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Quality Control in E-learning for Medical Education

E-learning has been a part of the education system for a long time. Massive open online courses with dedicated curriculum and learning modules have been quite effective and gained a lot of traction in various streams of education by giving flexibility of time and finances to learners and students. COVID-19 has changed the scenario drastically and brought mainstream medical education into the foray of e-learning, although the technology was being used in the form of offline e-learning (popular among medical students by way of sharing PDFs, learning resources, and so on) and online e-learning (popular for continuing professional development programs). There is a sudden need to teach undergraduate medical students remotely using various online platforms such as Zoom, WebEx, Google Meet, and Microsoft Teams. The usage of novel technology to enhance medical education has come to the forefront.[1] The quality of teaching and content needs to be much higher in online teaching when compared to that of face-to-face teaching, considering students are not in a controlled environment. This realm of teaching requires faculty to be more creative in maintaining and engaging students' interest in the subject and the concept of learning. The success of e-learning depends on it being "brain friendly", on engaging the learners from an understanding of how the cognitive system works.[2] To maintain this quality, one has to consider the following factors:

- Need for medical colleges to provide technology that enables the faculty to maintain the standards of teaching
- Sensitization of faculty and students toward the usage of the software (various platforms, learning management system [LMS]) which the college has provided
- Content of the lectures has to be created keeping in mind that we are not teaching in a physical classroom
- Content should help promote interactions among faculty and students (student engagement)
- Constant evaluation and assessment need to be done to positively impact and improve the ongoing classes
- Students should be provided access to digital library remotely and other e-resource material by way of LMS.

The focus should be on the curriculum design and planning of the teaching sessions rather than on the technologies themselves.[3] Adapting the principles of Kern's model of curriculum design for medical education toward the e-learning that we are employing could help yield more productive outcomes.[4] The six steps Kern's model are as follows:

Step 1: Problem Identification and General Needs Assessment

Identifying and categorizing competencies into higher-level and lower-level knowledge domains. Lower-level knowledge domain competencies could be taught using flipped classroom model by providing relevant study material pre-session instead of didactic mode (This is just an example to initiate other modes of teaching methods among both students and faculty). This increases student engagement and also will inculcate the concept of self-directed learning in students. This model also motivates students to spend more time in acquiring knowledge outside of a formal class.[5]

Step 2: Targeted Needs Assessment

Identifying students' baseline knowledge will optimize the design, planning, and delivery of the lectures. This step will help us in including all levels of learners, and slow learners would not feel left out. This could be done by taking presession polls and surveys. This also shifts onus onto students, as they identify their own levels.

Step 3: Goals and Objectives

End of session goals should be crisp and clear so that students follow the flow of the lecture.

Step 4: Educational Strategies

Extrapolating from Step 1, students should be encouraged to speak up during the session, this could be by predeciding the speakers or randomly picking volunteers during the session. Positive reinforcement should be the mantra rather than negative reinforcement. Breakout room sessions followed by plenary could also be employed in short bursts for discussions to improve student engagement.

Step 5: Implementation

Instead of only an audio lecture, mitigating it with video of the faculty by switching on the web camera would give a sense of connection to the students. Pausing in between the lecture and giving students time to post doubts through audio or chat box will keep them engaged and breaks the monotony of the lecture.

Step 6: Assessment, Evaluation, and Feedback

Assessment of students can be done using polling and quiz features which are inbuilt in the conferencing platform itself. Evaluation and feedback forms may be designed using Google Forms and sent to students to evaluate the effectiveness of the session also get feedback from students which forms a base to improve the quality of the lectures. The forms should be designed to be anonymous to encourage constructive criticism.

The six steps listed above are nonlinear and interdependent, principles of each step are dependent on one another to

achieve an effective outcome and they should not be treated as independent entities. The National Medical council (NMC) in coordination with nodal centers of medical education units (MEU) should issue guidelines for online teaching to maintain uniformity and quality of the content. This will also decrease ambiguity of e-learning among all the stakeholders (faculty, students, and parents). Strictly speaking, the teaching that we are perceiving as "online" or "e-learning" in fact, may be termed as "remote teaching" by the assistance of technology.

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Original Article

Anatomical Considerations Regarding the Posterior Interosseous Nerve for Surgical Approaches in the Proximal Forearm: A Cadaveric Study

Abstract

Introduction: The posterior interosseous nerve (PIN) is at risk of injury when surgical procedures are undertaken in the proximal forearm. The aim of the present study was to determine the relationship of the PIN to adjacent anatomical landmarks, which can be used to prevent iatrogenic injury to the nerve. **Material and Methods:** Forty upper extremities were used for this study. The landmarks used to measure the required parameters were intercondylar reference point, styloid process of ulna, proximal and distal borders of superficial layer of supinator muscle, and head of radius. The number of trunks of PIN and the innervation pattern of supinator muscle were studied. **Results:** The mean values and standard deviations of the measurements obtained were determined. There was no statistical difference of data between right and left sides. **Discussion and Conclusion:** The data obtained in the study will be of use to surgeons and orthopedicians during interventional procedures on the proximal part of radius and in decompression procedures of the PIN.

Keywords: *Arcade of Frohse, radius, supinator*

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Introduction

The posterior interosseous nerve (PIN) is vulnerable to injury during surgical exposures of the radial head and neck, due to the closeness of the nerve to the proximal radius and the absence of clear intermuscular planes.[1-3] Moreover, the use of retractors to allow adequate exposure of the radial head and neck could lead to compression or traction injuries of the PIN.[4]

Extensive exposure of the proximal radius is required in cases of fractures of the proximal radius, trauma, and in certain conditions of the elbow.[5] Incisions in radial head fractures are placed over the radial head and knowledge of the relationship of the PIN to the radial head is important in such cases. In addition, decompression procedures undertaken for PIN in cases of its entrapment require the exact localization of PIN.[6,7]

The radial nerve passes from the posterior to the anterior compartment, after piercing the lateral intermuscular septum in the lateral part of the distal arm. Here, it divides into its two terminal divisions-the superficial branch and the deep branch or the PIN. The PIN descends, passing over the anterior aspect of the elbow joint, and travels deep to the proximal border of the superficial layer of supinator muscle (arcade of Frohse). It passes between the superficial and deep layers of the supinator and after exiting from the supinator muscle gives branches to the muscles of the extensor compartment of the forearm. It travels posterior to the interosseous membrane and anterior to the extensor pollicis longus muscle onto the dorsum of the carpus, where it sends filaments to the ligaments and articulations of the dorsal carpus.[8]

The aim of the present study was to determine the distances of the PIN to certain adjacent landmarks that can be used intraoperatively to locate the nerve and prevent iatrogenic injury during the proximal dissection of the radius. The pattern of innervation of supinator was studied, as it is essential for effective regional anesthetic block and for harvesting the motor branches for nerve transfer procedures.

Material and Methods

The study was an observational type of study, and the duration of the study was

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2 years. Forty embalmed upper limbs belonging to 28 male and 12 female adult cadavers were dissected. The age at death ranged from 40 to 90 years (mean 74.5 years). All the upper limbs were scar free and had no signs of trauma or deformities. Limbs were maintained in a midprone position during dissection. The study was conducted after the approval from the Institutional Review Board.

A vertical incision was made extending 5 cm proximal to the interepicondylar line to the wrist. A fasciocutaneous flap was removed from the lower third of the arm to the middle of the forearm. The radial nerve and its main branches were dissected from the lateral intermuscular septum of arm to the distal arcade of the supinator muscle. The lateral epicondylar muscles were identified. The proximal and distal borders of the superficial layer of supinator were defined, and the PIN was dissected out carefully. All measurements were made with a measuring tape. Measurements included distances from the interepicondylar reference point and styloid process of ulna to exit of PIN from supinator, and distance from the origin of PIN to proximal border of the superficial layer of supinator (arcade of Frohse). The length of the forearm and the distance from the lateral epicondyle to the entry of PIN at the arcade of Frohse were determined.

Other measurements included the distances from the radial head to the entry and exit of PIN from supinator and the distances from the radial head to the proximal and distal borders of superficial layer of supinator. In addition, the number of trunks of PIN, length of PIN within supinator, and the branches to supinator were delineated.

Data were expressed as mean ąnd standard deviation. The data were analyzed by using paired *t*-test. SPSS, version 16.0 software was used IBM Corp. Newyork, USA.

Results

The PIN was consistently identified in all 40 embalmed cadaveric forearms. The distances of the PIN from important adjacent anatomic landmarks like midpoint of interepicondylar line (interepicondylar reference point), ulnar styloid process, radial head, and proximal border of superficial layer of supinator (arcade of Frohse) are shown in Table 1.

