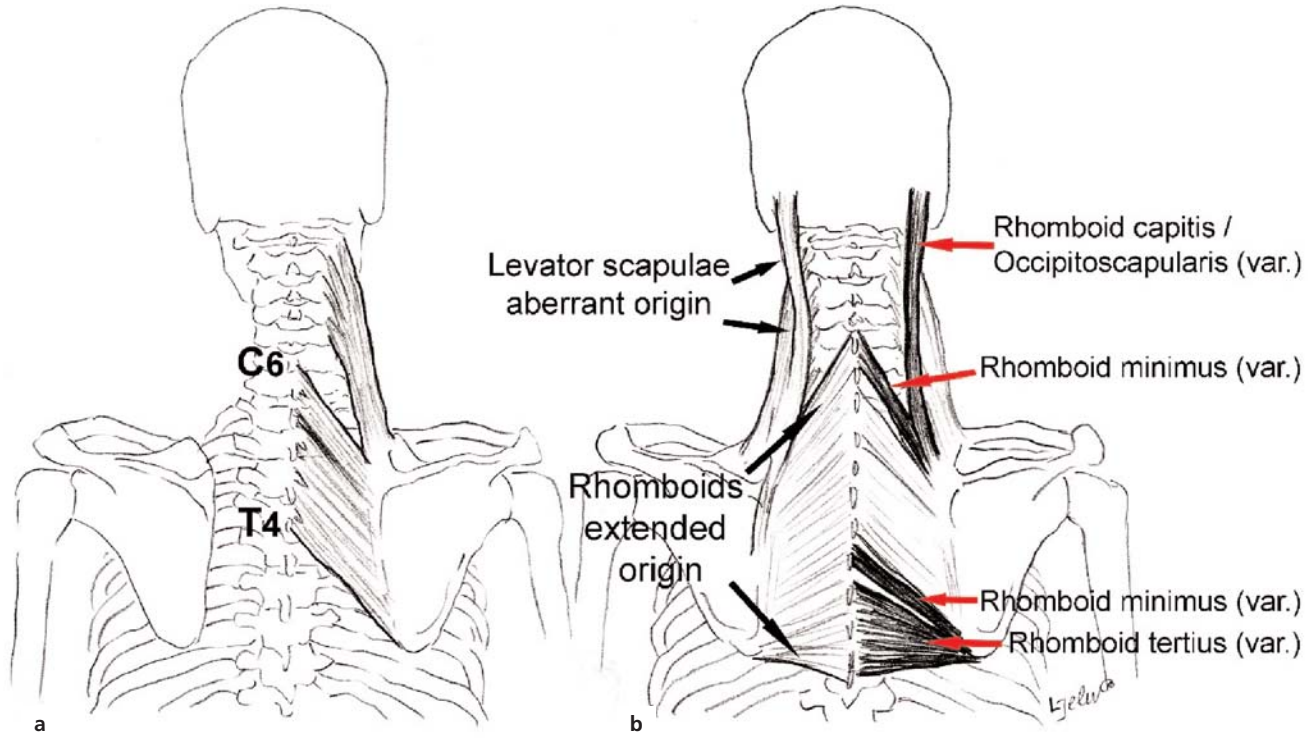

Figure 3. Diagrams presenting the normal anatomy (**a**) and variations (**b**) of the rhomboids. (**b**) Variations of extended origin and aberrant attachment are presented on the left side, while on the right side the red arrows show similar muscular structures, separated from the main muscles and named differently.

Some interesting descriptions of non-vertebral origins of a muscle originating from the skull and closely related to rhomboids can be noted in previous reports reviewing the variations of the levator scapulae (**Figure 3b**).[12,21] This might be another example of a variation, same as rhomboid capitis, which is fused completely with the usual levator scapulae. In summary, after all these notes on the rhomboid muscles variations, it seems quite difficult to present a classification. The classification principles are simply not clear. To present one and the same structure in different groups with different names simply because it might be well-separated or non-separated is not reasonable. Instead, we propose a scheme that demonstrates the range of rhomboid muscles variations (**Figure 3b**).

Conclusion

All of these variant muscles can manifest, despite rare, with some clinical symptoms. The rhomboids, rarely presenting aberrant attachments which might influence the proximal myofascial pain of the upper limb.[22] On ultrasound, CT scan and MRI, variant and non-expected muscles like rhomboid capitis, can mimic a tumor.[23] So, it is important to have knowledge about the variations of these muscles for avoiding misinterpretations of diagnostic imaging and approaching the patients with myofascial pain of the upper limb.

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Author Contributions

All authors equally contributed.

