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CONTENTS

continued...

Recent Advances in Speech Areas and Associated Neural Structures of the Brain

Introduction

Speech is a communication or expression of one's thoughts through linguistic mode, i.e. through spoken or written words. The language is phonetic communication of well-articulated speech.

The human speech is comprehended, processed, planned, initiated, and controlled by the brain.

The neural structures that are responsible for speech consist of the Wernicke's area, Broca's area, arcuate fasciculus connecting these two areas, and motor cortex. All these structures are located in the left dominant cerebral hemisphere.[1]

The language is produced by the language production apparatus consisting of the lungs, larynx, oral cavity, and nasal cavity.

Speech Areas of the Brain

There are two well-known cortical areas in the brain responsible for the production and comprehension of speech. These are Broca's motor speech area and Wernicke's sensory speech area.

Broca's Motor Speech Area (BA45 and BA44)

The Broca's motor speech area was discovered by a French Physician and Anatomist Pierre Paul Broca, in 1861. It is located in the inferior frontal gyrus (areas BA45 and BA44) of the left cerebral hemisphere.

Now, functional magnetic resonance imaging (fMRI) has shown that the processing of language production also involves the third part of the inferior frontal gyrus – the pars orbitalis (BA47). Therefore, these areas together form a larger speech area called Broca's region of speech.[2] In addition, there is a supplementary motor speech area in the lateral most part of the superior frontal gyrus. The Broca's speech area is connected with the supplementary motor area by the frontal aslant tract (FAT).[3]

The functions of Broca's speech area include:
- Production of expressive speech. It interacts with the flow of sensory information of speech from Wernicke's area and devises a plan for speaking and passing this plan to the motor cortex of the brain, which initiates and controls the action of muscles involved with the production of speech with the speech apparatus
- The speech production apparatus consists of the respiratory system, larynx, pharynx, oral cavity, palate, and nasal cavity.

Wernicke's Sensory Speech Area (BA22, BA40, and BA39)

Wernicke's sensory speech area was discovered by a German neurologist, Carl Wernicke, in 1874. It is located in the posterior part of the superior temporal gyrus (pSTG 22) and the posterior part of the parietal lobe (BA40 and BA39) of the left cerebral hemisphere. Recently, the BA37 located in the posterior part of the inferior temporal gyrus is involved in object naming and recognition memory.[4] Hence, Wernicke's speech area is now termed as Wernicke's sensory speech region.

The functions of Wernicke's speech area include:
- Comprehension of spoken and written language received by auditory, visual, and tactile input
- Is a source of constant availability of learned words.

Arcuate Fasciculus

It is an arched bundle of nerve fibers in the left cerebral hemisphere which connects Wernicke's area with the Broca's area.

Now, with the help of a diffusion tensor imaging tractography (DTIT) of the association fibers of a left cerebral hemisphere, it is found that the Wernicke's sensory speech area is connected with Broca's speech area by two distinct fasciculi as under:
1. Superior longitudinal fasciculus associated with phonological processing of language
2. Inferior-fronto-occipital fasciculus associated with semantic processing of language.

Neuronal Circuitry of Speech Production

Areas 22, 39, and 40 receive input from hearing, vision, touch, and proprioception. After comprehension of input the information is sent through arcuate fasciculus to Broca's area [Figure1].[5]

Applied Aspects

The lesions of the brain involving neural structures involved in speech production lead to aphasia. These are cerebral stroke, head injury, brain tumor, infections, and Alzheimer's disease.

Aphasia is a language disorder in which a person fails to communicate spoken and written words properly.

These are commonly classified into four types as follows:
- Broca's aphasia (nonfluent aphasia/expressive aphasia): In this, the person has:
  - Difficulty in speaking fluently, hence also called as
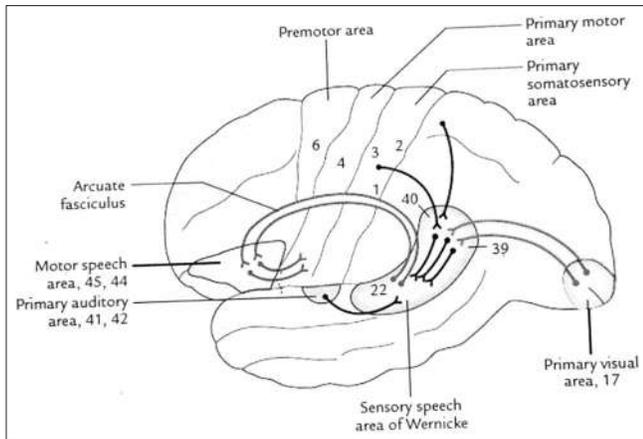
Figure 1: Neuronal circuitry of speech production

nonfluent aphasia
- He is able to understand what is being said to him but is not able to choose the correct words to express it.
- Wernicke's aphasia (fluent aphasia): In this, the person has:
  - Impaired language comprehension, i.e. loss of ability to understand spoken and written words, but he is himself able to speak fluently but incoherently
  - He is not able to read (alexia), write (agraphia), compute (acalculia), and recognize the names of known objects (anomia)
  - Intrusion of irrelevant words in severe cases
  - Impaired reading and writing.

Conduction Aphasia (Associative Aphasia)

People with conduction aphasia have inability to repeat the words or sentences that have spoken to them when asked by an examining doctor.

Global Aphasia

It occurs due to extensive damage of the brain involving both Broca's and Wernicke's areas. It impacts both ability to speak and ability to comprehend the speech.

Treatment of Aphasia

- Speech and language therapy (SLT) by different techniques
- Certain drugs are being used for aphasia. These drugs either improve the blood flow in the region involved or help replace the depleted neurotransmitters in the brain
- Brain stimulation either by transcranial magnetic stimulation or by transcranial direct current stimulation. This is aimed to stimulate damaged nerve cells of the brain.

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Analysis of Anterior Circulation Diameters According to Age, Gender, and Side Using Computed Tomography Angiography

Abstract

Background: The anterior circulation is the blood supply to the anterior portion of the brain. Computed tomography angiography (CTA) is a noninvasive and effective anatomic evaluation method. **Objective:** The objective of the study was to investigate the relationship between the diameters of the anterior circulation arteries and age, gender, and side using CTA. **Materials and Methods:** In this single-center cross-sectional study, 200 cases that presented to the hospital between January 2019 and January 2022 were retrospectively examined using CTA. The diameters of the anterior circulation arteries (common carotid artery [CCA], internal carotid artery [ICA], anterior cerebral artery [ACA], medial cerebral artery [MCA], posterior communicating artery [PcomA], and anterior communicating artery [AcomA]) were measured and recorded by two radiologists. The mean diameters of CCA, ICA, ACA, AcomA, and PcomA were analyzed and compared based on age, gender, and side. **Results:** The mean diameters of the right CCA, ICA, MCA, and ACA and the left CCA, ICA, and MCA were statistically significantly greater in the elderly ($P < 0.001$, $P < 0.001$, $P = 0.01$, $P = 0.024$, $P < 0.001$, $P < 0.001$, and $P = 0.024$, respectively). There was no statistically significant difference between the right and left vascular structures in CCA, ICA proximal, ICA distal, PcomA, MCA, and AcomA ($P = 0.16$, $P = 0.48$, $P = 0.07$, $P = 0.62$, $P = 0.27$, and $P = 0.09$, respectively). A statistically significant difference was observed between the right and left ACA in the whole cohort ($P = 0.05$). The mean diameters of the right CCA, ICA proximal, ICA distal, MCA, and ACA and the left CCA, ICA proximal, ICA distal, and MCA were statistically significantly higher in men than in women ($P < 0.001$, $P < 0.001$, $P = 0.002$, $P < 0.001$, $P = 0.038$, $P < 0.001$, $P < 0.001$, $P = 0.002$, and $P < 0.001$, respectively). **Conclusion:** CTA is a valuable modality for vascular evaluation. It revealed statistically significant differences in anterior circulation based on age, gender, and side.

Keywords: *Anatomic variations, anterior circulation, computed tomography angiography*

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Introduction

The anterior circulation is the blood supply to the anterior portion of the brain, including most supratentorial structures excluding the occipital lobes. Anterior cerebral circulation consists of the anterior cerebral artery (ACA) and middle cerebral artery forming the circle of Willis, as well as their branches. It is very variable and sometimes complex. The perfusion area of the ACA extends medially through all the frontal and parietal lobes, septum, and basal forebrain structures, such as the hypothalamus, pituitary, and optic chiasma. The ACA also supplies blood to the rostrum, genu, and trunk of the corpus callosum. Knowing the distinct and precise anatomy, pathological variations, and possible pathological consequences of the anterior cerebral circulation is essential for surgical interventions and postoperative follow-up. Although digital subtraction angiography (DSA) is the gold standard in vascular imaging, it has been shown that computed tomography angiography (CTA) has become as effective as DSA with the advances in technology.[1] A brain CTA examination is a noninvasive evaluation method. There are several morphologic studies which evaluate the brain arterial system.[1-4] There are several studies investigating variations in the anterior circulatory system; however, the number of those involving the measurement of arterial diameter is limited. To our knowledge, this is the first study in the English language literature to simultaneously investigate the relationship between the diameters of the anterior circulation arteries and age, gender, and side.

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Materials and Methods

This retrospective study included data obtained from the patient files stored in the local image archiving and communication systems for the period between January 2019 and January 2022. A total of 269 patients were evaluated. CTA examinations were performed using a 320-row detector computed tomography (Aquilion ONE Vision; Toshiba Medical Systems Corporation, Otawara, Japan) or a 256-row detector (Somatom® Definition Flash, Siemens Healthcare, Forchheim, Germany) device. The CT acquisition protocol was also performed with the following parameters: 0.5 s gantry rotation time, 0.5 mm slice thickness, 128 mm × 0.6 mm or 192 mm × 0.6 mm collimation, z-flying focal point, 200 mAs tube current, and 120 kVp tube voltage. For optimum intraluminal contrast enhancement, the delay time between the start of contrast agent administration and the start of scanning was determined for each patient individually using the bolus tracking technique. A total of 60–75 mL of iopromide (Ultravist 370 mg/mL, Bayer Schering Pharma, Berlin, Germany) was administered through the 18G intravenous route placed in the right antecubital vein over 15 s at a rate of 4–5 mL/s using an automatic injector (MCT Plus; Medrad, Pittsburgh, PA, USA). Immediately after the iodinated contrast injection, 50 mL of saline was infused with the same syringe through the same route. Cases with trauma, tumor, or vascular pathology, pediatric patients, and repeated examinations were excluded [Figure 1]. As a result, a total of 200 brain CTA examinations on axial, coronal, or sagittal images were evaluated by two radiologists with 3 and 13 years of neuroradiology experience.

The diameters of the common carotid artery (CCA) were measured from the 1-cm area below the bifurcation, those of the internal carotid artery (ICA) from the C1 and C7 segment, those of the ACA from the A1 segment, those of the medial cerebral artery (MCA) from the M1 segment, those of the anterior communicating artery (AcomA) from the mid portion, and those of the posterior communicating artery (PcomA) from the first 1-cm segment of the artery. Each measurement was performed for both the right (R) and left (L) sides. The measurements and patients' demographic data were recorded [Figure 4].

Statistical analysis

Statistical analyses were performed using SPSS version 22.0 (SPSS Inc., Chicago IL, USA). The suitability of the data to the normal distribution was evaluated with the one-sample Kolmogorov–Smirnov test. The Levene statistics were used for the homogeneity analysis of the group variances. The independent samples t-test was used to determine differences between the male and female biometric measurements, and the paired samples t-test was conducted to determine differences between the left and right measurements of men and women. $P < 0.05$ was accepted as the significance level.

Results

Of the patients, 102 (51%) were female. The mean age of the male patients was 48.58 ± 15.84 (range: 18–82) years and that of the female patients was 48.47 ± 15.48 (range: 18–91) years.

The mean diameters were calculated as 6.74 ± 0.92 (range: 4.07–8.91) mm for R-CCA, 6.63 ± 0.92 (range: 4.62–8.91) mm for L-CCA, 4.51 ± 0.67 (range: 3.08–6.67) mm for R-ICA proximal, 4.48 ± 0.59 (range: 2.77–6.75) mm for L-ICA proximal, 3.24 ± 0.6 (range: 1.65–5.15) mm for the R-ICA distal, 3.3 ± 0.64 (range: 1.78–5.1) mm for L-ICA distal, 1.2 ± 0.13 (range: 0.15–1.55) mm for AcomA, 1.28 ± 0.64 (range: 0.42–2.77) mm for R-PcomA, 1.24 ± 0.6 (range: 0.13–2.8) mm for L-PcomA, 2.41 ± 0.47 (range: 1.28–4.21) mm for R-MCA, 2.39 ± 0.45 (range: 1.33–4.1) mm for L-MCA, 1.72 ± 0.44 (range: 0.44–2.93) mm for
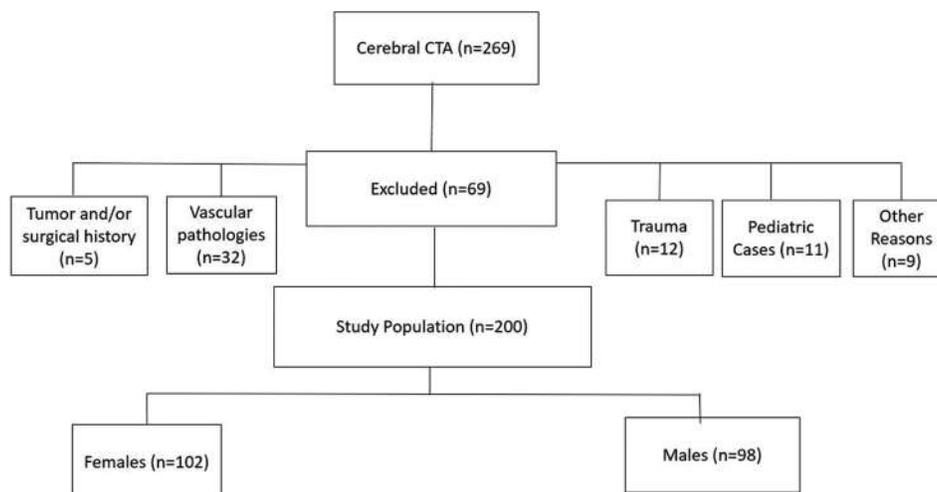
Figure 1: Patient selection diagram. CTA: Computed tomography angiography

R-ACA, and 1.85 ± 0.45 (range: 0.6–3.21) mm for L-ACA. No statistically significant difference was found between the right and left vascular structures in CCA, ICA proximal, ICA distal, PcomA, MCA, and AcomA ($P = 0.16$, $P = 0.48$, $P = 0.07$, $P = 0.62$, $P = 0.27$, and $P = 0.09$, respectively).

The only statistically significant difference between the right and left sides was observed in relation to the ACA measurements in the whole cohort ($P = 0.05$).

The measurements were evaluated separately for the male and female patients [Figures 2 and 3]. In the male patients, the mean diameters of the arteries were calculated as 7.16 ± 0.88 (range: 5.42–8.91) mm for R-CCA, 7.03
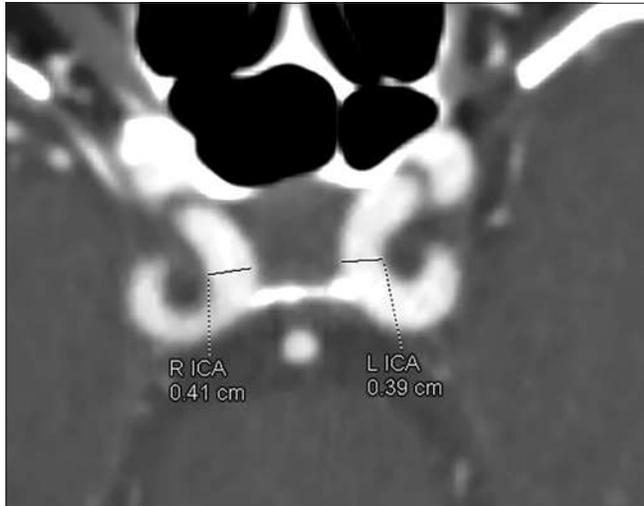
Figure 2: Axial computed tomography image of a 34-year-old male patient showing the measurement of the left and right internal carotid arteries. R-ICA: Right internal carotid artery, L-ICA: Left internal carotid artery
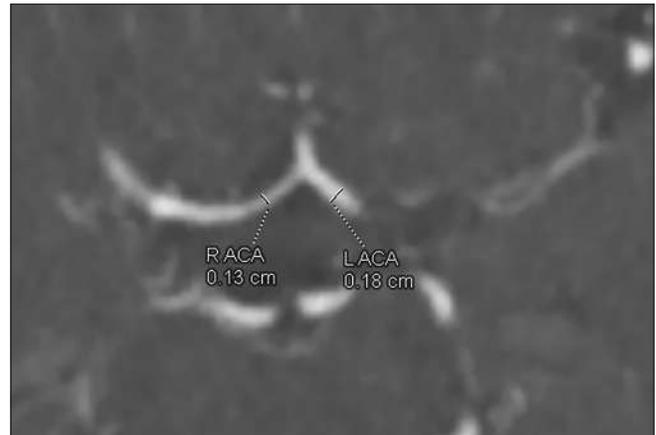
Figure 3: Axial computed tomography image of a 55-year-old female patient showing the measurement of the left and right anterior cerebral arteries. R-ACA: Right anterior cerebral artery, L-ACA: Left anterior cerebral artery

Table 1: Intergroup comparison of the anterior circulation artery measurements by gender

Artery	Gender	*n*	Mean±SD (minimum–maximum)	*P*
Right-CCA	Male	36	7.16±0.88 (5.42–8.91)	0.00
	Female	43	6.39±0.81 (4.07–8.09)	
Right-ICA proximal	Male	95	4.71±0.71 (3.08–6.67)	0.00
	Female	105	4.33±0.56 (3.2–6.62)	
Right-ICA distal	Male	95	3.38±0.64 (1.65–5.15)	0.00
	Female	105	3.11±0.53 (1.7–4.53)	
Right-PcomA	Male	49	1.34±0.67 (0.43–2.7)	0.429
	Female	59	1.24±0.62 (0.42–2.77)	
Right-MCA	Male	95	2.58±0.47 (1.68–4.21)	0.000
	Female	105	2.26±0.41 (1.28–3.4)	
Right-ACA	Male	93	1.79±0.43 (0.44–2.93)	0.038
	Female	102	1.66±0.44 (0.8–2.85)	
Left-CCA	Male	36	7.03±0.87 (5.73–8.91)	0.000
	Female	43	6.29±0.84 (4.62–8.41)	
Left-ICA proximal	Male	95	4.64±0.62 (3.4–6.75)	0.000
	Female	105	4.34±0.54 (2.77–5.75)	
Left-ICA distal	Male	95	3.44±0.64 (2.08–5.09)	0.002
	Female	105	3.16±0.62 (1.78–5.1)	
Left-PcomA	Male	46	1.25±0.60 (0.46–2.86)	0.863
	Female	55	1.23±0.60 (0.13–2.66)	
Left-MCA	Male	95	2.57±0.46 (1.76–4.1)	0.000
	Female	105	2.23±0.39 (1.33–3.35)	
Left-ACA	Male	94	1.91±0.47 (0.6–2.86)	0.092
	Female	102	1.8±0.44 (0.94–3.21)	
AcomA	Male	77	1.33±0.15 (0.25–1.55)	0.155
	Female	91	1.14±0.24 (0.15–1.42)	

ACA: Anterior cerebral artery, ICA: Internal carotid artery, MCA: Medial cerebral artery, CCA: Common carotid artery, PcomA: Posterior communicating artery, AcomA: Anterior communicating artery, SD: Standard deviation

± 0.87 (range: 5.73–8.91) mm for L-CCA, 4.71 ± 0.71 (range: 3.08–6.67) mm for R-ICA proximal, 4.64 ± 0.61 (range: 3.4–6.75) mm for L-ICA proximal, 3.38 ± 0.64 (range: 1.65–5.15) mm for R-ICA distal, 3.44 ± 0.64 (range: 2.08–5.09) mm for L-ICA distal, 1.33 ± 0.15 (range: 0.25–1.55) mm for AcomA, 1.34 ± 0.67 (range: 0.43–2.7) mm for R-PcomA, 1.25 ± 0.6 (range: 0.46–2.86) mm for L-PcomA, 2.58 ± 0.47 (range: 1.68–4.21) mm for R-MCA, 2.57 ± 0.45 (range: 1.76–4.1) mm for L-MCA, 1.79 ± 0.43 (range: 0.44–2.93) mm for R-ACA, and 1.91 ± 0.47 (range: 0.6–2.86) mm for L-ACA.

In the female patients, the mean diameters of the arteries were calculated as 6.39 ± 0.81 (range: 4.07–8.09) mm for R-CCA, 6.29 ± 0.83 (range: 4.62–8.41) mm for L-CCA, 4.32 ± 0.56 (range: 3.2–6.62) mm for R-ICA proximal, 4.34 ± 0.54 (range: 2.77–5.75) mm for L-ICA proximal, 3.11 ± 0.53 (range: 1.7–4.53) mm for R-ICA distal, 3.16 ± 0.62 (range: 1.78–5.1) mm for L-ICA distal, 1.14 ± 0.24 (range: 0.15–1.42) mm for AcomA, 1.24 ± 0.62 (range: 0.42–2.77) mm for R-PcomA, 1.23 ± 0.6 (range: 0.13–2.66) mm for L-PcomA, 2.26 ± 0.41 (range: 1.28–3.4) mm for R-MCA, 2.23 ± 0.39 (range: 1.33–3.35) mm for L-MCA, 1.66 ± 0.44 (range: 0.8–2.85) mm for R-ACA, and 1.8 ± 0.43 (range: 0.94–3.21) mm for L-ACA.

The mean diameters of R-CCA, R-ICA proximal, R-ICA distal, R-MCA, R-ACA, L-CCA, L-ICA proximal, L-ICA distal, and L-MCA were statistically significantly higher in men than in women ($P < 0.001$, $P < 0.001$, $P = 0.002$, $P < 0.001$, $P = 0.038$, $P < 0.001$, $P < 0.001$, $P = 0.002$, and $P < 0.001$, respectively).

Among the female patients, the only difference between the right and left side measurements was observed in relation to the ACA diameters ($P = 0.025$). The left ACA diameter

was larger than the right in both groups, but this was not significant in men. No statistically significant difference was found in the measurement of any of the arteries in the male patients [Table 1].

In the whole cohort, the mean diameters of R-CCA, R-ICA distal, R-MCA, R-ACA, L-CCA, L-ICA distal, and L-MCA were statistically significantly greater in the elderly (aged 50 years and older) ($P < 0.001$, $P < 0.001$, $P = 0.01$, $P = 0.024$, $P < 0.001$, $P < 0.001$, and $P = 0.024$, respectively) [Table 2].

In the male patients aged 50 years and older, the mean diameters of R-CCA, R-ICA distal, L-CCA, and L-ICA distal were statistically significantly greater compared to the nonelderly male patients ($P = 0.003$, $P = 0.012$, $P = 0.034$, and $P = 0.017$, respectively) [Table 3].

In the female patients aged 50 years and older, the mean diameters of R-CCA, R-ICA proximal, R-ICA distal, R-PcomA, R-MCA, R-ACA, L-CCA, L-ICA proximal, L-ICA distal, and L-MCA were statistically significantly greater compared to the nonelderly female patients ($P = 0.004$, $P = 0.003$, $P < 0.001$, $P = 0.003$,

Figure 4: Three-dimensional volume-rendered image of a 42-year-old female patient showing the anterior circulation and right anterior cerebral artery fenestration (arrows). R-ICA: Right internal carotid artery, L-ICA: Left internal carotid artery, R-MCA: Right medial cerebral artery, L-MCA: Left medial cerebral artery, R-ACA: Right anterior cerebral artery, L-ACA: Left anterior cerebral artery

Table 2: Intergroup comparison of the anterior circulation artery measurements by age

	Age (years)	*n*	Mean±SD	*P*
Right-CCA	≥50	37	7.15±0.87	0.000
	<50	42	6.39±0.83	
Right-ICA proximal	≥50	93	4.58±0.63	0.154
	<50	107	4.45±0.70	
Right-ICA distal	≥50	93	3.45±0.50	0.000
	<50	107	3.06±0.63	
Right-PcomA	≥50	49	1.42±0.71	0.071
	<50	59	1.19±0.57	
Right-MCA	≥50	93	2.51±0.45	0.01
	<50	107	2.34±0.48	
Right-ACA	≥50	90	1.80±0.43	0.024
	<50	105	1.66±0.44	
Left-CCA	≥50	37	7.01±0.90	0.000
	<50	42	6.29±0.82	
Left-ICA proximal	≥50	93	4.57±0.61	0.064
	<50	107	4.41±0.58	
Left-ICA distal	≥50	93	3.50±0.64	0.000
	<50	107	3.13±0.60	
Left-PcomA	≥50	44	1.34±0.65	0.165
	<50	57	1.17±0.55	
Left-MCA	≥50	93	2.48±0.46	0.024
	<50	107	2.33±0.45	
Left-ACA	≥50	92	1.88±0.45	0.5
	<50	104	1.83±0.47	
AcomA	≥50	80	1.06±0.55	0.095
	<50	88	1.23±0.51	

ACA: Anterior cerebral artery, ICA: Internal carotid artery, MCA: Medial cerebral artery, CCA: Common carotid artery, PcomA: Posterior communicating artery, AcomA: Anterior communicating artery, SD: Standard deviation

Table 3: Intergroup comparison of the anterior circulation artery measurements in the male patients by age

	Age (years)	*n*	Mean±SD	*P*
Right-CCA	≥50	17	7.61±0.78	0.003
	<50	19	6.77±0.78	
Right-ICA proximal	≥50	45	4.66±0.66	0.515
	<50	50	4.76±0.77	
Right-ICA distal	≥50	45	3.55±0.50	0.012
	<50	50	3.23±0.73	
Right-PcomA	≥50	23	1.28±0.68	0.572
	<50	26	1.39±0.68	
Right-MCA	≥50	45	2.64±0.47	0.252
	<50	50	2.53±0.47	
Right-ACA	≥50	43	1.85±0.34	0.267
	<50	50	1.75±0.49	
Left-CCA	≥50	17	7.36±0.90	0.034
	<50	19	6.74±0.76	
Left-ICA proximal	≥50	45	4.61±0.63	0.620
	<50	50	4.67±0.61	
Left-ICA distal	≥50	45	3.61±0.64	0.017
	<50	50	3.30±0.61	
Left-PcomA	≥50	18	1.29±0.66	0.779
	<50	28	1.23±0.58	
Left-MCA	≥50	45	2.61±0.48	0.494
	<50	50	2.55±0.45	
Left-ACA	≥50	45	1.90±0.47	0.815
	<50	49	1.92±0.49	
AcomA	≥50	37	1.03±0.55	0.080
	<50	40	1.26±0.51	

ACA: Anterior cerebral artery, ICA: Internal carotid artery, MCA: Medial cerebral artery, CCA: Common carotid artery, PcomA: Posterior communicating artery, AcomA: Anterior communicating artery, SD: Standard deviation

$P = 0.008$, $P = 0.043$, $P = 0.002$, $P = 0.001$, $P < 0.001$, and $P = 0.006$, respectively) [Table 4].

CCA entered the imaging area in 79 patients, and therefore, the evaluation of CCA could only be made in these patients. R-PcomA could not be visualized in 46 male and 46 female patients, L-PcomA in 47 male and 51 female patients, and AcomA in 18 male and 14 female patients. This was considered to be secondary to agenesis. Finally, R-ACA could not be visualized in two male and three female patients and L-ACA in one male and three female patients. Data shown in Tables 2-4.

Discussion

CTA can reveal various pathologies and variations, including carotid system stenosis, aneurysms, vasospasm, arteriovenous malformations, dissections, and venous thrombus. Although CTA is a rapid and noninvasive imaging method, it has disadvantages, such as the need for contrast material, exposure to radiation, long data processing times, and difficulties in evaluating the arteries at the base of the skull due to bone structures.

The knowledge of cerebrovascular dimensions is an integral part of neurovascular procedures. These procedures may require the placement of an endoluminal device, and therefore, knowing the diameter of these structures can assist in device selection and modification, potentially making them more compatible with arterial anatomy. In this study, we used CTA due to its noninvasive and ubiquitous nature. The role and accuracy of CTA in the imaging of the cerebral vasculature are well established, and this modality is increasingly used for screening and investigating neurovascular pathologies.[5]

In this study, the diameters of R-CCA and L-CCA were similar to the measurement ranges reported in the literature (6.74 mm vs. 6.5–8.03 mm and 6.63 mm vs. 6.4–8.5 mm, respectively).[6,7] The reported diameter of the ICA terminal ranges from 3.7 mm to 4.57 mm,[8,9] depending on the distance from the terminal where these measurements are taken. Rai *et al.* found the mean R-ICA distal and L-ICA distal diameters to be 3.6 ± 0.4 and 3.7 ± 0.3, respectively.[10] In the current study, the diameters of R-ICA proximal, R-ICA distal, L-ICA proximal, and L-ICA distal were similar to the ranges given in previous studies.

In the literature, the MCA diameter varies between 2.5 mm and 3.82 mm, again depending on its proximity to the measurement point and MCA source.[8,9] Rai *et al.* found the mean R-MCA M1 and L-MCA M1 diameters to be 3.1 ± 0.4 and 3 ± 0.3, respectively.[10] However, in our study, the bilateral MCA diameter was lower compared to the literature range (R-MCA: 2.41 ± 0.47 mm; L-MCA: 2.39 ± 0.45 mm). This may be related to the differences in the methods (cadaver vs. CTA), imaging protocol (1 mm vs. 0.5 mm slice thickness), or patient selection (inclusion and exclusion criteria).

In our study, we discussed the diameters of the anterior cerebral arteries, which provide blood supply to important cerebral areas. The presence of only a few studies in the literature in this area encouraged us to conduct this study.[11] Karatas *et al.* found the PcomA diameter to be 1.30 ± 0.50 mm on the right side and 1.27 ± 0.55 mm on the left side using CTA.[11] In a cadaveric study, the right and left PcomA diameters were determined to be 0.90 ± 0.39 mm and 0.90 ± 0.36 mm, respectively.[12] Yeniçeri *et al.* reported the PcomA diameter as 1.12 mm using three-dimensional time of flight magnetic resonance angiography (3D-TOF-MRA).[13] In our study, we obtained similar results to the literature.

In a previous CTA study, the ACA A1 diameter was measured as 2.15 ± 0.63 mm on the right and 2.26 ± 0.61 mm on the left.[11] Shatri *et al.* found the ACA A1 diameter to be 2.04 ± 0.28 mm for the right side and 2.06 ± 0.26 mm for the left side using 3D-TOF-MRA.[14] In another 3D-TOF-MRA study, Yeniçeri *et al.* measured the right and left ACA A1 diameters as 1.58 mm and

Table 4: Intergroup comparison of the anterior circulation artery measurements in the female patients by age

	Age (years)	n	Mean±SD	P
Right-CCA	≥50	20	6.76±0.76	0.004
	<50	23	6.08±0.73	
Right-ICA proximal	≥50	48	4.51±0.59	0.003
	<50	57	4 18±0.50	
Right-ICA distal	≥50	48	3.35±0.49	0.000
	<50	57	2.91±0.49	
Right-PcomA	≥50	26	1.53±0.73	0.003
	<50	33	1.02±0.41	
Right-MCA	≥50	48	2.38±0.39	0.008
	<50	57	2.17±0.42	
Right-ACA	≥50	47	1.76±0.49	0.043
	<50	55	1.58±0.38	
Left-CCA	≥50	20	6.72±0.81	0.002
	<50	23	5.93±0.69	
Left-ICA proximal	≥50	48	4.53±0.59	0.001
	<50	57	4.18±0.45	
Left-ICA distal	≥50	48	3.40±0.62	0.000
	<50	57	2.97±0.56	
Left-PcomA	≥50	26	1.38±0.66	0.101
	<50	29	1.10±0.52	
Left-MCA	≥50	48	2.34±0.40	0.006
	<50	57	2.13±0.36	
Left-ACA	≥50	47	1.86±0.40	0.239
	<50	55	1.75±0.36	
AcomA	≥50	47	1.05±0.56	0.580
	<50	44	1.20±0.48	

ACA: Anterior cerebral artery, ICA: Internal carotid artery, MCA: Medial cerebral artery, CCA: Common carotid artery, PcomA: Posterior communicating artery, AcomA: Anterior communicating artery, SD: Standard deviation

1.6 mm, respectively.[13] In cadavers, the right and left ACA A1 diameters were determined as 1.87 ± 0.48 mm and 1.96 ± 0.49 mm, respectively.[12] Our results (R-ACA A1: 1.72 ± 0.44 mm; L-ACA A1: 1.85 ± 0.45 mm) were consistent with the literature.

A transcranial color Doppler ultrasonography study of 120 patients showed that the arteries on the left side were larger than those on the right.[15] However, according to a study by Rai *et al.*, there was no significant relationship between arterial diameter and gender or measurement side.[10] In our study, L-ACA A1 was found to be greater than R-ACA in the whole cohort and in the female patients. There was no statistically significant difference between the diameters of the right and left arteries in the male patients.

Krabbe-Hartkamp *et al.* showed that the diameters of the main arteries forming the circle of Willis, such as CCA and ICA, increased with advancing age.[16] In our study, the mean diameters of CCA and ICA were even higher in individuals older than 50 years of age. We associated this condition with atherosclerosis, compensatory dilatation of the arteries as a result of a decrease in cardiac output, and a decrease in vascular elasticity in the elderly population. These factors can also explain the lower rate of blood flow in the arteries of older individuals. Therefore, in TOF-MRA studies, the arterial diameters forming the circle of Willis were reported to decrease with increasing age.[16,17]

In the current study, the mean diameters of R-CCA, R-ICA proximal, R-ICA distal, R-MCA, R-ACA, L-CCA, L-ICA proximal, L-ICA distal, and L-MCA were statistically significantly higher in men than in women. Similarly, in a study by Krabbe-Hartkamp *et al.*, the mean vessel diameter tended to be larger in male patients.[16]

The most common circle of Willis variations in our study were similar to those reported in the literature. In several radiological studies, the most common variation was determined to be the absence of bilateral PcomA or the absence of unilateral PcomA.[16-19] This was followed by the absence of AcomA, P1, and the ACA at decreasing frequency.

Limitations

This study has several limitations. First, a CTA study cannot provide as comprehensive data as a cadaveric study. Second, we used a 0.5-mm slice thickness; therefore, we could not evaluate arteries smaller than 0.5 mm in diameter; however, 0.5 mm is the lowest available section thickness of CTA devices in current medical use. Another limitation concerns the small sample size. Finally, we excluded patients with vascular diseases, which may have affected our age-related assessment.

Conclusion

CTA is a valuable modality for vascular evaluation. In our study, the mean diameters of R-CCA, R-ICA proximal, R-ICA distal, R-MCA, R-ACA, L-CCA, L-ICA proximal, L-ICA distal, and L-MCA were statistically significantly higher in men than in women. We also found that most arteries tended to increase in diameter with increasing age. In our study, the most common variations were the absence of PcomA, AcomA, and ACA A1 in order of frequency.

Conflicts of interest

There are no conflicts of interest.

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A Microdissectional Study on Galen's Anastomosis: Anatomical Perspective with Clinical Emphasis

Abstract

Purpose: Galen's anastomosis, which is placed over the dorsal surface of the posterior cricoarytenoid muscle, is formed by the internal branch of the superior laryngeal nerve and the dorsal branch of the recurrent laryngeal nerve (RLN). This study aims to contribute literature about the prevalence of Galen's anastomosis which is still a controversial issue and indicates the prevalence of this type of anastomosis in both sides of the larynx and indicate the importance of this anastomosis in different neck surgeries and procedures. **Subjects and Methods:** Twenty-two adult formalin-fixed hemilaryngeal (11 larynx) specimens' anatomical micro-dissection were performed on both sides (right-left) posteriorly. Every specimen consisted of larynx, trachea, epiglottis, and hyoid bone. Internal laryngeal nerve, recurrent laryngeal nerve, and inferior thyroid artery were freed up connective tissue to better analyze their relationship and to find their exact course with termination point. **Results:** In our current study, total Galen's anastomosis prevalence was found %54.53 with %27.27 right single trunk, %18.18 left single trunk, 4.54 left plexus formation, and 4.54 left double trunk. There has not been any anastomotic structure in %22.72 of the left side and in %22.72 of the right side microdissection of laryngeal specimens. **Conclusion:** During laryngeal or thyroid surgery, observation of an unknown intralaryngeal branching pattern may lead to confusion and may increase the risk of iatrogenic nerve injury, thus it is crucial to contribute to the literature about microanatomy and prevalence of Galen's anastomosis.

Keywords: *Galen's anastomosis, larynx, microdissection, recurrent laryngeal nerve, superior laryngeal nerve*

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Introduction

Gladius Galen (129–200 AD), also known as "Second Hypocrates," was the first to describe recurrent laryngeal nerve (RLN) and its function. He depicted RLN as the nerve of most of the laryngeal muscles and emphasized its importance about voice.[1] It's been shown that RLN provides innervation to all intrinsic muscles of the larynx except the cricothyroid muscle.[2] Superior laryngeal nerve (SLN) on the other hand contributes to the innervation of larynx by its two branches – internal branch of the SLN (ibSLN) and external branch of the SLN (ebSLN). Whilst ibSLN is responsible for the sensory innervation of the supraglottis and vocal cords,[3] ebSLN innervates cricothyroid muscle, it increases tension in ipsilateral vocal cords.[4]

The origin of the two mentioned nerves (SLN and RLN) is important to better understand their relationship with surrounding anatomical structures. The SLN, before medially following its course toward the thyrohyoid membrane, arises from the inferior vagal ganglion and it gives off internal and external branches at the level of C2.[5] The right RLN branches off RLN ahead of the subclavian artery when the left RLN arises on the left side of the aortic arch.[6]

Sañudo *et al.*[7] classified different relationships between ibSLN and RLN, between ebSLN and RLN, and between ebSLN and ibSLN. Nerve connections between ibSLN and RLN have been frequently studied and four different anastomosis of ibSLN and RLN has been defined which are Galen's anastomosis, arytenoid plexus, cricoid anastomosis, and thyroarytenoid anastomosis.[7]

Galen's anastomosis was first described by May in 1968 in the book edited and translated from Galen's work in Greek (Peri chreias moriōn). May reported: *"At the larynx itself these recurrent nerves with which this whole discussion of mine has been concerned are mingled to some extent with the nerves (n. laryngeal superior)*

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which grow off from the sixth pair and go to the depths of the larynx.''[8]

Galen's anastomosis is formed by the dorsal branch of ibSLN and the dorsal branch of RLN.[7] The anastomosis is placed over the dorsal surface of the posticus, transverse interarytenoid, and oblique interarytenoid muscles also under the mucosa of hypopharynx.

Temporary and permanent palsy of ibSLN and RLN after thyroid surgery and anterior cervical spine surgery have been a subject for literature. Since RLN injury is more noticeable postoperatively compared to ibSLN, it has been studied more than ibSLN injuries. Damage to the RLN can cause many morbidities, including dysphagia and hoarseness due to vocal cord damage.[9,10] Voice damage due to RLN injury is particularly important for patients since it results with difficulties in communication and causes social-, psychological-, and work-related problems.[11] SLN injury, on the other hand, may lead to aspiration and pneumonitis since the nerve has a role in initiating protective reflexes.[12]

This study aims to contribute literature about the prevalence of Galen's anastomosis (GA) which is still a controversial issue and indicates the prevalence of the type of anastomosis in both sides of larynx and to indicate importance of this anastomosis in different neck surgeries and procedures.