The radial head can be easily identified, as it moves during pronation and supination of the forearm. Distances from the radial head to the proximal and distal borders of the superficial layer of supinator offers surgeons a consistent method of predicting the borders preoperatively before making incisions to relieve compression in cases of PIN entrapment [Table 1 and Figure 1]. There was no statistically significant difference between the sides.

The distance between the tip of lateral epicondyle and proximal border of superficial layer of supinator muscle (distance AF) and the mean forearm length are shown in Table 2.

The "ratio AF" was found by dividing the distance AF by the forearm length (ratio AF = distance AF/forearm length). Then, the mean value of the ratio AF was calculated. The mean ratio AF may be used to predict the distance AF of any upper extremity with a known forearm length. Thus, the predicted distance AF of any upper extremity may be found by multiplying its forearm length by the mean ratio AF (predicted distance AF = measured forearm length x mean ratio AF).

The PIN entered most commonly as a double trunk [Figure 2]. Nine of the PIN dissected entered the supinator muscle as a single trunk (22.5%) and 31 entered as a double trunk (77.5%) [Table 2]. The course of the PIN and whether the nerve supplied branches to supinator before entering the muscle or after it entered the muscle interstice were observed and shown in Table 3.

The length of PIN within supinator was found to be 48.35 ± 9.37 mm. The average number of total branches supplying supinator was found to be 6.65 ± 1.03, the number of radial branches being 3.30 ± 1.34 and the number of ulnar branches being 3.35 ± 1.46. The type of exit of PIN – whether proximal to the distal border [Figure 3] or at the distal border of supinator are shown in Table 4.

Discussion

There are many studies describing the course and branches of the PIN to the muscles of the forearm.[9-11] Palsies of the PIN can develop after an unreduced radial head dislocation, associated with proximal ulnar fractures, and with anterolateral dislocations of the radial head.[12] Injury to the PIN is a major potential complication of surgery involving the proximal radius.[1,5] The posterolateral or Kocher approach, (Kocher, 1911), and the Thompson approach, are

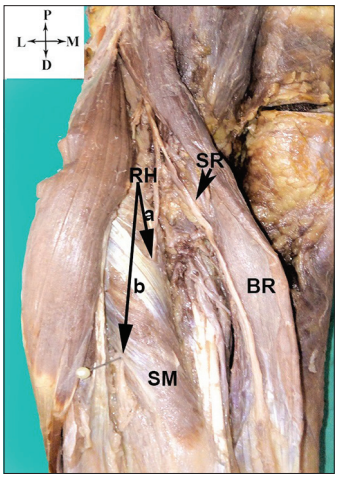

Figure 1: Radial head and arcades of superficial layer of supinator muscle. (a) Distance between head of radius and proximal border of superficial layer of supinator muscle (b) Distance between head of radius and distal border of superficial layer of supinator muscle. RH: Radial head, SM: Supinator muscle, SR: Superficial branch of radial nerve, BR: Brachioradialis

Table 1: Parameters measured in the study in relation to the posterior interosseous nerve

Parameter	Mean±SD (mm)	Range (mm)
Distance from interepicondylar reference point to exit of PIN from supinator	88.87±11.98	67-109
Distance between styloid process of the ulna and exit of PIN from supinator	177.30±15.27	154-205
Distance between origin of PIN and proximal border of superficial layer of supinator (arcade of Frohse)	31.75±16.59	−25-50
Distance between PIN entry at proximal border of superficial layer of supinator (arcade of Frohse) and radial head	25.25±5.91	11-37
Distance between PIN exit point from supinator and radial head	69.45±8.86	47-85
Distance between radial head and proximal border of superficial layer of supinator (arcade of Frohse)	25.17±6.50	12-37
Distance between radial head and distal border of superficial layer of supinator	83.87±9.87	59-100

(-): Proximal to interepicondylar line. PIN: Posterior interosseous nerve, SD: Standard deviation

Table 2: Forearm length and distance AF

Parameter	Mean distance±SD (mm)		
	Total	Males	Females
Distance between the tip of lateral epicondyle and proximal border of superficial layer of supinator muscle (distance AF)	59.60±8.49 (50-74)	61±10.08	56.3±9.26
Forearm length	258.12±19.63	265.3±17.4	241.25±13.36
Ratio AF (distance AF/forearm length)	0.23±0.031	0.22±0.04	0.22±0.03

SD: Standard deviation, AF: Arcade of Frohse

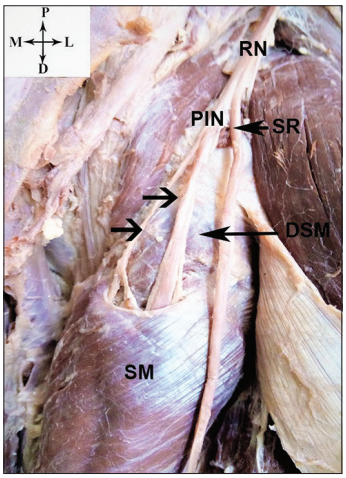

Figure 2: Double trunks of posterior interosseous nerve. RN: Radial nerve, PIN: Posterior interosseous nerve, SM: Supinator muscle, SR: Superficial branch of radial nerve, DSM: Deep layer of the supinator muscle. Double trunks of PIN (arrows)

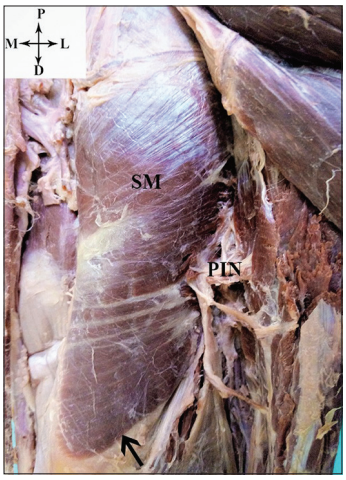

Figure 3: Posterior interosseous nerve exiting proximal to the distal border of superficial layer of supinator muscle. PIN: Posterior interosseous nerve, SM: Supinator muscle. Distal border of superficial layer of the supinator muscle (arrow)

two approaches used by surgeons for the proximal radius but these interventions seem to place the PIN at risk of injury.[5,13] In addition, repair undertaken for the rupture of the distal biceps tendon can jeopardise the safety of the PIN.[14,15] Injury to the PIN is a known complication in elbow arthroscopy.[16-18] Hence, it is imperative to visualize and protect the PIN while performing surgical interventions on the proximal radius.[1]

Other causes of paralysis of PIN include neuromas,[19] schwannomas,[20] traumatic aneurysms of the posterior interosseous artery,[21] neurofibromas,[22] and ganglion cysts.[23] Understanding the anatomical relationship between the supinator muscle and the PIN is important to limit the surgical morbidity when interventions are undertaken in that area.[2]

Comparison between studies to locate the PIN intraoperatively using certain anatomic landmarks is shown in Table 5.

Calfee *et al*.[1] found the PIN crossed the radius at a mean of 4.2 cm (range, 2.5 to 6.2 cm) distal to the radiocapitellar joint in neutral rotation. During pronation, the distance increased to 5.6 cm (range, 3.1–7.4 cm) ($P < 0.01$) and in supination, the distance decreased to 3.2 cm (range, 1.7–4.5 cm) ($P < 0.01$).

Table 3: Trunks of posterior interosseous nerve and pattern of innervation of supinator muscle

Parameter	Total, *n* (%)	Right, *n* (%)	Left, *n* (%)
Single trunk	9 (22.5)	7 (35)	2 (10)
Double trunk	31 (77.5)	13 (65)	18 (90)
PIN supplied supinator before entry into the muscle	12 (30)	4 (20)	8 (40)
PIN supplied supinator as it travelled between its superficial and deep layers	28 (70)	16 (28)	12 (60)

PIN: Posterior interosseous nerve

Table 4: Type of exit of posterior interosseous nerve from supinator

Parameter	Total, *n* (%)	Right, *n* (%)	Left, *n* (%)
PIN exited proximal to the distal border of the superficial layer of supinator	37 (92.5)	18 (90)	19 (95)
PIN exited at the distal border of the superficial layer of supinator	3 (7.5)	2 (10)	1 (5)

PIN: Posterior interosseous nerve

Table 5: Studies showing the distances between the posterior interosseous nerve and adjacent landmarks (mm)

	Duquin *et al*.[24]	**Present study (2018)**
Distance from interepicondylar reference point to exit of PIN from supinator	90.21±15.61	88.87±11.98
	Thomas *et al*.[2]	**Present study (2018)**
Distance between PIN and proximal border of superficial layer of supinator (arcade of frohse)	36±7	31.75±16.59
	Tubbs *et al*.[25]	**Present study (2018)**
Distance between ulnar styloid process and exit of PIN from supinator	180	177.30±15.27
	Hazani *et al*.[6]	**Present study (2018)**
Distance between PIN entry at the proximal border of superficial layer of supinator (arcade of frohse) and radial head	35	25.25±5.91
Distance between PIN exit point from supinator and radial head	74±4	69.45±8.86

PIN: Posterior interosseous nerve

In another study, Hohenberger *et al*.[26] studied the distance between the tip of the radial head and the PIN's exit point from the supinator during maximum supination and pronation. It was found that the distance was significantly shorter during supination in comparison to pronation. With the lateral approach to the proximal radius, the distance was found to be 60.3 mm during supination and 62.7 mm in pronation ($P < 0.001$). In the dorsal approach, the distance was 60.2 mm during supination and 62.9 mm in pronation ($P < 0.001$). In the present study, the distance between the tip of the radial head and the PIN's exit point from the supinator in the midprone position of the forearm was found to be 69.45 ± 8.86 mm. Hence, supination should be avoided during the lateral and dorsal approaches to the proximal radius to protect the PIN.