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Case Report

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Bilateral atresia of the external acoustic meatus: a case report

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Abstract

Bilateral atresia of the external acoustic meatus is a rare condition. It is a subtype of congenital aural atresia, which comprises a spectrum of developmental ear abnormalities. In this case report, we present the computed tomography (CT) findings of a patient with this congenital anomaly and emphasize the importance of the findings with regard to treatment options. CT revealed bilateral atresia of the external acoustic meatus in coronal and axial sections of an 8-year-old boy was admitted to hospital due to hearing loss. No congenital anomaly was detected in the middle and inner ear structures. Early detection of congenital aural atresia is critical. Speech retardation and accompanying anomalies associated with hearing loss may be seen in these patients. CT is essential for the diagnosis and classification of congenital bilateral aural atresia, identification of concomitant ear anomalies, and determination of the appropriate surgical treatment method.

Keywords: computed tomography; ear anomaly; external acoustic meatus

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Introduction

Congenital aural atresia (CAA) is a developmental anomaly that includes auricular, external acoustic meatus, and middle ear deformities.[1] In CAA, embryologically, the epithelial plate of the first branchial groove fails to canalize.[2] CAA is seen in 1 per 10,000–20,000 live births, and it is more common in males. Unilateral atresia is five times more common than bilateral atresia.[3] Altmann[4] classified CAA as per severity evaluated based on pathology and symptoms as follows: mild (Grade I) CAA is characterized by mild malformation of external acoustic meatus, malformation of the auditory ossicles, and good mastoid pneumatization; moderate (Grade II) CAA, by the absence of the external acoustic meatus, malformation of the auditory ossicles, and poor mastoid pneumatization; and severe (Grade III) CAA, by the absence of the external acoustic meatus, malformation of the auditory ossicles, and lack of mastoid pneumatization. In CAA, hearing loss is conductive. Early diagnosis is crucial because speech development depends on hearing. Computed tomography (CT) is required for the evaluation of external acoustic meatus, a subtype of CAA, since otoscopic examination is unsuitable in case of external ear hypoplasia or atresia.[5] Inner ear functions are generally normal. Conductive hearing loss can be corrected by surgical intervention at an appropriate age.[6] Here, we describe the CT findings in bilateral atresia of external acoustic meatus and emphasize their importance with regard to treatment options.

Case Report

An 8-year-old boy was admitted to our faculty hospital because of bilateral hearing loss. Informed consent of the patient's family was obtained before CT examination. CT images revealed bilateral atresia of external acoustic meatus in coronal and axial sections (**Figures 1** and **2**). No congenital anomaly was detected in the middle and inner ear. The auditory ossicles were normal. Mastoid pneumatization was adequate (**Figure 3**). Although these findings did not fully comply with Altmann's classification, they were categorized as moderate (Grade II) CAA due to the absence of the external acoustic meatus and the presence of mastoid pneumatization.[4]