Subjects and Methods

Specimens and ethical approval

Twenty-two adult hemilaryngeal specimens' (11 larynx-both sides) anatomical micro-dissection were performed posteriorly. Every specimen consisted of larynx, trachea, epiglottis, and hyoid bone. The specimens were fixed in 10% formalin and preserved in ethyl alcohol. These specimens were provided by our universities' department of anatomy. This study has been approved by the local institutional ethics committee in conformity with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. (Protocol number: E-22481095-020-91, Approval date: January 07, 2022).

Dissections

Specimens were microdissected cautiously under the Leica M320 microscope. Internal laryngeal nerve, RLN, and inferior thyroid artery were freed up connective tissue to better analyze their relationship and to find their exact course and the termination point. Then, they were pursued through their path until they connected. The type of anastomoses (single, double, or plexus) were determined. All specimens were photographed immediately after dissection [Figures 1-3]. Prevalence of Galen's anastomosis and type of anastomoses were documented on both sides separately [Figure 4].

Results

In this study, the connecting branch(es) between ibSLN and RLN were classified according to whether they
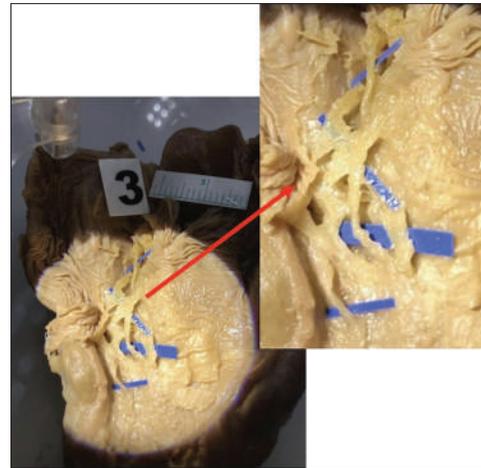
Figure 1: Plexus type of Galen's Anastomosis. The connection between the internal branch of the superior laryngeal nerve and the recurrent laryngeal nerve in the left half of the 3rd specimen is highlighted with blue markings and enlarged at the right upper side. Red arrow indicates the plexus

Figure 2: Single trunk type of Galen's anastomosis. The connection between internal branch of the superior laryngeal nerve and recurrent laryngeal nerve in the left half of the 9th specimen is highlighted with blue markings and enlarged at the right upper side. Red arrow indicates the trunk

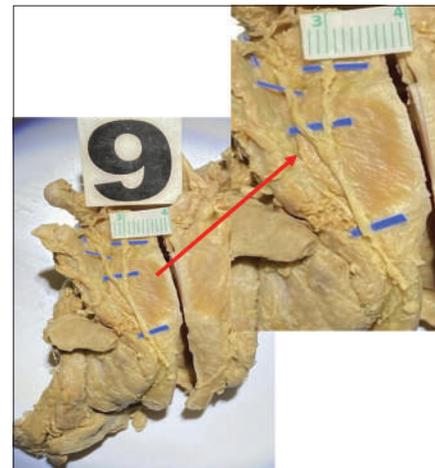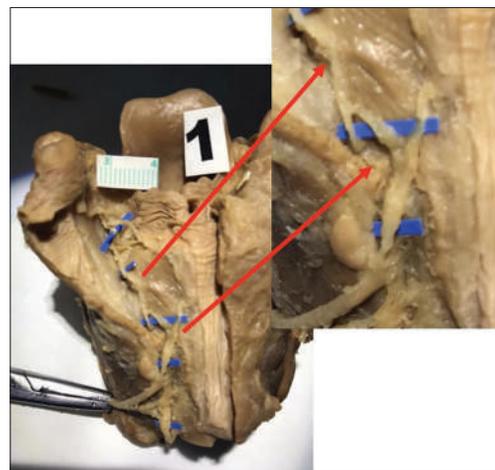**Figure 3:** Double trunk type of Galen's anastomosis. The connection between superior laryngeal nerve and recurrent laryngeal nerve in the left half of the 1st specimen is highlighted with blue markings. The arrows indicate the double trunks

were single trunk, double trunk, or plexus [Figure 4]. In our study, 22 hemilarynxes were dissected from 11 adult larynx in total. Galen Anastomosis was not found in 10 of 22 half-larynxes (45.45%). In terms of single trunk formation, 6 right-sided (27.27%) and 4 left-sided (18.18%) Galen Anastomosis were observed. As for the double trunk formation, a single left-sided double trunk formation (4.54%) is observed. Finally, 1 plexus formation (4.54%) was dissected in one left half-larynx.

The connection between the ibSLN and the RLN in the left half of the 3rd, 9th, and 1st specimens was given as an example of the plexus, single trunk, and double trunk, respectively, in Figures 1-3.

Discussion

Anatomical prevalence in literature

In this study, the morphology of the connection between the dorsal branch of ibSLN and the dorsal branch of RLN has been described as a single trunk, double trunk,

Figure 4: Percentage and types of anastomosis found in our current study and their distribution as a percentage

and plexus, and Galen anastomosis prevalence was found %54.53 [Table 1]. According to the reviewed literature, Galen anastomosis varies between %15.8 and %100.[13]

Our results showed that Galen anastomosis can appear in all three forms which are single trunk, double trunk, and plexus as mentioned in the past literature. According to Henry *et al.*, the single trunk is the most seen variation with a prevalence of 92.3%, followed by a double trunk with a prevalence of %4.2, and the least common variation is the plexus with a prevalence of %3.5.[2] We found similar results as in this study single trunk was the most seen variation, followed by double trunk and plexus formation.

Furthermore, as the prevalence of the single trunk of Galen anastomosis is the most common variation, they suggested considering the single trunk subtype as normal anatomy, whereas other studies have different varieties of prevalences about the subtypes. We think it is difficult to say, considering the most seen variation of Galen's anastomosis as a part of typical anatomy, even when the existence of Galen's anastomosis and the prevalence of subtypes are still unclear. Even with the limitations of this study, many studies[14] show that the prevalence of subtypes may differ with sex and geography, which supports the difficulty of what to consider a typical result.

Naidu *et al.* suggest that the internal laryngeal nerve can have a greater contribution to anastomosis due to its greater diameter if it is compared with RLN.[13] This information differs with authors, for instance, according to Dilworth Galen's Anastomosis can be considered as the continuation of the internal laryngeal nerve upwards.[15] As shown in the reviewed literature and also in our current study, the RLN has an important contribution to the Galen's anastomosis.

According to Song *et al.* 2009, Galen's anastomosis was thought of as sensory nature initially, 3 years later with the study from Naidu *et al.*, it is shown that 13% of branches of Galen anastomosis supply posterior cricoarytenoid
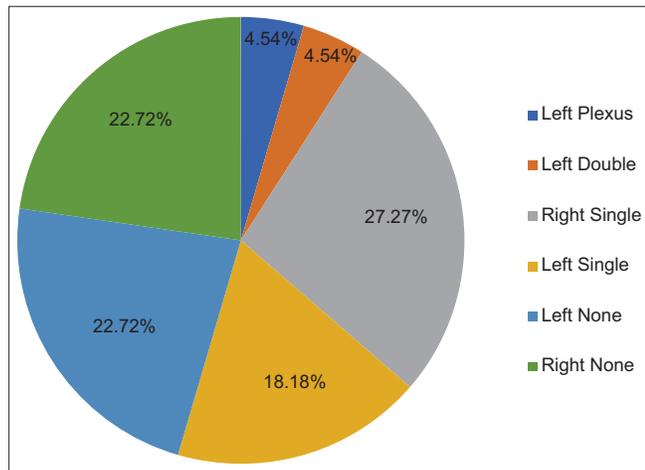
Table 1: Comparison of the prevalence of Galen's anastomis				
Author	**Number of dissections**	**Material**	**Magnification power**	**Prevalence (%)**
Berlin and Lahey (1929)	12	ND	ND	25
Norland (1930)	19	ND	ND	15.8
Lemere (1932)	10	ND	ND	Nonconstant
Williams (1951)	60	ND	ND	75
Pichler and Gisel (1957)	100	ND	Binocular microscope	100
Rueger (1972)	19	Fresh cadavers	6	89.5
Souza *et al.* (1981)	150	Fixed cadavers	10	42
Migueis *et al.* (1989)	47	Fresh cadavers	6	88
Schweizer and Dörfl (1996)	32	Fixed cadavers	Operative microscope	84.4
Sanudo *et al.* (1999)	180	Fixed cadavers	6	100
Liebermann-Meffert (1999)	6	Fixed cadavers	ND	33.3
Furlan *et al.* (2001)	100	Fresh cadavers	2,5	87
Naidu *et al.* (2012)	100	En bloc laryngeal specimens	4 light microscope	81
Current study	22	Formalin-fixed laryngeal specimens	2.5	54.53

The table was adapted from Naidu *et al.*[13] with permission from Copyright 2014 by Wiley.

muscle.[13,16] As this study was purely anatomical, it is hard to contribute to the function of Galen's anastomosis.

Clinical importance

It is very important to identify the RLN during thyroidectomy procedures. According to Pironi *et al.*, good identification of RLN can reduce the risk of nerve damage by up to 6.6%.[17] RLNs have many variations in terms of size, shape, and path. It enters the larynx through the berry ligament and provides stimulation of the intrinsic laryngeal muscles, with the exception of the cricothyroid muscle.[18] Inferior and superior thyroid poles are one of the places where RLN variations are frequently seen.[18] New-onset hoarseness, changes in vocal pitch, or noisy breathing which start in the patient after thyroid surgery or intubation should make us think of RLN damage. It is vital for surgeons to have knowledge of Galen's anastomosis and its types to minimize nerve damage.

As for the ibSLN, which is the other component of anastomosis, it is reported that injury to this branch disrupts the laryngeal cough reflex, which can cause aspiration pneumonia and other respiratory system diseases.[19] The ibSLN can also be used for therapeutic purposes. According to Zhipeng *et al.*, ultrasound-guided ibSLN blocks are used to reduce the risk of perioperative stress during intubation before surgeries.[20] In addition to preventing surgical complications, it is necessary to have good knowledge of the location of Galen's anastomosis to obtain maximum therapeutic efficiency.

Limitations

Certain limitations of our study deserve mention. We had a limited number of specimens (11 larynx) due to difficulties in obtaining cadavers. In addition to that, it was difficult to measure sensitively the diameters of the fibers which contribute to Galen's anastomosis because of the lack of measurement equipment.

Conclusion

From the laryngeal surgery perspective, because of the complexity and variety of the anatomical structures in this region, elaborative knowledge about the communication type of nerves is crucial. During laryngeal or thyroid surgery, observing an unknown intralaryngeal branching pattern may lead to confusion and an increased risk of iatrogenic nerve injury.

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Conflicts of interest

The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The Association of Vascular Loops of Anterior Inferior Cerebellar Artery and Vestibulocochlear Symptoms

Abstract

Aim: The association of vascular loops of anterior inferior cerebellar artery (AICA) with vestibulocochlear symptoms including hear loss, tinnitus, and vertigo is controversial. We aimed to investigate the relationship between vestibulocochlear symptoms and AICA vascular loop syndrome on magnetic resonance imaging (MRI). **Materials and Methods:** The patients underwent a posterior fossa MRI examination were reviewed regarding the presence of hear loss, tinnitus, and vertigo by an experienced ear-nose-throat specialists' physical examinations. The incidences of these lesions in the patients with and without AICA vascular loop syndromes were compared. Furthermore, the correlation between the AICA vascular loop syndrome subtypes (grade 1–3) and the incidence of the symptoms were analyzed. **Results:** A total of 502 patients (1004 ears) were included in this study. Vascular loops were demonstrated in 150 ears (14.9%). Subtype 1 was observed in 97 (9.7%), subtype 2 in 40 (4.0%) and subtype 3 in 13 (1.3%) ears. The incidences of tinnitus, hear loss, and tinnitus + hear loss were statistically significantly higher in the patients with vascular loops than without vascular loops (p: 0.000042, p: 0.0446906, p: 0.028106, respectively). However, there was not a significant correlation between the incidence of the symptoms and the grade of the vascular loop formation ($p > 0.05$). Vertigo incidence was very similar among the patients with no, with one-sided and with both-sided AICA vascular loops (41.5%, 39.8% and 46.2%, respectively) with no statistical difference ($p > 0.05$). **Conclusion:** The AICA vascular loop is associated with either tinnitus or hear loss but there is no correlation with the degree of the vascular loops. There is no relationship between AICA vascular loops and vertigo.

Keywords: *Anterior inferior cerebellar artery vascular loop, hear loss, tinnitus, vertigo, vestibulocochlear symptoms*

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Introduction

Tinnitus, hearing loss, and vertigo are the most common vestibulocochlear symptoms. The incidence of tinnitus was found to be 22%, hearing loss 9%, and vertigo 42% in general population which increase with age.[1-3]

The contrast-enhanced magnetic resonance imaging (MRI) of the posterior fossa is essential for the detailed examination of posterior fossa, internal acoustic canal, and cerebellopontine angle (CPA) structures which can be associated with vestibulocochlear symptoms.[4] Although otological symptoms including tinnitus, hearing loss, and vertigo reported to occur secondary to malignant (acoustic schwannoma, etc.,) and vascular conditions (vascular loop syndromes,) in CPA and internal acoustic canal, these symptoms can be seen also in asymptomatic individuals.[5]

Vascular compression loop syndrome was first described by McKenzie but the association of this syndrome with otological syndromes is still controversial.[6,7] In this study, we aimed to examine the possible association of Vascular loops of the anterior inferior cerebellar artery (AICA) and vestibulocochlear symptoms including tinnitus, hearing loss and vertigo.

Materials and Methods

Patients

The data of the patients who underwent an MRI of posterior fossa 1 week within the admission of the otorhinolaryngology department because of various complaints between January 2016 and January 2018 were collected from the hospital and clinic database. Demographic features, results of physical examination regarding having vestibulocochlear findings, and radiological images were obtained. This retrospective

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study was approved by a university ethics committee on September 18, 2018 with a number of 2018-18/155.

Magnetic resonance imaging

MRI examinations were performed using a 1.5 Tesla MRI system (GE Signa Excite) with an 8-channel neurovascular head coil. The imaging protocol of posterior fossa consisted of axial T2-weighted images (TR/TE, 4000/100 ms; NEX, 4; section thickness, 5 mm; intersection spacing, 1.5 mm; matrix size, 256 × 160), axial T1-weighted images before and after the administration of intravenous contrast material (TR/TE, 540/8 ms; NEX, 4; section thickness, 5 mm; intersection spacing, 1.5 mm; matrix size, 288 × 192) and 3D-FIESTA images (TR/TE, 4/1.28 ms; flip angle, 60°, FOV, 19; matrix size, 352 × 224; section thickness, 1 mm).

All the images were transferred to a workstation and interpreted by a radiologist with 10 years' experience on neuroradiology who was blinded to the otological examination results of the patients.

Anterior inferior cerebellar artery vascular loop compression syndrome

The AICA supplies the ventral-inferior parts of cerebellum and lateral lower portions of pons which originates from the lateral wall of the caudal third of the basilar artery. After AICA usually arises from the basilar artery as a single trunk, it courses laterally and posteriorly [Figure 1], frequently bifurcating into the superior and inferior trunk at the pontomedullary junction close to where the facial and vestibulocochlear nerves exit the brain stem and enter to internal auditory canal.[8]

AICA vascular loop refers to an anatomic variation in that AICA locates close to 7–8 cranial nerves in CPA or internal auditory canal. The classification of the vascular loop of AICA is based on the anatomical location of AICA as in type 1 AICA lies in the CPA but does not enter to internal auditory canal [Figure 2], in type 2 enters the CPA and extends less than half of length of internal auditory canal [Figure 3] and in type 3 enters the CPA and extends more than half of the length of internal auditory canal [Figures 4 and 5].[9]

Assessment of hearing loss

Audiological evaluation hearing test examinations were made by an ear–nose–throat specialist with the assistance of an audiometrist. A resonance A R37A audiometer (Italy) device was used to perform the audiometric evaluation with a pure-tone audiometer inside a sound-proof cabin. Pure-tone thresholds were examined at 0.25, 0.5, 1, 2, 3, 4, and 8 kHz.[10] The patients with a value >15 were accepted as with hearing loss.

Assessment of tinnitus

The patients completed the tinnitus handicap inventory questionnaire during the first examination. When the score
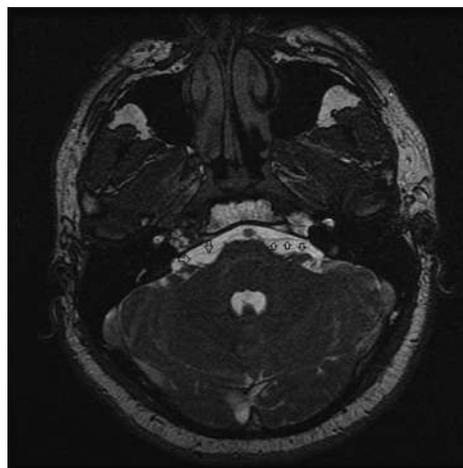
Figure 1: Normal location of bilateral anterior inferior cerebellar artery (arrows) as they are far from internal auditory canals
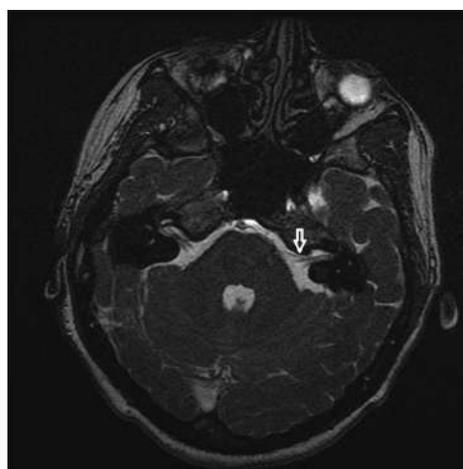
Figure 2: Type 1 anterior inferior cerebellar artery (AICA) loop syndrome in left side as the AICA lying close to the internal auditory canal but is not entering (arrow)
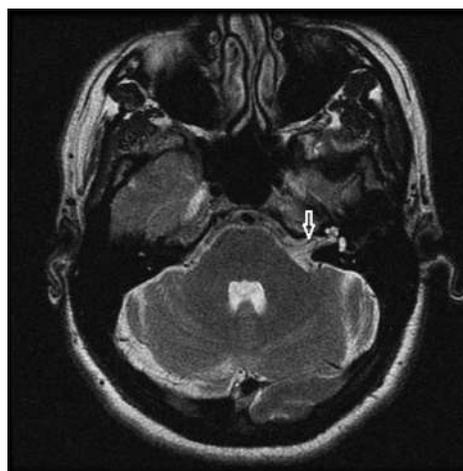
Figure 3: Type 2 anterior inferior cerebellar artery (AICA) vascular loop syndrome in left side as the AICA is entering less than half of internal auditory canal (arrow)

in this questionnaire, 0–16 it was defined as slight tinnitus, 18–36 mild tinnitus, 38–56 moderate, tinnitus, and 58–76
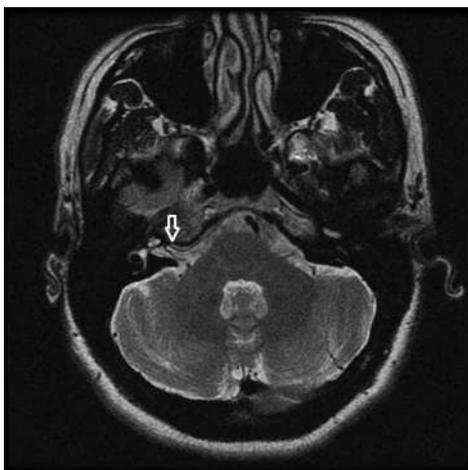
Figure 4: Type 3 anterior inferior cerebellar artery (AICA) vascular loop syndrome in right side as the AICA is entering more than half of internal auditory canal (arrow)

Figure 5: Type 2 (left side) and type 3 (right side) anterior inferior cerebellar artery vascular loops (arrows)

severe tinnitus. The patients with a score >1 were accepted as with tinnitus.[11]

Assessment of vertigo

The patients who had no identified cause including cardiovascular, hematological, metabolic and endocrine disorders, admitted with complaints of dizziness and imbalance were accepted as having vertigo.

Groups

Patients were classified into 4 groups as group N (with no AICA vascular loop syndrome), group 1 (patients with type 1 AICA vascular loop syndrome), group 2 (patients with type 2 AICA vascular loop syndrome), and group 3 (patients with type 3 AICA vascular loop syndrome) and group 4 (patients with all types [group 1 + 2 + 3] of AICA vascular loop syndrome). For all these 5 groups, the presence of only tinnitus, only hearing loss, and tinnitus + hear loss in the same ear were analyzed and compared with each other. Also in the groups, a comparison of the presence of otological symptoms was performed between males and females.

In addition, patients were classified into three other groups according to the side location of AICA vascular loop syndrome as group N (the patients with no AICA vascular loop compression syndrome in any ear), group S (the patients with AICA loop vascular loop syndrome in only one ear) and group D (the patients with AICA vascular loop syndrome in both ears). The frequency of presence of vertigo was compared between these three groups. In each group, comparison of the presence of vertigo was performed also between males and females.

Statistical analysis

Categorical variables were presented as frequency (n) and percentage (%); numerical variables were expressed as mean ± standard deviation, minimum and maximum. A Chi-square test was used for the comparison of

categorical variables. A $P < 0.05$ was considered statistically significant. All the statistical analyses were made by an SPSS 20 software program (IBM Corporation, Armonk, NY, USA).

Results

Among 596 patients, 29 ones with previous intracranial or ear surgery anamnesis, 21 with posterior fossa or internal auditory canal lesions, 3 with inner ear anatomical variations were excluded from the study. Detailed medical records of 41 patients were not available. Finally, a total of 502 patients (1004 ears) were included in this study.

Male/female ratio was 1.02 (253/249) and the mean age was 43.4 ± 19.1 (18–79) years. The mean age of the groups was similar with no significant differences.

The control group was consisted of 854 ears (429 males and 425 females), group 1 of 97 ears (38 males and 59 females), group 2 of 40 ears (24 males and 16 females), group 3 of 13 ears (7 males and 6 females), and group 4 of 150 ears (69 males and 81 females) [Table 1].

Only tinnitus frequency was statistically significantly higher in group 1 (30.9% 30/97) than in group N (14.5% 124/854) (*p*:0.000032). The difference between group 2 (27.5% 11/40) and group N (14.5% 124/854) was significant (*p*:0.025034). The difference between group 3 (7.7% 1/13) and group N (14.5% 124/854) was nonsignificant (*p*:0.486718). The difference between group 4 (28.0% 42/150) and group N (14.5% 124/854) was significant (*p*:0.000042). The difference between group 1 and 2 (*p*:0.69037), 1 and 3 (*p*:0.080345, and 2 and 3 (*p*:0.138211) were all nonsignificant [Table 1]. Only hear loss frequency was nonsignificantly higher in group 1 (17.5% 17/97) than group N (12.6% 108/854) (*p*:0.177721). The difference between group 2 (20.0% 8/40) and group N (12.6% 108/854), between group 3 (33.3% 3/10) and group N (12.6% 108/854), between group 2 (20.0% 8/40) and group 1 (17.5% 17/97), between group 3 (33.3% 3/10) and group 1 (17.5% 17/97), and between group 3 (33.3% 3/10) and group 2 (20.0%

Table 1: Groups and the incidences of tinnitus, hear loss and tinnitus+hear loss

	Group N (Grade 0)			Group 1 (grade 1)			Group 2 (grade 2)			Group 3 (grade 3)			Group 4 (group 1+2+3)			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
No finding	303 (49.4)	310 (50.6)	613 (61.1)	17 (35.4)	31 (64.6)	48 (4.8)	9 (47.4)	10 (52.6)	19 (1.9)	4 (50.0)	4 (50.0)	8 (0.8)	30 (40.0)	45 (60.0)	75 (7.5)	333 (48.4)	355 (51.6)	688 (68.5)
Tinnitus	64 (54.6)	60 (48.4)	124 (12.4)	16 (53.3)	14 (46.7)	30 (3.0)	7 (63.6)	4 (36.4)	11 (1.1)	0	1 (100)	1 (0.1)	23 (54.8)	19 (45.2)	42 (4.2)	87 (52.4)	79 (47.6)	166 (16.5)
Hear loss	59 (54.6)	49 (45.4)	108 (1.1)	5 (29.4)	12 (70.6)	17 (1.7)	6 (75.0)	2 (25.0)	8 (0.8)	2 (66.7)	1 (33.3)	3 (0.3)	13 (46.4)	15 (53.6)	28 (2.8)	72 (52.9)	64 (47.1)	136 (13.5)
Tinnitus + hear loss	3 (33.3)	6 (66.7)	9 (9.0)	0	2 (100.0)	2 (0.2)	2 (100.0)	0	2 (0.2)	1 (100.0)	0	1 (0.1)	3 (60.0)	2 (40.0)	5 (5.0)	6 (42.9)	8 (57.1)	14 (1.4)
Total	429 (50.2)	425 (49.8)	854 (85.1)	38 (39.2)	59 (60.8)	97 (9.7)	24 (60.0)	16 (40.0)	40 (4.0)	7 (53.8)	6 (46.2)	13 (1.3)	69 (46.0)	81 (54.0)	150 (14.9)	498 (49.6)	506 (50.4)	1004 (100.0)

8/40) were all nonsignificant (p:0.176142, p:0.263948, p:0.733173, p:0.626042, p:0.812154, respectively). However, the frequency of only hearing loss was statistically significantly higher in group 4 (18.7% 28/150) than group N (12.6% 108/854) (p:0.046906) [Table 1].

Tinnitus + hear loss frequency of group N (1.1% 9/854) was statistically lower than group 2 (5.0% 2/40) (p: 0.026918) ,group 4 (3.0% 5/150) (p: 0.028106) and group 3 (7.7% 1/13) (p: 0.026096). The difference between group N and group 1 (2.1%) was nonsignificant (p:0.378948). The difference between group 1 and 2, group 1 and 3, and group 2 and 3 was all nonsignificant (p:0.35025, p:0.214829, p:0.71558, respectively) [Table 1].

Vertigo was recorded in 41.5% (160/386) of the patients with group N (no involvement in ears), 39.8% (35/88) of in group S (single ear involvement) and 46.2% (13/28) in group D (Double ear involvement). The difference of the vertigo frequency between group N and group S (p:0.77283), group N and group D (p:0.60683) and group S and group D (p:0.533389) was all non-significant [Table 2].

Discussion

AICA usually arises from the lateral wall of the proximal segment of basilar artery (98%) at the level of CPA or from rarely vertebral artery (2%) as a single (92%) or duplicate (8%) branch.[12] AICA gives three branches as an internal auditory branch (passes into internal acoustic meatus), lateral branch (supplies superior/inferior semilunar lobules), and medial branch (supplies biventral lobule).[13]

Vertigo or tinnitus not only results from inner ear or cranial nerve lesions but also from vascular compression syndromes in the pontocerebellar angle. Various vascular compression syndromes may lead to hemifacial spasm, trigeminal neuralgia, and glossopharyngeal neuralgia.[14,15] Compression or close neighborhood of the vestibulocochlear nerve by vascular structures is associated with vertigo and hearing loss. The pathomechanism of this condition is suggested as edema and gliosis followed by demyelination, fibrosis, and subsequently axonal degeneration of the nerve by chronic compression.[16,17] Besides AICA, PICA, and petrosal arteries may lead to vascular compression syndromes.[18,19]

Contrast-enhanced temporal MRI is an excellent modality to discriminate inflammatory processes such as labyrinthitis or mastoiditis and neoplastic conditions such as acoustic schwannoma and meningioma. Furthermore, it provides the best view to detect and grade the vascular loop syndrome in pontocerebellar angle and internal acoustic canal. MRI is superior to computed tomography as it can differentiate soft tissues from fluids and also shows inner ear structures very clear in especially patients with sensorineural hearing loss.[20,21] Fast spin echo T2-weighted images have been widely used for the examination of posterior fossa and CPA, currently CISS sequence is very useful for evaluating

	Table 2: Groups and the incidences of vertigo											
	Group N (normal) no involvement of ear			Group S (single) involvement of one ear			Group D (double) involvement of two ear			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Vertigo (−)	117 (51.8)	109 (48.2)	226 (45.0)	29 (54.7)	24 (45.3)	53 (10.6)	7 (46.7)	8 (53.3)	15 (29.9)	153 (52.0)	141 (48.0)	294 (58.6)
Vertigo (+)	79 (49.4)	81 (50.6)	160 (31.9)	13 (37.1)	22 (62.9)	35 (7.0)	4 (30.8)	9 (69.2)	13 (2.6)	96 (46.2)	112 (53.8)	208 (41.4)
Total	196 (508)	190 (49.2)	386 (76.9)	42 (47.7)	46 (52.3)	88 (17.5)	11 (39.3)	17 (60.7)	28 (5.6)	249 (49.6)	253 (50.4)	502 (100.0)

the course of cranial nerves and the association of vascular structures with them in the internal acoustic canal and CPA.[22]

In literature, there are some inconsistent data about the association between vestibulocochlear symptoms and AICA vascular loop syndrome.[7] Various studies did not show a marked association[10,23-27] between AICA compression syndrome and tinnitus while some reported significant[28-32] results. In our study, we found statistically significantly higher tinnitus rates among the patients with AICA vascular loop syndrome (group 4) than ones without AICA vascular loop syndrome (group N) (*P*: 0.000042). However, we did not detect any correlation between the grade of AICA loop syndrome and tinnitus rate as the difference between group 3 (type 3) and the control group was nonsignificant while the difference was higher when compared group 1 and controls. Furthermore, differences between all AICA syndrome groups (group 1–4) were nonsignificant.

Similarly, the data about the association of hear loss and AICA vascular loop syndrome are very inconsistent. Most of the studies did not report a significant[24,25,32-34] association between hear loss and AICA loop syndrome since a few studies suggested significant results.[28,35] We also found statistically significant higher hear loss rates in the patients with AICA vascular loops than in controls. This rate was highest in group 3 followed by group 2, group 1, group N, but the differences between these groups were nonsignificant. As the result, we detected a significant difference on hear loss rate between patients with and without AICA vascular loops but not a significant correlation with the AICA vascular loop grades.

In literature, we did not find any study about the association between AICA vascular loop syndrome and the presence of either hear loss and tinnitus in the same side. We found statistically significant higher rates of either hear loss + tinnitus in the same ear in the patients with AICA loop syndrome when compared with ones without AICA loop syndrome. In all groups with AICA vascular loops (groups 2, 3, and 4) except from group 1, the rates of hear loss + tinnitus were statistically significantly higher than controls.

Almost all previous studies did not suggest a significant association[23,24,27,32] between AICA vascular loop syndrome and vertigo while only one study[31] reported a significant relationship. In our study, the vertigo incidence in controls was slightly higher than the patient with AICA in only one ear and slightly lower than with AICA in both ears. Hence, there was no significant association between vertigo incidence and AICA loop syndrome in this study.

The major limitations of this study are retrospective design and relatively small sample size. We also could not evaluate the patients regarding hemifacial spasm, nystagmus, and otalgia.

Conclusion

We found that individuals with AICA loop syndrome have significantly higher incidence of only tinnitus, only hearing loss and either tinnitus + hear loss while the incidence of these symptoms does not correlate with the degree of the vascular loop formation. However, there was not such association between vertigo and AICA loop syndromes.

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Conflicts of interest

There are no conflicts of interest.

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Relationships of Matrix Metalloproteinase 3 Expression in Skeletal Muscle with Demographic Changes: Manual Microarray Study

Abstract

Background: Skeletal muscle enzymes in the matrix metalloproteinase (MMP) family play a key role in myogenesis, tissue remodeling, and muscle regeneration. It is an extensive family of enzymes that are active in both the physiological and pathological processes of many tissues. This study aimed to investigate the differences of MMP-3 along with different age groups, histopathological changes, and other clinical data. **Materials and Methods:** Samples from 34 intercostal space muscles were used in this study. Samples were preferred to be taken from young and elderly. Paraffin blocks were prepared with a manual microarray method. They were also immunohistochemically stained with MMP-3. They were rated and scored as no staining, weak, moderate, and strong. The results were evaluated in terms of age, gender, histopathological changes, and chronic disease. Then, they were statistically analyzed. **Results:** In statistical evaluation, substance use was statistically significantly higher in the group aged 65 years and older than in the younger group ($P = 0.02$). Although there was no statistically significant difference between the young and old groups in histopathological evaluations, it was observed that the staining rate of MMP-3 was significantly higher in the older group ($P < 0.01$). It was understood that there was a statistical relationship between MMP-3 staining and chronic obstructive pulmonary disease ($H = 4.23$, $P = 0.04$); this relationship was understood to be due to the relationship between weak staining and strong staining groups ($Z = -2.05$, $P = 0.04$). **Conclusion:** Although MMP-3 expression prevalence increases in the elderly, its degree decreases. This variability can be useful in terms of tracking the degree of aging and degeneration.

Keywords: *Demographic data, histopathology, matrix metalloproteinase-3, skeletal muscle*

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Introduction

Aging is a complex and multifactor process characterized by a loss of muscle mass and impaired physiological functions and damaging changes in multisystems.[1] These changes include an increase in collagen concentration and the appearance of cross-bonds between collagen fibers in the extracellular matrix (ECM).[2,3] ECM, which surrounds the skeletal muscle fibers, provides structural support, protection, and maintenance of the functional integrity of the skeletal muscle through various mechanisms.[4] The modulation of the function is controlled by matrix metalloproteinases (MMPs). MMPs are a family of zinc- and calcium-dependent enzymes that support the breakdown and synthesis of ECM components such as collagen, proteoglycans, and glycoproteins during normal and pathological tissue remodeling.[5] These enzymes stimulate the release of local growth factors in skeletal muscles.[6] In addition, MMPs are related to the modulation of inflammatory processes at various levels, for example, they regulate the bioavailability and activity of inflammatory cytokines, as well as the survival and escape of inflammatory cells.[7,8] It has even been shown that MMPs can regulate the transmigration of inflammatory cells.[7,8]

In collagen degradation, MMP-3 activates MMP-1, which acts as an important role in the degradation of collagen I.[9,10] MMP-3 digests components of the ECM can activate hidden forms of MMPs, and induce apoptosis.[11] MMP-3 plays an important role in the physiological process of tissue remodeling, but its improper expression can lead to the progression of cancer and facilitate the formation of invasion and metastasis.[12,13]

This study aimed to reveal the relationship of MMP-3 expression degree in striated muscle with age, clinical data as well as morphological changes.

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Materials and Methods

This study was deemed ethically appropriate by the Clinical Research Ethics Committee of Ordu University (240/2018). In addition, official permissions have been obtained from the judicial authorities. In this study, samples were taken from cases that were autopsied for different reasons between 2018 and 2019. Samples of these cases were divided into two groups according to their age to make comparisons. In the study, the elderly group (EG) was considered to be over 65 years old, and the younger group (YG) was considered to be under 50 years of age. The age range was grouped by the age distribution of the cases and the number of cases.

The fourth intercostal space muscle sample was used as a skeletal muscle sample. Paraffin blocks were prepared with the manual microarray method from the existing samples. Sections with a thickness of 5 μm were taken from these muscle samples. Sections were stained with H and E. Parameters such as acidophilic sarcoplasm, prominence in striation, nucleus placement, vacuolization, deterioration in fibers, disruption, cellular infiltration, lipofuscin pigment accumulation, and acidophilic fluid accumulation were assessed under a light microscope [Figures 1-3].

Immunohistochemical analysis

During the immunohistochemical study stages, the Leica Bond-Max IHK staining device (VisionBiosystems, Melbourne, Australia) was employed, and an MMP3 antibody was used. The MMP-3 antibody (100 μg, GTX103647) was diluted in a ratio of 1:200. Immunohistochemical findings were evaluated on the basis of staining frequency and intensity. The staining intensity was rated from 0 to 3. The staining was 0 (negative), 1 (weak), 2 (medium), and 3 (strong). The staining intensity was rated between 0 and 4. Rating 0 showed <3% staining; rating 1: 3%–25%; rating 2: 26%–50%; rating 3: 51%–75%; and rating 4: >75% staining. The score was calculated by multiplying the intensity and diffusiveness scores. Results were shown in order: score 0 = 0; score 1 = 1–2; score 2 = 3–5; and score 3 = 6–7.[14,15]

Immunohistochemical staining scores were evaluated in terms of age, gender, chronic disease, and histopathological changes.

Statistical analysis

The data were analyzed statistically using computer software. The Shapiro–Wilk test was performed to investigate the distribution of data. The Chi-square testing, as well as descriptive statistics, was used in the classification of categorical data. Kruskal–Wallis test and Bonferroni corrected Mann–Whitney U-test from *post hoc* tests were performed in the investigation of the relationship between MMP-3 staining and other parameters. $P < 0.05$ was taken for statistical significance.