High-resolution ultrasound can help in the rapid assessment of the nerve in cases of posttraumatic radial nerve or PIN palsy. The affected segment of the nerve is identified by decreased echogenicity, change in caliber, or loss of continuity of the nerve. Magnetic resonance imaging helps in identifying soft-tissue details and in characterizing the lesion.[27]

Knowledge of the trunks of PIN and branches of PIN as it passes through the supinator muscle may be useful to neurosurgeons during decompressive or neurotisation procedures. Seradge *et al*.[28] have reported a case in which the PIN split, with half of the fibers exiting at the distal border of the supinator and the other half exiting proximal to the distal border. If the PIN entered the supinator as two trunks, or branched and exited as two, both have to be decompressed for complete relief of symptoms.

Tubbs *et al*.[29] conducted a study on the branching pattern of PIN to supinator in 52 cadaveric upper extremities and their findings are compared with those of the present study [Table 6].

Abrams *et al*.[30] found a mean of 3.9 ± 1.4 branches to the supinator in a study of 20 cadavers, which is similar to the present findings.

The number of trunks of PIN, its length within the supinator, branches to that muscle and exit of PIN is important to the anesthetist, while performing a regional block of PIN for doing surgical exploration in the region of the supinator muscle.[30]

The function of the hand is impaired in lesions of the lower brachial plexus. In C7 – T1 injuries, there is the absence of finger flexion and intrinsic muscle control, as well as thumb and finger extension.[31] Since the supinator is innervated by the upper roots of the brachial plexus, it is unaffected in lower brachial plexus palsy.[30-32] The motor branches supplying supinator muscle could be transferred

Table 6: Posterior interosseous nerve and the supinator muscle

	Tubbs *et al.*[29]	Present study (2018)
PIN entered supinator as single trunk	29	9
PIN entered supinator as double trunks	23	31
Distance between division of the radial nerve and proximal border of superficial layer of supinator (cm)	2.2	3.1
Length of PIN within supinator (cm)	4	4.8
Average number of branches of PIN to the supinator	2.5	6.65
PIN exited proximal to the distal border of supinator	10	37
PIN exited at the distal border of supinator	42	3

PIN: Posterior interosseous nerve

directly to the PIN, without using a nerve graft, resulting in a fair return of finger and thumb extension.[31]

Conclusion

The findings in the present study have documented many potentially useful anatomic landmarks for locating the PIN that can be used intraoperatively during the surgical management of fractures of the proximal radius to avoid iatrogenic injuries. Decompressive procedures undertaken for entrapment neuropathies require intimate knowledge of PIN anatomy. In addition, the findings on the branching pattern of PIN to supinator muscle may be useful when considering transfer of these branches to PIN for restoration of hand function.

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Original Article

A New Method in Anatomical Education of Medical Faculty: Storytelling

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Abstract

Introduction: The difficulty to learn anatomy makes it crucial to find the best way to effectively transfer the anatomic knowledge from educators to students. Stories can be used as an advantageous tool, which makes information more rememberable by stimulating cognitive behavior. **Material and Methods:** In order to determine the efficiency of the storytelling technique on the effects of grade point average in the anatomy session, stories were told to term II medical students (n = 132) at the end of the theoretical neurological lesson. A questionnaire with 12 questions was distributed to the students belonging to the pilot study. Grade point average, as well as gender and age (mean: 19.95 ± 0.995) of the students was the other parameters. **Results:** More than 90% of the students agreed that storytelling helps them to understand the subject and more than 70% of the students agreed that storytelling helps them to gather their attention. Furthermore, the statistical comparison with the previous 2 years demonstrated that the grade point average of the storytelling years was higher than the others. **Discussion and Conclusion:** Therefore, we believe that incorporating a storytelling learning style into the traditional anatomy curriculum, will be advantageous for education and will have a positive effect on the grade average. If we are able to revive the story in the minds of the students, we think that the lessons will be more permanent in their memory.

Keywords: *Anatomy, medical education, storytelling*

Introduction

Anatomy is a primordial education for medical schools, as it is accepted as a core course for all other subsequent medical courses. Hence, the anatomy curriculum is usually taught as a combination of theoretical courses and laboratory sessions. As the part of understanding anatomy, appreciation of the architecture of the human body, interpretation of clinical images, effective physical examination; topography of the organs and its variations are indispensable topics of knowledge for the medical student. Due to the large volume of participants presented in anatomy courses as well as due to the utilization of Latin terminology during teaching, students usually adopt a strategy of superficial learning. Superficial learning strategies negatively impact the retention of anatomic knowledge and usually much of the anatomic knowledge is not retained after the examinations. In fact, it is known in the literature that 25% of the knowledge can be lost after only 1 year.[1,2] "Therefore, evaluation of knowledge retention could elucidate the most effective methods of teaching basic sciences such as anatomy to ultimately increase the clinical acumen."[3]

The successful anatomy course contributes to a successful achievement of academic learning, as it constitutes the infrastructure of the other courses in medical sciences. Hence, anatomy education is usually a combination of theoretical lectures and dissection sessions. When we consider the difficulty of learning anatomy, it will be important to find the best way to transfer effectively the knowledge from the educators to students. Preservation of knowledge depends on intelligence as well as on learning strategies. Different approaches to teaching anatomy are being used around the world, but the best way would be to implement a technique that allows longer retention of the knowledge in the student's mind. In this sense, stories are advantageous tools, which use both visual and auditory learning styles. Thus, it can be said that stories can stimulate cognitive behavior. According to Uri Hasson, a story is the only way to activate the certain parts of the brain and thus it makes information more rememberable, because it has the effect that listeners plant the ideas

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presented in the stories into their minds, and hence, they involve the story in their life experience.[4,5] Unfortunately, storytelling is not yet a method which is frequently used in medical schools. By referring to the literature, storytelling reflects the teacher's enthusiasm and evokes interest in the subject by the students who implement the story in their lives. Furthermore, as the chosen subject becomes more meaningful, storytelling can be an important way to improve satisfaction and to reflect learning in students.[6]

Therefore, it seems that combining multiple pedagogical techniques which complement each other can be beneficial in teaching modern anatomy.[7] Furthermore, we think that storytelling will be more permanent as it affects the cognitive features of the brain. Teaching the anatomy course by incorporating it to their daily life could also stimulate an empathic response in students. In this context, hypothesis was that if storytelling is more rememberable and can also activate the brain, then it may also increase the performance of the students during examinations [Figure 1]. Hence, to improve the understanding of the anatomy lesson, we aim to determine the efficiency of the storytelling both in the satisfaction of the medical students and also in their grade point average as an academic success indicator.

Material and Methods

This study was approved by the Deanery of the Faculty of Medicine of the University. The participants of the study were Term II students of Medical faculty. Sixty-six girls (50%) and 66 boys (50%) participated in the questionnaire. The mean age of the students was 19.95 ± 0.995 [Table 1].