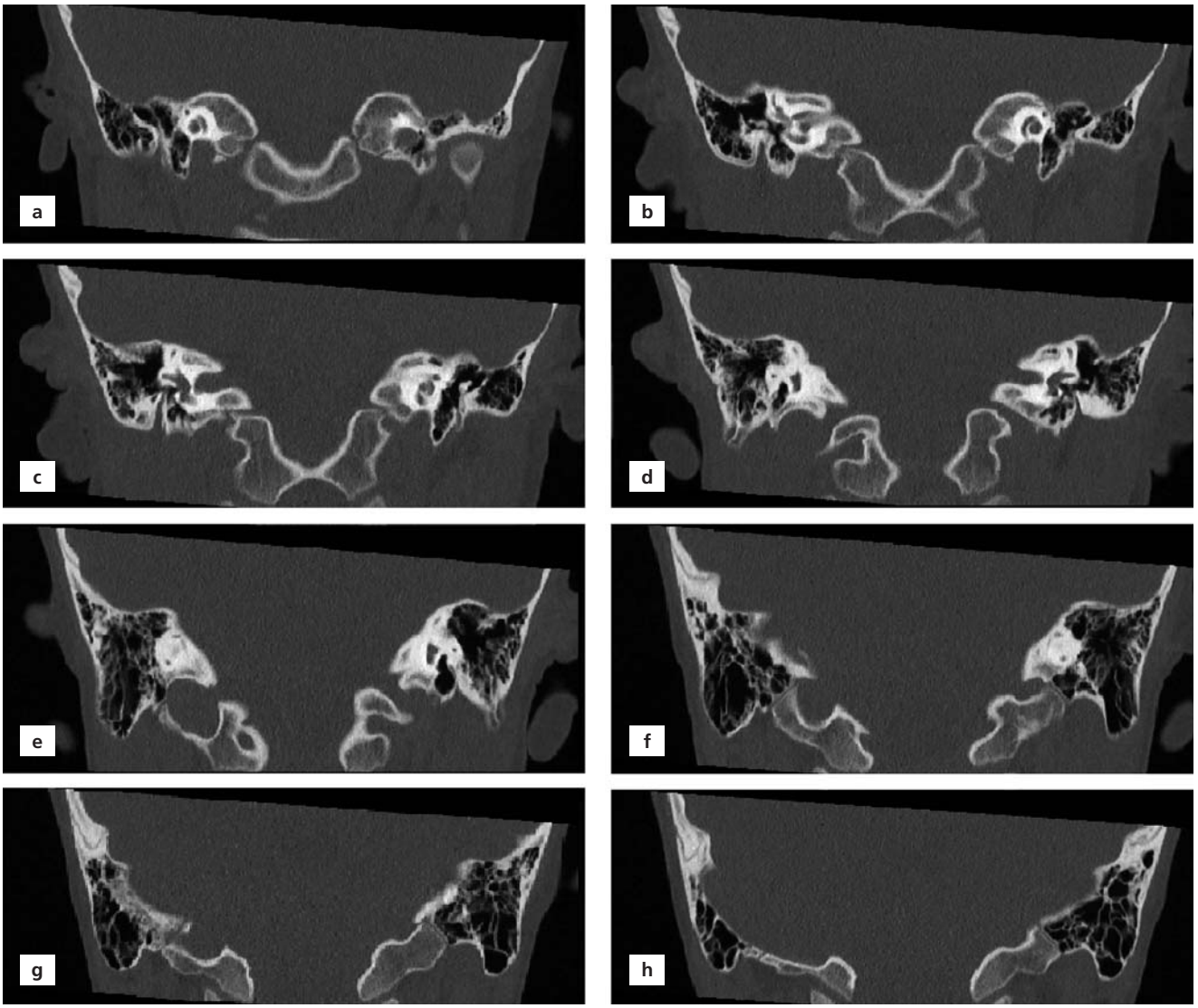

Figure 1. Coronal thin-section CT scans (**a**–**h**). The continuity of the atresia of the external acoustic meatus can be followed in sequential sections.

Discussion

CAA may show autosomal recessive inheritance, but is generally sporadic. It can be accompanied with DiGeorge, VATER, Klippel–Feil, Fanconi, Pierre Robin, and CHARGE syndromes. Concomitant anomalies include cleft palate, hemifacial microsomia, posterior cranial hypoplasia, hydrocephalus, and genitourinary abnormalities.[3] None of these anomalies was observed in our patient.

Colman[7] divided patients with CAA with conductive hearing loss into three groups. The first group includes those with narrow but open external acoustic meatus; the second group with completely closed external acoustic meatus and complex anomalies in the middle ear; and the third group with severe external acoustic meatus malformation and no mastoid pneumatization. Our patient presented with hearing loss, but the findings did not match any of the groups in the Colman's classification; only external ear canal atresia was observed.

Schuknecht[8] divided CAA into four types based on choosing the right surgical technique and evaluating important findings at the time of surgery: Type A includes atresia in the fibrocartilaginous part of the external acoustic meatus; Type B includes stenosis of the external acoustic meatus and malformation of the auditory ossicles; Type C includes complete atresia of external acoustic meatus and good mastoid pneumatization; Type D includes complete atresia of external acoustic meatus and poorly pneumatized middle ear. The findings in our patient were entirely consistent with Type C CAA.

A 10-point scale was developed by Jahrsdoerfer et al.[9] by evaluating the anatomical structures in the temporal bone using high-resolution CT, and this system is key for