Results

The average age of 34 patients participating in the study was 63.08 ± 17.77, the youngest was 35 years old and the
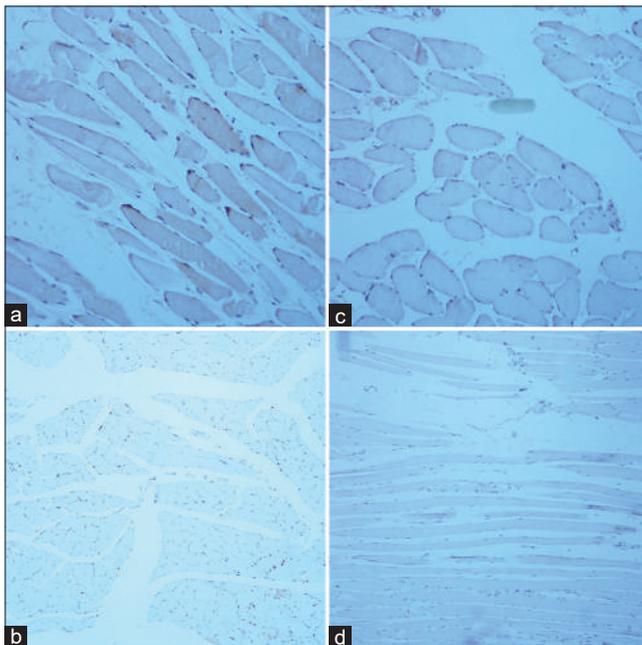
Figure 1: (a) Mild staining with matrix metalloproteinase (MMP)-3 in a striated muscle tissue (MMP3 ×200), (b) no staining with MMP-3 in muscle tissue (MMP3 ×100), (c) mild staining with MMP-3 in striated muscle tissue (MMP-3 ×200), (d) no staining with MMP-3 was observed in striated muscle tissue (MMP-3 ×100)
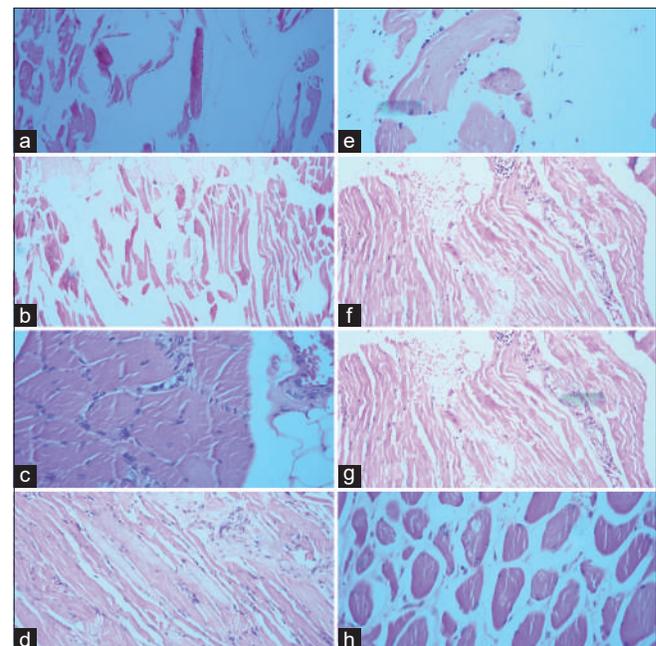
Figure 2: (a) Mild degree acidophilic sarcoplasm in muscle fibers (H and E ×200), (b) mild degree fiber deterioration in muscle fibers (H and E ×100), (c) moderate increase in cellularity in muscle fibers (H and E ×400), (d) mild degree striation of muscle fibers (H and E ×40), (e) deposition of lipofuscin in muscle fibers (H and E ×40), (f) moderate cellularity in muscle fibers (H and E ×200), (g) moderate cellularity in muscle fibers (H and E ×200), (h) moderate cellularity in muscle fibers (H and E ×400)
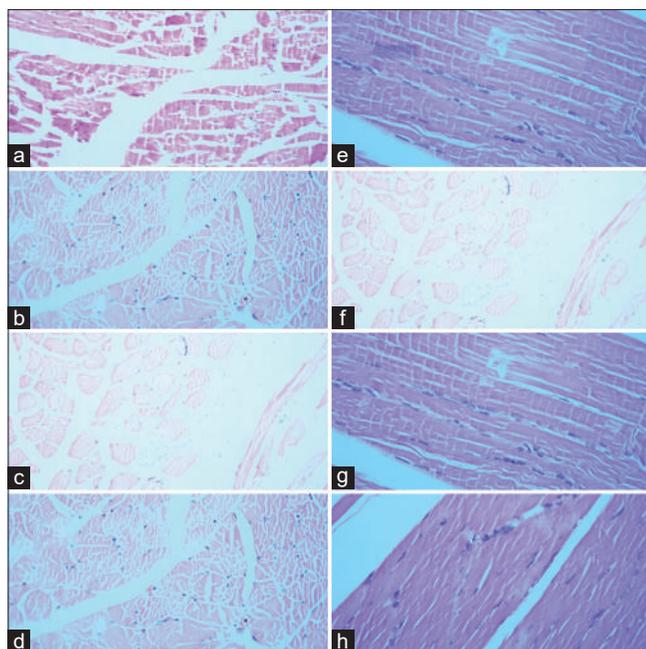
Figure 3: (a) Mild degree acidophilic sarcoplasm in muscle fibers (H and E ×200), (b) mild fragmentation of muscle fibers (H and E ×100), (c) multinucleation in muscle cell (H and E ×200), (d) mild degree streaking in muscle cell (H and E ×40), (e) moderate streaking in muscle cell (H and E ×200), (f) multinucleation in muscle cell (H and E ×200), (g) mild degree streaking in muscle cell (H and E ×40), (h) moderate vacuolization of muscle fibers (H and E ×40)

oldest was 90 years old. Of the cases, 94.1% ($n = 32$) were male and 5.9% ($n = 2$) were female. The mean body mass index (BMI) of the cases was 25.22 ± 4.87, the lowest BMI was 17.04, and the highest BMI was 36.24.

Of the cases, 73.5% ($n = 25$) were found to smoke, 8.8% ($n = 3$) smoked and had alcohol use, 2.9% ($n = 1$) had only alcohol use, and 14.7% ($n = 5$) had no substance use in the story. Furthermore, 55.9% had a history of atherosclerotic heart disease ($n = 19$) and 17.6% ($n = 6$) had a chronic obstructive pulmonary disease (COPD). Substance use in the group aged 65 years and older was statistically significantly higher than in the young group ($P = 0.02$). The distribution of sociodemographic characteristics of the young group aged 50 years and under and the older group aged 65 years and over was presented in Table 1.

In the histopathological examination, acidophilic fluid accumulation was not observed in both groups. Although there were no statistically significant differences between the two groups in histopathological assessments, staining with MMP-3 was statistically significantly higher in the EG ($P < 0.01$), Graph 1. Histopathological characteristics of Group 1 and Group 2 were compared in Table 2. In addition, the correlation analysis showed a statistically significant relationship between MMP3 staining and histopathological disruption ($P < 0.05$, $r = -0.35$).

No significant differences were found between Group 1 and Group 2 in terms of staining with MMP-3 ($H = 1.32$,
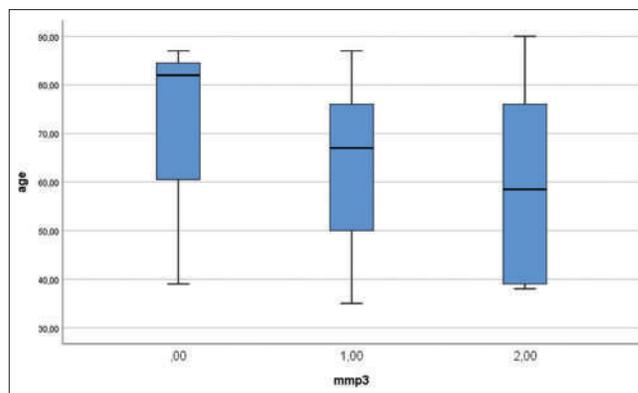
Graph 1: Distribution of matrix metalloproteinase-3 staining levels by age. MMP3: Matrix metalloproteinase-3

$P = 0.24$). In the Kruskal–Wallis test, it was understood that there was a statistical relationship between MMP3-staining and COPD ($H = 4.23$, $P = 0.04$), and in the *post hoc* test, this relationship was understood to be due to the relationship between weak staining and strong staining groups ($Z = -2.05$, $P = 0.04$) (strong staining was observed in all COPD patients). Data representation in Tables 1 and 2.

Discussion

Chronic muscle degeneration is quite common in the elderly, and the molecular mechanisms affected in chronic conditions have not been fully understood.[16]

Here, we present a study that reveals changes in MMP-3 expression and histopathological changes through the intercostal muscle sample.

MMP-3 belongs to the MMP family and is additionally induced during development, wound repair, inflammation, and cancer.[17-20] With the increasing knowledge of MMP function and its effect on physiological and pathological processes, interest in MMP substrates has increased further.[20]

MMP-3 also plays a role in many inflammatory diseases such as ultraviolet-B irradiation and photo-aging, arthritis, lung damage, vascular disease, and inflammation of the intestine. In studies, MMP-3-silenced mouse have been found to show decreased inflammatory responses to various stimuli and decreased cutaneous wound contraction.[21-23]

In addition, numerous bone pathologies, including arthritis, osteoporosis, osteonecrosis, periodontitis, sinonasal osteitis, degenerated lumbar disc tissues, and bone cancer metastasis, were reported to contribute to MMP activity and were associated with various stimuli and reduced cutaneous wound contraction.[17-19]

As for wound healing and inflammation, Çıraklı *et al.* found that MMP-3 expression was higher in the tenotomy group than in the treatment group, which was associated with inflammation.[15]

In this study, although the number of cases showing expression of MMP-3 in EG is higher than in YG, its

Table 1: Distribution of sociodemographic data of the groups

	Group 1		Group 2		P
	n	SD (%)	*n*	SD (%)	
Age	13	42.53±4.89	21	75.80±7.91	<0.01
BMI	13	25.86±4.08	21	24.83±5.36	0.55
Gender	13	13/0	21	19/2	0.02
Substance use					
Smoking	6	17.64	19	55.8	0.02
Smoking and alcohol	3	8.82	-	-	
Alcohol	1	2.94	-	-	
No substance use	3	8.82	2	5.88	
Atherosclerotic heart disease					
There is	11	32.35	4	11.76	<0.01
None	2	5.88	17	50.00	
Chronic obstructive pulmonary disease					
There is	11	32.35	16	47.05	0.23
None	1	2.94	5	14.70	

BMI: Body mass index, SD: Standard deviation

Table 2: Histopathological properties of Group 1 and Group 2 and staining status of matrix metalloproteinase 3

	Group 1	Group 2	P
	n	*n*	
Acidophilic sarcoplasm			
None	5	10	$\chi^2=0.27$;
There is	8	11	$P=0.60$
Prominence in striation			
None	10	15	$\chi^2=0.12$;
There is	3	6	$P=0.72$
Nucleus placement			
0	9	14	$\chi^2=4.21$;
1	2	7	$P=0.12$
2	2	0	
Vacuolization			
None	13	19	$\chi^2=1.31$;
There is	0	2	$P=0.25$
Deterioration in fibers			
None	7	12	$\chi^2=1.31$;
There is	6	9	$P=0.25$
Disruption			
None	7	9	$\chi^2=0.38$;
There is	6	12	$P=0.53$
Cellular infiltration			
None	13	17	$\chi^2=2.80$;
There is	0	4	$P=0.09$
Lipofuscin accumulation			
None	7	11	$\chi^2=2.80$;
There is	6	10	$P=0.09$
MMP3			
0	1	0	$\chi^2=10.65$;
1	5	19	$P<0.01$
2	7	2	

MMP: Matrix metalloproteinase

intensity is weak. It was observed that the degree of MMP-3 expression decreased in cases with the fragmentation of muscle fibers in terms of striated muscle degeneration. In a study on muscle degeneration that confirms this result, it was reported that MMP-3 levels decreased in the degenerated group compared to the healthy group.[19]

Lakemeier stated that while an increase in MMP-9 and 1 was monitored, a decrease in MMP-3 was observed, and it was responsible for regulating MMP-1 and 9.[19]

When these patients were examined, it was seen that COPD patients were mostly in the EG. However, this relationship was thought to be independent of age and staining score and was associated with inflammation.

An increase in muscle fiber fragmentation is noted in the EG. While the expression of MMP-3 is (weak degree) increased, the degree of intensity is weak compared to the EG. This weak MMP-3 elevation may be due to the effect of inflammatory cytokines in the inflammatory-aging mechanism.[24]

As a result of pronounced inflammation after infarction rupture in men, especially the interstitial collagen network activated by MMP-9 shows greater damage.[25] MMP-9 was not studied in this research. However, MMP-3 can be associated with the regulation of MMP-9.

In this study, the increase in expression intensity in people with COPD led to the conclusion that it may be related to the effect of cytokines released in the inflammatory response.

In a study involving morphological changes in normal skeletal muscle by age group, it was reported that the cell nucleus shrank in the EG compared to the young and child group; sarcoplasm was irregular and there was

ballooning and degeneration in mitochondrial clusters.[26] In this study, parameters such as acidophilic sarcoplasm, prominence in striation, nucleus placement, vacuolization, deterioration in fibers, disruption, cellular infiltration, lipofuscin pigment accumulation, and acidophilic fluid accumulation were assessed according to age groups. It was observed that the disruption of muscle fibers was more common in the older group than in the YG, but this difference was not statistically significant. However, it is thought that differences in MMP-3 staining may be related to this disruption. The absence of other MMPs such as MMP-1 and MMP-9, which were claimed to increase in degeneration by many publications and could illuminate this relationship, is one of the parameters that limit our work.

Data obtained by Si-Tayeb *et al.* show that nuclear MMP-3 is associated with the beginning of apoptosis. In the study, cells expressing the nuclear form of MMP-3 contained a higher proportion of apoptotic cell fraction than control cells. Furthermore, evidence suggests that MMP-3 is directly effective in apoptosis induction.[27] In addition, considering the relationship between smoking and apoptosis, Zhang *et al.* found that apoptosis activation is related to smoking and contributes to the pathogenesis of muscular atrophy.[28]

As seen in the literature, apoptosis is induced by smoking. This is also associated with an increase in MMP-3. In this study, the weak degree increase in MMP-3 expression in EG compared to YG may also be associated with smoking and apoptosis activation. Studying apoptotic markers in this group can be enlightening in terms of apoptosis.

Limitations of the study

Causes of death such as drowning or gas poisoning were not included in this study. Again, those with color changes on the body were not included in the study. The sampled muscles were selected from hidden areas so as not to disturb body integrity. In addition, MMP-9, MMP-1, inflammatory markers, and apoptosis markers were not investigated. These reasons are the limitations of the study.

Conclusion

MMP-3 expression increases with age and its intensity decreases. In addition to inflammatory conditions that affect this variability, the parameters that cause degeneration and aging affect the expression level. The degree and expression of MMP-3 may be indicative of the aging process. It will be illuminating to reveal this relationship with more case groups. In addition, we also believe that MMP-3 follow-up may be beneficial in terms of tracking the degree of aging and degeneration.

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Conflicts of interest

There are no conflicts of interest.

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Effects of 60-day Sodium Benzoate Exposure on the Ultramicroscopic Structure of Rat's Thyroid Gland Follicular Cells

Abstract

Background: The sodium benzoate is widely used as a preservative in the food and pharmaceutical industries. There is information about the ability of this food additive to cause hepato- and nephrotoxicity, gonadotoxicity by initiating oxidative stress in cells. However, information on the effect of long-term exposure to sodium benzoate on the ultrastructure of endocrine cells, particularly of those thyroid follicular cells is completely absent. **Aim:** The aim of the study was to investigate electron microscopic changes in thyroid gland follicular cells in mature rats after 60 days of sodium benzoate administration. **Materials and Methods:** The first group consisted of rats injected daily with 1 ml sodium benzoate solution at a dosage of 1000 mg/kg of body weight through a feeding tube for 60 calendar days. The second group consisted of control animals injected with 0.9% saline solution under the same conditions. Thyroid gland pieces were processed according to the standard protocol for electron microscopy. **Results:** Microscopic examination of the thyroid gland of experimental animals showed that the follicular cells had a cubic or flattened shape. The apical surface of these cells contained a small number of low microvilli. The rough endoplasmic reticulum (rER) of most thyrocytes was enlarged and its cisterns contained homogeneous material, but some had abnormal electron dense deposits. In most cells, the nuclei were often irregular in shape with irregular contours, compared to the control. Heterochromatin occupied almost the entire periphery of the karyoplasm. The mitochondrial matrix was electron dense. Lysosomes were evenly distributed in the cytoplasm. A small number of small pinocytic vesicles with colloids were located in the apical part of most thyrocytes. A wide electron light pericapillary space was observed between the basal part of the latter and fenestrated capillaries. **Conclusion:** The 60 day administration of sodium benzoate to rats causes adverse ultrastructural changes in thyroid follicular cells. The rER undergoes the greatest morphological changes.

Keywords: *Follicular cells, rats, sodium benzoate, thyroid gland, ultrastructure*

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Introduction

At present, sodium benzoate is widely used as a preservative for food and beverages, in the pharmaceutical industry. It can be found as part of canned food, dairy and meat products, seasonings, and semi-finished products, as well as in the outer shell of drugs and personal hygiene products.[1] However, concerns remain about its complete safety for human health. The experimental and clinical studies show ambiguous results in this regard.

Thus, there is experimental evidence that the introduction of sodium benzoate causes chromosomal aberrations in cultured human lymphocytes;[2] induces the development of oxidative stress, reduces the activity of enzymes of the antioxidant system, increases the level of liver biochemical markers (alanine aminotransferase and aspartate aminotransferase) and pro-inflammatory cytokines (interleukin 6, tumor necrosis factor-alpha) in cells.[3]

According to other sources, sodium benzoate has no mutagenic and teratogenic effects[4] and is also used in clinical practice in the therapy of resistant forms of schizophrenia, dementia, chronic liver diseases, and Parkinson's disease.[5-8]

The endocrine system, together with the nervous system, ensures the regulation and coordination of body functions and is one of the first to be exposed to adverse factors of both the external and internal environment.[9]

Physical and emotional health requires the normal functioning of the thyroid gland, which regulates the body's executive systems, metabolic rate, behavior, and cognitive function. The earliest

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morphological changes under the influence of unfavorable factors are found at the subcellular and cellular levels of the organization of matter. The aim of the study was to investigate electron microscopic changes in thyroid gland follicular cells in mature rats after 60 days of administration of sodium benzoate.

Subjects and Methods

For the experiment, 12 white male mature rats weighing 200–250 g were selected. The animals were divided into two groups of six individuals each. The first group consisted of rats injected daily with 1 ml sodium benzoate solution at a dosage of 1000 mg/kg of body weight through a feeding tube for 60 calendar days. The second group consisted of control animals injected with 0.9% saline solution under the same conditions.

The animals were kept and manipulated in accordance with the rules for keeping experimental animals established by EU Directive 2010/63/EU of the European Parliament and the Council of September 22, 2010.[10] All procedures were approved by the bioethics committee of the State Establishment "Saint Luka Lugansk State Medical University," Lugansk, People's Republic of Lugansk (protocol number 2 dated March 25, 2022). The animals were removed from the experiment by the decapitation method. Immediately after removal, the thyroid gland was divided into pieces of 1 mm³ sizes, then fixed in 2.5% glutaraldehyde solution, followed by treatment in 1% osmium tetroxide, according to Palade.[11] After dehydration in increasing concentration of ethanol and absolute acetone, the material was poured with a mixture of epoxy resins (epon-araldite). Polymerization was carried out for 36 h at 60°C. Ultrathin sections were made on a UMTP-4 ultramicrotome of the Sumy PO Electron, contrasted in a solution of uranyl acetate and lead citrate according to Reynolds[12] and studied under an EM-125 electron microscope with further photography.

Results

The results of the study showed that in the animals of the control group, the thyroid gland consisted of typical follicles filled with colloids. Follicular cells are closely opposed to each other, had a predominantly cubic or columnar shape, and their apical surfaces are characterized by numerous irregularly spaced microvilli. Typical tight junctions or interdigitations are found between neighboring cells.

The nucleus of the follicular cell is predominantly oval or round in shape, located in the central or basal part of the cell, had slightly sinuous contours. Heterochromatin is located in a narrow, discontinuous rim under the nuclear membrane. The nucleolus is visualized in the peripheral part of the karyoplasm and had a different electron density. The rough endoplasmic reticulum (rER) of the

follicular cell is distributed throughout the cytoplasm, and its cisterns are expanded toward the base of the cell. The cytoplasm contained single free ribosomes, numerous typical elongated mitochondria with a homogeneous, and fine-grained matrix. A moderate number of electron-dense lysosomes are distributed mainly in the apical part of cells. A noticeable zone is visualized near the nucleus, containing the Golgi complex, consisting of a group of cisterns with densely packed vacuoles and small vesicles. The apical part of the cytoplasm contained several small bubbles and typical large colloidal droplets with a substance having a similar electron density to the colloid.

The bases of the epithelial cells of the follicles are adjacent to the fenestrated capillaries, in the lumen of which electron-dense blood cells are determined.

The stroma in the thyroid gland of the control animals is moderately developed [Figure 1].

Electron microscopic examination of the thyroid gland of experimental animals revealed that the follicular cells had a cuboidal shape, less often flat. The apical surface of these cells contained a small number of low microvilli. The rER of most thyrocytes was enlarged. In general, the rER tubules contained homogeneous material, but some had abnormal electron-dense deposits. In some cases, the assembly in the tubules progressed to well-defined clusters of wavy structures of various sizes with a circular orientation, located loosely relative to each other.

In most cells, the nuclei were often irregular in shape with irregular contours, compared to the control. Heterochromatin occupied almost the entire periphery of the karyoplasm. The mitochondrial matrix was electron-dense. Lysosomes were evenly distributed in the cytoplasm. A small number
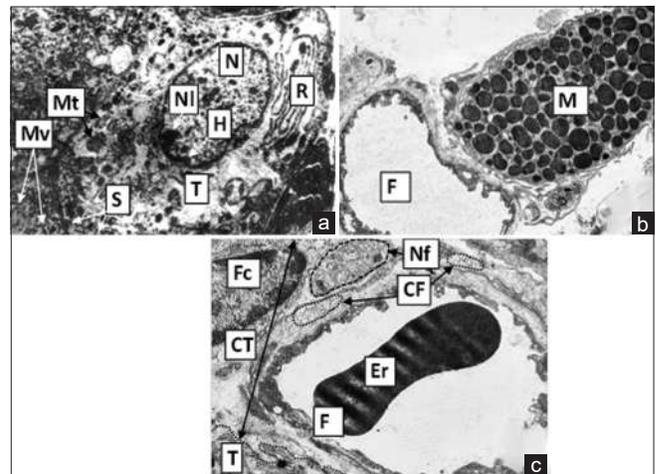
Figure 1: The piece of the thyroid gland of control mature rats ([a] piece of the thyroid gland with thyrocyte, [b] piece of thyroid gland with mast cell, [c] piece of the thyroid gland with connective tissue between follicles). T: Thyrocyte, N: Nucleus, Nl: Nucleolus, H: Heterochromatin, R: Rough endoplasmic reticulum, Mt: Mitochondria, M: Mast cell, S: Secretory granules, Mv: Microvillus, F: Fenestrated capillary, Er: Erythrocyte, CT: Connective tissue between follicles, Fc: Fibrocyte, CF: Collagen fibers (cross-section), Nf: Nerve fiber (×8000)

of small pinocytic vesicles with colloids were located in the apical part of most thyrocytes. A wide electron-light pericapillary space was observed between the basal part of the latter and fenestrated capillaries [Figures 2 and 3].

Discussion

Thus, ultramicroscopic examination showed that the thyroid gland of mature male rats contains thyrocytes of typical structure. Follicular cells delimit the colloid cavity and form the follicles. The stroma is moderately developed. A similar ultramicroscopic structure of thyroid follicular cells is confirmed by the data obtained by other researchers:

- In control, male mature outbred rats, thyrocytes of columnar shape contain interdigitations on the lateral surfaces, microvilli – on the apical surface and tight junctions on apicolateral borders. The nucleus is located in the basal part of the cell. Nucleolus of different electronic density occupies the area under the nuclear membrane. The rER is well developed, and mitochondria were randomly spread in the cytoplasm. The Golgi apparatus is located near the nucleus[13]

- In control male mature African giant rats, the thyroid gland is enclosed by a thin connective tissue capsule. The parenchyma consists of round, oval, or sometimes irregularly shaped follicles of variable sizes. The peripheral part of the thyroid gland contains large follicles lined with cuboidal or squamous follicular cells, while the central part – small- and medium-sized follicles lined with columnar or cuboidal cells. The apical surface of the thyrocyte has microvilli, apicolateral borders, tight junctions, and the base of the cell rests on the basement membrane. The nucleus was oval-shaped in the cuboidal or columnar follicular cells and flattened in squamous cells. In general, the nucleus occupies the central or basal part of the cell. The cisterns of rER and round- or rod-shaped mitochondria were distributed throughout the cytoplasm. Golgi apparatus is well developed and situated close to the nucleus[14]

- In control male mature Wistar rats, the thyrocytes contain a prominent nucleus, well developed rER, and small dense lysosomes. The Golgi complex is placed near the nucleus of the cell. The numerous long, regular
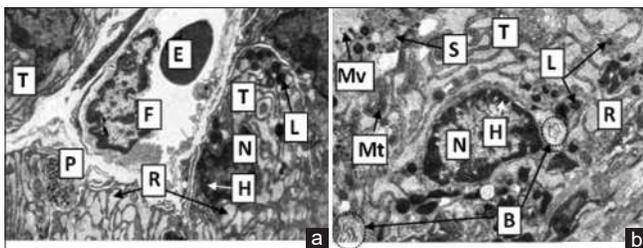
microvilli projecting into the follicular lumen are situated on the apical surface of thyrocytes.[15]

In the experimental group, in comparison with the control, a small number of microvilli and small secretory granules in the apical part of thyrocytes were visualized on electronograms. Lysosomes were evenly distributed in the cytoplasm. Follicular cells were found to be cuboidal, less often flat in shape. Similar structural changes in thyrocytes were observed with exogenous administration of thyroid hormones into the body of rats, which, as shown by the study, reduced the level of endogenous thyroxine.[15] The systematic intake or high concentration of sodium benzoate in mice, reduces the synthesis of leptin by adipocytes.[16] The decrease in leptin, acting through the arcuate nucleus of the hypothalamus, leads to a decrease in the production of thyroliberin, and, consequently, reduces the production of thyrotropine.[17] The latter acts on the follicular cells of the thyroid gland and reduces the synthesis of thyroxine.

It should be noted that in the cytoplasm of the follicular cells of the thyroid gland of experimental animals, dilated cisterns of the rER are observed, in which there are single wavy structures of various sizes with a circular orientation, located loosely to each other. On the periphery of the nucleus, there are significant accumulations of heterochromatin, the mitochondrial matrix is electron-dense. The high doses of sodium benzoate cause DNA damage not only to the nuclei of rat liver epithelial cells but also to mitochondria.[18] DNA mutations can lead to impaired protein synthesis and a slowdown in its transport from the rER.[19,20] These studies can explain the changes revealed in the electronograms of the experimental group of rats.

Conclusion

In animals of the control group, the thyroid gland follicular cells had a typical structure. The 60-day administration

Figure 2: The piece of the thyroid gland of experimental mature rats ([a and b] pieces of thyroid gland with thyrocytes). T: Thyrocyte, N: Nucleus, H: Heterochromatin, R: Rough endoplasmic reticulum, B: Fibrous deposits in the cisterns of the rough endoplasmic reticulum, Mt: Mitochondria, L: Lysosomes, S: Secretory granules, Mv: Microvillus, F: Fenestrated capillary, E: Erythrocyte, P: Parafollicular cell (×8000)

Figure: 3: The area of the thyroid gland of mature rats (experimental group). F: Follicular cells, N: Nucleus, Ch: Chromatin, rER: Rough endoplasmic reticulum, Mt: Mitochondria, L: Lysosomes, IJ: Intercellular junctions (interdigitations) (×16,000)

of sodium benzoate to rats causes adverse ultrastructural changes in thyroid follicular cells. The rER undergoes the greatest morphological changes. The above-mentioned ultrastructural changes can be explained by the direct effect of the sodium benzoate on the DNA of the nucleus and mitochondria of thyrocytes or indirectly through a decrease in the level of leptin and, as a consequence, the effect on the hypothalamic–pituitary–thyroid axis.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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A Study of Morphometrical Analysis of the Human Malleus

Abstract

Introduction: Malleus is one of the three ear ossicles which are the largest among all. It is present in the middle ear cavity and is responsible for the conduction of sound waves from external to inner ear. The malleus has a head, neck, manubrium, and anterior and lateral processes. The aim of this study was to study the morphometry of human malleus and to determine the normal range of the various measurements of malleus. **Materials and Methods:** A total of 120 dry adult human mallei were used in this study. Malleus bones were collected during the routine dissection of cadavers by the MBBS students of first professional in the dissection hall of anatomy department of various medical colleges of Uttar Pradesh. These dimensions of malleus bone were taken with the help of digital Vernier caliper which has an accuracy of 0.01 mm. **Results:** The mean value of total length of malleus was found 7.915 mm, mean value of length of handle was found 4.74 mm, and mean value of total width of head was found 2.63 mm. **Discussion and Conclusion:** No statistical significant difference was found when compared with the morphometric parameters of malleus of the right and left sides.

Keywords: *Ear ossicles, malleus, middle ear, ossiculoplasty, prosthesis*

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Introduction

The auditory ossicles malleus, incus, and stapes are the smallest bones in the human body and are structurally and functionally most complicated.[1,2] The presence of malleus was noted by Alessandro Achillini (1463–1513) for the first time in 15th century.[3] The malleus is derived from Meckel's cartilage of the first pharyngeal arch and ossification begins in the 4th month of intrauterine life and is completed by the 8 month.[1,2] Malleus assumes adult size at birth.[4] The malleus is the largest ear ossicles.[5] It is 8–9 mm long.[6] Malleus does not have periosteum and cannot be regenerated.[1,2] The malleus has a head, neck, manubrium (handle), and anterior and lateral processes.[5] The head is the larger upper end of the malleus and is situated in the epitympanic recess. It is ovoid in shape and articulates posteriorly with the body of the incus.[2] To form the incudomalleolar joint, this is a saddle type of synovial joint.[7] The neck is the narrowed part below the head and proceeds inferiorly as handle of the malleus.[5] The handle is directed downward, medially, and backward. The size of the handle decreases toward its free end, which is curved slightly forward and is flattened transversely. The anterior process is a delicate bony spicule, which is directed forward from the enlargement below the neck. In fetal life, anterior process is the longest process of the malleus and is continuous in front with Meckel's cartilage.[6] The lateral process is a conical projection from the root of the handle of the malleus and is directed laterally.[2] This study is designed to find the morphometry of the human malleus and to determine the normal range of the various measurements of it.

Materials and Methods

In the present study, 120 dry adult malleus bones were used. Malleus bones were collected during the routine dissection of cadavers by the MBBS students of the first professional in the Dissection Hall of Anatomy Department of various Medical Colleges of Uttar Pradesh, India. Out of total 120 malleus bones used, 60 were retrieved from the male cadavers (30 from right side and 30 from left side) and 60 were retrieved from the female cadavers (30 from right side and 30 from left side). Malleus was cleaned, dried and finally kept into the plastic satchel bags with zip locking mechanism. These pouches were assigned the serial number, age, date, side, and sex.

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Table 1: Side comparison and statistical significance of malleus

Parameters	Side	n	Range (minimum–maximum)	Mean±SD	Mean±SD	P
Total length of malleus (mm)	Right	60	7.40–8.55	7.95±0.347	7.603–8.297	0.122
	Left	60	7.20–8.50	7.88±0.314	7.566–8.194	
Length of handle (mm)	Right	60	4.40–5.46	4.77±0.234	4.536–5.004	0.095
	Left	60	4.19–5.00	4.71±0.238	4.472–4.948	
Total width of head of malleus (mm)	Right	60	2.20–3.16	2.62±0.284	2.336–2.904	0.341
	Left	60	2.06–3.35	2.64±0.320	2.32–2.96	

$P<0.05$ mm was regarded as statistically significant. *n*: Number of bones taken, SD: Standard deviation

Table 2: Morphometric data of the human malleus

Parameters	Mean±SD
Total length of malleus (mm)	7.915±0.330
Length of handle (mm)	4.74±0.236
Total width of head of malleus (mm)	2.63±0.302

SD: Standard deviation

Pathological and fractured mallei were excluded from the study. Only fully ossified malleus was included in this study. The dimensions of malleus bones were studied from selected points as depicted in Figure 2. These dimensions of malleus bone were taken with the help of digital Vernier caliper which has an accuracy of 0.01 mm. The parameters of the malleus bones are studied [Figures 1 and 2]:

1. Total length of malleus (mm): Total length of malleus was measured as the maximum straight distance between the top of the head and the end of the handle of the Malleus (A-B)
2. Length of handle of malleus (mm): Length of handle of malleus was measured as the maximum straight distance between the end of the lateral process and the end of the handle of the Malleus (C-A)
3. Total width of head of malleus (mm): Maximum width of the head of malleus (D-E).

To avoid intraobserver variation, each measurement was done by the principal investigator at three different times and mean of all these three readings was taken as the final reading [Table 1]. For abovementioned measurements, mean value, standard deviation (SD), and mean ± SD were calculated. Independent sample "*t*"-test was applied, and "*P*" value was calculated at 95% confidence interval using advance Excel/SPSS (Statistical Package for the Social Sciences) software version 26 [Table 2].

Results

In the present study, no statistically significant difference was found when we compared morphometric parameters of malleus of the right and left sides when analyzed collectively from both the sexes as shown in Table 1.

Discussion

Variations occur in the morphometric data of human malleus might be due to regional population or racial difference, and also variations occur in the dimension
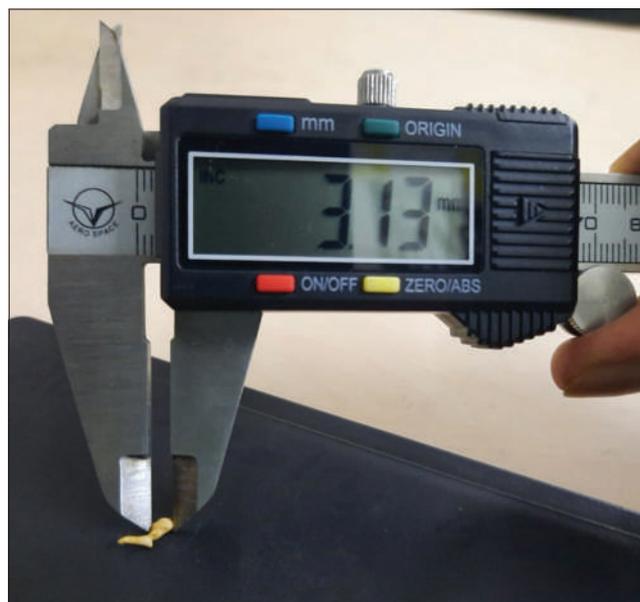
Figure 1: Method of measuring malleus

of malleus might be due to various types of instruments used for measurement; methods used for measurement of malleus or interobserver error by other researchers. Ear ossicles play an important role in hearing. Malleus provides 1.3 time mechanical advantage due to lever ratio, hence potentiates sound energy by that ratio. Morphometric analysis of ear ossicles has been the subject of interest since mid-15th century.[3] Malleus bones obtain full adult size during fetal life but continue to undergo changes throughout life, so the variations of the size of malleus bones are expected.[8] In present study, *P* values for all the parameters were more than 0.05 mm, which suggest that there is no statistically significant difference for these parameters of malleus between the right and left sides.

Total length of malleus (mm)

In the present study (2021), the mean value of the total length of malleus was 7.915 mm which is similar to the study reported by Nadeem[9] (8 mm), Rathava *et al*.[10] (7.81 mm) and Sodhi *et al*.[11] (7.83 mm).

In the present study (2021), the mean value of total length of malleus was higher than the study reported by Vinaychandra[12] (7.45 mm) and Radha[13] (7.4 mm).

		Table 3: Comparison of morphometric data of malleus between present and previous studies		
Researcher	Side	Total length of malleus (mm)	Length of handle (mm)	Total width of head of malleus (mm)
Singh et al.[19]	Right	7.94±0.41	4.76±0.45	-
	Left	7.94±0.40	4.72±0.37	-
Makhija et al.[20]	Right	7.59±0.36	4.64±0.30	2.34±0.19
	Left	7.62±0.14	4.49±0.32	2.54±0.20
Sodhi et al.[21]	Right	7.68±0.51	4.35±0.42	-
	Left	7.79±0.47	4.42±0.51	-
Present study	Right	7.603–8.297	4.536–5.004	2.336–2.904
	Left	7.566–8.194	4.472–4.948	2.32–2.96
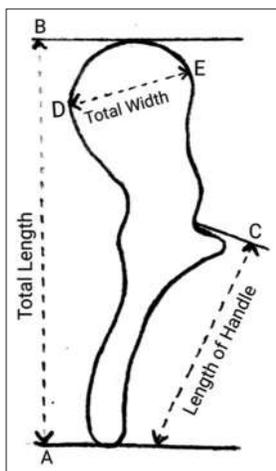
Figure 2: Various measurements of Malleus bone. Total length (A-B), Length of handle (C-A), Total width of head (D-E)

Figure 3: Malleus bone

In the present study (2021), the mean value of the total length of malleus was lower than the study reported by Ramirez and Ballesteros[14] (8.18 mm), Mogra et al.[15] (8.53 mm) and Kumar et al.[16] (8.23 mm) [Table 3].

Length of handle (mm)

In the present study (2021), the mean value of length of handle (4.74 mm) was almost similar to the study reported by Bhatnagar et al.[17] (4.65 mm) and Unur et al.[18] (4.7 mm).

In the present study (2021), the mean value of length of handle was higher than the study reported by Nadeem G (2012-13)[9] (4.58 mm), Rathava et al.[10] (4.59 mm), Radha[13] (4.2 mm), Sodhi et al.[11] (4.44 mm), and Kumar et al.[16] (4.17 mm).

In the present study (2021), the mean value of length of handle was lower than the study reported by Ramirez and Ballesteros[14] (4.91 mm) and Mogra et al.[15] (5.2 mm).

Total width of the head of malleus (mm)

In the present study (2021), the mean value of total width of the head of malleus (2.63 mm) was almost similar to the study reported by Kumar et al.[16] (2.56 mm).
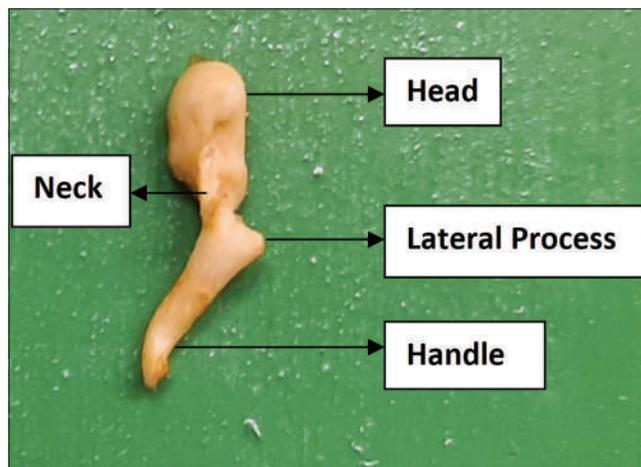
Conclusion

In the present study, we determined the normal range of the values of the various measurements of the human malleus [Figure 3]. The mean value of total length of malleus was found to be 7.915 mm, mean value of length of handle was 4.74 mm, and mean value of total width of head was 2.63 mm. No statistically significant difference was found when compared with the morphometric parameters of malleus of the right and left sides. The detailed knowledge of the morphometric data of various dimensions of the human malleus will help the otologist during reconstructive surgery and provide necessary information for the prosthesis designer for designing the prosthesis more appropriately suited for North Indian population. Human malleus can be used as homograft ossicles which are available in the regional tissue banks. This study will also give a basis for teaching the medical students about the human malleus.

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Conflicts of interest

There are no conflicts of interest.

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An Introduction and Evaluation of Direct Observation with Checklist as a Teaching–Learning and Assessment Method in Anatomy

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Abstract

Background: Surface anatomy, which correlates with clinically relevant structural outlines and palpable features, is a core clinical skill that forms an essential component of physical examination. The teaching methodologies used currently lack clarity and adequacy of content as well as the assessment methods are ambiguous. With curricular reforms in India, there is a need for a student-centric teaching that integrates the principles of active and collaborative learning, feedback, and student autonomy. **Methodology:** The current study introduced and evaluated a new methodology, i.e. "Direct Observation with Checklist" for surface anatomy in 1st-year MBBS undergraduate students to gather their perception and gauge any improvement in learning. Students were taught and observed during their performance of a particular surface marking with the checklists and relevant improvements in their performances were suggested. At the end of the month, an examination was arranged and each student was individually assessed by two separate examiners during his/her performance. This was followed by an anonymous feedback to gather the student as well as faculty perception using a five-point Likert scale. **Results:** *Z*-test computation revealed a significant difference between the scores obtained through direct observation with checklist and without checklist. The faculty and student feedback provided encouraging results and suggestions in the implementation of direct observation with checklist. **Conclusion:** Direct observation with checklist is a novel teaching–learning and assessment method implemented for the first time in anatomy for teaching psychomotor skills of surface anatomy and can be explored further to educate and empower students.