The storytelling technique was used at the end of the lessons of the Neurological System Committee to the term 2 students belonging to the Faculty of Medicine. Stories were prepared by faculty members and researchers of the Department of Anatomy. Participants were repeated with storytelling technique after the theoretical course. The Evaluation of Storytelling Agreement Scale Questionnaire for Learning Anatomy was applied to determine the effectiveness of the technique as well as the satisfaction level of the students. The questionnaire consisted of 12 Likert type questions with an agreement scale between 1 and 5 [Table 2]. The scale score of 1 signified disagreement with the statement and 5 signified complete agreement with the statement. Furthermore, in order to understand and highlight the personal idea of the students, an open-ended question was also included in the questionnaire. In addition, to determine the effect of the storytelling in the grade average of students, neuroanatomy examinations score of 3 consecutive education years of term 2 students was compared. The collected data were analyzed under the IBM SPSS 22.00 Statistical Package (IBM SPSS Statistic for Windows 22.00, NY, USA) software. The descriptive statistics of the collected data were evaluated. Chi-square and Spearman correlation test were used to assess whether there was a relationship among gender and age with agreement score of the questionnaire. Hence, statistical analyses of the agreement score demonstrated that there was no statistical difference between agreement score related to gender and age ($P > 0.05$). Mann–Whitney U-test was used to analyze the term 2 students' grade average belonging to the academic years of 2015–2016, 2016–2017 without applying storytelling and the term 2 students of the academic year 2017–2018 where storytelling was applied.

Results

The statistical analyses of the agreement score with gender and age of the term 2 students demonstrated that there was no statistical difference between agreement score relation to gender and age ($P > 0.05$).

The distribution of the agreement score percentages is described in Table 2. The table demonstrates clearly a high percentage of students who were strongly in agreement or have completely agreed with the storytelling technique. More than 90% (Q7) of the students strongly or completely agreed with the fact that visual components increase the efficiency of the storytelling and it helps them in understanding the anatomy topics. Once more, 90% (Q11) of the students strongly or completely agreed that storytelling was helpful to understand the lectures related to classical theoretical anatomy lesson. Furthermore, more than 70% (Q4, Q5) of the students strongly or completely agreed with the fact that storytelling helps them to gather their interest and attention regarding the lesson and leads

Table 1: Statistical analysis of the agreement score with gender and age of the term 2 students

Term II students	Mean values/ number	Agreement score	*P*
Gender	66 males	49.64±7.024	0.147
	66 females	51.73±6.024	
Age	19.95±0.995	50.68±6.602	0.861
			cc=−0.016

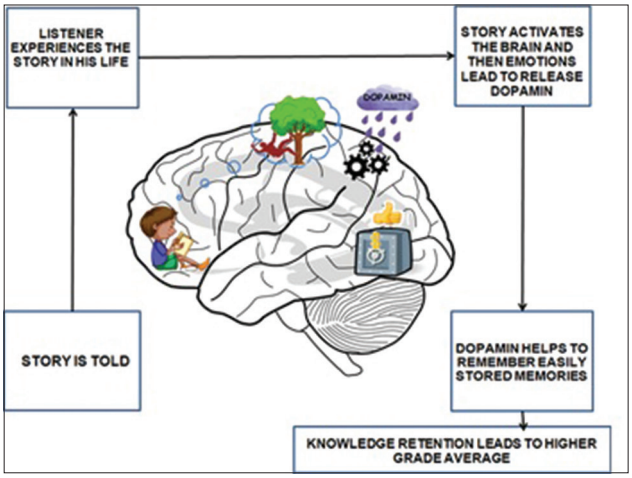

Figure 1: Effect of the storytelling on the stored memories

them to listen to the lessons until the end. Furthermore, more than 70% (Q12) of the students did not agree with the idea that storytelling lowers the value of the anatomy lesson. The most commonly encountered answer of the open-ended question was that the storytelling technique needs to be applied to other wide curriculum lessons as well as like histology and embryology.

Table 3 represents the mean grade average of term 2 students belonging to academic years of 2015–2016 and 2016–2017 (the periods where storytelling techniques were not applied) and also the term 2 students of 2017–2018 academic year (where storytelling was applied). No statistical difference was found between the academic periods of 2015–2016 and 2016–2017 (P = 0.779) where storytelling was not applied during their anatomy education. However, a statistically significant difference was found between the grade average of the term 2 students with storytelling compared to other groups without storytelling (P = 0.026; P = 0.017).

Discussion

The preparation of our stories was especially based on the special anatomical topics that cannot remain in the mind or be easily recalled with the traditional teaching methods. The teaching topics were chosen from daily life with a funny story to capture the students' attention. According to Neuhauser, as the stories become more rememberable, funny and believable, then they could be more effective as educational tools for teachers.[4] The believability is related to the fact that stories are involved in real-life human life experiences. Stories make information more rememberable because they get us involved in the actions and intentions of the characters. Creating a story based on the anatomical lesson related to human life could stimulate the empathic response of the students. Particularly, the specific situations, the small details, the vivid images of human experience enhance the capability to memorize and to recall the information more easily. Therefore, educational programs that focus on the diversity and the capacity for perspective could benefit from this technique.[8]

As anatomy is a critical course for doctors to practice medicine safely, anatomy courses need to be attractive and rememberable. In a study conducted to facilitate the comprehension of the anatomy, a different teaching approach has been applied to 1st-year medical students by anatomy teachers. They applied simultaneous sketch drawing, as an interactive learning technique. As a result, more than 80% of the students agreed with the fact that learning anatomy concepts with this method is simpler. They preferred to attend these anatomical classes and found that this class was less boring as compared to classical teaching. These students also found that sketching

Table 2: Evaluation of storytelling agreement scale questionnaire for learning anatomy

Agreement score	Disagree (%)	Slightly agree (%)	Moderately agree (%)	Strongly agree (%)	Completely agree (%)
	1	2	3	4	5
Q1: Storytelling is a good teaching method	0	0	10.6	40.2	49.2
Q2: Storytelling is helpful to explain the anatomy topics	0	1.5	11.4	37.9	49.2
Q3: Storytelling technique is helpful for understanding the subject	0	2.3	6.8	40.2	50.8
Q4: Storytelling technique helps to listen until the end of the lesson	0.8	3	18.2	27.3	50.8
Q5: Storytelling technique attracts my interest and helps me to gather attention more easily	0.8	3	16.7	26.5	53
Q6: Listening to the lesson described by storytelling technique is more effective than reading the book	1.5	8.3	22	30.3	37.1
Q7: Storytelling technique can be more effective if it is supported by visual items	0	1.5	3.8	18.2	76.5
Q8: Telling lessons by the classical theoretical method is more effective than storytelling technique	26.5	31.8	22.7	9.8	7.6
Q9: Storytelling technique accelerates the anatomy learning process	0	3	18.2	40.9	37.9
Q10: Storytelling technique gives me a new perspective on how to study	2.3	9.8	24.2	27.3	34.1
Q11: Storytelling technique supports by classical theoretical method	0.8	1.5	6.8	31.1	59.1
Q12: Storytelling technique decreases the value of the lesson	73.5	15.9	1.5	1.5	7.6

I think that storytelling the lesson is

Table 3: Comparison of the grade average of the neuroanatomy examination scores among 3 consecutive years

Education years	Grade average (n=132), mean±SD	2015-2016 (P)	2016-2017 (P)
2015-2016 (without storytelling)	58.23±25.589	-	0.779
2016-2017 (without storytelling)	57.18±27.164	0.779	-
2017-2018 (with storytelling)	62.06±30.06	0.026	0.017

SD: Standard deviation

was a good method for learning anatomy in-depth. Also, more than 60% of the students agreed with the idea that sketching anatomical figures simultaneously with the professor helped them to learn anatomical concepts more easily. They also found that sketching makes anatomy more attractive as a subject and thus it has reduced the time for learning.[9] Similar to this study, when the agreement scale was analyzed, it was observed that more than 90% [Table 3, Q7] of the students strongly or completely agreed with the fact that visual components increase the efficiency of the storytelling and they help them to understand their anatomy course. Once more, 90% [Table 3, Q11] of the students strongly or completely agreed that storytelling was helpful for understanding the anatomy lectures. Furthermore, more than 70% [Table 3, Q4-Q5] of the students strongly or completely agreed with the fact that storytelling helps them to gather their interest and attention about the lesson and leads them to listen to the lessons until the end. Furthermore, more than 70% [Table 3, Q12] of the students did not agree with the idea that storytelling lowers the value of the anatomy lesson. The most commonly encountered answer to the open-ended question was that the storytelling technique needs to be applied to other wide curriculum lessons such as histology and embryology. In addition, gender and age of students were the other parameters which were analyzed statistically [Table 1]. The answers' scale score of the questionnaire was analyzed with the agreement score. The fact that there was no statistically significant correlation between these data ($P > 0.05$) showed that the gender or the age of the student did not influence the anatomical storytelling technique; thus all the students were satisfied with this new educational technique. Furthermore, the grade average of the term II students (2017–2018 education year) with storytelling was higher than term II students of previous years without storytelling. In this context, storytelling can make the subject more rememberable, as it activates the parts of brain and involves the subject in the life of students. Hence, this can increase the knowledge retention and therefore can lead to a higher-grade point average. In another study, Kieser *et al*. used spontaneous storytelling in problem-based learning in clinical anatomy teaching in half of the 3rd-year dentistry class. For the purposes of the study, they explained the chosen lesson in two ways. One group was lectured by the storytelling method and the other group was taught with the classical theoretical method. They encountered positive feedback, as the satisfaction was higher with students "with stories" than those "without stories." They define that "factor analysis provides evidence that storytelling nurtures reflective learning, while students work on their clinical anatomy problems."[6]