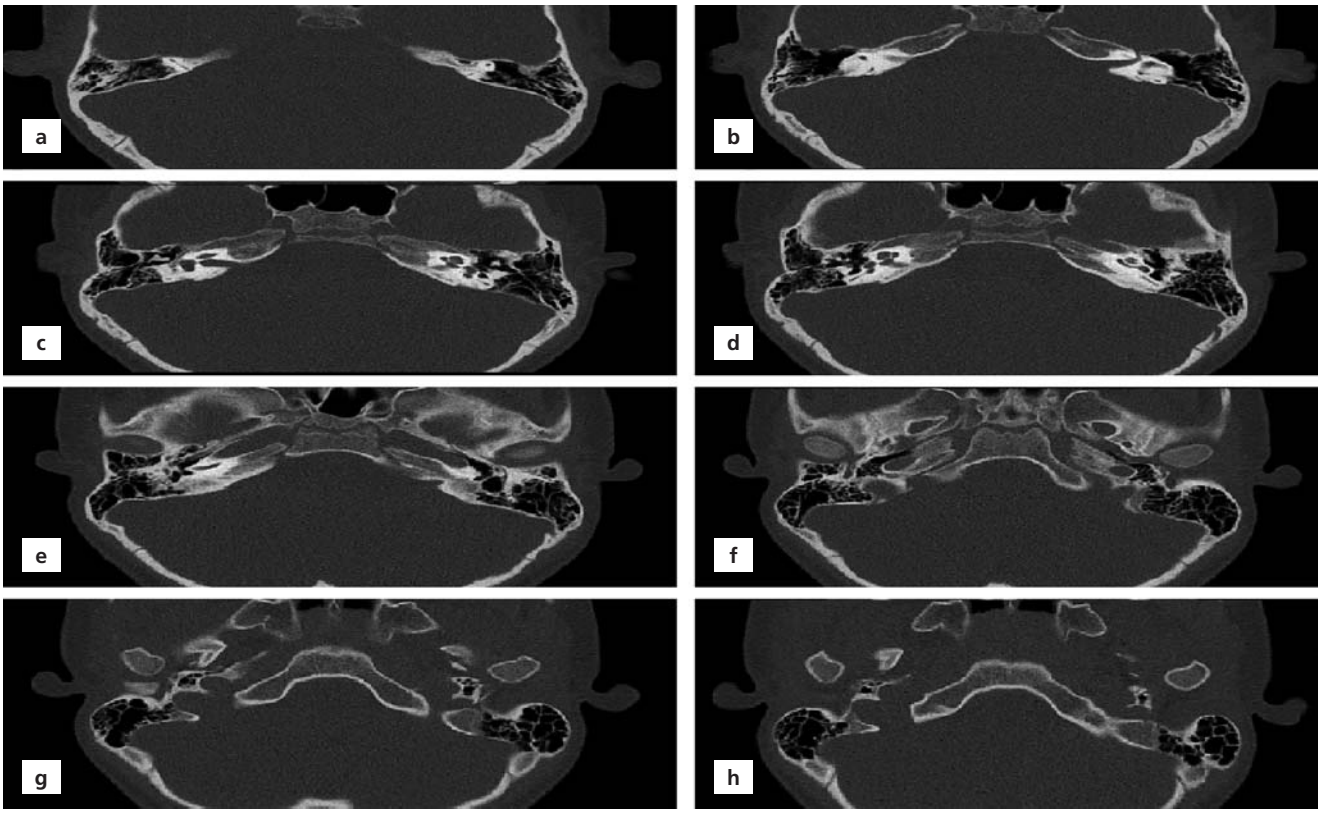

Figure 2. Axial thin-section CT scans (**a**–**h**). The continuity of the atresia of the external acoustic meatus can be followed in sequential sections.