Keywords: *Competency-based medical education, direct observation of procedural skills, medical education, objectively structured clinical examination, surface anatomy*

Introduction

Historically, anatomy has been considered the foundation stone for medical education and continues to be so.[1] Even today, despite the technological advances in medicine, anatomical knowledge is not only essential for surgeons but also for anyone who performs a physical examination of a patient, examines radiological imaging, interprets any diagnostic tests, carries out emergency procedures, or explains a procedure to a patient.[2]

Surface anatomy, in particular, correlates with palpable surface features such as bony protuberances, tendons, and clinically relevant structural outlines that form an essential component of physical examination and interventional procedures.[3] A core clinical skill for the vast majority of general practitioners,

interventionists, anaesthetists, and surgeons, surface anatomy provides ample opportunities to assess structures under the skin, recognize their palpable characteristics demonstrate the techniques of physical examination and familiarize oneself in a safe environment before the clinical practice.[4] In spite of the clearly evident need for a solid foundation in surface anatomy, anatomy textbooks, barring a few, devote very less learning resources and time to it. The teaching methodologies being used currently are vaguely defined and lack clarity, quality as well as adequacy of content.[5] Moreover, living and surface anatomy has been designated as a skill that can be better assessed at the "Shows How" level of Miller's pyramid with ambiguous assessment methods in the form of "skill assessment."[6]

To top this, with the worldwide reforms in medical education in the 21st century, anatomy education has also entered into

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a renaissance to move toward a student-centered teaching framework that is not only functionally and clinically relevant but also integrates the principles of active and collaborative learning, feedback, and student autonomy.[7] However, designing a pedagogical framework alone will not address the challenges of anatomy education. The designed teaching approach needs to be implemented through pertinent teaching–learning and assessment methods in the delivery of anatomy education and then evaluated.[8] Taking these into consideration, the present study was designed to introduce and evaluate direct observation with checklist as teaching–learning and assessment method in surface anatomy for undergraduate students and gather the perception of students and faculties for its implementation.

Methodology

The present interventional study was conducted on Phase I MBBS students during the academic year 2019–2020. After obtaining necessary permissions from the Institutional Ethics Committee and concerned authorities, clinically relevant surface anatomy topics were identified by the principal investigator for the lower limb region of gross anatomy from Volume I of the Medical Council of India booklet for competency-based undergraduate curriculum for Indian medical graduate [Table 1].

These topics representing the desired competencies were further analyzed into specific learning objectives and the expected outcomes. Based on the guidelines provided by Degani and Wiener[9] and Stufflebeam,[10] 18 individual checklists, one for each identified topic, were developed

Table 1: List of identified topics for checklist

Front of thigh
  Saphenous opening
  Great saphenous vein
  Small saphenous vein
  Femoral opening
  Femoral artery
  Femoral vein
  Femoral nerve
  Profunda femoris artery
Popliteal fossa
  Popliteal artery
  Tibial nerve
  Common peroneal nerve
Back of thigh
  Sciatic nerve
Front, lateral, and medial sides of the leg
  Superior extensor retinaculum
  Anterior tibial artery
  Deep peroneal nerve
  Dorsalis pedis artery
  Superficial peroneal nerve
Back of leg
  Posterior tibial artery

using the reference textbooks and through performance of surface marking on mummified cadavers by the principal investigator. Each individual topic checklist consisted of specific and sequentially arranged observable checkpoints. The checkpoints, in turn, comprised statements with brief descriptors in the form of criteria to be met by the students. Reference material was cited at the end of the checklist for the purpose of explanation of the descriptors. Each individual checkpoint was taught and assessed on a Yes or No Scale during student demonstration of a particular surface marking. Each checklist weighed 5 marks with each checkpoint scored individually from a minimum of 0.25 to 1.5 maximum based on the significance of that particular checkpoint in the expected outcome of the checklist. Each checklist also incorporated a space for open-ended suggestions from the assessor. The initial version of all the checklists was forwarded to subject experts both internally and externally (see acknowledgments) for their critical review in terms of clarity and applicability of the content, usability, effectiveness, and feasibility. The review comments and suggestions from subject experts were incorporated and the marking scheme of each checklist was prevalidated and finalized unanimously [Table 2].

First-year MBBS students and faculties of the anatomy department were sensitized and trained about the checklists and using direct observation with checklist as a teaching–learning and assessment method. Over the next month, the final version of the checklists along with their marking schemes was printed on A4 sheet and hard copies of appropriate topics were distributed to the students in small groups during routine dissection classes for surface marking of that particular topic. Students were observed during their performance of a particular surface marking with the checklists and relevant improvements in their performance were suggested.

At the end of the month, an examination for surface marking of the lower limb was arranged, where each student was individually assessed during his/her performance of surface marking. A single performance of an individual student was simultaneously assessed by two separate examiners, one through direct observation with checklist and another with direct observation without checklist. A total of 150 students were divided into 3 batches of 50 each and each batch (50 students) was assessed by two examiners, one with direct observation with checklist and another with direct observation without checklist. Both simultaneous assessments were scored out of 5 and the best score obtained by the student irrespective of the method of assessment was considered for summative assessment.

Informed written consent was procured from students before pooling the data and filling feedback forms. Students not willing to participate in the study or failing to provide informed written consent were excluded from the sample without any bias. The assessment scores of the

Table 2: Sample checklist

Surface marking – great saphenous vein			
Points to assess	Yes	No	Marks
Uses appropriate color chalk for marking			0.5
Correctly palpates and marks point 1 at the proximal end of 1st metatarsal bone			0.5
Correctly palpates medial malleolus			0.25
Marks point 2 at the anterior surface of the medial malleolus			0.25
Correctly palpates the medial border of the tibia			0.25
Marks point 3 approximately at the junction of the upper 2/3rd and lower 1/3rd on the medial border of the tibia			0.25
Correctly palpates and marks adductor tubercle as point 4			0.5
Correctly palpates pubic tubercle			0.5
Marks point 5 approximately 5 cm below and lateral to pubic tubercle			0.5
Draws a line joining all the above-mentioned 5 points			1
Handles the cadaver/mummy respectfully (wipes the marking with cloth)			0.5
Total=(___/5)			

students marked by direct observation with checklist and direct observation without checklist were computed using descriptive statistics such as mean, median, mode, and relational statistics Z-test for analyzing significance. An anonymous feedback using a five-point Likert scale was obtained through a Google Forms questionnaire to gather the student's perception and their level of satisfaction with both the assessment methods as well as faculty perceptions regarding teaching–learning and assessment techniques using direct observation with checklist. The questionnaire also included open-ended statements and suggestions for improvement from the students as well as faculties.

Results

Student feedback

The impact of direct observation with checklist as a teaching and assessment method was evaluated at level 1 (reaction) and level 2 (learning) using the four levels of evaluation by Kirkpatrick. Figure 1 shows the results of the Student's feedback ($n = 110$), where majority of the students agreed that the method was simple, clear, and easy to understand as well as helps them learn and perform better in examinations. The students perceived that it increases objectivity in the assessment, provides timely feedback, and reduces their stress in terms of any ambiguity with the assessment. Similarly, all faculty ($n = 6$) agreed that direct observation as a teaching–learning and assessment method is simple, clear, and easy to implement (6/6) and that it helps to teach more effectively (6/6) and give timely feedback (6/6). As an assessment method, it reduces bias (4/6) and should be frequently used in other examinations as well (5/6).

Student scores

As for level 2, while it was difficult to comment on the direct observation with checklist as a teaching method through acquisition of knowledge and skills, there is a definite improvement in the scores of the students. Pooled data of the scores obtained by students ($n = 148$) revealed a significant difference in the assessment conducted through direct observation with checklist and direct observation without checklist. The mean and median values of the corresponding scores are mentioned in Figure 2. Z-test computation to test the difference between the scores obtained through direct observation with checklist and without checklist revealed sufficient evidence that there exists a significant difference between the scores obtained through direct observation with checklist and without checklist [Table 3].

Faculty scores

Additionally, an insight into the mean of scores given by individual faculties in pairs for 3 separate batches through direct observation revealed that while using checklist for assessment a higher score can be achieved by the students as compared to the method wherein the checklist is not used [Figure 3].

Discussion

We found that there was a significant improvement in the scores obtained by the students through direct observation with checklist and the method was well received by the students and faculties alike because it was easy and clear to understand as well as helped the students to learn and perform better in examinations. It enabled a timely feedback and increased the objectivity in assessment which encouraged further frequent use in other examinations.

As for the scores, there is enough evidence to suggest that educational interventions with attention to teaching methods are one of the foremost parameters for improvement of academic performance.[11] In particular, topics of clinical relevance garner more attention from students especially when presented through newer and innovative methods.[12] Furthermore, apart from student feedback, high academic performance of the students is also a reliable parameter to ensure effective teaching.[13] These could indicate the improvement in scores obtained by the students through the newer teaching method we implemented.

Moreover, direct observation and corrective feedback are the cornerstones of teaching clinical skills since they guide learners to potential improvement by providing particulars about their performance.[14,15] In a prospective observational study by Benenson and Pollack[16] in emergency trainee performance for actual death notifications, constructive feedback by supervising doctors on unsatisfactory performance after direct observation led to improved
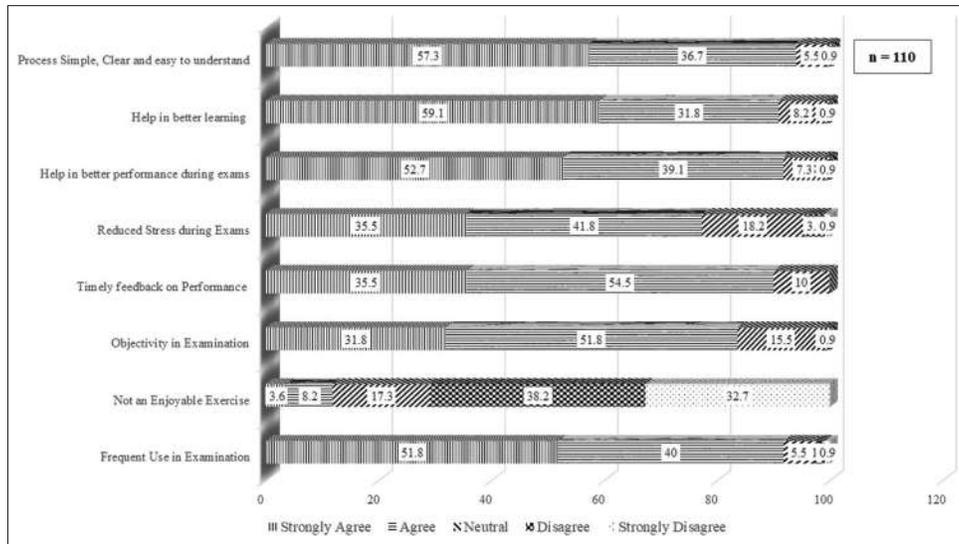
Figure 1: Student's feedback on direct observation with checklist
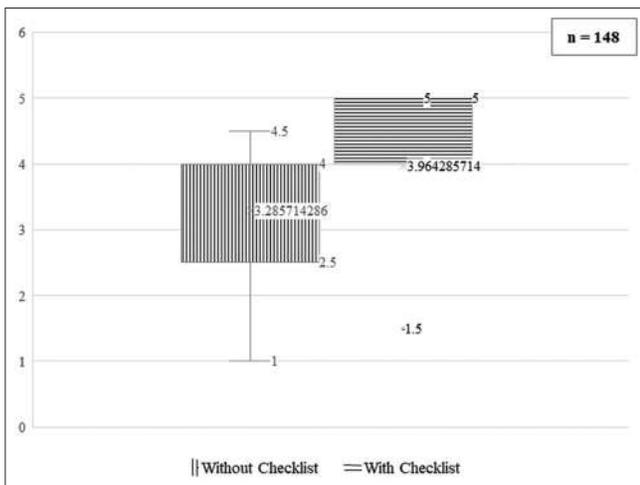
Figure 2: Differences in scores obtained for direct observation with checklist and without checklist
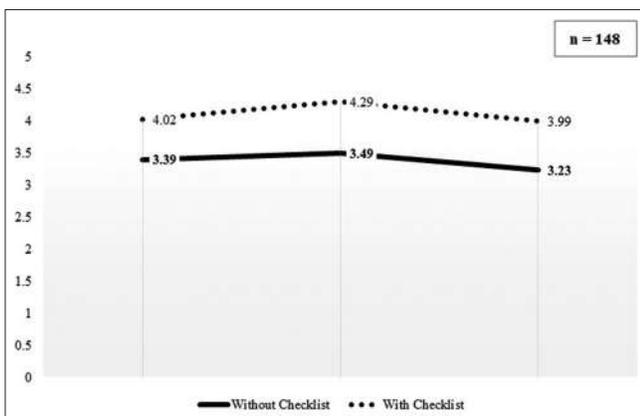
Figure 3: Differences in faculty scoring for direct observation with checklist and without checklist

Table 3: Z-test analysis for scores obtained through both methods

Scores obtained through direct observation	Mean scores	SE	Z
With checklist	4.11	0.12	6.18
Without checklist	3.37		

SE: Standard error

of emergency medicine residents in physical examination skills after receiving observer feedback. Furthermore, in the absence of direct observation and feedback, learners might acquire incorrect techniques.[18] In this context, specific feedback through checklists can be highly effective in terms of explaining the learners on what they need to do differently.[19] Similar feedback was shared by the students through their open-ended statements that a checklist gives them the "exact and necessary steps," "makes learning very simple and structured," "increases transparency as well as reduces the stress of vagueness" and "helps them improve on their performance through corrective measures."

Another important factor to explore is the peer feedback. Since the checklists were distributed in small groups ($n = 17$) and students practiced the surface marking on mummified cadavers in small groups, observing their peers could have played a substantial role in better learning.[20] Similar improvements have been report by Zaidi *et al*.[21] where skills practice with positively deviant peers led to a better clinical skill performance of participating students.

While literature search did not yield direct observation with checklist as a teaching–learning or assessment method being implemented in various subjects or colleges, methods such as direct observation of procedural skills (DOPS) and objective structured clinical examination (OSCE) closely resemble the pattern we implemented with minor

performance in those initially assessed as unsatisfactory. Dorfsman and Wolfson[17] also reported improved efficiency

differences. In effect in both these methods too, students are assessed by multiple assessors on multiple encounters aimed at improving performance and hence they serve the twin purpose of assessment as well as learning by direct observation of the trainee at the workplace.[22,23]

Similar to the feedback of our study for direct observation with checklist, Singh *et al.*[24] in their study to evaluate the feasibility, acceptability, and utility of DOPS for undergraduate dental students stated that DOPS had good acceptability among faculty and students in spite of no exposure to DOPS earlier. Students felt that this helps them in better skills learning and should cover other areas of the curriculum. The faculty, on the other hand, felt that training in observation and providing feedback would improve their effectiveness as assessors. Hoseini *et al.*[25] also reported high satisfaction scores with DOPS as compared to logbook documentation for practicing skills in midwifery students at University Hospitals Affiliated to Mashhad University of Medical Sciences, Iran. Similarly, Lagoo and Joshi[26] recently reported positive perceptions of postgraduate students as well as faculties in the Anaesthesia Department at St John's Medical College, Karnataka, regarding DOPS as an effective assessment and teaching–learning tool.

As for OSCE, Majumder *et al.*[27] in their study on students and examiners who participated for the MBBS exit OSCE held at the Cave Hill Campus, UWI, observed OSCE to be covering a wide range of clinical skills and knowledge as well as being a standardized examination for all students. Previously, Pierre *et al.*[28] in their cross-sectional survey on students during evaluation of child health clerkship received overwhelming response to OSCE as a fair and objective assessment method. Moreover, nursing students and lecturers at University of Hertfordshire perceive that principles of OSCE can also be used in a formative way to enhance skill acquisition.[29]

Pertaining to acquisition of knowledge and skills, Tsui *et al.*[30] concluded that clinicians can enhance clinical skills education in certain circumstances with strategic incorporation of tools like DOPS into medical student training programs. Similarly, randomized controlled trials carried out by Hengameh *et al.*[31] and Roghieh *et al.*[32] on undergraduate nursing trainees' performance reported a high educational impact of formative DOPS against routine assessment methods like subjective judgment of the assessor and logbook assessment. Even for OSCE, Lien *et al.*[33] and Pell *et al.*[34] reported a gradual but observable increase in the mean learning curve.

Limitations

The method, direct observation with checklist, was used for the first time as a teaching method in the Department of Anatomy and it was not possible to have control group in order to avoid ethical issues or to prevent sharing of checklists amongst the students. A focused group discussion is planned with the students to further explore the perceptions and views shared in this article.

Conclusion

Direct observation with checklist is a method suitable for psychomotor skills in surface marking of anatomy. It can also be used as a teaching learning and assessment method to educate and empower students.

Conflicts of interest

There are no conflicts of interest.

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Vascular Foramina of Talus in North Indian Population: A Dry Bone Study

Abstract

Background: The talus, which serves as a bony connection between the leg and foot, is the foundation of the medial longitudinal arch. Its main role is to stabilize the ankle joint through ligaments without any muscular attachments. Hence, the vessels are closely related to bony surfaces for the blood supply. The late consequence of talus fracture led to avascular necrosis (AVN). Knowing the vascular foramina can assist one in better comprehending the vascularity of the various talus surfaces. Hence, the knowledge of the distribution of nutrient foramina in the talus is helpful in assessing the jeopardy of damage to vessels during surgical interventions and the likelihood of AVN. **Aim and Objective:** The aim of this study was to describe the dispersion of foramina for vessels on the talus. In every aspect of the body and neck surfaces of the talus, the distribution of nutritional foramina was counted and macroscopically analyzed. **Materials and Methods:** A total of 600 human tali dry bone from the Anatomy Department's Osteology Laboratory at King George's Medical University in Lucknow, Uttar Pradesh served as the study's subject. By inserting a k wire of 0.5 mm diameter through each surface of the talus' neck and body and using a hand lens, the number and size of foramina for vessels on each surface were examined. **Results:** Medial, superior, lateral, and inferior surfaces of the talus' neck had vascular foramina. On observing the talus body, its medial, lateral, and posterior surfaces had foramina for vessels. In our research, we noted that most of the foramina for vessels were located on the inferior surface of the neck with a range of 2–24, which is more as compared to its lateral surface, and the majority were located on the medial surface of the body range of 1–15 which are more as compared to the lateral surface of the talus bone. Foramina of more than 0.5 mm in size accounted for 72.83%, with foraminal indices ranging from 39.04% to 69.99% of the inferior surface of tali. **Conclusion:** The orthopedic, vascular, and podiatric surgeons must be aware of the location of vascular foramina while performing procedures on the hindfoot. Because there is less vascular foramina on the lateral approach compared to other surfaces, we believe this method would be more beneficial for surgical procedures on the talus.

Keywords: *Avascular necrosis, neck and body of talus, talus, vascular foramina*

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Introduction

The talus is a tarsal bone (second biggest tarsal) in the human foot, which has a head, neck, and body. The articular surface present on the body and head of the talus articulates with the tibia, fibula, navicular, and calcaneus bones to form the supratalar, pretalar, and subtalar joints, respectively.[1] The blood supply of the talus is provided by multiple branches of extraosseous arteries, including the anterior tibial or dorsalis pedis, posterior tibial, and perforating fibular arteries that anastomose to form slings around the talus to form the periosteal network and intraosseous vasculature of the talus.[2] The sinus tarsi, which is situated on the plantar aspect of the talus neck and lies in anterior relation to

the posterior facets as well as posterior to the middle facet of the subtalar joint. The tarsal canal is a continuation in the medial aspect of the sinus tarsi, which allows the tarsal canal artery branch of the posterior tibial artery to pass through it.[3] The intraosseous blood supply of the talus gets its nourishment through several vascular foramina present on its different surfaces, which give pathways to the dorsalis pedis artery branches, the artery of the tarsal sinus for the head, and the anastomotic artery of the tarsal canal for the body.[4] The basic understanding of the presence of foramina for vascular supply on different surfaces of the talus provides arterial topography and may aid in risk assessment in talus surgical techniques and talar neck fractures like avascular necrosis (AVN), which is a more common complication.[5] The extent of involvement of the talus by

osteonecrosis is directly related to the degree of vascular disruption.[5,6] Determining the foramina for vessels may aid in the estimation of its dispersion over the various surfaces, as well as assessing the threat of vascular injury during surgical approaches and the possibility of talus AVN. Reference data pertaining to the distribution of talus vascular foramina in the North Indian population will be available in the present study.

Materials and Methods

The present observational study of 600 human tali (right = 249 and left = 351) of unknown age and sex was carried out in the Department of Anatomy at King George Medical University, Lucknow, from April 2022 to September 2022. Ethical Clearance was obtained from the Institutional Ethics Committee, King George Medical University, Lucknow, through (Ref.code: 121 ECMIIA/ P3). As far as could be ascertained, samples were free of physical and pathological changes or anomalies. All the 600 tali were numbered and photographed.

The presence of vessel impressions leading to foramina was identified as vascular foramina of the talus [Figure 1a]. Krischner wire (k wire = 0.5 mm diameter) and hand lens were used to confirm the foramina patency, size, location, and number. The nonarticulating and articulating surfaces of the talus, including the body, head, and neck, were examined for vascular foramen. Vascular foramina is classified as either >0.5 mm or <0.5 mm in size by passing k wire.

The total length, farthest foramina, and nearest foramina of the talus were measured from the posterolateral tubercle on the inferior surface of the talus [Figure 1b]. The Lf1 was the nearest foramen distance measured from the posterolateral tubercle. Lf2 was the farthest foramen distance measured from the posterolateral tubercle, and Tol was the total length of the talus from the posterolateral tubercle to the head. The evaluation of the foraminal index was done by implying the formula Lf/Tol × 100, where Lf is the foraminal distance measured from the posterolateral tubercle in each talus, i.e., Lf1 and Lf2. The foraminal index

of the farthest and nearest foramina represented Ff and Fn, respectively. The digital Vernier caliper was used for the measurements with a precision of 0.02 mm. Using SPSS version 26, the data were analyzed. Descriptive statistics were presented in the form of means, and frequencies were depicted as bar charts. The Wilcoxon rank-sum test was used to evaluate the number of foraminal openings on different surfaces of the talus and to compare the number of distributions with one another. Thereafter, interpretations were drawn from the analyzed data. P =0.05 demonstrated the statistical significance.

Results

All over the nonarticular surfaces of 600 tali vascular foramina were examined. The articulating surfaces of the talus, for example, head and trochlear surface, were devoid of vascular foramina [Figure 1]. The nonarticulating aspect of the body of talus foramina was present on the posterior [Figure 2e and f], lateral, and medial [Figure 3g and i] surfaces. The talus's nonarticulating surface had foramina on the inferior, superior [Figure 1], lateral, and medial surfaces [Figure 3]. The count of foramina for vessels on the inferior side of the neck varied from 2 to 24, with a mean of 13.67, whereas the vascular foramina on the medial surface of the body ranged from 1 to 15, with a mean of 3.64. Calculating the total count of foramina in 600 tali revealed 8203 (52.49%) foramina on the inferior surface of the talus and 659 (4.21%) foramina on the lateral surface of the talus's neck [Table 1]. In 21.33% of cases, the lateral aspect of the talar neck was totally devoid of foramina for vessels.

The Wilcoxon rank-sum test was used to evaluate and compare the count of foramina present overall on the talar neck surfaces, which revealed that the inferior surface had significantly more than the superior (U = 87,094; P = 0.001), medial (U = 25,634; P = 0.001), and lateral (U = 4352, P = 0.001) surfaces [Table 1].

The minimum (least) and maximum (highest) numbers of foramina were present on the lateral and medial surfaces of the body, respectively. The total count of vascular
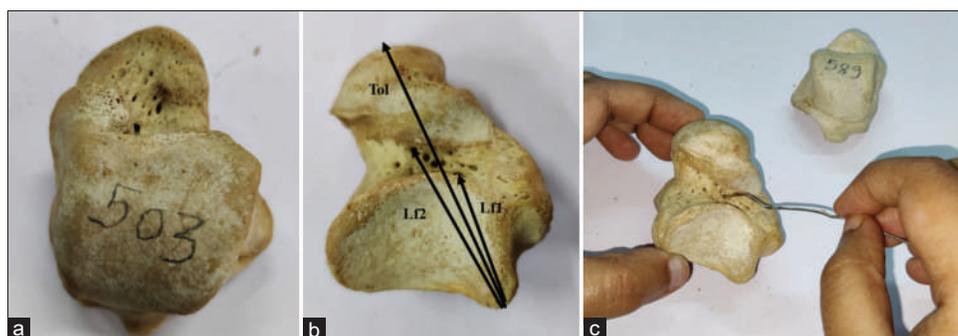
Figure 1: Illustrative images displaying the presence of foramina for vessels on different surfaces of the talus with (a), the neck's superior surface. (b), the measurements of: Lf1 – distance between the posterior tubercle and the nearby vascular foramina, Lf2 – distance between the posterior tubercle and the furthest foramina for vessels, Tol – total length of bony talus at the inferior surface of the right talus. (c), neck's inferior surface

Figure 2: Posterior surface (e and f) of the body of the talus with vascular foramina

foramina was 2185 (54.42%) and ranged from 1 to 15 on the medial surface of the talar body, with a mean of 3.64 showing a greater number as compared to the lateral (621) and posterior (1209) surfaces [Table 1]. Foramina were completely absent on the lateral and posterior surfaces of the talar body in 21.5% and 3.33% of bones, respectively. The total count of foramina found on the medial surface of the talar body was significantly greater than the number noted on the lateral ($U = 20,294$; $P = 0.001$) and posterior ($U = 73,937$; $P = 0.001$) surfaces [Table 1]. The superior and medial surfaces of the left-sided tali neck had the greatest count of foramina, with a mean of 7.54 and 4.36, respectively, compared to the right-sided tali, with a mean of 6.87 and 3.51 of the superior and medial aspects, respectively [Figure 4]. However, the Wilcoxon rank-sum test revealed a statistically significant difference in the aggregated count of foramina on the superior and medial surfaces of the neck among the right and left tali ($U = 38,158.5$, $P = 0.008$ and $U = 33,441.0$, $P = 0.001$). The lateral surface of the left-sided talus body had the highest count of foramina, with a mean of 0.9 as compared to the right talus with a mean of 1.23 [Table 2]. However, the Wilcoxon rank-sum test revealed a statistically significant difference in the foramina's total number on the lateral surface of the body between the right and left tali ($U = 32,117.0$, $P = 0.001$).

Right and left tali had mean total lengths of 55.57 ± 29 mm and 56.45 ± 3.99 mm, respectively. Table 3 provides a summary of the foraminal indices measurements made on the inferior surface of the tali neck [Figure 1]. The mean Fn for left-sided tali was 39.04% ±6.3%, whereas it was 40.25% ±6.55% for right-sided tali, yet 351 (50%) left-sided tali had indices that range from 18.41% to 75.38%. The mean Ff for left-sided tali was 66.34% ±8.69%, compared to 69.99% ±8.97% for right-sided tali, whereas the majority of left-sided tali had an index ranging from 41.6% to 99.8%. The measurements of the distances and foraminal indices of the foramina for vessels between the right and left tali are listed in Table 3. There was no statistically significant difference between the left and right
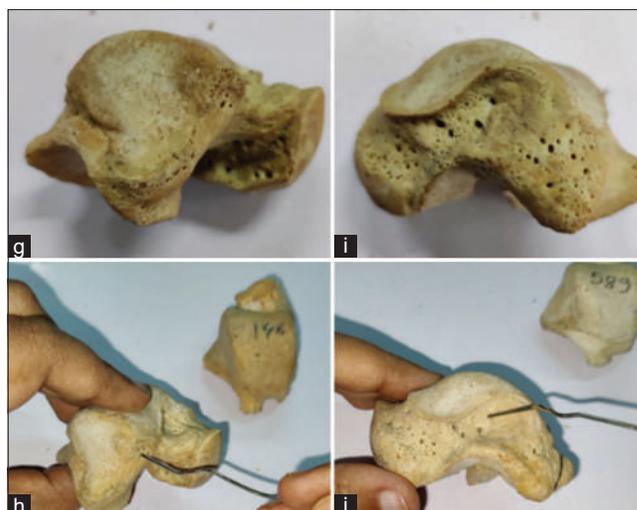
Figure 3: Illustrative images displaying vascular foramina on surfaces of talus with (g and h) lateral surface of body and neck. (i and j) Medial surface of body and neck

Table 1: Dispersion of foramina for vessels on the body and neck surfaces of tali (*n*=600)

	Surface	Vascular Foramina count			
		Minimum (least)	Maximum (highest)	Mean	Total (%)
Neck	Superior	1	18	7.27	4359 (27.89)*
	Inferior	2	24	13.67	8203 (52.49)
	Medial	0	12	4.01	2405 (15.39)**
	Lateral	0	5	1.1	659 (4.21)***
Body	Medial	1	15	3.64	2185 (54.42)
	Lateral	0	5	1.04	621 (15.46)>
	Posterior	0	6	2.02	1209 (30.11)>

*Test of Wilcoxon Rank Sum U=87,094; P=0.001 implies that there were statistically significantly more foramina on the neck's inferior surface than its superior surface, **Test of Wilcoxon Rank Sum U=25,634; P=0.001 implies that there were statistically significantly more foramina on the neck's inferior surface than its medial surface, ***Test of Wilcoxon Rank Sum U=4352, P=0.001 implies that there were statistically significantly more foramina on the neck's inferior surface than its lateral surface, >Test of Wilcoxon Rank Sum U=20,294; P=0.001 implies that there were statistically significantly more foramina on the body's medial surface than its lateral surface, >Test of Wilcoxon Rank Sum U=73,937; P=0.001 implies that there were statistically significantly more foramina on the body's medial surface than its posterior surface

tali. There were 19,641 numbers of vascular foramina; out of the majority, 14,304 (72.83%) and 5337 (27.17%) foramina were more than 0.5 mm and <0.5 mm in size, respectively, on the body and neck of the talus.

Discussion

The injury or fracture of the talus, which leads to AVN, has been a longtime concern for orthopedics.[7] In our study, the nonarticular surfaces of the talus had vascular foramina
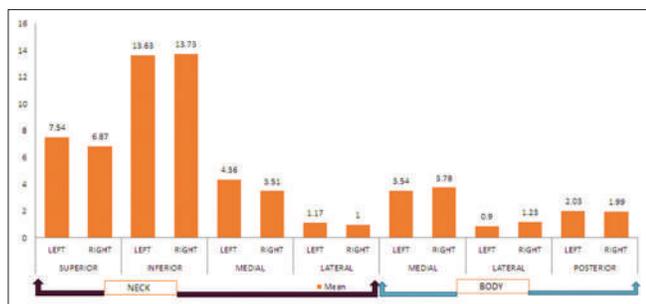
Figure 4: Bar graph showing mean value of the number of foramina present on neck and body based on laterality

with the impression of a groove for entering vessels, which was reported by Giebel *et al.*[8] and Vani *et al.* (2020)[9] in their studies.

Giebel *et al.*[8] reported the entering of vessels from the superior, inferior, medial, and lateral surfaces of the neck of the talus as well as the medial, lateral, and posterior surfaces of the body, which was also reported by Vani *et al.* (2020),[9] who observed the number of foramina on 56 talus bones. In the present study, we also observed a number of foramina on the nonarticulating surface of the neck and body of 600 talus. In this study, the mean distribution of the number of foramina for vessels on nonarticular surfaces of the neck, like the superior aspect, was 7.27 (range 1–18), inferiorly, 13.67 (range 2–24), medially, 4.01 (0–12), and laterally, 1.1 (range 0–5), which was slightly higher than those reported by Vani *et al.* (2020).[9]

The mean count of foramina for vessels on the medial surface of the body of the talus was 6 (range 2–16), reported by Vani *et al.* (2020),[9] which was greater than the present study, i.e., 3.64 (range 1–15), whereas the mean count of foramina on other surfaces in the present observations was 1.04 (range 0–5) on the lateral surface and 2.02 (range 0–6) on the medial surface, which were similar to those reported by Vani *et al.* (2020)[9] as 1 (0–7) for the lateral and 2 (0–7) for the medial surfaces.

Based on laterality Vani *et al.* (2020)[9] reported that the difference between the number of foramina on the right tali and the left tali was statistically relevant, which was found to be different in the present study. As we observed, the mean count of the number of foramina for vessels on the left talus of its superior surface was 7.54 (1–18) and the medial surface was 4.36 (0–12) greater than the right-sided talus of its superior surface, which was 6.87 (1–12) and the medial surface was 3.51 (0–9). Hence, according to laterality, there was statistical significance with *P* = 0.008 and *P* <0.001 for the superior and medial surfaces of the talus neck, respectively.

In the previous study of Vani *et al.* (2020),[9] it was reported that within 56 dry tali, the foramina was absent on the medial aspect of the neck in 5.36% of bones and that 19.66%, 26.79%, and 30.36% of tali lacked foramina on

Table 2: Dispersion of foramina for vessels on the neck and body surface between left (*n1*=351) and right (*n2*=249) tali

			Vascular foramina count			
	Surface	Side	Minimum (least)	Maximum (highest)	Mean	*P*
Neck	Superior	Left	1	18	7.54	0.008^
		Right	1	12	6.87	
	Inferior	Left	2	24	13.63	0.838
		Right	2	23	13.73	
	Medial	Left	0	12	4.36	<0.001^
		Right	0	9	3.51	
	Lateral	Left	0	6	1.17	0.092
		Right	0	5	1	
Body	Medial	Left	1	12	3.54	0.476
		Right	1	15	3.78	
	Lateral	Left	0	5	0.9	<0.001^
		Right	0	4	1.23	
	Posterior	Left	0	6	2.03	0.411
		Right	0	5	1.99	

^The Wilcoxon rank-sum test (*P*=0.008, *U*=38,158.5 and *P*=0.001, *U*=33,441.0) implies a statistically significant variation between the number of foramina on the superior and medial surface of the neck between the right and left tali, ^The Wilcoxon rank-sum test (*P*=0.001, *U*=32,117.0) implies a statistically significant variation between the number of foramina on the body's lateral surface on the right and left tali. The disparities in rest among the right and left tali did not significantly vary

Table 3: Foramina for vessels on the inferior surface and their respective distances and foraminal indices of the left (*n1*=351) and right (*n2*=249) tali

	Side	Minimum (least)	Maximum (highest)	Mean±SD	*P*
Total length (mm)	Left	40.2	64.9	56.45±3.99	<0.001
	Right	48.3	63.4	55.57±2.9	
Neck-inferior surface					
Lf1 (mm)	Left	11.1	34.9	21.93±3.18	0.095
	Right	11.1	39.8	22.3±3.38	
Lf2 (mm)	Left	24.5	51.3	37.29±4.35	<0.001
	Right	22.6	48.9	38.74±4.09	
Fn (%)	Left	18.41	75.38	39.04±6.3	0.017
	Right	18.41	73.98	40.25±6.55	
Ff (%)	Left	41.6	95.49	66.34±8.69	<0.001
	Right	42.01	99.8	69.99±8.97	

SD: Standard deviation

the lateral surface of the body, the neck, and the posterior tubercle, respectively, which was slightly different in the present study. We observed the absence of foramina on the lateral surface of the neck in 21.33% and the lateral surface of the body in 21.5% of 600 dry tali. The present study depicted the absence of foramina on the medial surface of the neck in a very small number of bones (<0.008%) and on the posterior surface of the body in 3.33% of

bones. In our study, 72.83% of the total number of foramina were ≥0.5 mm, which was approximately similar to the previous study reported by Vani *et al.* (2020),[9] for orthopedic surgeons it is necessary information while performing bone graft preparation, congenital pseudoarthrosis, tumor resections, instrumentation, and fixation described by Haris (2021).[10] The previous study suggests that the arterial branches that give major blood supply to the talus come from posterior tibial vessels, including deltoid vessels, and tarsal canal vessels may be catastrophically damaged by the anteromedial or medial approach due to the existence of foramina on the superior and inferior surface necks, as well as on the medial surface of the talar body, as reported by Giebel *et al.*[8] The present study confirms that the absence of foramina on the lateral surface of the neck, lateral surface of the body, and posterior surface in 21.335%, 21.5%, and 3.33% implies that any surgical intervention through the lateral, anterolateral, and sometimes posterolateral aspects of the talus might cause a smaller degree of vascular injury. Hence, a lateral approach should be more preferable than a medial approach for talar surgeries, as reported by Giebel *et al.*[8]

We observed that the talus length mean was 56.45 mm and 55.57 mm on the left and right sides, respectively. This observation was similar to earlier research on the Indian population conducted by Motagi *et al.*,[11] Prasad and Rajasekhar,[12] and Vani *et al.* (2020).[9] The data gathered on the mean length could improve the design of the tools employed for invasive talus intervention or realignment. On the inferior aspect of the bone's neck, the nearest foramina of the left and right-sided tali had mean foraminal indices of 39.04% ±6.3% and 40.25% ±6.5%, respectively. The mean foraminal indices of the Ff on the inferior surface of the neck of the left and right tali were 66.34% ±8.7% and 69.99% ±8.97%, respectively, which was less than the previous study reported by Vani *et al.* (2020).[9] The measurement of the closest and farthest nutrient foramen from the proximal end is valuable for determining the overall length of the bone, which is significant in medicolegal and anthropological investigations. In addition, the foraminal index may be used to predict the prognosis of grafts, tumors, and bone fractures.[13] Understanding vascular foramina distribution and their foraminal indices could facilitate the development of surgical strategies to decrease the likelihood of iatrogenic causes of vascular damage.[12] According to Ibrahim,[14] there were many surgical techniques utilized to deal with fractures of the neck of the talus, including osteotomy from the anterior approach, either medial or lateral, whereas the present study was more in favor of proceeding from the lateral aspect of the talus bone. The gender-related gap and age were not taken into consideration, which is one of the study's limitations. The results of the current study may be useful for orthopedic, podiatric, and vascular surgeons doing procedures on the hindfoot.

Conclusion

- The orthopedic, vascular, and podiatric surgeons must be aware of the location of foramina for vessels while performing procedures on the hindfoot because the incidence of AVN is usually associated with trauma to the neck and body of the talus
- During talus fixation or procedure, it was assumed that the surgeon should proceed with the talus by giving more priority to its lateral aspect of the body as well as the neck due to the lesser number of foramina noted after comparing it with other surfaces foramina for vascular supply.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Gender and Height Estimation from Hand and Handprint Sizes ın the Turkish Population

Abstract

Introduction: In forensic medicine, it becomes impossible to identify corpses in events that affect a large part of the population, such as natural disasters, accidents, and wars. The aim of this study is to determine the height and gender of the Turkish population with hand and handprint morphometric measurements. **Materials and Methods:** The sample size of the study consists of 600 Turkish population aged between 18 and 58 years (mean ± standard deviation: 22.18 ± 5.43) living in Middle Anatolia. In the morphometric measurements of the hand, 21 anthropometric measurements were taken from each volunteer. **Results:** It was determined that men had higher values than women in all hand and handprint measurements and were statistically significant. When the correlation between hand and handprint measurements and statue was examined, it was determined that hand length and handprint length had the highest correlation with height in both genders (male: *r*: 0.57, *r*: 0.62; female: *r*: 0.49, *r*: 0.50). When comparing the bilateral asymmetry of the right and left hands of both sexes, it was observed that there was a statistically significant difference between the lengths of the thumb distal phalanx, little finger proximal, and middle phalanx in men and between the lengths of the index finger distal phalanx, middle finger middle and distal phalanx, and ring finger distal phalanx in women (*P* < 0.05). **Conclusion:** As a result, it was seen that the use of hand and handprint measurements to determine height and gender in the Turkish population gave high results.