Another method used to teach anatomy is the utilization of interactive computer programs. Interactive computer programs have been designed to allow the student to learn anatomy independently, but we thought that the cooperation of the teacher to teach anatomy using interactive methods will enhance the learning ability of the students. A study was attempted to define the best way to teach anatomy to medical students and they determined as a result that cadaver dissection accompanied by three-dimensional (3D) computerized programs was the best way to teach anatomy. Hereby, only the 3D computerized program alone was not enough to understand the anatomy. They stated that the imaging structures cannot fully replace the concept of direct contact with tissues and other anatomical elements and they suggested to involve the best association teaching models as a complement of each other.[10] It is accepted that conducting a dissection in a laboratory environment involves active student participation, and thus represents the main means of highlighting the anatomical formations. But the dissection activity cannot always be conducted by all the students at the same time considering the high number of medical students. For this reason, we suggest applying the storytelling technique during theoretical lessons to a large group of students at the same time and to subsequently consolidate the lesson with dissection. Moreover, it will be possible to improve students' active participation in storytelling during anatomical lessons.

To improve anatomy learning, several teaching methods have been used by different faculty. For example, McMenamin incorporated the painting technique during teaching anatomy. By painting the body with nontoxic paints, the researcher integrated clinical skills with the teaching sessions, which included clinically important aspects of the musculoskeletal system, the respiratory system, the head and the neck. They stated that adding body painting as a tool in clinical anatomy teaching will consolidate the surface anatomy and clinical skills teaching.[11] Another different technique to teach anatomy is the peer-teaching method. Peer teaching is the way to transfer some basic lecture from senior students to classmates or underclassmen, in other words, some students take on a teaching role to share their knowledge with other students. The peer teachers and all other students in class start their learning course from the beginning in accordance with their capabilities and provide cognitive harmony. Cognitive harmony allows more appropriate level explanations during teaching. Furthermore, peer teachers have the opportunity to enhance their communication skills and their public speaking abilities.[12] Therefore, peer-teaching was described as a useful program and students defined that it fulfills their aims of providing an effective environment for developing deeper learning in anatomy.[13,14] Furthermore, incorporating the peer teaching in the classical anatomy curriculum can provide an effective method for a perfect anatomy teaching.[15] In future, it will be useful to apply the storytelling method by peer-teaching in anatomy education.

Conclusion

Multiple teaching techniques have been used in medical schools to promote a deep knowledge of anatomy and to

improve understanding of the subject. The chosen teaching approach needs to help the anatomy teachers to constitute an adequate curriculum with their students and also the approach needs to be suitable for students. Therefore, incorporating anatomy storytelling technique into the traditional anatomy curriculum will be advantageous for anatomy education and it will enhance the fundamental knowledge which needs to be recalled throughout the educational and professional life of the student. In addition, storytelling enhances knowledge retention which leads to a higher-grade average. Furthermore, completing the storytelling with visual effects will be more efficacious for teaching anatomy.

Story example 1: Thalamus

The Thalamus Wedding Salon consists of three main divisions. A long corridor named internal medullary lamina, splits the salon into the anterior, medial and lateral compartments. In the middle of the Thalamus Salon, there is a pillar called interthalamic adhesion that connects the right and left Thalamic Salon. In the anterior part of the Thalamus Wedding Salon there are 3 tables named anterodorsal (where the groom is sitting), anteromedial (where the bride is sitting) and anteroventral (where the mother-in-law is sitting) nuclei. As the mother-in-law is sitting on the anterior part of the Thalamus Wedding Salon, spontaneous attention and memory recognition functions are very active in this part (She can remember who brought which present). While the bride spreads both the sense of fear (due to the mother-in-law) and joy (due to her spouse), the groom spreads the sense of excitement. If an incident damages the mother-in-law, then Amnesia will occur in the anterior part of the Thalamus Wedding Salon.…

Story example 2: Median nerve versus ulnar nerve

One day in the brachial plexus ulnar nerve challenged the median nerve. Who will innervate more muscles in the upper extremity. The race starts. Upon arriving to brachium, they realized that musculocutaneus nerve has already innervated the anterior part and decided to take different paths. While the median nerve took the fossa cubiti path, ulnar nerve went through groove for the ulnar nerve. Then median nerve squeezed through two heads of pronator teres muscle and relieved, no muscle in anterior antebrachium was taken yet. It took the middle lane and innervated as many muscles as possible. Then, the ulnar nerve reaches the backside of the antebrachium and shocked upon the scenery. The posterior part of both brachium and antebrachium was taken by the radial nerve. However, the race was not over yet. The ulnar nerve took the medial lane and innervated the flexor carpi ulnaris muscle and medial half of the deep digital flexor muscle. It was a start none the less. The race in the antebrachium was won by the median nerve but the hand has not been concluded yet. The ulnar nerve saw that the median nerve is trying to get through carpal tunnel which is under the flexor retinaculum. Ulnar nerve found a faster route with less traffic and went over the flexor retinaculum. With the happiness of reaching the hand before anyone, the ulnar nerve innervated most of the hand muscles. Then, the median nerve reaches the hand and got surprised. Most of the hand muscles were already taken either by ulnar nerve or radial nerve. Then, it realized that no one reached the thumb yet. As a last effort median nerve innervated abductor pollicis brevis muscle, superficial head of flexor pollicis brevis muscle, opponens pollicis muscle and the first and the second lumbrical muscles. The race on the hand was won by the ulnar nerve.

Story example 3: Oculomotor nerve

Oculomotor nerve has bought itself a tiny flat from the upper floors of the famous housing estate mesencephalon. The name of the flat was oculomotor nucleus. Having only little amount of money it could only afford a two-room flat. Hence, it put his parasympathetic neurons in one room and somatic motor neurons on the other. Every morning axon bundles from both rooms left the mesencephalon and met at the cafe interpedincular fossa and formed oculomotor nerve. Oculomotor nerve would then take the bus named cavernous sinus. It liked the front seat and always sits by the window. Hence, it would travel on the lateral wall of the cavernous sinus. After getting off of the bus, it went through a tunnel called a superior orbital fissure. Then, it separated into two braches called superior ramus and inferior ramus to finish things faster. Superior ramus was thinner, so it climbed over the optic nerve, crossed it superiorly and reached superior rectus muscle and superior levator palpebrae muscle. Inferior ramus, on the other hand, stood on its way and visited the medial rectus muscle, inferior rectus muscle, inferior oblique muscle, and ciliary ganglion.

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Original Article

Omega Sign: An Indicator of Motor Hand Area on Cerebral Hemisphere

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Abstract

Introduction: With advances in the field of technology microneurosurgery is performed with the use of transcisternal, transfissural, and transsulcul approaches, where sulci present on brain are used as fundamental landmarks. Detailed knowledge of various cerebral sulci and gyri is also essential for neuroimaging techniques. Often neurosurgeons need to work in the central lobe to approach the cortical or subcortical lesions. The aim of the study was to identify and locate omega sign on the precentral gyrus as an indicator of hand area and to provide anatomical basis for the surgical landmark on the cortical surface. **Material and Methods:** Fifty-five cerebral hemispheres were studied in the Department of Anatomy. On the superolateral surface, the central sulcus, pre- and post-central gyri were identified. On the precentral gyrus, the presence of omega sign was observed. When present the height of the omega sign, width at the base, its distance from superior and inferior Rolandic point was noted. Data collected were statistically analyzed using SPSS version 25.0 software. **Results:** We observed the presence of omega sign in 26 hemispheres (47.27%). The average height of omega was 9.31 ± 2.94 mm, average width at base was 16.03 ± 3.34 mm. Distance from the superior Rolandic point was 27.53 ± 7.05 mm, while from inferior Rolandic point, it was 52.55 ± 7.8 mm. **Discussion and Conclusions:** Although technology offers modern intraoperative localization tools such as MRI and neuronavigation, anatomical knowledge is important for the surgical planning.