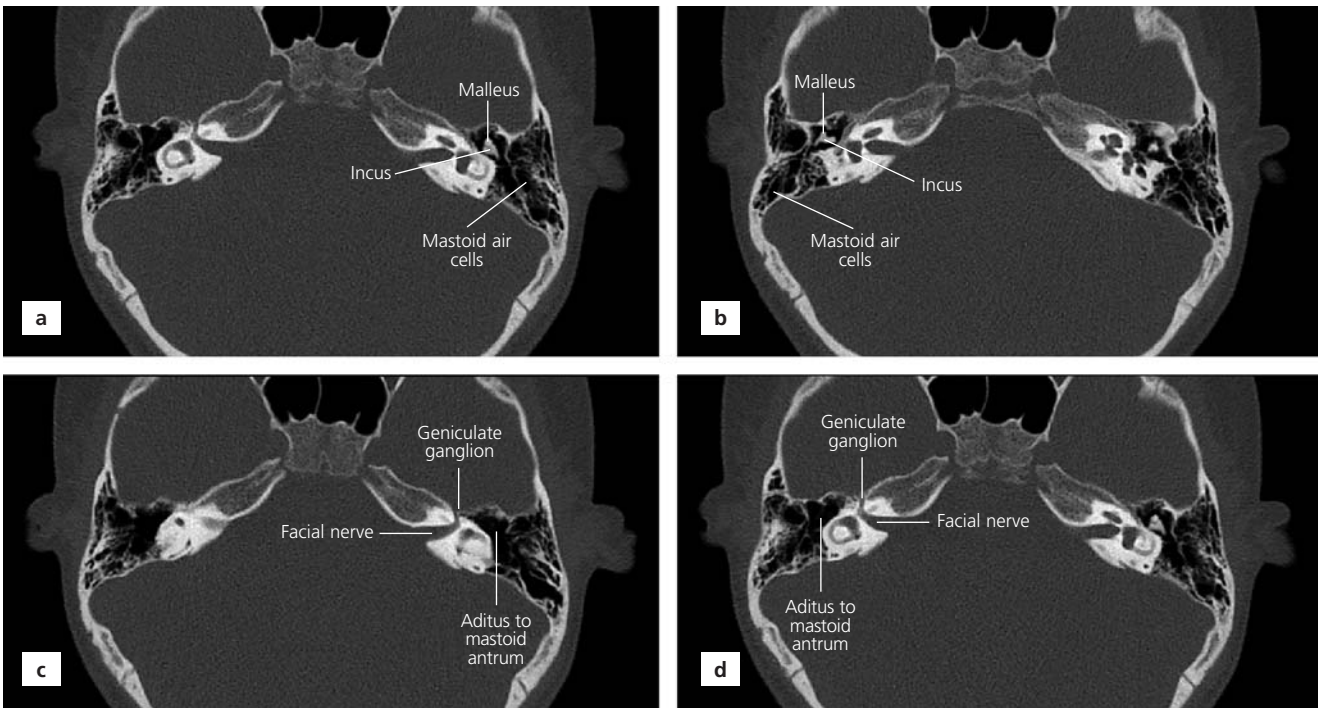

Figure 3. Axial thin-section CT scans (**a**–**d**). (**a**) Mastoid pneumatization and auditory ossicles are normal on the left side; (**b**) mastoid pneumatization and auditory ossicles are normal on the right side; (**c**) presence of aditus to mastoid antrum and facial nerve (labyrinthine segment) on the left side; (**d**) presence of aditus to mastoid antrum and facial nerve (labyrinthine segment) on the right side.

preoperative decision-making.[9] In another study, a 28-point scale was developed by evaluating the anatomical structures examined to determine prognosis after surgery.[10] Since only bilateral atresia of external acoustic meatus was present in our patient and no abnormalities were noted in other structures, the Jahrsdoerfer score (9) with the modified Siegert score (26) were high and these high scores indicate an excellent postoperative prognosis.[9,10]

A study modified Altmann's classification and considered conditions such as poor mastoid pneumatization, malformation of the fenestra vestibuli, and abnormal course of the facial nerve as major anomalies and the absence of these conditions as minor anomalies.[11] In our patient, only minor malformations were seen.

High-resolution CT allows a detailed examination of the middle ear, bony structures, and the course of the facial nerve in the temporal bone, and essential information can be obtained before surgical intervention.[6] The goal of surgery is to provide a good level of hearing and establish an open and noninfectious external acoustic meatus.[12] In our patient, CT findings revealed only bilateral atresia of external acoustic meatus. No congenital anomaly was detected in the middle and inner ear structures; the auditory ossicles were normal, and mastoid pneumatization was good. In light of these findings, an excellent postoperative outcome was expected.

Bilateral atresia is usually corrected at 4 or 5 years of age regardless of the presence of an auricular deformity. In patients with unilateral atresia, surgery can be postponed until young adulthood or nonsurgical recommendations can be made. Correction of auricular deformities is generally performed before atresia repair.[13]

In this case, CT of the 8-year-old patient with hearing loss was taken to detect anomaly of the external acoustic meatus and other pathologies. Detailed image analysis was performed to determine the appropriate treatment option for the surgeon. We evaluated it as a teaching case with CT results.

CT is essential for the detection and evaluation of congenital anomalies of the middle ear, and inner ear in children with atresia of external acoustic meatus, and the results obtained are essential in surgical candidate evaluation and surgery planning.

Author Contributions

ES: designing, evaluation of the data, writing text, MO: image acquisition and analysis, evaluation of the data, ZF: designing, evaluation of the data, writing text, BS: evaluation of the data, writing text, NUD: writing text, final check of the manuscript.

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Table of Contents

Volume **14** / Issue **1** / April **2020**

(Continued from back cover)

On the Front Cover:
Andreas Weiglein (1961–2020), Professor of Anatomy and Vice Chairman, Institufe of Anatomy, Medical University Graz, Austria. From Feigl G. Andreas Weiglein: exceptional teacher and scientist not only for Graz. *Anatomy* 2020;14(1):1–2.

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Table of Contents

Volume **14** / Issue **1** / April **2020**

Editorial

Obituaries

Original Articles

(Contents continued on inside back cover)

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