Keywords: *Forensic medicine, hand and handprints, sex estimation, height estimation, Turkish population*

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Introduction

In disasters that affect the whole society such as natural disasters, terrorist incidents, accidents, and war, the identification, which is the most comprehensive subject of forensic medicine, and the usage of related techniques are increasing and becoming more significant.[1] Cases such as dismemberment or incineration of a dead body make it impossible to identify the body. It is, therefore, important to develop methods to accurately estimate the physical characteristics and gender of individuals. Height can be determined by combinations of the skull, vertebrae, pelvis, lower limbs, hand, and each part of the body. In cases where gender and height cannot be determined, it can be analyzed by morphometric measurements of reference anatomical structures on bodies with intact anatomical structures.[2,3]

When the literature is examined, it is observed that morphometric measurements

of the hands and feet were used to determine gender in a number of studies from the 19th century to the 21st century.[2,4-6] The related earliest studies were conducted by Ecker in 1875. In his studies, Ecker revealed that the 2nd and 4th finger length ratio of the hand varies according to gender.[7] In 1952, Phelps revealed that there was some similarity in finger ratios between the genders, but he also noted that there were differences between men and women. In this regard, he found that while the ratio of the length of the 2nd finger to the length of the 4th finger was approximately 1.00 in women, this ratio was considerably lower in men.[8] In addition, Case and Ross stated in 2007 that phalanx lengths give better outcomes than ossa metatarsi and ossa metacarpi lengths in gender determination from hand and foot bones.[5]

Ishak *et al*. have recently addressed the lack of research examining the accuracy of gender and height determination using hand size.[9]

Since anthropometric hand measurements in forensic anthropology are a newer method

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for determining gender estimation, it is essential to make measurements using statistical methods in the population to be implemented to prove reliability and accuracy. Previous studies have revealed that morphometric characteristics of body measurements have distinctive features according to race due to the influence of genetic and environmental factors. For this reason, the morphometric values of any measurements derived for one race cannot be used for different races.[3,10]

Therefore, the aim of this study is to evaluate the hand and handprint morphometric measurements and to determine the gender and height of the Middle Anatolia Turkish population, which are not available in the existing literature.

Materials and Methods

The design of the study

This study was approved by the Ethics Committee of Niğde Ömer Halisdemir University Non-Interventional Clinical Research Ethics Committee with decision number 2021/87. The sample size of the study consisted of 600 Turkish individuals aged between 18 and 58 years (mean ± standard deviation: 22.18 ± 5.43) living in Middle Anatolia. Exclusion criteria for this study included pregnancy and the presence of any injury that would affect the morphometric properties of the hand and neck, disease, and developmental disorder. The volunteers participating in the study were informed before the measurement and asked to sign a consent form. The volunteers were not pressured to participate in the study by any means. All data were annihilated at the end of the study to ensure the confidentiality of the data obtained.

Morphometric measurements of height and hand

In the study, the height of each volunteer was measured in cm with a stadiometer while the volunteers were standing upright with their heels joined together and their arms next to their thighs. In hand morphometric measurements, 21 anthropometric measurements were obtained from each volunteer [Table 1 and Figure 1]. Measurements were made bilaterally using calipers and a ruler when necessary. For handprint anthropometric measurements, a disposable plain acetate paper was used for each volunteer. Black finger paint, which washes off quickly when washed in water, was implemented evenly on the acetate paper with a paint roller. The volunteer was then instructed to place his/her hands on the finger-painted acetate paper and then place his/her hands on a plain white A4 paper. Two anthropometric measurements were carried out on the handprints obtained: handprint length (HPL) and handprint width [Figure 2]. At the end of the measurement, the papers with handprints were destroyed. All measurements were performed between 11:00 and 17:00 as a standard since height and hand morphometric characteristics change during the day and after sleep.

Statistical analysis

The data obtained in the study were analyzed with the SPSS (software version 23.0, IBM, SPSS Inc, Chicago, IL, USA) statistical data package program (SPSS 23.0 evaluation version for Windows, Trial Version). Descriptive statistical values of all parameters were revealed. A paired sample *t*-test was performed to compare the differences between bilateral asymmetry and hand and handprints, and an independent samples *t*-test was performed to compare the measurements between male and female individuals. The Pearson correlation test was employed to examine the correlation between height and hand and handprint measurements. Discrimination analysis was carried out to evaluate gender estimation from hand and handprint measurements.

Results

Descriptive statistics, bilateral asymmetry, and comparison of measurements between hand and handprint

When the findings of the study were analyzed, it was observed that it was statistically significant ($P < 0.05$)
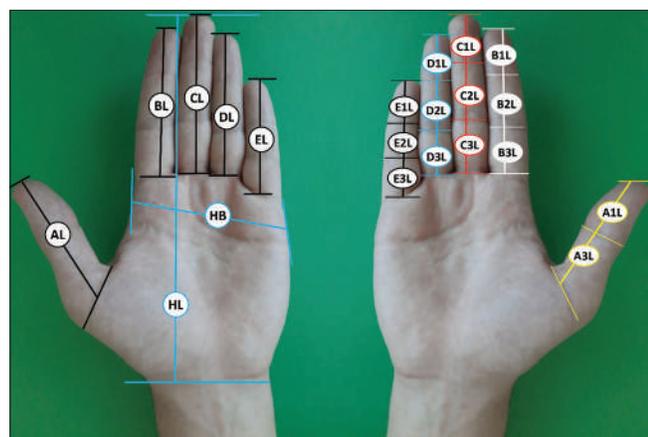

Figure 1: Hand morphometric measurements. HL: Hand length, HB: Hand breadth, AL: 1st finger length, BL: 2nd finger length, CL: 3rd finger length, DL: 4th finger length, EL: 5th finger length
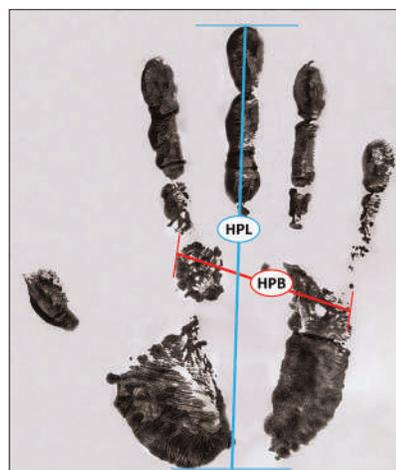
Figure 2: Handprint length and breadth measurement. HPL: Handprint length, HPB: Handprint breadth

that the height of males (mean ± standard deviation: 178.10 ± 5.12) was longer than the height of females (mean ± standard deviation: 163.37 ± 5.98). The results of hand and handprint measurements for both genders for both right and left hands are presented in Table 2. In Table 2, it was statistically significant ($P < 0.05$) that all values of hand and handprint measurements for both sides were larger in the male gender than in the female gender [Table 2]. The relationship between height and

hand and handprint measurements is presented in Table 3. Table 3 indicates that there are statistically significant correlations between hand and handprint measurements and height ($P < 0.05$) [Table 3]. When the correlation coefficient values were examined, it was noticed that the highest correlation with height was observed between hand length (HL) (*r*: 0.57, *r*: 0.62) and HPL (*r*: 0.49, *r*: 0.50) in men and women [Table 3]. The comparison of right and left hands in terms of bilateral asymmetry in both genders

Table 1: Hand and handprint measurements and explanations

Measurement	Explanations
HL	The most distal point of the 3rd finger and the distal wrist line (measured in cm)
HB	The most lateral point of the 2nd metacarpal bone and the most medial point of the 5th metacarpal bone (measured in cm)
AL, BL, CL, DL, EL (finger lengths)	The distance between the proximal flexion folds of the fingers and their most distal points (measured in mm)
A1L, B1L, C1L, D1L, E1L (distal phalanx lengths of the fingers)	The distance between the most distal points of the fingers and the distalis fold of the interphalangeal joint (measured in mm)
B2L, C2L, D2L, E2L (middle phalanx lengths of fingers)	The distance between the distal interphalangeal joint fold and the proximal interphalangeal joint fold (measured in mm)
A3L, B3L, C3L, D3L, E3L (proximal phalanx lengths of fingers)	The distance between the proximal interphalangeal joint fold and the metacarpophalangeal joint fold (measured in mm)
HPL	The distance between the most proximal border of the palm and the most distal point of the 3rd finger in the handprint (measured in mm)
HPB	The distance between the trace of the most lateral point of the extremitas distalis of the os metacarpale II and the most medial point of the extremitas distalis of the os metacarpale V (measured in mm)

HL: Hand length, HB: Hand breadth, HPL: Handprint length, HPB: Handprint breadth

Table 2: Comparison of right and left hand and handprint measurements for both genders

Measurement	Right hand, mean±SD		P	Left hand, mean±SD		P
	Male (*n*=260)	Female (*n*=340)		Male (*n*=260)	Female (*n*=340)	
HL	18.93±0.98	17.19±0.83	<0.001	18.96±0.95	17.23±0.87	<0.001
HB	8.62±0.60	7.55±0.37	<0.001	9.03±5.84	7.90±4.74	<0.001
AL	67.94±5.40	61.17±5.15	<0.001	67.50±5.32	61.11±4.98	<0.001
A1L	33.49±3.33	29.40±2.77	<0.001	32.83±3.13	29.06±2.64	<0.001
A3L	34.11±5.31	31.79±4.56	<0.001	34.72±5.22	32.28±4.42	<0.001
BL	71.74±5.32	66.92±4.43	<0.001	72.26±5.13	67.23±4.64	<0.001
B1L	25.72±2.17	24.02±1.98	<0.001	25.74±2.22	23.62±1.88	<0.001
B2L	22.91±2.26	21.34±2.21	<0.001	22.62±2.29	21.18±2.33	<0.001
B3L	23.85±2.82	22.54±2.29	<0.001	23.95±2.89	22.52±2.44	<0.001
CL	78.28±5.17	72.28±4.59	<0.001	78.08±5.40	72.47±4.27	<0.001
C1L	26.39±2.58	24.38±1.96	<0.001	26.57±2.50	24.02±2.23	<0.001
C2L	25.43±2.74	23.84±2.16	<0.001	25.91±3.62	23.37±2.49	<0.001
C3L	25.73±2.72	24.34±2.79	<0.001	25.47±2.93	24.08±2.72	<0.001
DL	71.81±5.37	66.07±4.44	<0.001	72.04±5.00	66.44±4.42	<0.001
D1L	26.22±2.42	24.27±2.01	<0.001	26.09±2.46	23.59±2.17	<0.001
D2L	23.58±2.60	22.08±2.41	<0.001	23.52±2.26	21.84±2.26	<0.001
D3L	22.23±2.59	21.13±2.45	<0.001	22.41±2.67	21.11±2.71	<0.001
EL	59.38±4.61	55±4.51	<0.001	59.44±4.44	54.68±3.87	<0.001
E1L	23.68±2.38	21.98±1.94	<0.001	23.40±2.26	21.86±2.04	<0.001
E2L	17.64±2.46	16.47±2.38	<0.001	18.19±2.46	16.45±2.27	<0.001
E3L	18.44±2.75	17.11±2.13	<0.001	17.74±2.54	16.86±2.37	<0.001
HPL	17.35±0.93	15.80±0.92	<0.001	17.32±0.92	15.84±0.89	<0.001
HPB	7.05±0.58	6.41±0.46	<0.001	7.02±0.53	6.37±0.49	<0.001

SD: Standard deviation, HL: Hand length, HB: Hand breadth, HPL: Handprint length, HPB: Handprint breadth

Table 3: Correlation between stature and hand and handprint measurements

Measurement	Male (*n*=260)												Female (*n*=340)											
	Right			Left									Right			Left								
	Mean±SD	r	P	Mean±SD	r	P							Mean±SD	r	P	Mean±SD	r	P						
HL	18.93±0.98	0.57	0.00	18.96±0.95	0.55	0.00							17.19±0.83	0.57	0.00	17.23±0.87	0.62	0.00						
HB	8.62±0.60	0.33	0.00	9.03±5.84	0.01	0.86							7.55±0.37	0.30	0.00	7.90±4.74	0.11	0.41						
AL	67.94±5.40	0.22	0.00	67.50±5.32	0.33	0.00							6117±5.15	0.20	0.00	61.11±4.98	0.24	0.00						
A1L	33.49±3.33	0.29	0.00	32.83±3.13	0.13	0.26							29.40±2.77	0.29	0.00	29.06±2.64	0.28	0.00						
A3L	34.11±5.31	0.24	0.00	34.72±5.22	0.20	0.01							31.79±4.56	0.05	0.29	32.28±4.42	0.07	0.20						
BL	71.74±5.32	0.39	0.00	72.26±5.13	0.35	0.00							66.92±4.43	0.41	0.00	67.23±4.64	0.35	0.00						
B1L	25.72±2.17	0.30	0.00	25.74±2.22	0.25	0.00							24.02±1.98	0.25	0.00	23.62±1.88	0.26	0.00						
B2L	22.91±2.26	0.31	0.00	22.62±2.29	0.19	0.01							21.34±2.21	0.20	0.00	21.18±2.33	0.30	0.00						
B3L	23.85±2.82	0.27	0.00	23.95±2.89	0.18	0.03							22.54±2.29	0.17	0.02	22.52±2.44	0.24	0.00						
CL	78.28±5.17	0.47	0.00	78.08±5.40	0.30	0.00							72.28±4.59	0.45	0.00	72.47±4.27	0.48	0.00						
C1L	26.39±2.58	0.30	0.00	26.57±2.50	0.27	0.00							24.38±1.96	0.29	0.00	24.02±2.23	0.36	0.00						
C2L	25.43±2.74	0.31	0.00	25.91±3.62	0.23	0.00							23.84±2.16	0.22	0.00	23.37±2.49	0.20	0.00						
C3L	25.73±2.72	0.31	0.00	25.47±2.93	0.10	0.81							24.34±2.79	0.24	0.00	24.08±2.72	0.16	0.02						
DL	71.81±5.37	0.38	0.00	72.04±5.00	0.31	0.00							66.07±4.44	0.40	0.00	66.44±4.42	0.35	0.00						
D1L	26.22±2.42	0.28	0.00	26.09±2.46	0.34	0.00							24.27±2.01	0.26	0.00	23.59±2.17	0.24	0.00						
D2L	23.58±2.60	0.27	0.00	23.52±2.26	0.21	0.00							22.08±2.41	0.29	0.00	21.84±2.26	0.31	0.00						
D3L	22.23±2.59	0.26	0.00	22.41±2.67	0.19	0.02							21.13±2.45	0.24	0.00	21.11±2.71	0.29	0.00						
EL	59.38±4.61	0.36	0.00	59.44±4.44	0.35	0.00							55±4.51	0.26	0.00	54.68±3.87	0.30	0.00						
E1L	23.68±2.38	0.23	0.00	23.40±2.26	0.14	0.16							21.98±1.94	0.22	0.00	21.86±2.04	0.15	0.05						
E2L	17.64±2.46	0.35	0.00	18.19±2.46	0.30	0.00							16.47±2.38	0.34	0.00	16.45±2.27	0.23	0.00						
E3L	18.44±2.75	0.24	0.00	17.74±2.54	0.29	0.00							17.11±2.13	0.27	0.00	16.86±2.37	0.24	0.00						
HPL	17.35±0.93	0.41	0.00	17.32±0.92	0.49	0.00							15.80±0.92	0.50	0.00	15.84±0.89	0.48	0.00						
HPB	7.05±0.58	0.31	0.00	7.02±0.53	0.34	0.00							6.41±0.46	0.25	0.00	6.37±0.49	0.24	0.00						

SD: Standard deviation, HL: Hand length, HB: Hand breadth, HPL: Handprint length, HPB: Handprint breadth

Table 4: Comparison of hand and handprint measurements in terms of bilateral asymmetry in both genders

Measurement	Male (*n*=260), mean±SD		P	Female (*n*=340), mean±SD		P
	Right hand	Left hand		Right hand	Left hand	
HL	18.93±0.98	18.96±0.95	0.742	17.19±0.83	17.23±0.87	0.543
HB	8.62±0.60	9.03±5.84	0.256	7.55±0.37	7.90±4.74	0.184
AL	67.94±5.40	67.50±5.32	0.352	61.17±5.15	61.11±4.98	0.893
A1L	33.49±3.33	32.83±3.13	0.022	29.40±2.77	29.06±2.64	0.096
A3L	34.11±5.31	34.72±5.22	0.186	31.79±4.56	32.28±4.42	0.155
BL	71.74±5.32	72.26±5.13	0.251	66.92±4.43	67.23±4.64	0.365
B1L	25.70±2.17	25.74±2.22	0.861	24.02±1.98	23.62±1.88	0.008
B2L	22.91±2.26	22.62±2.29	0.150	21.34±2.21	21.18±2.33	0.364
B3L	28.85±2.82	23.95±2.89	0.683	22.54±2.29	22.52±2.44	0.919
CL	78.28±5.17	78.08±5.40	0.660	72.28±4.59	72.47±4.27	0.572
C1L	26.39±2.58	26.57±2.50	0.404	24.38±1.96	24.02±2.23	0.026
C2L	25.43±2.74	25.91±3.62	0.086	23.84±2.16	23.37±2.49	0.009
C3L	25.73±2.72	25.47±2.93	0.290	24.34±2.79	24.08±2.72	0.224
DL	71.81±5.37	72.04±5	0.615	66.07±4.44	66.44±4.42	0.284
D1L	26.22±2.42	26.09±2.46	0.535	24.27±2.01	23.59±2.17	*P*<0.001
D2L	23.58±2.60	23.52±2.26	0.782	22.08±2.41	21.84±2.26	0.186
D3L	22.23±2.59	22.41±2.67	0.458	21.13±2.45	21.11±2.71	0.916
EL	59.38±4.61	59.44±4.44	0.876	55±4.51	54.68±3.87	0.319
E1L	23.68±2.38	23.40±2.26	0.178	21.98±1.94	21.86±2.04	0.444
E2L	17.64±2.46	18.19±2.46	0.011	16.47±2.38	16.45±2.27	0.921
E3L	18.44±2.75	17.74±2.54	0.003	17.11±2.13	16.86±2.37	0.154
HPL	17.35±0.93	17.32±0.92	0.721	15.80±0.92	15.84±0.89	0.613
HPB	7.05±0.58	7.02±0.53	0.446	6.41±0.46	6.37±0.49	0.316

SD: Standard deviation, HL: Hand length, HB: Hand breadth, HPL: Handprint length, HPB: Handprint breadth

is demonstrated in Table 4. Table 4 reveals that there is a statistically significant difference between the lengths of the distal phalanges of the thumb and the proximal and middle phalanges of the pinkie finger in males and between the distal phalanges of the index finger, middle and distal phalanges of the middle finger, and the distal phalanges of the ring finger in females (*P* < 0.05) [Table 4]. There was no statistically significant difference between the length and width of the handprint between the right and left hands in both genders (*P* > 0.05) [Table 4]. The comparison of the length and width values between the right and left hand and handprint for both genders is listed in Table 5. Table 5 shows that there was a significant difference between hand and HPL in terms of HL on both the right and left sides in males (*P* < 0.05), while there was a significant difference in hand and handprint width on the right side in terms of hand width (*P* < 0.05), while there was no significant difference on the left side (*P* > 0.05) [Table 5]. In women, a statistically significant difference was observed between hand and HPL and width in terms of HL and hand width on both the right and left sides (*P* < 0.05).

Simple linear regression

The standard error of estimate (SEE) and linear regression formulas for height estimation from hand and handprint measurements are presented in Table 6. When Table 6 is evaluated, the standard error of prediction for both left and right hand and handprint measurements was higher in females than in males (Left-hand male: 4.26–5.12; left-hand female: 4.64–5.92; right-hand male: 4.21–5.01; right-hand female: 4.90–6.04) [Table 6].

Discrimination analysis

The metrics useful for gender estimation and their demarcation values are provided in Table 7. Demarking point values are calculated using the average of the relevant measurements for both males and females and represent the range above which an individual is classified as male and below which an individual is classified as female. Table 7 illustrates that height (92.7%), HL (83%), and HPL (80.2%) are the measurements that give the highest accuracy of gender classification.

Discussion

Gender is the most important factor in identifying the body. Many physical characteristics such as height and weight depend on gender. Studies have found that the morphometric characteristics of body measurements have distinctive features according to race under the influence of genetic and environmental factors. In general, the morphometric value of anybody measurement derived for one race is not applied to different races. Therefore, in this study, it was aimed to estimate gender and height from hand and handprint dimensions in the Turkish population. When the results of the study were evaluated, it was statistically significant that males had higher values than females in all hand and handprint measurements. When the correlation between hand and handprint measurements and height was analyzed, it was determined that HL and HPL had the highest correlation with height in both genders (male: *r*: 0.57, *r*: 0.62; female: *r*: 0.49, *r*: 0.50). In the comparison of the right and left hand in terms of bilateral asymmetry in both genders, there was a statistically significant difference between the lengths of the distal phalanx of the thumb, proximal and middle phalanx of the little finger in males, and between the distal phalanx of the index finger, middle and distal phalanx of the middle finger, and distal phalanx of the ring finger in females (*P* < 0.05). When the discrimination analysis for gender prediction from hand and handprint dimensions was analyzed, it was concluded that the measurements that gave the highest accuracy of gender classification were height (92.7%), HL (83%), and HPL (80.2%).

When the studies conducted on different populations in the literature were examined, it was observed that there was a significant difference in hand and handprint measurements on both right and left sides in both genders[11-13] and that hand and handprint measurements were higher in men than in women.[9,12,14-18] In the results of our study [Table 1], a significant difference was detected in all hand and handprint measurements between men and women, and it was statistically significant that all measurements were higher in men than in women (*P* < 0.05).

When bilateral asymmetry in hand and handprint measurements in both genders is examined, it was observed that some studies in the literature did not

Table 5: Comparison of hand and handprint measurements in both genders in terms of right and left sides								
Measurement	Right hand, mean±SD		*P*	*r*	Left hand, mean±SD		*P*	*r*
	Hand	Handprint			El	El izi		
Male (*n*=260)								
HL	18.93	17.35	<0.001	0.58	18.96	17.32	<0.001	0.72
HB	8.62	7.05	<0.001	0.35	9.03	7.02	0.879	0.00
Female (*n*=340)								
HL	17.19	15.80	<0.001	0.61	17.23	15.84	<0.001	0.67
HB	7.55	6.41	<0.001	0.28	7.90	6.37	<0.001	0.21

SD: Standard deviation, HL: Hand length, HB: Hand breadth

Table 6: Standard estimation error and regression formulas for height estimation from hand and handprint measurements

Male (*n*=260)				Female (*n*=340)		
Formula	SEE	*r*		Formula	SEE	*r*
Left hand						
121.78 + (HL × 2.966)	4.26	0.55		90.603 + (HL × 4.222)	4.64	0.62
177.94 + (HB × 0.009)	5.12	0.01		162.49 + (HB × 0.138)	5.90	0.11
156.25 + (A × 0.323)	4.82	0.33		145.43 + (AL × 0.293)	5.75	0.24
170.61 + (A1L × 0.226)	5.07	0.13		144.96 + (A1L × 0.632)	5.69	0.28
171.18 + (A3L × 0.197)	5.02	0.20		160.32 + (A3L × 0.093)	5.92	0.07
152.23 + (BL × 0.357)	4.78	0.35		132.56 + (BL × 0.458)	5.54	0.35
162.97 + (B1L × 0.585)	4.95	0.25		143.58 + (B1L × 0.836)	5.72	0.26
168.13 + (B2L × 0.438)	5.02	0.19		147.05 + (B2L × 0.769)	5.65	0.30
170.27 + (B3L × 0.324)	5.04	0.18		150.18 + (B3L × 0.584)	5.76	0.24
155.42 + (CL × 0.289)	4.88	0.30		114.40 + (CL × 0.675)	5.18	0.48
162.99 + (C1L × 0.566)	4.92	0.27		140.22 + (C1L × 0.962)	5.53	0.36
169.37 + (C2L × 0.334)	4.98	0.23		152.06 + (C2L × 0.482)	5.81	0.20
173.21 + (C3L × 0.189)	5.09	0.10		154.56 + (C3L × 0.365)	5.85	0.16
154.66 + (DL × 0.324)	4.86	0.31		131.62 + (DL × 0.477)	5.54	0.35
159.13 + (D1L × 0.724)	4.80	0.34		147.81 + (D1L × 0.658)	5.76	0.24
166.51 + (D2L × 0.490)	5.00	0.21		145.28 + (D2L × 0.826)	5.63	0.31
169.62 + (D3L × 0.375)	5.02	0.19		149.86 + (D3L × 0.638)	5.68	0.29
153.43 + (EL × 0.414)	4.78	0.35		137.91 + (EL × 0.465)	5.65	0.30
170.13 + (E1L × 0.337)	5.07	0.14		153.65 + (E1L × 0.443)	5.86	0.15
166.51 + (E2L × 0.633)	4.88	0.30		153.20 + (E2L × 0.616)	5.76	0.23
167.49 + (E3L × 0.594)	4.89	0.29		153.15 + (E3L × 0.604)	5.76	0.24
130.68 + (HPL × 2.733)	4.45	0.49		112.77 + (HPL × 3.192)	5.19	0.48
154.78 + (HPB × 3.331)	4.80	0.34		145.00 + (HPB × 2.877)	5.76	0.24
Right hand						
121.17 + (HL × 3.010)	4.21	0.57		92.45 + (HL × 4.128)	4.90	0.57
153.40 + (HB × 2.871)	4.84	0.33		125.72 + (HB × 4.984)	5.75	0.30
163.61 + (AL × 0.214)	5.01	0.22		148.94 + (AL × 0.236)	5.92	0.20
162.92 + (A1L × 0.455)	4.92	0.29		144.79 + (A1L × 0.633)	5.79	0.29
170.01 + (A3L × 0.239)	4.99	0.24		161.01 + (A3L × 0.075)	6.04	0.05
157.61 + (BL × 0.383)	4.72	0.39		125.84 + (BL × 0.561)	5.51	0.41
159.54 + (B1L × 0.724)	4.90	0.30		144.51 + (B1L × 0.768)	5.84	0.25
161.64 + (B2L × 0.721)	4.88	0.31		151.91 + (B2L × 0.558)	5.92	0.20
166.40 + (B3L × 0.493)	4.95	0.27		153.32 + (B3L × 0.447)	5.96	0.17
141.40 + (CL × 0.470)	4.54	0.47		119.93 + (CL × 0.601)	5.38	0.45
162.36 + (C1L × 0.599)	4.91	0.30		141.24 + (C1L × 0.908)	5.78	0.29
163.32 + (C2L × 0.584)	4.89	0.31		148.38 + (C2L × 0.630)	5.89	0.22
163.18 + (C3L × 0.585)	4.89	0.21		150.70 + (C3L × 0.522)	5.87	0.24
151.79 + (DL × 0.367)	4.75	0.38		126.66 + (DL × 0.556)	5.52	0.40
162.34 + (D1L × 0.603)	4.93	0.28		143.84 + (D1L × 0.805)	5.83	0.26
165.58 + (D2L × 0.534)	4.95	0.27		146.99 + (D2L × 0.743)	5.78	0.29
166.29 + (D3L × 0.534)	4.96	0.26		150.83 + (D3L × 0.595)	5.87	0.24
153.97 + (EL × 0.407)	4.79	0.36		143.62 + (EL × 0.359)	5.83	0.26
165.98 + (E1L × 0.515)	5.00	0.23		147.84 + (E1L × 0.708)	5.89	0.22
165.28 + (E2L × 0.730)	4.82	0.35		148.94 + (E2L × 0.878)	5.67	0.34
169.82 + (E3L × 0.452)	4.99	0.24		150.15 + (E3L × 0.774)	5.82	0.27
138.50 + (HPL × 2.285)	4.68	0.41		110.95 + (HPL × 3.318)	5.22	0.50
158.55 + (HPB × 2.779)	4.88	0.31		142.22 + (HPB × 3.304)	5.85	0.25

SEE: Standart estimation error, HL: Hand length, HB: Hand breadth

evaluate bilateral asymmetry because they were conducted unilaterally.[17,19-21] When bilateral studies are examined, Abdel-Malek *et al.*[11] and Ishak *et al.*[9] suggest that there is a bilateral difference only in hand width measurement in both men and women. In some bilateral studies, there was no bilateral difference in

Table 7: Estimation rates of hand and handprint measurements in determining gender

	Measurement	Demarking points	Estimation rate (%)	Sex bias (%)
Function 1	Height (cm)	♀ <170.73< ♂	92.7	0.1
Function 2	HL (cm)	♀ <18.07< ♂	83	−10.7
Function 3	HPL (cm)	♀ <16.58< ♂	80.2	−16.6
Function 4	HB (cm)	♀ <8.28< ♂	56.5	−99.0
Function 5	HBP (cm)	♀ <13.43< ♂	75.5	−19.2
Function 6	AL (mm)	♀ <64.43< ♂	73.5	−14.3
Function 7	A1L (mm)	♀ <31.19< ♂	77.7	−13.5
Function 8	A3L (mm)	♀ <33.23< ♂	63.3	−40.2
Function 9	BL (mm)	♀ <69.54< ♂	71.5	−23.0
Function 10	B1L (mm)	♀ <24.77< ♂	70.0	−22.4
Function 11	B2L (mm)	♀ <22.01< ♂	66.8	−26.4
Function 12	B3L (mm)	♀ <23.22< ♂	63.8	−43.7
Function 13	CL (mm)	♀ <75.28< ♂	73.5	−19.1
Function 14	C1L (mm)	♀ <25.34< ♂	70.7	−23.8
Function 15	C2L (mm)	♀ <24.63< ♂	68.5	−36.7
Function 16	C3L (mm)	♀ <24.90< ♂	61.5	−46.8
Function 17	DL (mm)	♀ <69.09< ♂	75.0	−15.6
Function 18	D1L (mm)	♀ <25.04< ♂	70.5	−23.3
Function 19	D2L (mm)	♀ <22.75< ♂	64.2	−35.9
Function 20	D3L (mm)	♀ <21.72< ♂	59.2	−54.1
Function 21	EL (mm)	♀ <51.13< ♂	71.5	−21.7
Function 22	E1L (mm)	♀ <22.73< ♂	70.0	−29.1
Function 23	E2L (mm)	♀ <17.19< ♂	63.7	−35.6
Function 24	E3L (mm)	♀ <17.54< ♂	60.5	−48.9

HPL: Handprint length, HBP: Handprint breadth, ♂:Male, ♀:Female

hand and handprint measurements in both genders.[13,18,22] In this study, bilateral differences were statistically significant in the measurements of the distal phalanx of the thumb, medial phalanx of the little finger, and proximal phalanx of the little finger in the male gender ($P = 0.022$, $P = 0.011$, $P = 0.003$) [Table 4]. In the female gender, the bilateral difference was statistically significant in the distal phalanx of index finger, distal phalanx of middle finger, medial phalanx of middle finger, and distal phalanx of ring finger ($P = 0.008$, $P = 0.026$, $P = 0.009$, $P = 0.000$).

In the correlation between height and hand and handprint measurements, the SEE was lower in males than in females (SEE for males: 4.21–5.12; SEE for females: 4.64–6.04). In the study conducted by de Souza and Kunkel[10] in the Brazilian population, it was reported that the SEE was higher in men than in women (SEE: 5.35–5.41 for men; SEE: 4.72–4.77 for women).

The measurement with the least SEE for height estimation from hand and handprint measurements for males was HL measurement in both right and left hand (SEE: 4.21–4.26), and the measurement with the least SEE for females was HL measurement in both right and left hand (SEE: 4.64–4.90). In previous studies, it has been stated that HL is one of the best measures of height.[9,11,13,14,17-19,21,23-26]

In the discrimination analysis performed to determine gender from hand and handprint measurements, it was detected that the most accurate measurements for gender determination were height, HL, and HPL (92.7%, 83%, and 80.2%) [Table 7]. In the literature, hand width and HL are above 90% for gender determination in the Indo-Mauritius population,[27] and in the study conducted by Kanchan and Rastogi[28] in North and South Indian populations, hand width and HL were above 85%. It has been reported that handprint width and HPL have an accuracy rate of over 85% in gender identification in Croatian population,[29] and HPL and handprint width have an accuracy rate of over 90% in gender identification in Western Australian population.[9] The results obtained in this study support other community studies available in the literature.

Conclusion

As a result, it was observed that the accuracy of using hand and handprint measurements in determining height and gender in the Turkish population was satisfactory. Thus, this situation provides support for the use of hand and handprint measurements in the Turkish population both in fire, natural disasters, and terrorist incidents where corpses cannot be identified and in the identification of unidentified criminals involved in forensic crimes.

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Conflicts of interest

There are no conflicts of interest.

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Anatomical Study of Pterygoalar and Pterygospinous Bars/Foramina in West Anatolian Skulls

Abstract

Introduction: Pterygoalar bar (PTAB) is a bony bridge formed by the incomplete or complete ossification of the pterygoalar ligament extending between the lateral pterygoid lamina (LPL) and the greater wing of the sphenoid bone. Complete ossification of the pterygoalar ligament results in the formation of the so-called "pterygoalar foramen" (PTAF) or Hyrtl's foramen. On the other hand, pterygospinous bar (PTSB) is another bony bridge resulting from incomplete or complete ossification of the pterygospinous ligament, which extends from the pterygospinous process of the LPL to the sphenoidal spine. Complete ossification of this ligament forms the pterygospinous foramen (PTSF) or the Civinini's foramen. This study was undertaken to examine detailed anatomy and incidence of PTAB, PTSB, and the corresponding foramina, as well as to establish their relationship with foramen ovale (FO). **Materials and Methods:** A total of 152 dry adult human skulls (304 sides) obtained from the collection of the Anatomy Department of Dokuz Eylül University were examined in terms of the presence/absence of PTAB/PTSB, their incidence and side, degree of ossification (complete/incomplete), and their relationship with FO. The distance between the spinous processes was measured in cases with incomplete ossification of PTAB/PTSB, whereas a digital caliper with 0.01 mm sensitivity (Mitutoyo, Japan) was used to measure horizontal and vertical diameters of the foramina in cases with complete ossification (i.e., when PTAF and PTSF were present). SPSS 22.0 statistical software was used for statistical analysis with Student's t-test and Pearson's correlation analysis. The level of significance was set at $P < 0.05$. **Results:** Of the 152 skulls, 11 (7.23%) harbored PTAF and 2 harbored PTSF (1.3%). An incomplete PTAB or incomplete PTSB was present in 110/304 (33.4%) and 21/304 (6.9%) of the sides examined, respectively. PTAB was located medial, lateral, inferior, inferolateral, and inferomedial to FO in 15 (4.93), 29 (9.53%), 77 (25.32%), 28 (9.21%), and 3 (0.98%) of the sides. The distance between PTAB and FO was 7.43 ± 2.58 mm on the right and 7.51 ± 2.50 mm on the left. The distance between two PTABs was 10.43 ± 3.65 mm on the right and 10.29 ± 3.30 mm on the left. The vertical diameter of PTAF was 3.80 ± 2.08 mm, and the horizontal diameter was 4.96 ± 2.24. In the presence of a foramen, the mean thickness of PTAB was 2.27 ± 0.74 mm, the mean width was 3.45 ± 3.40 mm, and the mean length was 6.54 ± 3.64 mm. No significant differences were identified between right- and left-sided measurements ($P > 0.05$). **Discussion and Conclusion:** Close adjacency of PTAB/PTSB to FO as well as their ability to form foramina may hamper the procedures requiring placement of transcutaneous needles into FO or may present anatomical challenges in surgery involving the base of the cranium. Owing to the possibility of neural compression, they may also have clinical significance for craniofacial neurosurgeons, anesthesiologists, radiologists, and dental surgeons. Our results may provide some anatomical insights for planning infratemporal fossa surgery.

Keywords: *Foramen ovale, pterygoalar bar, pterygoalar foramen, pterygospinous bar, pterygospinous foramen, trigeminal neuralgia*

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Introduction

In the upper part of the infratemporal area, there are two ligaments originating from the interpterygoid aponeuroses that extend from the lateral pterygoid lamina (LPL) of the pterygoid process to the infratemporal surface of the sphenoid bone. The pterygoalar ligament (Hyrtl's ligament) is formed by the upper margin of the lateral interpterygoid aponeurosis, which extends from the root of LPL to the infratemporal surface of the greater wing of the sphenoid bone anterolateral to the foramen spinosum. This ligament courses lateral to the foramen ovale (FO) and anterolateral to the sphenoidal spine.[1] Pterygospinous ligament (Civinini's ligament), which represents a thickening of the fascia between lateral and medial pterygoid muscles, extends

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from the pterygospinous process of LPL to the sphenoidal spine. Therefore, as compared to pterygoalar ligament, pterygospinous ligament follows a course that is more medial, is further away from the base of the skull, attaches more posteriorly, and generally extends by crossing the lumen of FO.[2-4]

Partial or complete ossification of pterygoalar ligament leads to the formation of an anatomical structure known as pterygoalar bar (PTAB), which is closely located to FO.[4-9] Complete ossification of pterygoalar ligament results in the formation of pterygoalar foramen (PTAF), also known as Hyrtl's foramen, through which motor branches of the mandibular nerve (buccinator, lateral pterygoid, and temporalis muscle) as well as the auriculotemporal nerve, veins of pterygoid venous plexus, and certain arterioles[7,10-14] are reported to pass. The presence of PTAB may lead to certain neurological disorders such as difficulty in mastication, neuralgia, loss of taste sensation, paresthesia in the face or tongue, or reduced salivation from the parotid glands, as a result of compression effect on deep temporal, lateral pterygoid, buccal, auriculotemporal, and lingual branches of the mandibular nerve as well as on chorda tympani.[14-17] Furthermore, it has considerable clinical significance, since it may lead to nerve compression or trapped nerve during percutaneous anesthetic procedures for trigeminal neuralgia, in addition to the potential risk for interfering with needle access to FO.[3,6,18-20] Thus, a sound anatomical knowledge of these bony bridges and their prevalence is important for surgeons, neurologists, and anesthesiologists.[3,5,7-9,11,18]

Pterygospinous bar (PTSB) is a bony bridge formed by the incomplete or complete ossification of the pterygospinous ligament. Total ossification of this ligament creates the pterygospinous foramen (PTSF), or the foramen of Civinini, that conveys branches of the mandibular nerve and that may result in a variety of anatomical variations.[4,7,9,11] The branches of the medial meningeal artery and nerve supplying the medial pterygoid muscle as well as the masticatory branches of the mandibular nerve pass through PTSF.[21] An ossified pterygospinous ligament may cause paresthesia and pain in the presulcal areas of the tongue, base of the oral cavity, and gingival surfaces, impaired speech, anesthetic effect on the mucous glands of the tongue, as well as a loss of taste sense in the anterior two-thirds of the tongue due to compression of the adjacent chorda tympani.[3,11] The presence of PTSB may complicate surgery involving the lateral skull base as well as the parapharyngeal and retropharyngeal spaces approached through the infratemporal fossa.[11,13-15] Complete ossification of PTSB may also hamper the access of percutaneous needles to the trigeminal ganglion inserted through FO for mandibular nerve block and may complicate transzygomatic surgery.[3,5,8,10,11,22]

Ossification of the pterygospinous and pterygoalar ligaments and the resultant nerve compression may also manifest itself through symptoms such as mandibular neuralgia, nerve palsy, and headache, numbness, or syncope. While these ligaments are in close contact with important anatomical structures such as the mandibular nerve and its branches, otic ganglion median meningeal artery and vein, tympanic nerve, and medial and lateral pterygoid muscles, they occupy a deep and high position in the infratemporal fossa.[7]

This study was undertaken to examine the presence, incidence, and morphology of the ossified ligaments, i.e., PTAB and PTSB and the resultant PTAF and PTSF, as well as to evaluate their topographic relationship with FO.