Keywords: *Cerebrum, motor hand area, omega sign, sulci and gyri*

Introduction

With advances in the field of technology, microneurosurgery is performed with the use of transcisternal, transfissural, and transsulcul approaches. For which the sulci present on the surface of brain are used as fundamental landmarks. The detailed knowledge about the shape, position, and form of various cerebral sulci and gyri is essential for neuroimaging techniques. They also serve as a guide to a particular functional area during the surgery.[1] Many times the neurosurgeons need to work in the central lobe to approach the cortical or subcortical lesions. Even though modern technology like magnetic resonance imaging (MRI) is available, detailed knowledge about the anatomy of sulci and gyri is important to plan a surgery.[2]

On the superolateral surface of cerebrum, the region formed by precentral gyrus and postcentral gyrus is known as central lobule. It is bounded anteriorly by precentral sulcus and posteriorly by postcentral sulcus. Inferiorly, it is bounded by lateral sulcus and superiorly by the upper margin of the cerebrum.[3]

Various methods have been used to identify the motor hand area on precentral gyrus by various authors to help the neurosurgeons. When observed on the surface, the motor hand area is present where the superior frontal sulcus meets the precentral sulcus (at the same sagittal plane on the precentral gyrus). In another method, the precentral knob can be localized in the form of the Greek letter inverted omega in the axial plane. Direct electrical stimulation and the functional MRI (fMRI) studies have confirmed the presence of the motor hand area in the superior part of the precentral gyrus.[4]

Although variation in anatomy of sulci and gyri is observed commonly, it is a known fact that anatomically constant sulci are topographically related to more specialized areas.[1] During surgery, due to the presence of arachnoid mater, it may sometimes be difficult for a surgeon to understand the

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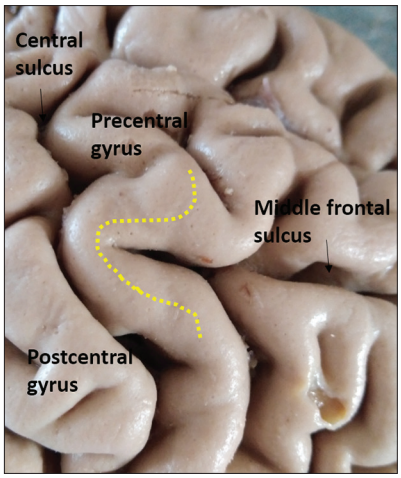

Figure 1: Omega sign seen on precentral gyrus

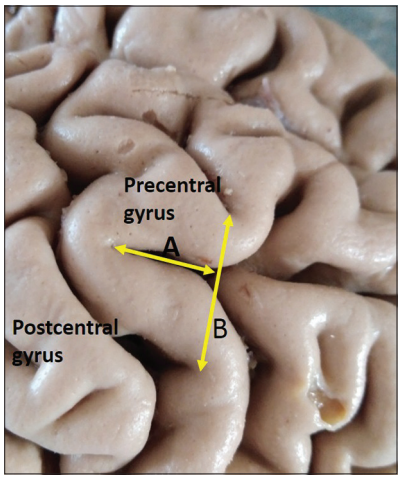

Figure 2: Height (a) and width the base of omeg asign (b)

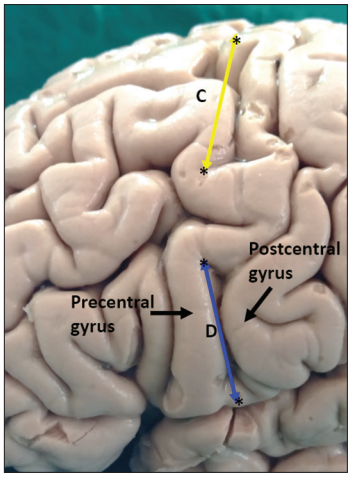

Figure 3: Distance of omega sign from other landmarks. C (Yellow line) – Distance between superior rolandic point and omega sign. D (Blue line) – Distance between inferior rolandic point and omega sign

anatomy of sulci and gyri. The variability of these sulci is well known. Therefore, neurosurgeons need multiple methods, such as identification of landmarks, some morphological and morphometric methods, to identify the sulci and gyri in this region. Although various techniques have been used including intrasurgical electrical stimulation for the identification of central region structures, researchers agree that additional landmarks for mapping of the motor cortex are always useful.[5]

With newer microsurgical techniques, and due to advances in the field of neuroradiological and neuroanesthesia in addition to good monitoring techniques during and after surgeries, many of the lesions located in the central sulcus region can be safely approached surgically and cured if the removal is based on anatomical data and refined microsurgical technique.[3] When the normal cerebral anatomy is distorted, identification of structural landmarks such as omega sign is important, with the help of which the central sulcus can be identified through MRI imaging.[6] Many scientists have described a hook-shaped hand area present in upper part of precentral gyrus.[6-8]

Material and Methods

After performing the craniotomy, dura mater was removed, and the brain was removed carefully. It was fixed in 10% formalin. Coverings of the brain and blood vessel were removed carefully. Fifty-five cerebral hemispheres (25 complete brain and five half brain) (right – 28, left – 27) were studied in the Department of Anatomy.

On the superolateral surface, the central sulcus, pre- and post-central gyri were identified. On the precentral gyrus, the presence of knob-like structure (omega sign) was observed in each the hemisphere [Figure 1]. If present, the height of the omega sign was measured form its base to the apex. Width at the base was measured as the maximum distance at the base of the knob [Figure 2]. Distance of the omega from the medial longitudinal fissure (Superior Rolandic point) and from the lateral sulcus (Inferior Rolandic point) was noted [Figure 3]. Data collected were statistically analyzed using SPSS version 25.0 software (C-Dot System Pvt. Ltd, Pune, India).

Results

After studying 55 cerebral hemispheres, we observed the presence of omega sign in 26 hemispheres. (47.27%) (right – 12 [42.85%], left– 14 [51.85%]). Bilateral presence was noted in seven brains out of 25 complete brains observed.

The average height of omega was 9.31 ± 2.94 mm (range: 3.3–13.93 mm), the average width at the base was 16.03 ± 3.34 mm (range: 11.1–23.44 mm). Its distance from the superior rolandic point was 27.53 ± 7.05 mm (range: 17.87–39.23 mm), while from inferior Rolandic point was 52.55 ± 7.8 mm (range: 32.63–65.84 mm) [Table 1].

Discussion

On the superolateral surface of cerebrum, central sulcus

Table 1: The morphometric measurements of omega sign

	Height of omega (mm)		Width of omega at base (mm)		Distance from the superior Rolandic point (mm)		Distance from the inferior Rolandic point (mm)	
	Right (*n*=12)	Left (*n*=14)	Right (*n*=12)	Left (*n*=14)	Right (*n*=12)	Left (*n*=14)	Right (*n*=12)	Left (*n*=14)
Average	9.17	9.46	14.88	17.73	28.52	26.54	52.13	52.98
SD	2.5	3.44	2.49	3.62	8.17	5.93	7.88	8.18
Range	5.17-12.91	3.3-13.93	11.1-18.44	12.68-23.44	19.4-37.67	17.87-39.23	32.63-65.84	42.36-63.45

SD: Standard deviation

is observed as one of the most important and consistent landmarks. As it descends down, it separates motor and sensory areas. It also forms the boundary between frontal and parietal lobes. Traditionally, three different curves or genua have been described along its course giving it an "S-"shaped appearance. The superior and inferior genua show convexity forward while the middle one, the deepest curve shows concavity forward. Thus, the middle curve resembles an inverted Greek letter omega.[6]

During 5th and 6th month of intrauterine life, the central sulcus appear in two parts, upper and lower, which usually coalesce shortly afterward, although they may remain discontinuous.[9] Alkadhi and Kollias.[10] suggested that, as the two sulci fuse with each other, the intervening eminence gets undermined (borne down) into the sulcus. Thus, the intervening portion is never entirely obliterated but can be discerned in the bottom of the sulcus. This is the pli de passage fronto-parie´tal moyen (PPFM) described by Broca[11] or deep annectant gyrus described by Cunnigham.[12]

Hopkins *et al*.[13] in their study of evolution of central sulcus morphology in primates have shown that the surface area, shape, and folding pattern of the central sulcus changed during Old World anthropoid primate evolution. This probably reflects the increasing importance of somatosensory and motor integration of hand functions. They also observed that, as brain size increased, folding in the central sulcus had to accommodate the increasing size of the PPFM, leading to the anatomical formation of the motor-hand area or Knob, seen on the cortical surface of the central sulcus.[13]

In their study of fMRI, Yousry *et al*.[5] defined the motor hand area in the axial plane as a knob-like, broad-based, posterolaterally directed structure of the precentral gyrus, which was inverted omega shape and sometimes a horizontal epsilon shape. They observed sites of signal intensity changes located in the precentral gyrus in 11 hemispheres out of 28 they studied (39.29%). With MRI, they detected the knob-like structure was in all 59 hemispheres examined in the axial plane. Caulo *et al*.[14] in their MRI study observed omega sign present in 78.2%.