Materials and Methods

A total of 152 adult dry skull samples of unknown sex and age from Western Anatolia were obtained from the Anatomy Department, Medical Faculty of Dokuz Eylül University. Ethical approval was not obtained for this study as it did not require participation of any live subjects instead only bony material was used. Skulls with evidence of significant trauma or pathology were excluded. The presence and incidence of PTAB/PTSB and PTAF/PTSF were examined in 304 sides [Figures 1-5].

Based on observations on both bones between which the ligaments extend, PTAB and PTSB were defined as "incomplete" when trabeculae and processes failed to unite, whereas they were designated as "complete" when union was present leading to formation of a foramen.[7,15] In case of incomplete ossification of PTAB/PTSB, the distance was measured using a digital sliding caliper (Mitutoyo, Japan) with a sensitivity of 0.01 in vertical and horizontal diameters for samples harboring PTAF/PTSF with two bony processes. In the presence of a complete bony bar, the width, length, and thickness of the bar obliterating the foramen were measured [Figures 1-5]. The relationship between these structures and FO was explored. In addition, the shortest distance from PTAB to FO was recorded.

Statistical analysis was performed using SPSS ver. 22.0 (SPSS Inc., Chicago, IL, USA) statistical software pack with Student's t-test and Pearson's correlation test. The level of significance was set at $P < 0.05$.

Results

Among 152 dry skulls overall, PTAF was present in 11 (3.6%; left sided in six and right sided in five) and PTSF was present in 2 (0.6%; one in the right and one in the left). Of these, concurrent PTAF and PTSF on both right and left sides were present in only one (0.3%). Among 304 sides, an incomplete PTAB was present in 110 (33.4%), and an incomplete PTSB was present in 21 (6.9%) [Figures 1-5].

PTAB's location was medial, lateral, inferior, inferolateral, and inferomedial to FO in 15 (4.93%), 29 (9.53%), 77 (25.32%), 28 (9.21%), and 3 (0.98%) cases, respectively. The PTAB-FO distance was 7.43 ± 2.58 mm on the right

and 7.51 ± 2.50 mm on the left; the distance between two incomplete PTABs was 10.43 ± 3.65 mm on the right and 10.29 ± 3.30 mm on the left; the distance between two incomplete PTSBs was 8.70 ± 3.15 mm on the right and 8.70 ± 3.52 mm on the left [Table 1]. The mean vertical and horizontal diameters of PTAF were 3.80 ± 2.08 mm and 4.96 ± 2.24 mm, respectively. In the presence of complete PTAB, the mean thickness, width, and length of the bar were 2.27 ± 0.74 mm, 3.45 ± 3.40 mm, and 6.54 ± 3.64 mm, respectively. The vertical and horizontal diameters of PTSFs were 3.20 ± 0.69 and 3.70 ± 0.23 mm, respectively [Table 2].

Discussion

The terminology used for the ossified structures under the sphenoid bone that are adjacent to FO is far from being consistent. PTAB and PTAF have been rarely defined in the anatomic literature, and although major anatomy textbooks do not routinely refer to these structures, they are relatively common.[6,9] Furthermore, pterygospinous and pterygoalar ligaments exhibit a significant degree of variability in terms of complete or incomplete ossification. As such, the published literature regarding the incidence and morphometric features of PTAB and PTSB lacks consensus and provides variable data.[11] Furthermore, mechanisms underlying the formation and development of these structures are poorly understood. Genetic and evolutionary factors have been proposed to be involved in the occurrence of these bony structures, due to the presence of significant differences between ethnic groups in humans.[6] Although the occurrence of PTAB has been regarded as a natural secondary process, studies in child skulls showing the presence of ossified PTAB suggest that this anomaly may represent a genetic variation.[12] Even more interesting is the fact that the widespread presence of PTAB has been reported in skulls from herbivores, rodents, and adult monkeys, and some authors have even claimed that PTAB may be an atavistic structure.[23,24] Some studies showed a higher prevalence of PTAB among the elderly.[18]

Clinical significance of pterygoalar bar/pterygospinous bar

The presence of PTAB has two major clinical consequences: the potential to produce neurological symptoms and to act as a mechanical barrier for needle entry when approaching FO.[25] Until now, no prospective clinical studies have evaluated symptoms associated with the presence of PTAB. Published data on clinically significant PTAB are limited to case reports or case series, hence the lack of accurate data on the incidence of symptomatic patients with PTAB.[6] Irrespective of gender, as opposed to more common presence of PTAF on the left, PTSFs are generally right sided.[13] PTAF has been considered to have more clinical significance based on higher incidence, lower surface area, proximity to FO, more frequent occurrence of superposition, and more lateral position as compared to PTSF.[13] During percutaneous mandibular or trigeminal nerve block, smaller PTAF surface and thicker PTAB closing the foramen increase the likelihood of blood vessel and nerve compression, and superior or lateral position relative to FO renders access to FO difficult or even impossible, causing significant clinical challenges.[13]

According to some researchers, complete ossification of pterygoalar ligament may be more dangerous than complete ossification of pterygospinous ligament, since the former

Table 1: Distance between processes or tubercles in incomplete pterygoalar bar and pterygospinous bar for both sides

	Side	Minimum	Maximum	Median	Mean	SD	P
PTAB-FO distance (mm)	Right	2.6	18.6	7.25	7.43	2.58	0.81
	Left	2.6	16.4	7.25	7.51	2.50	
Distance between two incomplete PTABs	Right	2.6	19.9	10.5	10.43	3.65	0.73
	Left	2.7	19.5	9.9	10.29	3.30	
Distance between two incomplete PTSBs	Right	4.0	12.65	9.2	8.70	3.15	1.0
	Left	4.4	17.6	8.55	8.70	3.52	

Diameters of PTAF and PTSF and the dimensions of complete PTAB. PTAB: Pterygoalar bar, PTSB: Pterygospinous bar, FO: Foramen ovale, SD: Standard deviation

Table 2: Diameters of pterygoalar foramen and pterygospinous foramen

	Measurement	Minimum	Maximum	Median	Mean	SD	P
PTAF diameter (mm)	Vertical	2.3	9.5	3.1	3.80	2.08	0.22
	Horizontal	2.8	10.7	4.5	4.96	2.24	
Complete PTAB (mm)	Width	1.4	13	2.4	3.45	3.40	0.06
	Length	3.1	16	5.7	6.54	3.64	
	Thickness	0.9	3.2	2.5	2.27	0.74	
PTSF diameter (mm)	Vertical	2.6	3.8	3.2	3.20	0.69	0.21
	Horizontal	3.5	3.9	4.5	3.70	0.23	

Measured values in the presence of complete PTAB. PTAF: Pterygoalar foramen, PTSF: Pterygospinous foramen, PTAB: Pterygoalar bar, SD: Standard deviation

may totally obstruct FO during thermocoagulation of trigeminal ganglion or mandibular nerve performed to treat trigeminal neuralgia, and these ossified ligaments may lead to inadequate anesthesia as a result of difficulties associated with the advancement of the needle through FO.[3,4,8,20,26]

Singh[20] in his anatomical study of 730 skull bases proposed a new and detailed classification to account for varying degrees of ossification of PTAB/PTSB. Literature search of that researcher showed a highly variable incidence of PTAF and PTSF reported in different populations, ranging between 1% and 31.2% and between 1.3% and 62.4%, respectively. Thus, morphological and topographical clarifications of these structures carry much significance.[20]

Pterygoalar bar/pterygoalar foramen prevalence and location

PTAB prevalence is considerably variable. In Chouke's study[23] involving 1544 dry skulls from America, complete PTAB was present in 10.3%, whereas in another study by the same author involving 2745 dry skulls, the prevalence was 5.9%. In Kapur et al.'s study,[13] incomplete ossification of the pterygoalar ligament was found in 20% of 100 dry skulls. In Pękala et al.'s meta-analysis,[6] the general prevalence of complete and incomplete PTAB was found to be 4.4% and 8.4%, respectively, with PTAB being more commonly observed unilaterally on the left. According to these authors, incomplete or complete PTAB prevalence was lowest among European populations. In a geographical subgroup analysis of that study, Asian populations were found to have the highest prevalence of PTAB (7.0%), followed by South (5.0%) and North (5.0%) America. A complete PTAB was least common in Europe (2.6%). In the current study of dry skulls from Western Anatolia, the PTAB occurrence rate was 3.6%. The reported prevalence of ossified PTAB exhibits significant variability between 1.3% and 62.4%.[4,14] According to Chouke,[23] the prevalence of Hyrtl's foramen was almost twice higher in Africans than in Caucasians (12.88% vs. 7.04%). While Kapur et al.[21] reported complete and incomplete PTAB in 5.9% and 14.4% of the skulls examined, respectively, the corresponding values reported by Peker et al.[15] in an Anatolian population were 9.7% and 10.2%. On the other hand, lower frequencies were reported in a Turkish population by Pinar et al.[27] and in an American population by Tubbs et al.;[14] the frequencies for complete and incomplete PTAB in these two studies were 1.1% and 0.7% and 4.98% and 0.7%, respectively. Interestingly, while Rosa et al.[4] observed the highest incidence of PTAB in the literature (12.9% for complete and 49.9% for incomplete ossification), Suazo et al.[28] reported much lower prevalence, again in a Brazilian sample (3.8% and 22.4%, respectively). Shaw[17] proposed that PTAB was present in approximately 1 out of 100 adults. A complete unilateral PTAB was present in approximately 5% of skulls from an Anatolian population, whereas bilateral PTAB

was significantly less common (1%).[9] A similar incidence was reported for PTAF by Kapur et al.[21] According to Rossi et al.,[7] complete and incomplete ossification of the pterygoalar ligament was present in 2.73% and 0.54% of the human skulls, respectively. In contrast with these reports, Skrzat et al.[9] in a Polish population and Chakravarthi and Bab,[29] in an Indian population, observed higher frequencies of complete PTAB (7.1% and 19.7%, respectively) as compared to incomplete PTAB (1.4% and 8.5%, respectively). In a recent meta-analysis of dried human skulls, 4.4% of the samples harbored a completely ossified PTAB, as compared to 8.4% for incompletely ossified PTAB.[3] Ossified PTAB was present in 8.4% of the samples (2.8% complete and 5.6% incomplete) in the study by Ryu et al.[8] In an Indian sample of dry skulls, Harikrishnan[11] observed the presence of PTAB in 11% of the cases. In 1951, Chouke and Hodes[30] determined the presence of PTAB in a total of 1234 samples (bilateral 0.89%). Lepp and Sandner[26] reported that PTAB was present in approximately 8%–10% of the population, and that pterygoalar ligament was more commonly ossified than pterygospinous ligament. In Rosa et al.'s study,[4] PTAB was found in 62.35% of the radiographic images examined (49.44% incomplete and 12.91% complete ossification). The reported rates of incomplete and complete PTAB by Antonopoulou et al.[25] were 7% and 1%, respectively. In a cadaveric study of 15 samples by Iwanaga et al.,[31] 27 of the 30 sides examined had at least one pterygoalar ligament/bar or pterygospinous ligament/bar.

Complete pterygoalar foramen

This was observed in 14.7% of a Croatian population by Kapur et al.,[21] in 0.65% of an American population by Tubbs et al.,[14] and in 0.65%, 19.7%, and 0.3% of three separate Indian populations by Chakravarthi and Babu,[29] Kavitha Kamath and Vasantha,[5] and Singh,[20] respectively.

Incomplete pterygoalar foramen

This was reported in 49.4% of a Brazilian population by Rosa et al.[4] and in 29%, 3.92%, and 3.3% of three different Indian populations by Kavitha Kamath and Vasantha,[5] De Villiers,[32] and Singh.[20]

Kapur et al.[13] determined the presence of PTAF in 15% of 100 human skulls, with left-sided dominance of this structure; again, complete ossification, i.e., PTAB, was significantly more common on the left (12%) than on the right (3%).

Natsis et al.[18] found that 31.7% of the 145 dry skull samples from a Greek population harbored PTAB, with 4.1% of these being completely ossified (i.e., foramen) and 27.6% being incompletely ossified. Skrzat et al.[9] found the presence of PTAB and foramen in 5 of the 70 skulls examined.

The most common type of PTAB is unilateral incomplete type.[6] In most of the previous studies, PTAB was more commonly reported on the left.[5,14,17,23,33] De Villiers,[32]

however, found more common presence of PTAB in an African sample of dry skulls. In Natsis *et al.*'s study,[18] no side dominance was observed. In our study, there was only a very small difference in the number of PTAB on the right and left sides of the skulls (one more PTAB on the right), consistent with Natsis *et al.*'s[18] observations.

Pterygoalar bar morphometry: The distance between two incomplete pterygoalar bars

The average distance between two incomplete PTABs reported by Natsis *et al.*[18] was 7.49 ± 2.76 mm. In our study, the corresponding values on the right and left were 10.43 ± 3.65 mm and 10.29 ± 3.30 mm, respectively. These differences may reflect geographical and ethnic differences.

Complete pterygoalar bar morphometry

The mean length of PTAB reported by Skrzat *et al.*[9] and Pękala *et al.*[6] was 4–8 mm and 6.27 mm, respectively. The mean PTAB length in our study, i.e., 6.54 ± 3.64 mm, was consistent with these previous reports. However, in contrast with these studies, PTAB width and thickness were also measured for the first time in our study which were found to be 2.27 ± 0.74 mm and 3.45 ± 3.40 mm, respectively.

Pterygoalar foramen morphometry

Published literature provides no information regarding the effect of the dimensions of PTAF on structures passing through it.[6] The mean diameter of PTAF reported by Kapur *et al.*,[13] Galdames *et al.*,[34] Skrzat *et al.*,[9] and Tubbs *et al.*[14] was 3.46 ± 1.26 mm, 5.2 mm, 8.4 ± 1.79 mm, and 9.42 mm, respectively. The horizontal and vertical diameters of this foramen reported by Patnaik *et al.*[35] were 4.45 and 4.7 mm, respectively. PTAF diameter ranged between 7 and 11 mm in Skrzat *et al.*'s study.[9] The horizontal and vertical diameters of PTAF were found to be 4.79 ± 1.39 mm and 3.21 ± 1.70 mm, respectively, in Natsis *et al.*'s study.[18] In a 2017 meta-analysis, the mean horizontal and vertical diameters for PTAF were reported to be 5.31 mm and 3.56 mm, respectively.[6] Despite measurements were performed on dry bones in the present study, our observations were consistent with these previous reports: the horizontal diameter of PTAF was 4.96 ± 2.24 mm, the vertical diameter was 3.80 ± 2.08 mm, and the length was 6.54 mm. The fact that comparable results were obtained in our study and Pękala *et al.*'s study[6] may be indicative of lack of significant geographical effects.

Relationship between pterygoalar bar/pterygoalar foramen and FO

FO is located on the greater wing of the sphenoid bone in the base of the skull, in close adjacency of the posterior margin of LPL, medial to foramen spinosum, and lateral to foramen lacerum. It provides a connection between the cranial fossa and infratemporal fossa, conveying mandibular nerve, accessory meningeal artery, lesser petrosal nerve, and emissary vein. An accurate understanding of the location of FO is of utmost importance for certain diagnostic and surgical procedures such as electroencephalographic analysis, microvascular decompression with percutaneous trigeminal rhizotomy, and percutaneous biopsy of cavernous sinus tumors.[8] Therefore, radiological guidance is required for visualizing FO and related structures.[15] Otherwise, higher doses of anesthesia may be required to achieve adequate anesthetic efficacy in the trigeminal nerve or its branches.[9]

In Kapur *et al.*'s study[13] of 100 dry skulls, PTAF was lateral to, across, or medial to FO in 40%, 40%, and only 20% of the cases, respectively. Skrzat *et al.*[9] reported that FO may be positioned medial or lateral to FO, and while it was found to cross FO in one case, PTAB's position may vary according to FO and its dimensions may range from short and narrow bony trabecular structures to wider laminae. According to Henry *et al.*,[36] PTAB is generally located lateral to FO or passes underneath FO by dividing it into two parts. Tubbs *et al.*[14] also reported that PTAB was generally lateral to PTAB. Natsis *et al.*[18] observed that PTAB was generally lateral to or crosses FO. In previous studies, PTAB was reported to lie medially, laterally, or inferior to FO.[4,9,20,22] In contrast, PTAB was lateral, inferior, and medial to FO in 17, 15, and 5 of the cases reported by Kavitha Kamath and Vasantha.[5] In our study, PTAB was medial, lateral, inferior, inferolateral, and inferomedial to the foramen in 15 (4.93%), 29 (9.53%), 77 (25.32%), 28 (9.21%), and 3 (0.98%) of the cases, respectively.

In Kapur *et al.*'s study,[13] the distance between PTAB and FO was 3.14 ± 1.82. In our study, the same distance was 7.43 ± 2.58 mm and 7.51 ± 2.50 mm on the right and left, respectively. The observed differences may stem from differences in measurement points as well as geographical and ethnic factors.

Pterygospinous bar incidence and location

In several studies, PTSB was more commonly reported to be present on the left side,[5,14,17,23] except for one study reporting mostly bilateral presence of PTSB.[3]

The incidence of PTSB observed by Harikrishnan[11] in 140 Indian dry skulls was 49%, whereas this figure was 28% in Ryu *et al.*'s[8] study examining dry skulls from Korea (complete and incomplete ossification 1.4% and 16.6%, respectively). Kapur *et al.*,[21] however, found a lower complete ossification rate of 1.31% for PTSB in a total of 305 skull samples from Croatia. Peker *et al.*[15] observed that this bony bridge was present in 8.8% of a sample of dry skulls from Anatolia. This figure for PTSB was 9.61% (5.76% complete and 3.84% incomplete) among 416 dry skull samples from an Indian population in Nayak *et al.*'s study.[37] Rosa *et al.*[4] examining the radiographies obtained from 93 dry skulls, identified the presence of pterygospinous ligament in 27.97% of the radiographs, 19.36% being incompletely, and 8.61% being completely ossified.

Wood and Jones[38] found ossification of pterygospinous ligament in 8% of a sample from Hawaii. Lang and

Hetterich[39] reported ossified pterygospinous ligament in 12%–13% of their samples from an African population. According to Shaw,[17] approximately 1 out of 10 adults may harbor such a pattern of ossification. Kavitha Kamath and Vasantha[5] found PTSB only in 26.83%, PTAB only in 58.54%, and both bony bars in 14.63% of 100 dry skull samples. Antonopoulou et al.[25] found a PTSB frequency of 25% and a completely ossified PTSB frequency of 2% in 100 dry skulls. The incidence of complete ossification of PTSB in studies by Kapur et al.,[13] Tubbs et al.,[14] Civinini,[2] Antonopoulou et al.,[25] Peker et al.,[15] and Rosa et al.[4] was 4%, 1.3%, 2.3%, 2%, 8.8%, and 8.61%, respectively. Matys et al.[3] found that 5.8% and 22% of their samples had complete or incomplete ossification of PTSB, respectively, and that this was more common than PTAB. Henry et al.,[36] in their meta-analysis, observed a higher rate of PTSB in Caucasians than Africans (10.7% vs. 2.78%). Henry et al.,[36] in their study, measured the length and width of PTSB as 7.48 mm and 3.06 mm, respectively. In Henry et al.'s[36] meta-analysis, the authors concluded that the general prevalence of PTSB was quite high. Iwanaga et al.[31] examined 15 cadaveric samples and found that 50.0% of them harbored PTSB or the ligament. In our study, the rate of complete and incomplete ossification of PTSB was 0.6% and 6.9%, respectively, and these figures were lower than those observed for PTAB. It is interesting to note that the rate of complete ossification of PTSB in this sample of dry skulls from Western Anatolia is lowest as compared to other previous reports.

Pterygospinous bar incidence and location

No consensus exists regarding the structures conveyed through PTSF. According to Henry et al.,[36] branches of the mandibular nerve supplying temporal, masseter, and lateral pterygoid muscles pass through PTSF. While Peker et al.[15] reported that medial pterygoid nerves and vessels passed through this foramen, Henry et al.[36] mentioned the passage of the medial pterygoid nerve and some vessels of the pterygoid venous plexus. Harikrishnan[11] observed an unusually large PTSF in 140 dry skulls from an Indian population and discussed its potential clinical implications.

Complete pterygospinous foramen

The lowest incidence (i.e., 0%) for this structure was reported by Das and Paul,[40] whereas Rosa et al.[4] observed the highest, i.e., 8.61%, in a Brazilian population. The same figure was 5.5% in an Anatolian population, as reported by Peker et al.[15] Again, this was present in 0.3% of the Indian samples in Singh's study[20] and in 1% in Kavitha Kamath and Vasantha's study.[5] The highest incidence reported in India was 5.76%, based on Nayak et al.'s study.[37] Kapur et al.[13] identified the presence of PTSF in 4% of 100 dry human skulls. De Froe and Wagenaar,[41] in their anatomical study of dry skulls from European populations, observed that 5% of the skulls harbored PTSF.

Saran et al.[22] found a complete ossification of PTSF in 1.2% of 80 skulls, whereas Henry et al.,[36] in their meta-analysis of 35 studies, found a complete PS bar rate of 4.4%. In Kapur et al.'s study[21] in a Bosnian population, the rate of PTSF was lower (1.31%). In our study, the incidence of PTSF formed by complete PTSB was 0.6%.

Incomplete pterygospinous foramen

The lowest incidence, 1%, was reported by Das and Paul,[40] as compared to the highest incidence of 19.36% reported by Rosa et al.[4] in a Brazilian population. The reported figures from India are 8.5% in Singh's study[20] and 16% in Kavitha Kamath and Vasantha's study.[5] Saran et al.[22] found that 7.5% of 80 skulls examined harbored an incomplete pterygospinous ligament. In Henry's et al.'s[36] meta-analysis of 28 studies, 11.6% of the samples had PS incomplete bar. This figure was 6.9% in the current study.

Pterygospinous foramen morphometry

In Henry's et al. meta-analysis,[36] the average horizontal and vertical diameters of PTSF were reported to be 9.05

Figure 1: Pterygoalar foramen, complete pterygoalar bar, and incomplete pterygospinous bar in dry skull. LPL: Lateral pterygoid lamina, PTAF: Pterygoalar foramen, PTAB: Pterygoalar bar, PTS: Pterygospinous
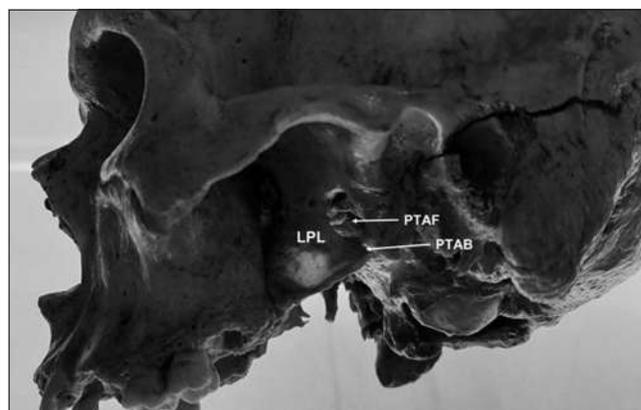
Figure 2: A very large pterygoalar foramen in dry skull and a highly thickened complete pterygoalar bar. LPL: Lateral pterygoid lamina, PTAF: Pterygoalar foramen, PTAB: Pterygoalar bar

and 5.75 mm, respectively. According to that study, dimensions of PTSF may vary, even in the same skull with bilateral presence of this structure. Furthermore, it may emerge as a large foramen (diameter of up to 10 mm) or may be divided into five separate foramens with varying dimensions.[36] The mean diameters/dimensions for PTSF reported by Kapur et al.,[13] Jansirani et al.,[12] and Galdames
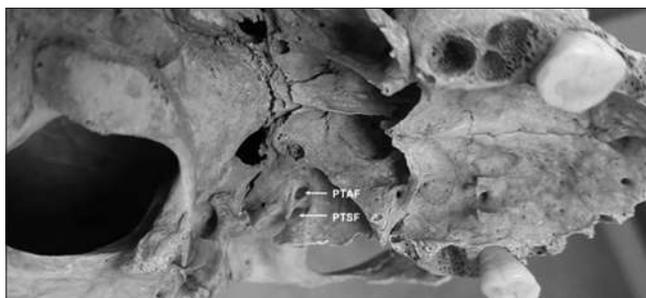
Figure 3: Pterygoalar foramen and pterygospinous foramen occurring concurrently in dry skull. PTAF: Pterygoalar foramen, PTSF: Pterygospinous foramen

Figure 4: Pterygoalar foramen and complete pterygoalar bar in dry skull. LPL: Lateral pterygoid lamina, PTAF: Pterygoalar foramen, PTAB: Pterygoalar bar

Figure 5: Occurrence of incomplete pterygoalar bar in dry skull. LPL: Lateral pterygoid lamina, PTAB: Pterygoalar bar

et al.[34] were 8.77 ± 1.53 mm, 7.5 mm × 7 mm, and 10.63 mm × 7.37 mm, respectively. The horizontal diameter of PTSF in the right and left sides was approximately 4 mm in Nayak et al.'s study.[37] In our study, the vertical diameter of PTSB was 3.20 ± 0.69 mm, and the horizontal diameter was 3.70 ± 0.23 mm [Table 2].

The relationship between pterygospinous bar/pterygospinous foramen and FO

Previous studies reported that PTSB was located medially or inferiorly relative to FO.[4,9,20,22] However, in Kavitha Kamath and Vasantha's study[5] of 100 dry skulls, PTSB was found to cross FO and was inferiorly (13 samples) or medially (5 samples) located. In contrast with PTAB, which is located laterally to or passes under FO dividing it into two parts, PTSB is located medially to or underneath FO.[18,36]

In the radio-anatomic study of Rosa et al.[4], PTSF was found to be located medially to FO in almost all cases, whereas Kapur et al.[13] found lateral position of PTSF in 50%, medial in 25%, and superimposed in 25%. According to the findings of Kapur et al.[13] in 100 dry skulls, PTSF was present in 4% of the samples, predominantly on the right side. In 50% of the cases, PTSF was located lateral to FO, whereas it was located medially in 2% and coursed across FO in 25%. In our study of 152 skulls, we observed PTSF in only two cases and on the left side, one of which occurred in conjunction with PTAF [Figure 3].

Conclusion

Although human populations have a low incidence of PTAB and PTAF, it appears that improving our understanding regarding the morphology and topography of these structures may have some clinical relevance. Better characterization of the variability of human morphology according to geographical and other factors is a prerequisite to improve surgical performance and to achieve further developments in medicine. Information on the ossification status of the ligaments in question is required for improved interpretation of radiological images in patients with trigeminal neuralgia as well as for better surgical planning and management strategies in procedures such as transfacial needle approaches requiring access to infratemporal fossa and parapharyngeal area. Close proximity of PTAB and PTSB to FO and occasional presence of the related foramen may be highly important for neurosurgeons, anesthesiologists, radiologists, craniofacial surgeons, and dental care specialists due to potential nerve compression. As opposed to previous reports, the width and thickness of PTAB were measured for the first time in the current study. We believe that the information provided herein may also prove to be valuable for cranial and maxillofacial surgeons when planning surgery in the skull base through the infratemporal fossa approach.

Conflicts of interest

There are no conflicts of interest.

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Study of Neck–Shaft Angle in Plain Radiographs of Adult Kashmiri Population

Abstract

Introduction: The knowledge about different diameters of the head and different dimensions of the neck of the femur is essential in orthopedic surgery, for radiological practice in identifying pathology of bone. **Aim:** The study aimed to determine the mean values of femoral neck–shaft angle. **Materials and Methods:** The present study was conducted in the Department of Anatomy, Government Medical College (GMC), Srinagar, in collaboration with the Department of Radiodiagnosis and Imaging GMC, Srinagar. Two hundred X-rays of males (100) and females (100) of the pelvis with both hips' anteroposterior view in the age group of 20–50 years were used in the present study. **Inclusion criteria:** (a) Patients complaining of pain in the hip, who had no joint pathology defined on the basis of radiological examination. (b) Patients of the age group of 20–50 years. (c) Patients without any deformity of the hip joint. **Exclusion criteria:** (a) Patients having a history of pathologies such as osteoarthritis, tuberculosis, and fractures around the hip joint. (b) Patients having a history of surgical intervention on proximal femur, acetabulum, or pelvis. (c) Patients who did not have the radiographs with appropriate technique. **Femoral neck–shaft angle:** The long axis of the shaft of the femur and long axis of the neck of the femur were marked with the help of marker, and the point of intersection of these two axes gave us the neck–shaft angle. This angle was measured with the help of goniometer. Two-sided P values were reported, and $P < 0.05$ was considered statistically significant. **Observations:** All the 200 X-rays belonged to the adult (20–50 years) population. The overall mean neck shaft angle (NSA) of all the 200 subjects on the right side was $128.18° \pm 2.92°$ and was statistically insignificant with $P = 0.841$. The overall mean NSA of all the 200 subjects on the left side was $127.37° \pm 3.40°$ and was statistically insignificant with $P = 0.607$. **Conclusion:** The results calculated provide important information about gender, age, and side variations of NSA for the anatomists, radiologists, and orthopedic surgeons. Radiological knowledge of NSA will help the orthopedicians in diagnosing and selecting various treatment modalities in fractures around the hip joint, dislocation of the hip joint, and also surgical procedures such as implantation of prosthesis. The data thus obtained can be used as a baseline for future studies in the departments of anatomy, radiodiagnosis, and orthopedics.

Keywords: *Femur, goniometer, neck–shaft angle*

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Introduction

The femur or the thigh bone is the longest and the strongest bone of the body. It has an upper end, a lower bicondylar end, and a long shaft which is convex forward. Proximally, the head is directed medially upward and slightly forward which articulates with the acetabulum to form the hip joint.[1]

The femoral neck is about 5 cm long and connects the head with the shaft of the femur. It is directed upward medially and slightly forward. The angle between the long axis of the neck and the long axis of the shaft of the femur is called as neck–shaft angle or angle of inclination and is about 125°.[2] This angle facilitates movement at the hip joint, enabling the limb to swing clear of the pelvis.

The knowledge about different diameters of the head and different dimensions of the neck of the femur is essential in orthopedic surgery, for radiological practice in identifying the pathology of bone.[3]

Knowing the normal morphology of the hip joint and proximal femur is highly important for the orthopedicians to repair the geometry of the proximal femur after both trauma and hip arthroplasty. The chief intent is the restoration of normal hip biomechanics.[4] One of the major

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problems arising after total hip arthroplasty is limb length discrepancy. The use of templates and radiographs in preoperative planning may minimize this problem, and pre- and intraoperative templating was suggested for this purpose.[5-7]

Aims and objectives

The aim of the study was to determine the mean values of the femoral neck–shaft angle.

Materials and Methods

The present study was conducted in the Department of Anatomy, Government Medical College (GMC), Srinagar in collaboration with the Department of Radiodiagnosis and Imaging GMC, Srinagar. Two hundred X-rays of males (100) and females (100) of the pelvis with both hips' anteroposterior view in the age group of 20–50 years were used in the present study. The radiographs belonged to patients who had presented with pain in the hip or lower back. Only those radiographs were included in the present study which did not show any pathological condition. The radiographs were obtained from the Department of Radiodiagnosis and Imaging, GMC, Srinagar.

Instruments used

1. Goniometer
2. Measuring scale
3. Markers
4. Divider.

Inclusion criteria

1. Patients complaining of pain in the hip, who had no joint pathology defined on the basis of radiological examination.
2. Patients of the age group of 20–50 years.
3. Patients without any deformity of the hip joint.

Exclusion criteria

1. Patients having a history of pathologies such as osteoarthritis, tuberculosis, and fractures around the hip joint
2. Patients having a history of surgical intervention on the proximal femur, acetabulum, or pelvis
3. Patients who did not have the radiographs with appropriate technique.

Methods

Radiological measurements used in the present study were obtained from the standard pelvic radiographs. The anteroposterior view of radiographs was used, whereas the patient was in the supine position and both the lower limbs internally rotated at 15°. The film focal distance of these radiographs was 1.2 m. The midpoint between the two anterior superior iliac spines and the upper boundary of symphysis pubis was used for centralization.

Radiographs having the following features were included in the study:
1. Symmetrical obturator foramen
2. Lateralization of greater trochanter
3. Clarity of the pyriform fossa
4. Pubis and coccyx in the same plane
5. Absence of hip joint arthrosis.

Femoral neck–shaft angle

Long axis of the shaft of the femur and long axis of the neck of the femur were marked with the help of marker, and the point of intersection of these two axes gave us the neck–shaft angle. This angle was measured with the help of goniometer.

Statistical methods

Data were entered into a Microsoft Excel Spreadsheet. Categorical variables were summarized as percentages. Continuous variables were summarized as mean and standard deviation. To test the hypothesis of no difference in measurements between males and females, unpaired *t*-test was used. Measurements were compared across age groups using one-way ANOVA. Paired *t*-test was used to compare the difference in measurements between the right and left sides. Analysis was done using SPSS version 23. Two-sided *P* values were reported, and $P < 0.05$ was considered statistically significant.

Observations and Results

Observation

In the present study, the radiographs were taken in digital format. The data were analyzed both separately and compared with other sides in both hips in both the sexes and summarized in the tables separately.

Table 1 shows the age distribution of the study population. All the 200 X-rays belonged to the adult (20–50 years) population. Of the age ≤30 years, there were 54 X-rays contributing 27% of the total X-rays. Similarly, in the age group of 31–40 years, there were 69 X-rays, making 34.5% of total X-rays. Of the age group of 41–50 years, there were 77 X-rays, making 38.5% of the total X-rays. The mean age of the study underpopulation was 37.3 ± 8.7 years.

Table 2 shows the overall dimensions of neck–shaft angle in the studied population (200 X-rays).

The mean of neck–shaft angle (rt.) was found to be 128.18° ± 2.92°. The mean of neck–shaft angle (lt.) was found to be 127.37° ± 3.40°.

Table 3 shows the neck–shaft angle in the right and left femurs of both the sexes each consisting of 100 males and 100 females. The mean neck–shaft angle in the males on the right side is 128.43°, with the standard deviation of ±2.78° and standard error mean of 0.27. On the left side, it is 127.52° with a standard deviation of ±3.43° and standard error mean of 0.34. Hence, in males, the neck–shaft angle

Table 1: Age distribution of the study population

Age (years)	Frequency (%)
≤30.0	54 (27.0)
31.0–40.0	69 (34.5)
41.0+	77 (38.5)
Total	200 (100.0)
Mean±SD (years)	37.3±8.47

SD: Standard deviation

Table 2: Distribution of overall dimensions of neck shaft angle in the study population

	Angle_rt	Angle_lt
Valid (*n*)	200	200
Missing (*n*)	0	0
Mean±SD	128.18±2.92	127.37±3.40
Minimum	121.0	120.0
Maximum		135.0

SD: Standard deviation

Table 3: Association of neck–shaft angle with gender

	Sex	*n*	Mean	SD	SEM	*P*
NSA_rt	Female	100	127.94	3.05	0.30	0.237
	Male	100	128.43	2.78	0.27	0.237
NSA_lt	Female	100	127.22	3.38	0.33	0.535
	Male	100	127.52	3.43	0.34	0.535

NSA: Neck–shaft angle, SD: Standard deviation, SEM: Standard error of mean

on the right side is higher as compared to that on the left side. In females, a slight difference in the neck–shaft angle on the right and left sides was observed with the mean value of 127.94° on the right side and the standard deviation of ±3.05° and standard error mean of 0.30. On the left side, the mean value observed was 127.22° with a standard deviation of ±3.38° and standard error mean of 0.33.

The association of females and males in NSA on the right side was insignificant with $P = 0.237$, and on the left side, the association of females and males in NSA was also insignificant with $P = 0.535$.

Table 4 shows the association of neck–shaft angle with age:

The mean NSA on the right side in the age group of 20–30 years in 54 subjects was 128.37° ± 3.03° with 95% confidence interval (127.54°–129.19°), and on the left side, it was 127.68° ± 3.65° with 95% confidence interval (126.68°–128.68°).

The mean NSA on the right side in the age group of 31–40 years in 69 subjects was 128.05° ± 2.61° with 95% confidence interval (127.42°–128.68°), and on the left side, it was 127.43° ± 3.29° with 95% confidence interval (126.64°–128.22°).

The mean NSA on the right side in the age group of 41–50 years in 77 subjects was 128.16° ± 3.13° with

95% confidence interval (127.45°–128.87°), and on the left side, it was 127.09° ± 3.34° with 95% confidence interval (126.33°–127.85°).

The overall mean NSA of all the 200 subjects on the right side was 128.18° ± 2.92° and was statistically insignificant with $P = 0.841$. The overall mean NSA of all the 200 subjects on the left side was 127.37° ± 3.40° and was statistically insignificant with $P = 0.607$.

Table 5 shows the comparison of NSA in bilateral hips in all 200 subjects of both genders. The values of NSA on two sides show $P = 0.001$ which is significant.

In case of females, the mean NSA on the right side of 100 subjects was 127.94° ± 3.05°, whereas on the left side, it was 127.22° ± 3.38°. The mean difference of 95% confidence interval was 0.72, and this association of the right and left sides was statistically significant with $P = 0.041$ [Table 6].

In case of males, the mean NSA on the right side of 100 subjects was 128.43° ± 2.78°, whereas on the left side, it was 127.52° ± 3.43°. The mean difference of 95% confidence interval was 0.91, and this association of the right and left sides was statistically significant with $P = 0.015$ [Table 6].

Table 8 depicts the paired sample statistics in the age group of 20–30 years of the subjects under study: The mean NSA on the right side in the age group of 20–30 years in 54 subjects was 128.37° ± 3.03° with the mean difference of 95% of confidence interval 0.69, and on the left side, it was 127.68° ± 3.65° with the mean difference of confidence interval of 0.69. This association of the right and left sides was statistically insignificant in this age group with $P = 0.137$.

Table 9 depicts the paired sample statistics in the age group of 31–40 years of the subjects under study: The mean NSA on the right side in the age group of 31–40 years in 69 subjects was 128.05° ± 2.61° with the mean difference 95% of confidence interval 0.62, and on the left side, it was 127.43° ± 3.29° with the mean difference of confidence interval of 0.62. This association of the right and left sides was statistically insignificant in this age group with $P = 0.159$.

Table 10 depicts the paired sample statistics in the age group of 41–50 years of the subjects under study: The mean NSA on the right side in the age group of 41–50 years in 77 subjects was 128.16° ± 3.13° with the mean difference 95% of confidence interval 1.08, and on the left side, it was 127.09° ± 3.34° with the mean difference of confidence interval of 1.08. This association of the right and left sides was statistically significant in this age group with $P = 0.012$.