The knob on the precentral gyrus was mainly formed by two sulci perpendicular to the central sulcus. These sulci were more prominent at deeper levels of the central sulcus and become smooth or even disappear on the cortex.[4] Due to this sulcal configuration, Rodrigues *et al*.[4] observed that, on direct cortical inspection sometimes, it was difficult to identify the presence of the knob on the precentral gyrus. Thus, they also noted the difficulty in finding the knob even if it was obvious on axial imaging (showing the omega sign).[4]

In their cadaveric study, it was found that the knob on the precentral gyrus, which represents the motor hand area, was present in 64 out of 82 hemispheres (78.05%).[4] While in our study of cadaveric cerebral hemispheres, we observed it in 47.27% of the hemispheres studied.

After studying ten cadaveric cerebral hemispheres, Campero *et al*.[6] noted that the average height of omega was 11.2 ± 3.35 mm and width at the base was 18.7 ± 2.49 mm. In the present study, the average height of omega was 9.31 ± 2.98 mm (range: 3.3–13.93 mm), the average width at the base was 16.03 ± 3.34 mm. Rodrigues *et al*.[4] noted average height of omega as 6.49 mm and average width as 17.66 mm. As majority of the individuals are right handed, height and width at the base of omega on the left side were expected to be larger than the right, but in the present study, the difference was statistically not significant. It might surface with a study with larger sample size.

The point where the central sulcus meets the interhemispheric fissure (superior longitudinal fissure) is known as superior Rolandic point. It lies about 5 cm behind the bregma, which is approximately 12 cm posterior to the nasion. The meeting point of the central sulcus with the Sylvian fissure is known as inferior Rolandic point, real, or projected.[3]

Campero *et al*.[6] observed the average distance between the medial edge of the hemisphere and the medial limit of the omega as 24.5 ± 5.35 mm. Rodrigues *et al*.[4] noted it as 20.617 mm and 18.633 mm on the right and left hemisphere, respectively. While in the present study, it was 28.53 mm ion the right side and 26.55 mm on the left side.

In a cadaveric study of 82 hemispheres by Rodrigues *et al*.,[4] the average distance of the knob on the precentral gyrus to the posterior ramus of the lateral sulcus was observed as 41.529 mm and 41.166 mm on the right and left hemisphere, respectively. In the present study, it was 52.13 mm and 52.98 mm, respectively. The difference can be attributed to the study population being different.

In recent years, different intraoperative monitoring methods have been often used. While operating on central sulcus

lesions generally, direct cortical stimulation, phase reversal technique, and subcortical stimulation are used.[4] Rodrigues *et al*.[4] suggested a combination method of anatomical landmarks along with morphometric measures to improve the accuracy along with the multimodality.

Rodrigues *et al*.[4] observed that it was difficult to find the knob present on the precentral gyrus even if it was obvious on axial imaging showing the omega sign. They therefore highlighted the importance of the morphometric data, various distances from the fixed points such as superior and inferior Rolandic points. Yousry *et al*.[5] also suggested the use of morphometric data for localization of the hand area intraoperatively.

Conclusion

Omega sign was observed on the precentral gyrus in 49.56% of cerebral hemispheres studied in the present study. Bilateral presence was observed in 28%. The morphometric data from the cadaveric study will be useful as an additional tool for locating the knob on the precentral gyrus for neurosurgeons. Variations in the gyral pattern are of interest for anatomists too.

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Conflicts of interest

There are no conflicts of interest.

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Original Article

An Analysis of Arches of the Foot: Grading the Severity of Pesplanus and Pescavus using a Newly Designed Podoscope and Parameters

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Abstract

Introduction: The aim of this study was to establish a new grading system of pesplanus (PP) and pescavus (PC) based on the severity by a newly proposed parameter plantar surface area (PSA) using a newly designed podoscope device. **Material and Methods:** A total number of 416 healthy participants; 208 men and 208 women aged 21–50 years were included in this study. Plantar surface images were obtained from the podoscope and measurements were made by using the newly proposed parameter and existing parameter. Statistical analysis was conducted using the SPSS Statistical software (version 16.0) and executed at 95% confidence interval. Mean and standard deviations were observed by using the descriptive analysis. The Chi-square test has been performed to find the association, dependency, and validity. **Results:** The analysis of the present study encompasses the grading system of "PP and PC" and also developed a classification system with three grades in PP and PC. This grading system will be a substantiate assessment tool for the diagnosis and also to record the prognosis during the treatment of PP and PC. **Discussion and Conclusion:** The present study has developed a newly designed podoscope and established a newly proposed parameters PSA index and analyzed the prevalence of normal, PP and PC. In this study, gender wise normative value for new parameters PSA index was proposed under the influence of height and foot length. According to our knowledge, this is the first study to grade the PP and PC in a proper scientific morphometric analysis using a newly designed podoscope with a PSA index.

Keywords: *Flat foot grades, high arch foot grades, pescavus, pesplanus, podoscope*

Introduction

The foot structure is a stable pliable platform in static condition, acting as a shock absorber helping in propelling of the body forward during locomotion.[1] The arches of the foot are formed by the tarsal and metatarsal bones and supported by tendons and ligaments in the foot.[2] Structurally, the arches of the foot are classified into transverse arch, medial longitudinal arch (MLA), and lateral longitudinal arch (LLA).[3] The MLA is higher than the LLA and acts like a spring during weight bearing.[4] Pesplanus (PP) or flat arched foot is a medical condition in which the height of MLA will be partially or completely flat and almost whole plantar surface of the foot comes in contact with the ground.[5] When the height of MLA exaggerates, it is termed as high arch foot.[6] In high arch foot, an excessive amount of weight is placed on the ball and heel of the foot when walking or standing.[7] Morphometric analysis and clinical assessment of the arches of foot were developed to compute the geometry as well as the purpose of diagnosis of certain ailments.[8-10] Foot print indices, anthropometric measurements, and radiographic methods are the classical methods for analyzing the arches of foot.[11] Chippaux index, Staheli index (SI), Arch index (AI), and truncated AI are the common parameters used to assess the integrity of the arches of the foot.[12] Studies reported that arches of the foot were analyzed using foot print indices to rule out the flat and high arched foot.[13] Johnson and Strom classification method of grading the flat foot composed of radiological, pathological, and clinical examinations to correlate with the progression of deformity.[14] Abousayed *et al*. in 2015 described that the Johnson and Strom method of flat foot classification is not a successful method because it does not contain the anatomical

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aspects of assessment.[15] Chang *et al*. in 2014 stated that the classification of flat foot should be established universally for assessment, treatment, and also to clear controversial issue regarding the diagnosis.[16] The above literature shows that foot print indices is a standard tool for measuring the integrity of arches of the foot but it is not a tool for classifying the grades of flat or high arched foot. Enormous scientific research papers have been published in relation to flatfoot but a few studies have been shown to controversial by other authors. Researchers and clinicians assess the arches of the foot by foot print parameters are unable to record the prognosis in the absence of a reliable grading system. There is no substantial research to show the grading of flat and high arch foot. Therefore, to address this issue and to fill the lacunae, the present study aims to develop the grading system of PP and pescavus (PC) by newly proposed parameter plantar surface area (PSA) index using a newly designed podoscope.

Material and Methods

Participants and study area

This is a comparative study conducted among 416 (208 males and 208 females) healthy participants aged between 21 and 50 years. Participants with open wounds, recent fractures, surgery (within 6 months), or any neurological conditions affecting the lower extremities were excluded. Ethical approval was obtained from the institutional ethics committee of Sri Ramachandra Medical College and Research Institute, Tamil Nadu, Chennai. Written consent was obtained from the patients after detailed explanation of the study, their role, risks and benefits involved, and their rights.

Instrumentation and podoscope specifications

A newly designed podoscope was used in the present study; it was made with wood, toughened glass and a document scanning machine. The device measures 60 cm length, 53 cm breadth, and 16 cm width can withstand up to 200 kg, when the subject stands over the equipment, as shown in Figures 1 and 2. The market price of standard readymade podoscope device was minimum Rs. 1.2 lakhs and an expert may be needed to operate certain devices, but the cost for designing our new device was just around Rs. 7000 and without an expert we can operate the device.