Discussion

In the present study, 200 subjects (100 males and 100 females) in the age group of 20–50 years were selected.

Table 4: The association of neck–shaft angle with age

NSA	n	Mean	SD	SE	95% CI for mean		Minimum	Maximum	P
					Lower bound	Upper bound			
NSA_rt									
≤30.0	54	128.37	3.03	0.41	127.54	129.19	121.0	134.0	0.841
31.0–40	69	128.05	2.61	0.31	127.42	128.68	124.0	133.0	
41.0+	77	128.16	3.13	0.35	127.45	128.87	121.0	134.0	
Total	200	128.18	2.92	0.20	127.77	128.59	121.0	134.0	
NSA_lt									
≤30.0	54	127.68	3.65	0.49	126.68	128.68	120.0	135.0	0.607
31.0–40	69	127.43	3.29	0.39	126.64	128.22	121.0	134.0	
41.0+	77	127.09	3.34	0.38	126.33	127.85	120.0	135.0	
Total	200	127.37	3.40	0.24	126.89	127.84	120.0	135.0	

CI: Confidence interval, NSA: Neck–shaft angle, SD: Standard deviation, SE: Standard error

Table 5: Paired sample statistics comparison of two sides in all 200 subjects

Pair 1	Mean	n	SD	SEM	Mean difference* (95% of CI)	P
Angle_rt	128.18	200	2.92	0.20	0.82 (0.32–1.31)	<0.001
Angle_lt	127.37	200	3.40	0.24		

SD: Standard deviation, SEM: Standard error of mean, CI: Confidence interval

Table 6: Paired sample statistics according to gender in females

Sex	Mean	n	SD	SEM	Mean difference* (95% of CI)	P
Angle_rt	127.94	100	3.05	0.30	0.72 (0.31–1.41)	0.041
Angle_lt	127.22	100	3.38	0.33		

SD: Standard deviation, SEM: Standard error of mean, CI: Confidence interval

Table 7: Paired sample statistics according to gender in males

Sex	Mean	n	SD	SEM	Mean difference* (95% of CI)	P
Angle_rt	128.43	100	2.78	0.27	0.91 (0.18–1.64)	0.015
Angle_lt	127.52	100	3.43	0.34		

SD: Standard deviation, SEM: Standard error of mean, CI: Confidence interval

Figure 1: Instruments used

Measurements were done separately on the radiographs on both sides of each gender [Figure 1]. The mean value was calculated, a comparison was done between the measurements of neck–shaft angle on two sides in each gender, and each side was also compared with the neck–shaft angle of the corresponding side in the other sex. In the study, the mean neck–shaft angle on the right side in males was found to be 128.43° ± 2.78°, and on the left side, it was 127.52° ± 3.43°. Thus, we observed a difference of 0.91° in the mean values of neck shaft angle on the two sides in males [Table 7]. In females, the mean neck–shaft angle values on the right side were found to be 127.94° ± 3.05°, and on the left side, it was 127.22° ± 3.38°. Thus, we observed a difference of 0.72° in the mean values of neck–shaft angle on the two sides in females [Table 6]. However, the mean neck–shaft angle on the right side in males was higher than those in females. The mean neck–shaft angle on the left side of the two sexes was close to each other.

Silva *et al.*, in 2003,[8] while conducting morphometric study in 66 femurs (33 right and 33 left) and found no significant difference in the neck–shaft angle values on the two sides which is contradictory to our study.

Atkinson *et al.*, in 2010,[9] used 100 consecutive Caucasian patients (61 males and 39 females) to study the differences in hip morphology between the genders in patients undergoing hip resurfacing; in the study, they compared the neck–shaft angle. The males had a mean neck–shaft angle of 129° (range: 119–138), and the females had a mean neck–shaft angle of 128° (range: 121–138). The present study is consistent with our study with respect to gender.

Our study findings were consistent with a study conducted by Kour *et al.*, in 2013[10] who found the average NSA in males on the right side to be 121.63° ± 2.41°, and on the left side, it was 121.33° ± 2.36°, whereas in females, the mean NSA on the right side was found to be 121.16° ± 2.50°, whereas on the left side, it was found to be 120.94° ± 2.51°.

Ma *et al.*, in 2014,[11] in a Chinese study analyzed neck–shaft angle with computed tomography and found no

Table 8: Paired sample statistics according to age between 20 and 30 years

	Mean	n	SD	SEM	Mean difference* (95% of CI)	P
Angle_rt	128.37	54	3.03	0.41	0.69 (0.22–1.59)	0.137
Angle_lt	127.68	54	3.65	0.49		

SD: Standard deviation, SEM: Standard error of mean, CI: Confidence interval

Table 9: Paired sample statistics according to age between 31 and 40 years

	Mean	n	SD	SEM	Mean difference* (95% of CI)	P
Angle_rt	128.05	69	2.61	0.31	0.62 (0.25–1.49)	0.159
Angle_lt	127.43	69	3.29	0.39		

SD: Standard deviation, SEM: Standard error of mean, CI: Confidence interval

Table 10: Paired sample statistics according to age between 41 and 50 years

	Mean	n	SD	SEM	Mean difference* (95% of CI)	P
Angle_rt	128.16	77	3.13	0.35	1.08 (0.24–1.91)	0.012
Angle_lt	127.09	77	3.34	0.38		

SD: Standard deviation, SEM: Standard error of mean, CI: Confidence interval

significant difference in the neck–shaft angle on the two sides in males which is contradictory to present study, but the same parameter in females on the two sides was close to each other which is contradictory with the present study. Moreover, the neck–shaft angle values when compared in the two sexes were also close to each other which is consistent with present study.

Boese *et al.*, 2016,[12] while measuring femoral neck–shaft angle on plain radiographs observed that the mean neck–shaft angle of healthy adults was 128.8º (98–180º), and in patients of osteoarthritis, it was 131.5. For rotation corrected, the mean NSA was 128.5, and for nonrotation corrected, it was 129.5º [Figure 2].

Yet, another study conducted by Pathak *et al.*, in 2016,[13] showed the mean value of NSA for males to be 129.26° and in females the mean value of NSA to be 126.62°, thus is in concinnity with our study.

Adekoya-Cole *et al.*, 2016,[14] studied femoral neck–shaft angle in 264 hip joints of 132 subjects, 68 males and 64 females in adult Nigerian population. The average neck–shaft angle for an adult Nigerian was 130.77° ± 6.03° with a mean neck–shaft angle of 131.28 ± 6.56 on the right side and 130.22 ± 5.18 for the left side. In males, mean neck–shaft angle was 131.57° ± 5.66°, whereas the mean value for the adult female was 129.97 ± 6.33. The above findings were consistent with our study; as in our study also, the mean value of male NSA was more than that of females and

Figure 2: The femoral neck–shaft angle

also the values on the right side are higher as compared to the left. Another radiological study conducted by Parashar *et al.*, in 2017,[15] for femoral NSA found the mean NSA on the right side was 130.22° and on the left side was 129.81° which was consistent with our study with respect to the side variation. Shrestha *et al.*, in 2018,[16] in their radiological study of NSA in the Nepalese population found that in males, average right NSA was 132.96° ± 6.05° and left NSA was 131.54° ± 13.66°, whereas in females, the average right NSA was 134° ± 6.57° and on left side 132.98° ± 6.23°. The above findings according to gender were not consistent with our study but right–left variation corroborated with our study.

Yin *et al.*, in 2018,[17] observed that neck–shaft angle was higher on the right side in males which is consistent with our present study, but in females also, it was higher on the right side which is consistent with present study.

Ates *et al.*, 2019,[18] while doing radiological measurement of neck–shaft angle in 200 subjects (100 males and 100 females) observed that the mean neck–shaft angle in males was 128.19° ± 5.08°, and in females, it was 128.4° ± 5.18°. No significant difference in the mean value of neck–shaft angle in the males on two sides was observed which is contradictory to the present study. However, the values on the two sides in female subjects and also the mean values of neck–shaft angle in both the sexes were close to each other which is inconsistent with the present study.

Conclusion

The results calculated provide important information about gender, age, and side variations of NSA for the anatomists, radiologists, and orthopedic surgeons. Radiological knowledge of NSA will help the orthopedicians in diagnosing and selecting various treatment modalities for fractures around the hip joint, dislocation of the hip joint, and also surgical procedures such as implantation of prosthesis.

The data thus obtained can be used as a baseline for future studies in the departments of anatomy, radiodiagnosis, and orthopedics.

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Conflicts of interest

There are no conflicts of interest.

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Determination of the Foot Deformities that May Occur during the Coronavirus Disease 2019 Lockdown Process in Ballet Students

Abstract

Aim: This study aimed to compare foot injury prevalence, causes, and risk factors before and after the coronavirus disease 2019 (COVID-19) lockdown in ballet dancers. In this study, it is also aimed to determine the foot deformities that may occur during the pandemic process and to obtain results that will enable the necessary measures to be taken. **Subjects and Methods:** Our study includes students between the ages of 13 and 21 years who study full time at the Dokuz Eylül University State Conservatory Ballet Department, which provides professional ballet education. This study used a cross-sectional measurements design to evaluate foot morphometry during two distinct periods of time: the first was before to COVID-19 lockdown, and the second was after end of the lockdown. Measurements were made on the photographs taken for the right and left sides. Our study includes anatomical and morphometric measurements of foot digit length, foot length, foot width, and foot angles (intermetatarsal angle, hindfoot varus angle, and hallux valgus angle). **Results:** Forty-one ballet students with a mean age of 15.81 ± 2.28 years and who had been taking ballet training for an average of 6.93 ± 2.32 years were included in our study. When the foot angles (intermetatarsal angle, hindfoot varus angle, and hallux valgus angle) were examined, a significant difference was found except for the hallux valgus angles before and after lockdown. There was no significant relationship between the lengths of digits, foot length, foot width, age and body mass index parameters, and foot angles (intermetatarsal angle, hindfoot varus angle, and hallux valgus angle). However, a relationship was found between the foot angles before and after the lockdown. **Conclusion:** We can say that this result shows us that the COVID-19 lockdown process increases the tend to foot injury in ballet students. We think that this is due to continuing their ballet training on their own or online without ballet instructors in ballet studios.

Keywords: *Ballet, foot injury, hallux valgus angle, morphometry*

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Introduction

The coronavirus disease 2019 (COVID-19) lockdown has led to a large reduction in physical activity for many children and young people across the country and has increased mental health and general well-being issues. Recent studies that have incorporated the lockdown period have focused on how dance can help the general population stay fit and healthy or how lockdown has changed preprofessional dancers' training and life.[1,2] Lockdown itself has meant that preprofessional training institutions alter their face-to-face dance classes to online delivery, which has been an exceptional challenge for both students and teachers as neither had any experience of such conditions. Although these online activities could never replace traditional dance classes, which did provide a stimulus to innovate the dance curriculum and education. Accompanied with unstable internet connections, which led to low image quality, their usual detailed movement feedback was made particularly challenging. Normally, face-to-face ballet education can cause many deformities by exposing the lower extremity to heavy stresses. Anatomical suitability and training technique are very important to minimize these deformities. There is a strong relationship between the development of deformities and disabilities and anatomical features and training technique. In this study, it was conducted to examine the effect of the pandemic process during COVID-19 on foot morphometry, which is important for ballet dancers. Currently, there are no published data on how the lockdown due to the pandemic has affected the foot morphometry in ballet students. This study aimed to compare foot injury

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prevalence, causes, and risk factors before and after the COVID-19 lockdown in ballet dancers. This study also aimed to determine the foot deformities that may occur during the pandemic process and to obtain results that will enable the necessary measures to be taken.

Subjects and Methods

To explore how the COVID-19 pandemic might impact ballet education, we present our own measurements that we wrote in the 1st weeks following university campus shutdowns, city lockdowns, and border closures. Our study includes students between the ages of 13 and 21 years who study full time at the Dokuz Eylül University State Conservatory Ballet Department, which provides professional ballet education. This study used a cross-sectional measurements design to evaluate foot morphometry during two distinct periods: the first was before the COVID-19 lockdown, and the second was after the end of the lockdown. The experimental procedures were conducted in conformity with the Declaration of Helsinki. The relevant guidelines and regulations were strictly followed when conducting the study. The study protocol was approved by the Ethics Committee of Cukurova University. Ethical approval was granted by the University of Cukurova (200/15). Each participant and their parents signed an informed consent form before participation and using their photo in our study. Inclusion criteria include the ballet students who are receiving full-time dance training at least 2 years at Dokuz Eylül University. The ballet students who have graduated or are at the master's or a higher level were omitted.

Photography design

All profile photographs were acquired using a Digital SLR Camera with fixed shooting values.(Canon EOS 80D; ISO 100 f/4.5). The students were taken to a meter-high platform, and they were allowed to take positions in the marked area. The photographic setup consisted of a tripod 1 m away from the student. The tripod height was adapted to each subject's knee level. This plane is described as a reference plane. In a standing position, each subject was asked to relax and was anatomic positioned. The photographs of the students were taken from the knee level down to the dorsum of the foot. In addition, foot photographs were taken from the lateral and posterior positions. Acquired images were then transferred to a computer. The measurement scale was divided into degree and was made on the computer screen as digital and estimations were expressed as degree. Measurements were made using Image J 1.52a with 1/100 mm sensitivity. Using the measurement feature of the software (image J 1.52a with 1/100 mm sensitivity), first the distal point of the angle is chosen, and a line is drawn to the mid position of the angle measurement where the mouse button is hold. The second line is drawn by moving the mouse to the third point, and the angle measurement results are recorded. All measurements were made three times by the same person.

Measurements were made on the photographs taken for the right and left sides. Our study includes anatomical and morphometric measurements of foot digit length, foot length, foot width, and foot angles (intermetatarsal angle, hindfoot varus angle, and hallux valgus angle).

Statistical analysis

SPSS 21.0 was used for statistical analysis of the measurement results. From these measurements, means, standard deviations, and minimum and maximum values were calculated; $P < 0.001$, $P < 0.01$, and $P < 0.05$ were considered statistically significant. Skewness and kurtosis statistics were used to determine the normality of the data distribution. Values between +1.5 and −1.5 were considered to be in accordance with the normal distribution. Pearson analyses were used for correlation analyses with data showing a normal distribution, and Spearman analyses were used for data that did not fit a normal distribution. In addition, data with a normal distribution were evaluated using ANOVA, and data not without a normal distribution were evaluated using the Mann–Whitney U-test.

Results

Forty-one ballet students with a mean age of 15.81 ± 2.28 years and who had been taking ballet training for an average of 6.93 ± 2.32 years were included in our study. The lengths of the foot digits, the foot lengths, and the foot widths were measured on the right and left sides in Table 1. When the foot angles (intermetatarsal angle, hindfoot varus angle, and hallux valgus angle) were examined, a significant difference was found except for the hallux valgus angles before and after lockdown. There was no significant relationship between the lengths of digits, foot length, foot width, age and body mass index (BMI) parameters, and foot angles (intermetatarsal angle, hindfoot varus angle, and hallux valgus angle) in Table 3. However, a relationship was found between the foot angles before and after lockdown in Table 4.

Discussion

Professional ballet dancers are dance artists, and due to the high-intensity training required and the technical discipline and difficulty needed for dance performance, "dance injury" is common in ballet dancers.[3] When the literature is examined, lower extremity injuries are among 65%–80% of all ballet injuries. If the most common damages are examined in detail, since they are located in the lower extremities; 7%–14% hip, 14%–20% knee, 5%–8% leg, 15%–22% wrist, and 13%–15% foot injuries are due to injuries. Studies have shown that 50% of injuries are due to overuse. The overuse percentages are: it was found to be 20% lower extremity, 15% wrist, and 15% foot.[4] Studies are lacking on the intense physical demands of dancing that exposes dancers' feet to a high risk of injuries such as hallux valgus, metatarsal injury, and subsequent ankle pain. We examined foot morphometry and foot

Table 1: Length measurements of ballet students

Parameters	Mean±SD (minimum–maximum)	
	Right	**Left**
First digit length (cm)	5.06±0.53 (3.99–6.38)	5.04±0.48 (4.10–6.38)
Second digit length (cm)	4.35±0.58 (3.03–5.50)	4.26±0.81 (3.90–5.31)
Third digit length (cm)	3.73±0.48 (2.63–4.68)	3.85±0.50 (2.68–4.95)
Fourth digit length (cm)	3.46±0.51 (2.34–4.63)	3.55±0.45 (2.40–4.63)
Fifth digit length (cm)	2.92±0.48 (2.14–3.99)	3.01±0.44 (2.17–3.88)
Foot length (cm)	22.90±1.90 (19.36–26.85)	22.79±1.83 (19.63–26.85)
Foot width (cm)	9.10±0.69 (7.39–10.34)	9.13±0.69 (7.41–10.91)

SD: Standard deviation

Table 2: Angle measurements of ballet students before and after lockdown

Parameters	Mean±SD (minimum–maximum)		*P*
	Before lockdown	**After lockdown**	
Body mass index	19.56±0.77 (18.50–21.80)	20.80±1.39 (19.30–24.00)	0.000
Intermetatarsal angle (right)	18.18±0.21 (15.19–22.00)	19.77±0.23 (16.19–24.94)	0.002
Intermetatarsal angle (left)	17.60±0.19 (14.19–2.25)	19.12±0.22 (15.23–23.51)	0.001
Hindfoot varus angle (right)	8.18±0.23 (4.38–12.21)	9.89–0.25 (4.98–0.1421)	0.002
Hindfoot varus angle (left)	8.32±0.20 (4.13–12.58)	9.05±0.23 (5.13–13.58)	0.001
Hallux valgus angle (right)	24.21±0.71 (12.34–42.39)	26.23±0.75 (13.34–44.39)	0.213
Hallux valgus angle (left)	23.73±0.59 (12.38–35.57)	25.58±0.61 (13.38–38.57)	0.166

P significance value (ANOVA). SD: Standard deviation

angles (intermetatarsal angle, hindfoot angle, and hallux valgus angle) in our study. The weight should be in the center of the foot. Otherwise, since only one side of the leg muscles are used, imbalance will occur. Wrist sprains are facilitated as weight is placed on the lateral ligaments in inward sickling and medial ligaments in outward sickling. Hallux valgus deformity may occur as the thumb will be pushed to the valgus position in outward sickling. Another factor of injury is making wrong practices without the supervision of the instructor. The arrival of the COVID-19 forced nearly all preprofessional dancers to train and study from home due to the lockdown. Before this, the reported injury prevalence for dancers was between 3% and 95%.[5] Injuries were mainly in the muscles of the lower limb and chronic in nature. Perceived causes of these injuries were overwork, fatigue, and the recurrence of an old injury.[6] Furthermore, the anatomical, biomechanical, and hormonal gender differences might have contributed to these results.

Globally, the outbreak of COVID-19 has forced different countries to implement strict social distancing measures and sanitary regimens. People were under the lockdown, working remotely, homeschooling children, and facing quarantine challenges related to eating habits, sleeping time, physical inactivity, and stress. A small-scale study in Italy during lockdown hypothesized based on previous evidence, that children and young people typically gain weight during Summer holidays, that the same would happen during the lockdown. This study concluded that activity decreased while sleep increased.[7] In our study, the mean BMI values of ballet students were 19.56 ± 0.77 before lockdown and 20.80 ± 1.39 after lockdown. We determined that there was

a significant increase in BMI values after the lockdown period. Outcomes were stratified by three BMI levels: healthy weight (BMI: 18.5–24.9 kg/m^2), overweight (BMI: 25.0–29.9 kg/m^2), and obesity (BMI: 30.0 kg/m^2 or above).[8] Even though there was an increase in BMI during the lockdown period, ballet students' BMI values remained within a healthy weight.

Hallux valgus was first proposed by Carl Hueter in 1871 and is one of the common diseases in the forefoot characterized by the outward deviation of the hallux beyond the normal physiological angle and first metatarsal adduction. It is a common deformity of the forefoot that usually exists on both feet.[1] It is generally believed that when the outward deviation of the hallux is more than 15°.[9] The normal value of the angle between the longitudinal axis of the first toe and the extended line of the longitudinal axis of the second toe is 8°–12°. For patients with metatarsal adduction, the normal value is 8°–10°. The hallux valgus can be classified according to the hallux valgus angle and the first/second intermetatarsal angle. Moderate intensity: the medial part of the first metatarsal head protrudes with pain, hallux valgus angle <30°, and intermetatarsal angle <13°. Moderate: the thumb has lateral deviation to compress the second toe, the sesamoid bone is dislocated, the hallux valgus angle is 30°–40°, and the intermetatarsal angle is 13°–16°. High intensity: the thumb has lateral deviation to ride across the second toe, the hallux has pronation, the dislocation of the sesamoid bone is located at the fibular margin of the metatarsal head (7°), hallux valgus angle >40°, and intermetatarsal angle >14°.[10] In our study, the hallux valgus angle on the right side was found to be 24.21 ± 0.71 before the lockdown and 26.23 ± 0.75

Table 3: Correlation analysis between anatomical parameters

	IA1R	IA1L	HA1R	HA1L	HVA1R	HVA1L	IA2R	IA2L	HA2R	HA2L	HVA2R	HVA2L
						r (*P*)						
Age	0.05 (0.73)	−0.15 (0.92)	0.05 (0.75)	0.02 (0.90)	0.14 (0.37)	0.03 (0.84)	0.03 (0.84)	−0.07 (0.68)	0.04 (0.80)	0.08 (0.61)	0.13 (0.44)	0.01 (0.93)
BMi1	−0.05 (0.76)	0.05 (0.78)	−0.01 (0.97)	0.08 (0.64)	−0.07 (0.65)	−0.15 (0.36)	−0.05 (0.78)	−0.03 (0.84)	−0.08 (0.63)	0.06 (0.70)	−0.05 (0.76)	−0.13 (0.42)
BMi2	0.01 (0.95)	0.14 (0.39)	−0.01 (0.99)	0.08 (0.63)	−0.01 (0.93)	−0.09 (0.59)	0.02 (0.99)	0.03 (0.88)	−0.03 (0.83)	0.10 (0.52)	−0.01 (0.96)	−0.08 (0.60)
Year	0.19 (0.23)	0.08 (0.64)	0.15 (0.36)	0.09 (0.56)	0.19 (0.23)	0.14 (0.40)	0.18 (0.27)	0.04 (0.82)	0.14 (0.39)	0.15 (0.36)	0.18 (0.26)	0.11 (0.50)
DL1R	0.09 (0.57)	0.06 (0.71)	0.02 (0.90)	0.12 (0.47)	−0.08 (0.60)	0.03 (0.85)	0.02 (0.91)	0.04 (0.80)	0.11 (0.51)	0.22 (0.17)	−0.11 (0.49)	0.02 (0.92)
DL2R	0.11 (0.49)	0.22 (0.16)	−0.01 (0.93)	0.13 (0.42)	0.07 (0.68)	0.11 (0.51)	0.03 (0.87)	0.14 (0.37)	0.09 (0.57)	0.23 (0.15)	0.02 (0.88)	0.08 (0.62)
DL3R	0.04 (0.81)	0.15 (0.36)	0.01 (0.94)	0.02 (0.90)	0.03 (0.84)	0.07 (0.68)	−0.03 (0.84)	0.07 (0.65)	0.09 (0.60)	0.09 (0.58)	−0.02 (0.93)	0.03 (0.84)
DL4R	0.16 (0.32)	0.21 (0.18)	0.18 (0.25)	0.31 (0.05)	−0.04 (0.81)	−0.02 (0.90)	0.07 (0.66)	0.17 (0.30)	0.25 (0.11)	0.33 (0.04)	−0.06 (0.71)	−0.02 (0.93)
DL5R	0.08 (0.60)	0.22 (0.17)	−0.10 (0.55)	0.11 (0.50)	0.08 (0.60)	0.10 (0.54)	0.01 (0.94)	0.11 (0.51)	−0.01 (0.94)	0.19 (0.24)	0.05 (0.75)	0.10 (0.55)
FLR	0.01 (0.95)	0.01 (0.99)	−0.16 (0.32)	−0.03 (0.87)	−0.03 (0.84)	−0.03 (0.87)	−0.03 (0.87)	−0.03 (0.85)	0.08 (0.63)	−0.08 (0.63)	−0.08 (0.63)	−0.09 (0.59)
FWR	0.27 (0.09)	0.11 (0.49)	0.08 (0.62)	0.15 (0.36)	0.13 (0.41)	0.01 (0.95)	0.16 (0.31)	−0.03 (0.88)	0.24 (0.13)	0.32 (0.04)	0.11 (0.48)	0.03 (0.87)
DL1L	0.09 (0.57)	0.05 (0.78)	−0.02 (0.88)	0.04 (0.82)	0.10 (0.52)	0.04 (0.82)	0.02 (0.93)	0.07 (0.67)	0.07 (0.59)	0.09 (0.59)	0.01 (0.99)	0.08 (0.63)
DL2L	0.09 (0.56)	0.08 (0.63)	−0.15 (0.34)	−0.02 (0.91)	0.02 (0.92)	0.20 (0.22)	0.02 (0.93)	−0.02 (0.94)	0.03 (0.86)	0.13 (0.42)	0.01 (0.95)	0.13 (0.42)
DL3L	−0.08 (0.61)	0.18 (0.27)	−0.19 (0.23)	−0.06 (0.69)	0.05 (0.75)	0.16 (0.33)	−0.20 (0.21)	0.04 (0.80)	−0.14 (0.40)	0.01 (0.99)	0.01 (0.97)	0.13 (0.44)
DL4L	0.03 (0.86)	0.12 (0.47)	0.01 (0.96)	0.09 (0.57)	−0.01 (0.98)	0.04 (0.81)	−0.11 (0.49)	0.03 (0.88)	0.08 (0.63)	0.14 (0.38)	0.04 (0.80)	0.03 (0.85)
DL5L	−0.03 (0.84)	0.20 (0.20)	−0.16 (0.33)	0.08 (0.64)	0.03 (0.84)	0.03 (0.84)	−0.10 (0.52)	0.08 (0.62)	−0.13 (0.44)	0.12 (0.46)	−0.01 (0.94)	0.04 (0.79)
FLL	0.02 (0.90)	0.03 (0.84)	−0.16 (0.33)	−0.07 (0.65)	−0.03 (0.83)	−0.01 (0.99)	−0.03 (0.87)	−0.07 (0.65)	−0.03 (0.85)	0.04 (0.82)	−0.07 (0.65)	−0.06 (0.71)
FWL	0.17 (0.29)	0.13 (0.44)	−0.06 (0.69)	0.17 (0.30)	0.03 (0.87)	−0.06 (0.69)	0.06 (0.71)	−0.08 (0.63)	0.11 (0.48)	0.33 (0.03)	0.01 (0.94)	−0.04 (0.79)

IA1R: Intermetatarsal angle right before lockdown, IA1L: Intermetatarsal angle left before lockdown, HA1R: Hindfoot varus angle right before lockdown, HA1L: Hindfoot varus angle left before lockdown, HVA1R: Hallux valgus angle right before lockdown, HVA1L: Hallux valgus angle left before lockdown, IA2R: Intermetatarsal angle right after lockdown, IA2L: Intermetatarsal angle left after lockdown, HA2R: Hindfoot varus angle right after lockdown, HA2L: Hindfoot varus angle left after lockdown, HVA2R: Hallux valgus angle right after lockdown, HVA2L: Hallux valgus angle left after lockdown, BMi1: Body mass index before lockdown, BMi2: Body mass index after lockdown, Year: The year she studied ballet, DL1R: Digit 1 length right, DL2R: Digit 2 length right, DL3R: Digit 3 length right, DL4R: Digit 4 length right, DL5R: Digit 5 length right, FLR: Foot length right, FWR: Foot width right, DL1L: Digit 1 length left, DL2L: Digit 2 length left, DL3L: Digit 3 length left, DL4L: Digit 4 length left, DL5L: Digit 5 length left, FLL: Foot length left, FWL: Foot width left, *r*: Pearson correlation analysis value, *P*: Degree of significance

Table 4: Correlation analysis between foot angles

r (P)

	IA1R	IA1L	HA1R	HA1L	HVA1R	HVA1L	IA2R	IA2L	HA2R	HA2L	HVA2R	HVA2L
IA1R	-	0.58 (0.00)	0.71 (0.00)	0.33 (0.03)	0.43 (0.01)	0.38 (0.02)	0.95 (0.00)	0.64 (0.00)	0.76 (0.00)	0.40 (0.01)	0.45 (0.00)	0.41 (0.01)
IA1L	0.58 (0.00)	-	0.24 (0.13)	0.37 (0.02)	0.38 (0.02)	0.13 (0.41)	0.04 (0.83)	0.61 (0.00)	0.93 (0.00)	0.27 (0.09)	0.39 (0.01)	0.48 (0.00)
HA1R	0.71 (0.00)	0.24 (0.13)	-	0.38 (0.01)	0.13 (0.41)	0.04 (0.83)	0.61 (0.00)	0.35 (0.03)	0.95 (0.00)	0.40 (0.01)	0.15 (0.35)	0.08 (0.60)
HA1L	0.33 (0.03)	0.37 (0.02)	0.38 (0.01)	-	-0.23 (0.15)	-0.29 (0.07)	0.33 (0.03)	0.36 (0.02)	0.38 (0.01)	0.94 (0.00)	-0.22 (0.17)	-0.23 (0.16)
HVA1R	0.43 (0.01)	0.38 (0.01)	0.13 (0.41)	-0.23 (0.15)	-	0.83 (0.00)	0.42 (0.01)	0.39 (0.01)	0.16 (0.31)	-0.13 (0.43)	0.99 (0.00)	0.85 (0.00)
HVA1L	0.38 (0.01)	0.46 (0.00)	0.04 (0.83)	-0.29 (0.07)	0.83 (0.00)	-	0.40 (0.01)	0.51 (0.01)	0.06 (0.69)	-0.19 (0.25)	0.83 (0.00)	0.99 (0.00)
IA2R	0.95 (0.00)	0.62 (0.00)	0.61 (0.00)	0.33 (0.03)	0.42 (0.01)	0.39 (0.01)	-	0.72 (0.00)	0.65 (0.00)	0.38 (0.02)	0.45 (0.00)	0.43 (0.01)
IA2L	0.64 (0.00)	0.93 (0.00)	0.36 (0.02)	0.35 (0.03)	0.39 (0.01)	0.51 (0.00)	0.72 (0.00)	-	0.32 (0.04)	0.32 (0.04)	0.41 (0.01)	0.53 (0.00)
HA2R	0.76 (0.00)	0.27 (0.09)	0.95 (0.00)	0.38 (0.01)	0.16 (0.31)	0.06 (0.69)	0.65 (0.00)	0.32 (0.04)	-	0.46 (0.00)	0.17 (0.28)	0.10 (0.55)
HA2L	0.40 (0.01)	0.38 (0.02)	0.40 (0.01)	0.94 (0.00)	-0.13 (0.43)	-0.19 (0.25)	0.38 (0.02)	0.32 (0.04)	0.46 (0.00)	-	-0.12 (0.45)	-0.14 (0.39)
HVA2R	0.45 (0.00)	0.39 (0.01)	0.15 (0.35)	-0.22 (0.17)	0.99 (0.00)	0.83 (0.00)	0.45 (0.00)	0.41 (0.01)	0.17 (0.28)	-0.12 (0.45)	-	0.86 (0.00)
HVA2L	0.41 (0.01)	0.48 (0.00)	0.08 (0.60)	-0.22 (0.16)	0.85 (0.00)	0.99 (0.00)	0.43 (0.01)	0.53 (0.00)	0.10 (0.55)	-0.14 (0.39)	0.86 (0.00)	-

IA1R: Intermetatarsal angle right before lockdown, IA1L: Intermetatarsal angle left before lockdown, HA1R: Hallux valgus angle right before lockdown, HA1L: Hallux valgus angle left before lockdown, HVA1R: Hindfoot varus angle right before lockdown, HVA1L: Hindfoot varus angle left before lockdown, HVA1R: Hallux valgus angle right before lockdown, HVA1L: Hallux valgus angle left before lockdown, IA2R: Intermetatarsal angle right after lockdown, IA2L: Intermetatarsal angle left after lockdown, HA2R: Hindfoot varus angle right after lockdown, HA2L: Hindfoot varus angle left after lockdown, HVA2R: Hallux valgus angle right after lockdown, HVA2L: Hallux valgus angle left after lockdown, r: Pearson correlation analysis value, P: Degree of significance

after the lockdown. We evaluated the hallux valgus angle on the left side before and after lockdown as 23.73 ± 0.59 and 25.58 ± 0.61, respectively. We observed an increase in the values on the right and left sides after lockdown. However, it was not statistically significant. We also noticed that the right side has more tendency to be hallux valgus deformity. The results of our study were found to be higher than the normal values in the literature. We think that this result is due to the fact that the individuals in our study have been doing ballet for an average of 6.93 ± 2.32 years. Hallux valgus degrees of ballet students in our study were found to be low. Hallux valgus deformity is usually accompanied by an increase in the intermetatarsal angle. In the ballet students in our study, the intermetatarsal angle values on the right side were found to be 18.18 ± 0.21 before lockdown, 19.77 ± 0.23 after lockdown, 17.60 ± 0.19 before lockdown, and 19.12 ± 0.22 after lockdown on the left side. A significant increase was observed after lockdown on both sides (right $P = 0.002$ and left $P = 0.001$). The increase in the intermetatarsal angle was also seen more on the right side. The increase in intermetatarsal angle values after lockdown in ballet students supports the increase in hallux valgus angle values [Table 2]. In our correlation analysis results, a strong positive correlation was found between the intermetatarsal angle and the hallux valgus angle on both the right and left sides before and after the lockdown. Another angle in our study that is positively correlated with the intermetatarsal angle on both sides and before and after lockdown is the hindfoot varus angle. In the ballet students in our study, the hindfoot varus angle on the right side was 8.18 ± 0.23 before lockdown and 9.89–0.25 after lockdown, 8.32 ± 0.20 before lockdown, and 9.05 ± 0.23 after lockdown on the left side. It was found that there was a significant increase in hindfoot varus angle values on both sides (right $P = 0.002$ and left $P = 0.001$) after lockdown. It occurs as a result of an imbalance in hindfoot varus muscle strength. During the lockdown process, we thought that there might be changes in muscle strength due to the disruption of the ballet training in the ballet studio. Therefore, we included the hindfoot varus angle, which will reflect the change in muscle strength, in our measurements. The back of the foot is in varus, the lateral part of the foot overloading and thus ankle instability, peroneal tendinitis, and stress fracture. Hindfoot movements were examined and showed within normal (5°–10°) inversion values and eversion values (10°–20°) at the subtalar joint.[11] The hindfoot varus degree values in our study showed a significant increase after lockdown on both the right and left sides. The hindfoot varus degrees of ballet students in our study before and after lockdown were within the normal range in both inversion and eversion. Moreover, in our study, we also included ballet students' morphometric measurements such as digit lengths, foot lengths, and foot widths. No relationship was found between the foot angles and these length and width measurements. Hallux valgus angle, intermetatarsal angle, and hindfoot varus angles increased after the lockdown period. We can say that this result shows us that the COVID-19 lockdown process

increases the tend to foot injury in ballet students. We think that this is due to continuing their ballet training on their own or online without ballet instructors in ballet studios. Most ballets are absolutely and completely committed to ballet, making great sacrifices during their training from a young age onward, with the aim of becoming professional ballet dancers. In the everyday schedule of training and rehearsals, discipline is a fundamental prerequisite for a career as a professional ballet dancer. Ballet students must work with perseverance, purpose, and concentration. They are used to accepting and swiftly reacting to criticism and constructively taking instructions.[12,13] Therefore, during the lockdown due to COVID-19, ballet students stayed away from ballet studios with mirrors, one-on-one guidance from their instructors, and training with their group mates. We think that this situation will increase the susceptibility to injuries. For example, during every relevé, pay attention to the optimal weight distribution in the foot. The main load should lie between the first and second metatarsals. Especially if the mobility of the metatarsophalangeal joint of the big toe is limited, it cannot compensate for this lacking range of motion by "sickling" the foot when rising to relevé. Otherwise, the first and second metatarsals will be overloaded; injuries and deformities may occur with the increase of the hallux valgus angle and the intermetatarsal angle.

Conclusion

With this study, we wanted to emphasize the importance of training with teamwork in ballet studios and training with a ballet trainer during the lockdown process. In addition, we think that we will guide orthopedists and physical therapists with measurement values that will affect foot deformities and tend to injury in ballet students. To prevent such injuries, we recommend performing supportive practices such as mobilizing the tarsus, strengthening the transverse arch respectively and the intrinsic foot muscles, strengthening the long peroneal muscle, contract-relax stretching of the calf muscles.[14] We also think that the following points will prevent injuries in daily life:

- Watch out when walking – and especially when jogging – to put down your feet as parallel as possible and push off from the transverse arch
- Let your feet have a rest sometimes. A footbath in the evening will relax the foot muscles. Massage the painful spots and pay particular attention to the inner side and the sole as well as to the insertion of the Achilles tendon
- Take your time when buying shoes. All of your shoes should fit properly, not only dance ones. Especially after long training days, your walking shoes should not put additional strain on your feet.

Since the COVID-19 is a pandemic process, measurements with instruments could not be made by direct physical contact. Evaluations were made quickly and safely with the photographing method. However, the flexibility factor, which we think will be affected by lockdown, could not be evaluated. This is one of the limitations of the study. We suggest that similar studies in which the flexibility factor is evaluated be produced with more ballet students.

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Conflicts of interest

There are no conflicts of interest.

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Pneumatized Crista Galli and its Correlation with Intraethmoidal Location of the Anterior Ethmoidal Artery

Abstract

Background/Aim: Crista galli (CG) is an essential anatomical formation located in the midline on the cribriform plate. In the presence of pneumatized CG (PCG) variations, changes will occur in the anatomy of the anterior skull base. Anterior ethmoidal artery (AEA) crosses the medial wall of the orbit and progresses intraethmoidally; in case it is damaged during endoscopic procedures, it may cause severe epistaxis or intraorbital hematoma. This study aims to examine the CG morphometric features in the Turkish population and to investigate the changes in the distance of the AEA from the nasion and sphenoidal sinus (SS) according to CG morphometry. **Materials and Methods:** In the study, computerized tomography images of 200 cases were used, CG height-in the coronal plane, PCG ratio, and the distances of the AEA from the nasion line to the anterior wall of the SS were measured in the horizontal plane. In the presence of PCG, the changes in AEA according to their distance from the mentioned formations were examined. **Results:** The mean CG height was 12.8 ± 2.4 mm; partial or total pneumatization was observed in 31.5% of the cases. The average distance from the anterior border of the AEA to the Nasion during its intraethmoidal course was 28.3 ± 3.6 mm, with males having a greater distance than females. Additionally, the average distance to the anterior wall of SS was 17.5 ± 2.9 mm. **Conclusion:** This study determined that the distance of the AEA to the nasion was greater in cases with PCG than in cases without pneumatization on both sides.

Keywords: *Anterior ethmoidal artery, computed tomography, crista galli, pneumatized crista galli, variation*

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Introduction

The anatomical structure known as the crista galli (CG) is located above the cribriform plate in the midline. It has a thin, curved shape that extends to the vertical line and serves as the falx cerebri's attachment point.[1] An important marker for transcribriform and extradural endoscopic interventions is the determination of the midline. As a result, numerous studies on its localization, variations in its morphometry, and its relationship with neighboring structures have been published in the literature.[2] Studies have also suggested that CG morphometric characteristics can be used to determine sex.[3]

In most cases, the CG is a compact bone; however, pneumatized CG (PCG) refers to separating the bone lamellae and air filling. Rates of PCG in the general population range from 2.4% to 66.6%.[1,4] It has been demonstrated that PCG is connected to air chambers in the frontal sinus and/or anterior ethmoidal cells.[5] Because it contributes to the etiology of recurrent headaches, pneumatization of the CG may be impacted by chronic sinusitis and results in complications. It has been suggested in the literature that patients with chronic headaches who evacuate their PCG content may have more success treating their chronic sinusitis and that there may be a connection between PCG and mucocele.[6,7]

Nasion is a popular anthropometric point for determining the midline of the skull in addition to CG. The deepest point of the nasofrontal groove is the nasion, which is where the frontal bone and nasal bones converge.[8] Different ethnic groups have different depths and morphometric traits.[9] This anthropometric point serves as an important landmark in endoscopic approaches to the frontal region and anterior skull base, including the modified Lothrop procedure.[8]

The term "sphenoidal sinus (SS)" refers to the numerous air chambers found within the body of the sphenoid bone.

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In transsphenoidal approaches to skull base lesions and interventions to the pituitary, optic chiasm, and cavernous sinus, the anterior wall of this sinus serves as a crucial anatomical barrier.[10] The anterior ethmoidal artery (AEA) is the most dangerous artery that could result in severe intra- and postoperative complications during endoscopic procedures approaching the skull base from the anterior and posterior directions.[11] After passing through the optic canal, the AEA becomes a branch of the ophthalmic artery. The ethmoidal labyrinth, the orbit, and the anterior cranial fossa are where the AEA is located throughout its path. It travels to the intraethmoidal/intranasal region after exiting the orbit through the same-named foramen. This section of the artery travels anteriorly either freely or in a bony canal. Numerous studies have demonstrated that changes or subsequent anomalies in the sinonasal region have an impact on the AEA either directly or indirectly.[12,13] This interaction will inevitably be clinically reflected. Surgery in the paranasal region, which experiences high variation rates, carries a high risk of AEA injury. Due to its elastic structure, it may retract into the orbit and cause hemorrhage into the orbit and hematoma if it is traumatized, which may also result in nosebleeds. If the orbital hemorrhage is not treated, the pressure in this compartment will increase, which could compress the optic nerve and have severe consequences such as blindness.[14]

This study sought to determine the distance between the anterior wall of the SS and the AEA during its intraethmoidal course, as well as the relationship between these measurements and the presence of CG height and PCG.

Materials and Methods

Study design

This descriptive study retrospectively examined multiplanar thin-section computerized tomography (CT) images obtained at the hospital archive, between 2018 and 2020. The images were captured using a "6-Slice Multidetector CT scanner" (Philips Brilliance 6, Philips Medical Systems, Amsterdam, The Netherlands), and the cases for the study were chosen from those with images containing at least 150–400 slices of 0.6–1 mm thickness and an acquisition dose of 120 kV to 220 mA. Coronal, sagittal, and horizontal CT slices from the images examined through the Sectra IDS7 version 21.2.15.6346©2019 program were evaluated together by two separate observers.

Study group

Two hundred patients (100 men and 100 women) aged between 18 and 70 were included in the research. Exclusion criteria were history of the previous skull base or paranasal sinus surgery, congenital facial anomaly, history of disease or trauma causing erosion of the ethmoid roof, presence of chromosomal anomaly, being younger than 18 years and older than 70 years at the time of image acquisition, and poor image quality in imaging methods.

Methods

The distance from the most anterior border of the intranasal part of AEA to the level of nasion was measured. The localization of the nasion was determined by comparison with the sagittal plane image at the same level [Figure 1a].

The anteroposterior distance of the AEA from the most anterior level of the anterior wall of the SS during its course in the ethmoidal labyrinth was measured. This measurement was performed by determining the level of the anterior wall of the SS in the sagittal plane and marking it in the horizontal plane [Figure 1b]. The values were compared between gender, age group, and the right and left sides. Statistical analyses were performed in the evaluations, and significance was investigated.

CG height was measured in the section where the CG was the highest in the coronal plane on computed tomography images. In the current study, cases with PCG were identified, and the presence of this variation was investigated regardless of partial or total ventilation [Figure 2]. In addition, in cases with PCG, the relationship between the distance of the posterior border to the anterior wall of SS and the distance of the anterior border to the nasion during the intraethmoidal course of the AEA was examined.

Statistical analysis

Statistical analyses were carried out using Stata, version 13.0, web-based R software (R Foundation for Statistical Computing, version 3.5.2, package: nparLD), and IBM SPSS Statistics 25.0 (IBM SPSS Statistics for Windows, version 25.0. Armonk, NY, USA: IBM Corp.) (StataCorp LLC, 4905 Lakeway Drive, College Station, Texas 77,845, USA). The Shapiro–Wilk test was used to determine whether the numerical variables fit the "Normal Distribution." In the study, categorical data
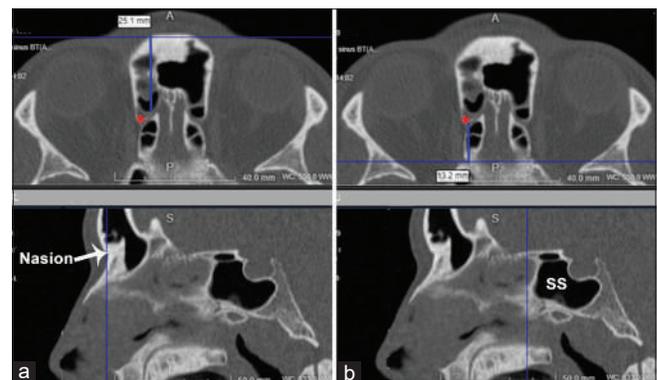
Figure 1: (a) In the sagittal section in the lower image, the line passing through the nasion is seen as a horizontal blue line in the upper image. The distance from the anterior border of the arteria ethmoidalis anterior (*) to this line was measured during its intraethmoidal course. (b) In the sagittal section in the lower image, the line passing through the anterior bony border of the sinus sphenoidalis is traced as a horizontal blue line in the upper image. The distance from the posterior border of the arteria ethmoidalis anterior (*) to this line was measured during its intraethmoidal course. SS: Sphenoidal sinus, *: Anterior ethmoidal artery where it leaves the orbit

were summarized using frequency and ratio values, while numerical data were summarized using mean, standard deviation, median, and range values. In all analyses, the significance level was set at $P < 0.05$. The Mann–Whitney U-test was used for two independent group comparisons for all quantitative variables. The relationship between qualitative variables was examined using either Fisher's exact probability testing or Pearson's Chi-square testing. The relationship between quantitative variables was evaluated using Spearman correlation analysis.

Ethics committee

This radioanatomical, descriptive study was evaluated by the Medical Research Ethics Committee and approved with protocol number 20-7.1T/12.

Results

The ages of the patients included in the study ranged from 18 to 70 years, with a mean of 46 ± 14 years (47 in women and 45 in men); 49% of the patients were in Group 1 and 51% were in Group 2, when we divided the patients into two groups according to their ages as Group 1: 18–45 and Group 2: 46–70.

The distance of the anterior border of the AEA during the intraethmoidal course of the AEA to the nasion in the

Figure 2: (a) A coronal section taken more anteriorly than in image b shows a pneumatized crista galli (PCG) associated with the sinus frontalis in the right image (white arrow). (b) A coronal section was taken more posteriorly than in image a, showing a normal crista galli in the right image (white arrow). This case can be given as an example of partial PCG

horizontal plane was measured as 28.3 ± 3.6 mm (16.1–40.0) on average in 400 arteries. This value was close to the mean and standard deviation on the right (28.4 ± 3.6 mm) and left (28.2 ± 3.5 mm) ($P = 0.202$). It was 28.4 ± 3.6 between 18 and 45 years and 28.2 ± 3.5 mm between 45 and 70 years ($P = 0.891$). The mean values were 29.3 ± 3.6 mm (17.6–40.0) in males and 27.3 ± 3.3 mm (16.1–37.0) in females, and there was a statistically significant difference with gender [$P < 0.001$, Table 1].

The distance perpendicular to the anterior wall of the SS during the progression of the AEA in the ethmoidal labyrinth until it leaves the orbit and enters the skull base (AEA-SS) averaged 17.5 ± 2.9 mm (8.6–26.2) in 400 arteries. When the right side was specifically evaluated, this value was 17.6 ± 2.8 mm, whereas 17.4 ± 3.0 mm on the left side ($P = 0.143$). In women, this value was 17.5 ± 3.2 and 17.4 ± 2.6 mm in men ($P = 0.492$). The distance was 17.5 ± 3.27 mm between 18 and 45 years and 17.5 ± 3.04 mm between 45 and 70 years; however, this difference was not statistically significant [$P = 0.806$, Table 1].

The mean CG height was 12.8 ± 2.4 mm (7.1–19.7). It was 12.9 ± 2.5 mm between 18 and 45 and 12.8 ± 2.2 mm between 46 and 70 years of age. This value was 12.9 ± 2.2 mm in women and 12.8 ± 2.6 mm in men. No significant difference was found in our data according to gender and age group variables [$P = 0.664$ and $P = 0.696$, respectively, Table 1].

CG pneumatization was found in 35% of men and 28% of women; 28% between 18 and 45 years and 35% between 46 and 70 years, but these differences were not statistically significant [$P = 0.149$ for gender and $P = 0.238$ for age groups, Table 1]. The current study group found PCG at an average rate of 31.5%.

The mean CG height was 12.9 ± 2.4 mm in patients with PCG. The mean distance of the AEA to the nasion was 29.2 mm on the left and 29.3 mm on the right, whereas the mean distance to the anterior wall of the SS was 17.4 mm on the left and 17.6 mm on the right in cases with PCG. It is statistically significant that the distance from the anterior border of the AEA to the nasion tends to increase in the presence of PCG ($P = 0.039$ on the right and $P = 0.022$ on the left).

Table 1: Comparison of the data related to the anterior ethmoidal artery, nasion, sphenoidal sinus, and crista galli according to age group and gender

Measurements; mean±SD (range) (mm)	Gender		Age groups		Total
	Female	Male	18–45	46–70	
AEA-Nasion	27.3±3.3*	29.3±3.6*	28.4±3.6	28.2±3.5	28.3±3.6 (16.1–40.0)
AEA-SS	17.5±3.2	17.4±2.6	17.6±2.8	17.4±3.0	17.5±2.9 (8.6–26.2)
CG height	12.9±2.2	12.8±2.6	12.9±2.5	12.8±2.2	12.8±2.4 (7.1–19.7)
PCG, *n* (%)	28 (28.0)	35 (35.0)	28 (28.0)	35 (35.0)	63 (31.5)

*$P<0.001$. PCG: Pneumatized crista galli, SD: Standard deviation, AEA: Anterior ethmoidal artery, CG: Crista galli, AEA-SS: AEA-sphenoidal sinus

Discussion

Studies investigating PCG found frequency of PCG between 2.4% and 66.6%. The average study group age, the study group's ethnicity, and methodological differences could all be contributing factors to the wide range. For instance, this rate was only 4.6% in histopathologic studies,[15] whereas 66.6% in a study using CT scans of adult human skulls.[4] In a radiologic study on children, this rate was 12.2%, but Al Quadah discovered a PCG rate of 28% in a radiologic study on adults.[16] This rate was 30.1% in a CT study on 196 patients admitted to the otorhinolaryngology clinic due to chronic sinusitis.[17] The frequency of PCG in our study was found to be 31.5%, which is consistent with that of another study in Turkey, with a rate of 29.8% with 402 asymptomatic patients.[18] The fact that we included nontotal PCGs may be why our value, which was higher than studies done in the general population, like the study by Al-Qudah,[16] is higher. Even though the presence of PCG was higher in women than in men and in the age group of 46–70 years compared to the age group of 18–45 years, this difference was not statistically significant. Similar to this outcome, no correlation between the presence of PCG and age was discovered in a study carried out in Turkey in 2021.[2]

CG is a crest-shaped structure extending into the anterior skull base cavity, and the falx cerebri and dura mater are attached to this bony protrusion. During the endoscopic intervention of some tumors located in the anterior skull base, the falx cerebri must be separated from its attachment to the CG. Throughout this surgical procedure, part of the upper end of the CG is removed by drilling. Therefore, the vertical height of the CG is as essential clinically as its morphologic type or anteroposterior length. In a radiological study by Lee *et al*. in Canada, the CG vertical height was 12.9 ± 2.5 mm.[19] In a study in Japan in 2020 on patients with brain tumors, the mean CG height was 15.9–3.2 mm (7.3–26.0 mm).[20] In studies conducted in Turkey on CG height, the results were close. While in the study by Uçar *et al*. on CT images, CG height was 14.0 ± 2.9 mm (6.0–23.4 mm),[2] in another study conducted in Turkey in 2021, CG height was 14.1 ± 3.1 mm (6.6–22.6 mm); in the most mentioned study, the likelihood of male gender in patients with a CG height above 15.15 mm was approximately 12 times higher than in patients with a CG height < 15.5 mm.[3] In the current study, the mean CG height was 12.8 ± 2.4 mm, which was minimally lower than other studies conducted in the same country and close to the study of Lee *et al*.[19] Although this value was 1 cm higher in males, this difference between genders was not statistically significant. The mean CG height was 12.9 ± 2.4 mm in patients with PCG. In a 2017 study conducted in Croatia on CT images of 102 skulls, the mean CG height was found to be 10.1 ± 3.0 mm (3.6–17.1 mm), and it was found to be statistically significant that CG height was higher in women (mean 14.2 in women and 9.5 in men) in cases with PCG.[4] According to the findings in our study, it cannot be said that there is a significant correlation between the presence of PCG and CG elevation independent of gender and age group.

In endoscopic interventions in the sinonasal region, the nasion and the anterior wall of the SS can be determined, and the potential distance of the AEA to these structures can be estimated. In cases where an anterior approach to the frontonasal region is required, such as the modified Lothrop procedure, the relationship between the nasion and the AEA is important. In our study, the distance from the point where the AEA was closest to the nasion during its intraethmoidal course to the vertical line passing through the nasion was found 28.3 ± 3.6 mm and longer in men. The difference in this distance between genders should be taken into consideration. The distance of the AEA from the vertical line passing through the anterior wall of the SS, which may also be important in approaching the posterior skull base in endoscopic interventions, was 17.5 ± 2.9 mm, although there was no significant difference between genders. Considering this information in cases where the artery should be approached posteriorly may help clinicians prevent possible intraoperative and postoperative complications.

The cases were not classified in this study, although various classification studies had been carried out based on the location and extent of PCG.[4,20,21] This study did not address the connection between the size of the PCG and the correlation with the distance between the AEA and the nasion and SS. Future research should examine the morphometry of CG and AEA in patients with chronic sinusitis and mucocele in addition to the general population, considering that symptomatic patients may require more frequent endoscopic intervention.

Conclusion

Our study determined that the distance of the AEA to the nasion was greater in patients with PCG compared to those without pneumatization on both sides. Therefore, it can be suggested that the presence of PCG is not riskier in arterial injury during interventional procedures.

Ethics approval

Approval was obtained from the institutional review board of Faculty of Medicine (approval number: 20-7.1T/12. H.). The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Financial support and sponsorship

Conflicts of interest

There are no conflicts of interest.

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Middle Mesenteric Artery: A Rare Vascular Anomaly

Abstract

Background: Normally, branches of superior mesenteric and inferior mesenteric arteries (IMA) supply the parts of intestine derived from midgut and hindgut and their variations are uncommon. One of the rarest variations is the presence of a middle mesenteric artery (MMA), an anomalous ventral branch of abdominal aorta originating in between the origins of superior and IMA supplying variable portions of the colon, sporadically reported mainly as case reports. **Materials and Methods:** While retrospectively examining multi-detector computed tomography angiographic abdominal scans of 500 subjects for analyzing the variations of branches of abdominal aorta, an anomalous artery supplying variable parts of colon was observed in one male patient. **Observations:** We report here an incidentally detected presence of MMA supplying large portions of colon in a male patient with nonrotation of gut, cholelithiasis, and portal hypertension. Computed tomography angiography of this patient also revealed variant celiac artery branching with hepatosplenic trunk and direct aortic origin of left gastric artery. Thus, there were five ventral branches of abdominal aorta supplying the gut which is a very rare presentation. Hepatic flexure of the colon was present between diaphragm and right lobe of the liver (Chilaiditi syndrome). **Discussion and Conclusion:** Our literature search has yielded 26 such cases reported globally, and to the best of our knowledge, this is the first report from India. Associated anomalies reported include abdominal aortic aneurysm, nonrotation of gut, and presence of other vascular anomalies. Failure to identify such an anomalous artery may result in its damage with subsequent bowel ischemia and other complications during surgery.

Keywords: *Anomalous mesenteric arteries, aortic origin of left gastric artery, hepato-splenic trunk, middle mesenteric artery, nonrotation of gut*

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Introduction

Normally, three ventral branches of abdominal aorta (AbA), namely the celiac (CA), superior mesenteric (SMA), and inferior mesenteric arteries (IMA) supply derivatives of embryonic foregut, midgut, and hindgut, respectively. Jejunal and ileal branches of SMA supply the loops of the small bowel. Ileocolic (ICA), right colic (RCA), and middle colic (MCA) branches from superior mesenteric and left colic and sigmoid branches from inferior mesenteric supply the colon and form an anastomotic marginal artery critical for nourishment of the colon. Detailed anatomical knowledge of colonic arterial supply is crucial for successful outcome of hemicolectomy and prevention of life-threatening mesenteric ischemia. Although variations in the branching pattern of CA are more frequently encountered, variant branching pattern of SMA and IMA are less common. One of the rarest variant is the middle

mesenteric artery (MMA) arising from the ventral aspect of abdominal aorta, between the origins of SMA and IMA and supplying variable portions of small and large intestines. Benton and Cotter were the first to report in the English literature, the presence of an artery arising directly from aorta and supplying entire transverse colon and proximal descending colon which was designated as duplicated IMA. There was a common trunk from SMA dividing into RCA and ICA and there was no MCA.[1] Reported prevalence of the MMA varies between 0.05% and 0.1%.[2,3] This anomalous artery has variously been reported as duplicated IMA, second SMA, accessory MCA, aortic origin of MCA, aortic origin of RCA, aortic origin of ICA, in previous reports. Lawdahl and Keller in 1987 coined the term "MMA" to denote an artery arising from aorta in between the origins of SMA and IMA.[4] In this report, we present an incidentally detected case of MMA supplying parts of intestine from terminal ileum to proximal descending colon.

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Materials and Methods

Contrast-enhanced multi-detector computed tomographic abdominal scans of 500 subjects were retrospectively assessed for branching variations of the AbA. The radiology center routinely obtains written informed consent from all patients before contrast injection.

Results

We present here a case of MMA detected incidentally in a male aged 63 years with a clinical diagnosis of cholelithiasis and portal hypertension and subjected to contrast-enhanced CT angiography for further evaluation (1/500; 0.2% prevalence). The MMA was arising from the ventral aspect of abdominal aorta at the level of lower border of L2 vertebra, 5.46 cm distal to origin of SMA, and 1.86 cm proximal to origin of IMA [Figure 1]. The diameter of MMA at its origin was 5.1 mm and that of SMA was 5.4 mm and IMA was 3.5 mm. After turning sharply to the right anterior to aorta and SMA, the MMA bifurcated into branches running horizontally in opposite directions. The right branch further divided into ascending and descending branches to supply transverse colon, ascending colon, cecum and terminal ileum, and the left branch supplied splenic flexure and proximal descending colon [Figure 2a and b]. Normal colic branches of SMA,
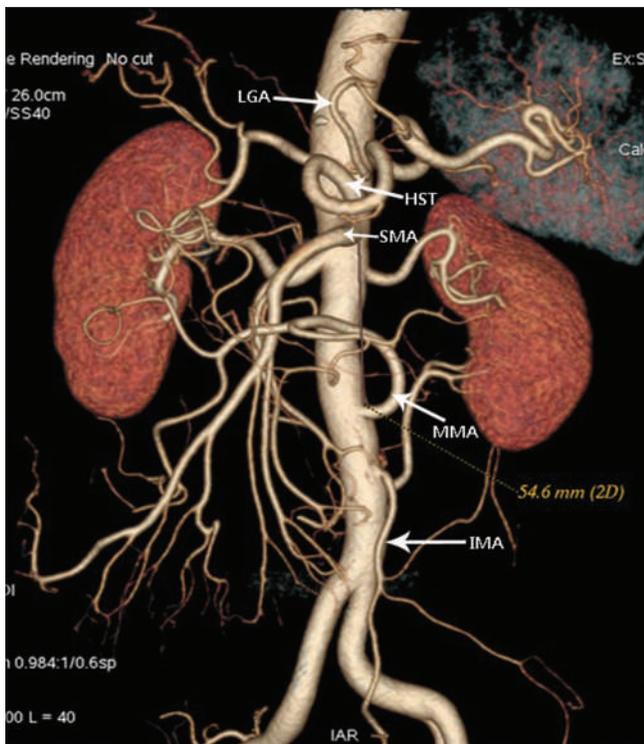

Figure 1: Volume rendered MDCT image showing origin of Middle Mesenteric Artery (MMA) from ventral aspect of abdominal aorta in between the origins of Superior Mesenteric (SMA) and Inferior Mesenteric arteries (IMA). Note the left gastric artery (LGA) arising directly from the aorta and presence of hepatosplenic trunk (HST). Observe the presence two left renal arteries one main and the other inferior polar. There is a single right renal artery

namely MCA, RCA, and ICA, arising from its right side were not present. Nonrotation gut was also noted with small bowel loops on the right and large bowel loops on the left side [Figure 3c]. The transverse colon extended obliquely downward from hepatic flexure which intervened between the right lobe of the liver and diaphragm. The patient exhibited Chilaiditi syndrome as a segment of the colon was seen intervening between the right lobe of the liver and diaphragm [Figure 3a]. Partial thrombosis of superior mesenteric and portal veins was seen. The presence of cholelithiasis was confirmed [Figure 3b]. Anomaly of celiac trunk was also observed in the form of hepatosplenic trunk and direct aortic origin of left gastric artery. Thus, there were five ventral branches arising from the abdominal aorta, left gastric artery, hepatosplenic trunk, SMA, MMA, and IMA [Figure 4].

Discussion

Infra-diaphragmatic parts of the gut derived from embryonic foregut, midgut, and hindgut are supplied by three ventral branches of AbA, namely the CA, SMA, and IMA, respectively. Of these three branches, the SMA is generally considered as an indispensable branch supplying loops of small intestine and major part of large intestine. Three colic branches, the middle, right and ileocolic from SMA supply midgut derived parts of the large intestine. In a recent meta-analysis involving 45 studies and 6090 specimens, Negoi *et al.* reported pooled prevalence of 94.6%, 60.1%, and 99.8% for MCA, RCA, and ICA, respectively, suggesting the rarity of their variations.[5] One of the rarest variation of colonic arterial supply is the presence of MMA, arising from the ventral aspect of AbA in between the origins of SMA and IMA, replacing one or all colic branches of SMA and IMA.
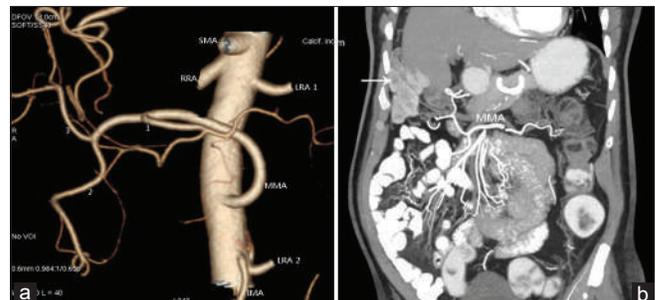
Figure 2: (a) VR image showing the branching pattern of middle mesenteric artery (MMA). For clarity other arteries and their branches were cropped. MMA is turning sharply to the right anterior to aorta and SMA and divides into left (1) and right branches. Right branch further divides into descending (2) and ascending (3) branches. MMA – Middle Mesenteric Artery; IMA- Inferior Mesenteric Artery; SMA- Superior Mesenteric Artery; LRA- Left Renal Artery; RRA- Right Renal Artery. (b) Coronal section showing Middle Mesenteric artery (MMA) branches. Note the presence of small bowel loops on the right and large bowel loops on the left. Also note the intervention of colon between the right lobe of liver and diaphragm (arrow) – Chilaiditi sign

Figure 3: (a) Axial sections showing a loop of large bowel (arrow) between right lobe of liver and the diaphragm. (b) Cholelithiasis is noted in gall b ladder (GB). (c) Coronal section showing non-rotation of gut

Figure 4: Sagittal scan showing 5 ventral branches arising from the abdominal aorta. 1 – Direct aortic origin of left gastric artery. 2- Hepatosplenic trunk -common origin of splenic and common hepatic arteries; 3- Superior mesenteric artery; 4- Middle mesenteric artery; 5- Inferior mesenteric artery

Our literature search has yielded 26 cases of MMA reported globally and ours is the 27th case and to the best of our knowledge, the first case to be reported from India. The general features of the MMA, the area of its distribution and associated abnormalities of the published cases are summarized in Table 1. Only the articles published in English and other language articles with English abstract were included in the table. There is a male preponderance (male 20: female 6) in the occurrence of this anomalous artery and gender was not mentioned in one report. Six cases were associated with abdominal aortic aneurysm, five cases with nonrotation of gut and three cases with the presence of celiaco-mesenteric trunk. In one case, the MMA gave origin to left testicular artery. In the present case, celiac trunk variant in the form of hepatosplenic trunk and direct aortic origin of left gastric was also observed.

Although Benton and Cotter[1] were the first to report this anomalous artery as duplicated IMA in 1963, a French article by Delannoy in 1923, describing a case of double SMA, one supplying jejunum and ileum and the second supplying right and transverse colon was quoted by Lawdahl and Keller, Kachlik *et al.*, Vandoni *et al.* and Dirrigl *et al.* as the first report.[4,6,18,19] In addition, Kachlik *et al.*[6] quoted three more French articles, Sato *et al.*[17] quoted two Japanese articles and Abe *et al.*[28] quoted one Japanese article, all reporting the presence of this anomalous artery.

Table 1: Reported cases of middle mesenteric artery

Author, year	Modality	Gender, age (years)	Nomenclature used	Distance from SMA (cm)	Distance from IMA (cm)	Structures supplied	Associated anomalies/ remarks
Benton and Cotter, 1963[1]	Cadaver	Male, 71	Duplication of inferior mesenteric			Transverse and proximal descending colon	
Lawdahl and Keller, 1987[4]	Angiography	Male, 70	Middle mesenteric artery			Splenic flexure	
LeQuire *et al.*, 1991[7]	Aortography	Male, 62	Middle mesenteric artery	11.0	4.0	Cecum, ascending and transverse colon	Splenic flexure hemorrhage
Yoshida *et al.*, 1993[8]	Arterio-graphy	Male, 49	Middle mesenteric (anomalous middle colic)	4.8	2.7	Transverse colon	Left renal tumor
Vahl *et al.*, 1997[9]	CT angio	Male, 75	Ileocolic artery from abdominal aorta			Ascending and transverse colon	Abdominal aortic aneurysm
Higashi and Hirai, 1998[10]	Cadaver	Female, 74	Second superior mesenteric artery			Cecum, ascending, transverse, proximal descending colon	Nonrotation of gut, Celiaco-mesenteric trunk
Koizumi *et al.*, 1999[11]	MDCT angio	Female, 55	Middle mesenteric artery	5.3	2.9	Cecum, ascending and transverse colon	
Uchida *et al.*, 2004[12]	Angiography CT	Male, 57	Middle mesenteric artery				Intestinal nonrotation, colon cancer
Skoulikaris *et al.*, 2005[13]	Angiography	Male, 70	Middle mesenteric artery			Proximal descending colon	
Woodfield and Torigian, 2006[14]	MDCT angio	Male, 72	Middle mesenteric	4.6	11.6	Distal small bowel, cecum, ascending colon, transverse colon, hepatic and splenic flexures	Abdominal aortic aneurysm, bowel nonrotation, three right renal arteries
Kawai *et al.*, 2006[15]	Cadaver	Female, 73	Middle mesenteric artery	4.7	3.3	Ascending colon, transverse colon	Nonrotation of gut
Falkensammer *et al.*, 2006[16]	CT angio angiography	Male, 81	Middle mesenteric artery			Cecum, ascending, transverse and descending colon	Abdominal aortic aneurysm, origin of IMA occluded
Sato *et al.*, 2007[17]	CT angio	Male, 66	Middle mesenteric artery		2.0	Transverse colon	Aortic aneurysm, celiacomesenteric trunk. Mobile cecum
Vandoni *et al.*, 2007[18]	Angiography	Male, 74	Middle mesenteric artery			Transverse colon, descending and sigmoid colon	Abdominal aortic aneurysm, occlusion of IMA
Kachlik *et al.*, 2009[6]	Cadaver	-	Middle mesenteric artery	5.0	2.0	Splenic flexure and descending colon	149 cadavers studied
Dirrigl *et al.*, 2009[19]	CT angio USG	Male, 69	Middle mesenteric artery	6.0	1.2	Distal jejunum, ileum, cecum, ascending, transverse and descending colon	Abdominal aortic aneurysm
Ulucam *et al.*, 2009[20]	Cadaver	Female, 32	Middle mesenteric artery (middle colic from aorta)	5.25	4.25	Transverse colon	
Naito *et al.*, 2011[21]	Cadaver	Male, 67	Middle mesenteric artery	3.0		Transverse and proximal descending colon	Gave origin to left testicular artery
Milnerowicz *et al.*, 2012[2]	Cadaveric arterio-graphy	Male, 55	Middle mesenteric (aberrant middle colic)			Transverse colon	Isolated transverse colon from 114 cadavers
Bryce *et al.*, 2013[22]	MDCT angio	Female, 30	Mesenteric anomaly			Ileum, cecum, ascending and transverse colon	
Abdel-Aal and Moustafa, 2015[23]	CT angio	Male, 51	Middle mesenteric artery	4.8	5.5	Ileum, cecum, ascending colon	Renal donor

Contd...

			Table 1: Contd...				
Author, year	Modality	Gender, age (years)	Nomenclature used	Distance from SMA (cm)	Distance from IMA (cm)	Structures supplied	Associated anomalies/ remarks
Ponti and Gailloud, 2016[24]	Spinal angiography	Male, 71	Right colic artery from abdominal aorta			Ascending colon, hepatic flexure	
Venieratos *et al*., 2018[3]	Cadaver	Male, 66	Middle mesenteric	3.3	3.8	Transverse colon, head of pancreas	
Manyama *et al*., 2019[25]	Cadaver	Female, 85			2.0	Ascending, transverse and descending colon	
Sheridan *et al*., 2022[26]	Cadaver	Male, 68	Middle mesenteric	1.0	0.5	Transverse colon, splenic flexure	Hepatogastrophrenic and celiacomesenteric trunks
Muraki *et al*., 2022[27]	Angiography 3-D CT	Male, 87	Middle mesenteric artery	7.2	1.2	Transverse colon and proximal descending colon	Hematoma, colonic ischemia and resection
Present study 2023	MDCT angio	Male, 63	Middle mesenteric artery	5.46	1.86	Terminal ileum, cecum, ascending, transverse and proximal descending colon	LGA from aorta and hepatosplenic trunk, nonrotation of gut

Abdominal aortic aneurysm: 6 cases, Nonrotation of gut: 5 cases, Celiacomesenteric trunk: 3, Variant celiac trunk: 1, Male: female: 20:6. Only articles published in English language and other language articles with English abstracts were included. CT: Computed tomography, MDCT: Multidetector CT, LGA: Left gastric artery, IMA: Inferior mesenteric artery, SMA: Superior mesenteric, USG: Ultrasound sonography
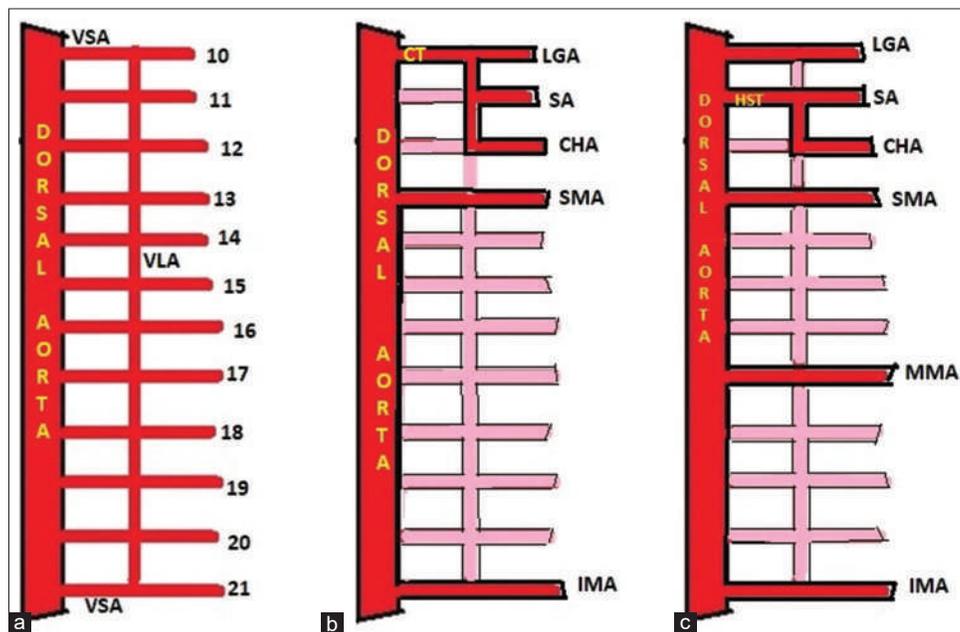
Figure 5: Development of celiac and mesenteric arteries from ventral splanchnic arteries (VSA). (a) A series of ventral splanchnic arteries (numbered 10-22) arise from dorsal aorta to supply the developing gut. These arteries are connected to each other by a Ventral longitudinal anastomosis (VLA). (b) Shows normal development. The 10th, 11th and 12th arteries with the regression of proximal parts of 11th and 12th contribute to the development of celiac trunk (CT) and its three branches left gastric (LGA), Splenic (SA) and Common hepatic (CHA). The 13th VSA develops into superior mesenteric (SMA) and 21st into inferior mesenteric artery (IMA). Normally the 14th to 20th VSA and VLA regress along with regression of VLA between 12th and 13th VSA. Parts which will undergo regression are shown in pink color. (c) Persistence of any one of the VSAs between 14th to 20th gives rise to Middle Mesenteric artery (MMA). Regression of VLA between 10th and 11th VSAs gives rise to direct aortic origin of left gastric artery (LGA). Persistence of proximal pat of 11th VSA forms the Hepatosplenic trunk (HST)

In a study of colonic arterial supply involving 149 cadavers, one case of MMA was observed supplying splenic flexure and proximal descending colon.[6] In another study of colonic arteriography of 114 cadaveric transverse colons, Milnerowicz *et al*. observed the presence of MMA supplying transverse colon.[2] Because of its infrarenal aortic origin, MMA is at a greater risk of occlusion and liable to damage during endovascular repair of abdominal aortic aneurysm. Wu *et al*. reporting an extremely rare variation of absence of SMA in an adult proposed a novel classification system for superior - IMA variations and suggested the existence of an aberrant MMA as Type IV.[29]

Embryology

During the early stages of the development, a series of ventral splanchnic arteries (VSA) originate from the dorsal aorta to supply the developing gut. Initially, dorsal aorta and the VSAs were paired vessels but later fuse to form unpaired vessels. These VSAs are interconnected to each other by a ventral longitudinal anastomosis (VLA) lying in front of dorsal aorta [Figure 5a]. The 10th, 11th, and 12th, ventral segmental arteries together with part of VLA develop into celiac trunk and its three branches [Figure 5b]. The proximal part of 11th and 12th VSAs from the dorsal aorta undergoes regression. The VLA between 12th and 13th VSAs regress and the 13th, VSA becomes the SMA. The 21st VSA becomes the IMA after the regression of VLA and 14th to 20th VSAs [Figure 5b]. Persistence of any one of the VSAs between the 14th and 20th leads to the development of a MMA [Figure 5c].

Normally, during the development, the U-shaped midgut loop herniates into umbilical coelom and remains as a physiological umbilical hernia outside the fetal body between 6th and 10th week undergoing first a 90° anticlockwise rotation and then a 180° anticlockwise rotation. Reduction of the hernia and return of the midgut loop into abdominal cavity occurs during the 11th week in an orderly manner such that caecum and colon are last to return. Nonrotation of the gut occurs due to failure of the second 180° rotation and return of colon first and small intestinal loops last resulting in colon occupying the left and the small bowel loops the right side of the abdomen.

Clinical importance and Conclusion

Thorough knowledge and complete familiarity of the occurrence of such rare vascular anomaly of presence of MMA will prevent its accidental ligature and subsequent infraction of the target organ. Because of its association with the abdominal aortic aneurysm, endovascular aneurysmal repair may result in occlusion of this anomalous vessel with a significant risk of bowel ischemia. Since lymphatic vessels draining a target organ generally follow the arteries and veins supplying that organ, precise presurgical mapping of the anomalous vessels will greatly help the oncosurgeon planning a locoregional lymph node clearance in cases of colonic cancer. Knowledge of possibility of presence of such anomalous vessel is important for anatomists, surgeons, surgical oncologists, radiologists, and interventional radiologists.

Conflicts of interest

There are no conflicts of interest.

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Articles in Journals

1. Standard journal article (for up to six authors): Parija S C, Ravinder PT, Shariff M. Detection of hydatid antigen in the fluid samples from hydatid cysts by co-agglutination. Trans. R.Soc. Trop. Med. Hyg.1996; 90:255–256.
2. Standard journal article (for more than six authors): List the first six contributors followed by *et al*.

Roddy P, Goiri J, Flevaud L, Palma PP, Morote S, Lima N. *et al*., Field Evaluation of a Rapid Immunochromatographic Assay for Detection of Trypanosoma cruzi Infection by Use of Whole Blood. J. Clin. Microbiol. 2008; 46: 2022-2027.

3. Volume with supplement: Otranto D, Capelli G, Genchi C: Changing distribution patterns of canine vector borne diseases in Italy: leishmaniosis vs. dirofilariosis.

Parasites & Vectors 2009; Suppl 1:S2.

Books and Other Monographs

1. Personal author(s): Parija SC. Textbook of Medical Parasitology. 3rd ed. All India Publishers and Distributors. 2008.
2. Editor(s), compiler(s) as author: Garcia LS, Filarial Nematodes In: Garcia LS (editor) Diagnostic Medical Parasitology ASM press Washington DC 2007: pp 319-356.
3. Chapter in a book: Nesheim M C. Ascariasis and human nutrition. In Ascariasis and its prevention and control, D. W. T. Crompton, M. C. Nesbemi, and Z. S. Pawlowski (eds.). Taylor and Francis,London, U.K.1989, pp. 87–100.

Electronic Sources as reference

Journal article on the Internet: Parija SC, Khairnar K. Detection of excretory *Entamoeba histolytica* DNA in the urine, and detection of *E. histolytica* DNA and lectin antigen in the liver abscess pus for the diagnosis of amoebic liver abscess. *BMC Microbiology* 2007, **7**:41. doi:10.1186/1471-2180-7-41. http://www.biomedcentral.com/1471-2180/7/41

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