Methodology

As preliminary procedure, the entire participant's foot was cleansed with mild soap water and wiped thoroughly with a towel. Each subject was requested to stand erect, facing forwards, on the podoscopic device; after a few trials of familiarization with the device, the digitalized plantar scan images were obtained.

Image calibration method

The images of the plantar surface were transferred to the computer. Calibration of images was carried out in AutoCAD software by placing the calibration marks on two points that are a known distance apart, and entering the actual distance spanned by the points in centimeters.

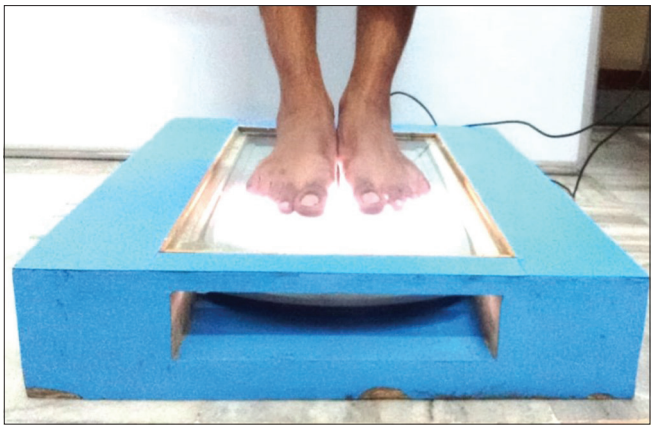

Figure 1: Newly designed podoscope

Observation

The images obtained from the podoscope device were observed and measured using existing parameter as well as new (PSA) index.

Existing parameters

Arch angle (AA), Chippaux-Smirak Index (CSI), Staheli index (SI), and Arch index(AI) are the existing parameters from the literature used to assess the arches of the foot, as shown in Figures 3 and 4.

i. AA is the angle between the medial line of the footprint (a) and the line connecting the most medial aspect of the metatarsus and the most lateral point of the medial foot (b)[17-20]
ii. CSI was measured by dividing the minimal distance of the (d) midfoot by the maximal distance of the (c) forefoot[21-23]
iii. SI obtained by dividing the minimal width of the midfoot (d) by the widest width of the (e) rear foot region[24-26]
iv. AI The length of the footprint excluding the toes (L) is divided into equal thirds. The AI is then calculated as the area of the middle third of the footprint divided by the entire footprint area (AI = B/A + B + C).[27-29]

Newly Proposed Parameter – Plantar surface area (PSA) index

PSA index was calculated based on the plantar surface area of the foot; the total plantar surface area (TPSA) [Figure 5] consists of plantar surface contact area (PSCA) and a plantar surface non-contact area (PSNCA). The PSCA [Figure 6] is formed by the width of forefoot, midfoot and hindfoot which will be in contact to the ground. PSNCA [Figure 7] is situated at the concavity of medial longitudinal arch which is not in contact to the ground.

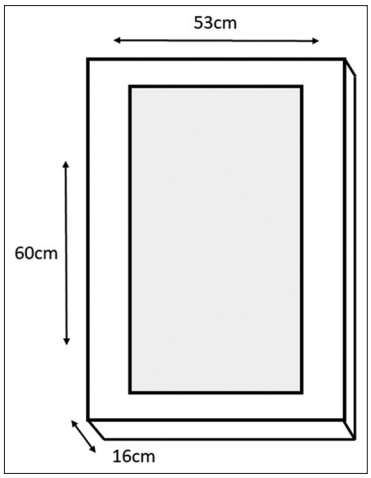

Figure 2: Specifications of newly designed podoscope

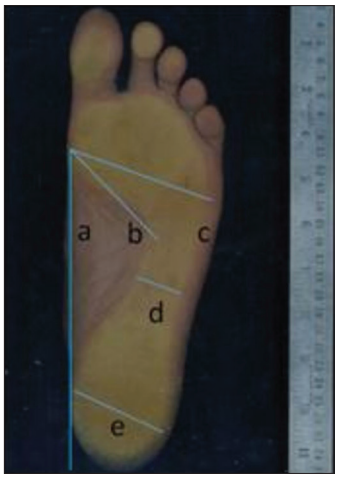

Figure 3: Podoscopic image shows the measurement of Arch angle, Chippaux-smirak index, Staheli index

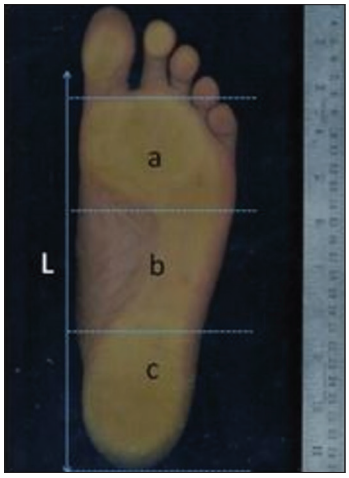

Figure 4: Podoscopic image shows the measurement of arch index

Figure 5: Podoscopic image shows the measurement of total plantar surface area (TPSA) in normal arched foot.

Grading pesplanus

Based on the PSA index, the flat arch foot was classified into three different grades. In Grade 1, the width of midfoot was increased, and the normal structure of MLA was altered, midfoot supports equal to or more than 1/3 of the total foot region, the plantar surface contact area PSCA is around 80%–90%. In Grade 2, the width of the midfoot reached to the level of the forefoot width, the MLA disappears, the PSCA was around 91%–100% and the PSNCA was 0%–10%. In Grade 3, the MLA was completely collapsed and dominant medial protuberance was seen rear foot width decreases, the contact region of the plantar surface was 100% and the PSNCA was 0%, as shown in Figure 8.

Grading pescavus

Based on the newly proposed parameters, the high arch foot was classified into three different grades. In Grade 1, the midfoot width was reduced, and the concavity of the MLA increases, the PSCA was around 51%–60%. In Grade 2, the structure of MLA was interrupted and complete absence of midfoot contact to the ground, the major contact region to the floor is the heel and the metatarsal region, and the PSCA was around 41%–50%. Grade: 3 – The overall contact area of the plantar surface to the floor was decreased; the PSCA is only around 21%–40%, as shown in Figure 9.

Results

The statistical analyses were undertaken using the SPSS Statistical software (version 16.0) and executed at 95% confidence interval. Mean and standard deviations for age, height, and weight were observed by the descriptive analysis, as shown in Table 1. The normative values for newly proposed parameters (PSA) are tabulated in Table 2. The Chi-square test has been performed to find the association, dependency, and validity of the newly proposed parameter PSA index with the existing parameters with statically significant $P < (0.001)$ for both males and females, as shown in Tables 3 and 4. Cramer's V is 0.985 for male and 1.00 for female group shows that newly proposed parameters

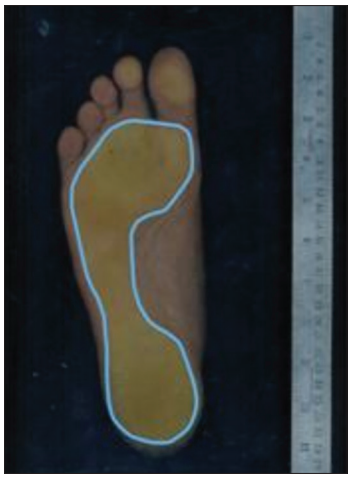

Figure 6:Podoscopic image shows the measurement of Plantar surface contact area (PSCA) in normal arched foot

Figure 7: Podoscopic image shows the measurement of plantar surface non-contact area (PSNCA) in normal arched foot

PSA index and the exciting parameters are highly correlated. The distribution of different types of arches among the participants is shown in Table 5. Grading of PP and PC using by PSA parameter is shown in Tables 6 and 7.

Discussion

In this study, among 416 participants, normal arch, (PP) and (PC) have been identified. The PP and PC are categorized as abnormal arches, and the normal arched foot remains the same, as shown in Table 4. The goal of the present study was to examine the ability of the newly proposed parameter (PSA index) compared with existing parameter using newly designed podoscope device. The analysis of the present study encompasses the grading system of "PP and PC" and also developed a classification system with three grades in PP and three grades in (PC) among 208 men and 208 women. This grading system will be a substantiate assessment tool for diagnosis and also to record the prognosis during the treatment of PP and PC.

Dunn *et al*.[30] conducted an epidemiological study among 784 participants and reported that the prevalence of flat foot was 19.0% (17.2% in men and 20.1% in women). Xiong *et al*.[31] analyzed the ankle and foot morphometry of 48 participants using footprint and also with static measurements and reported that 24% of them had abnormal arches. Nguyen *et al*.[32] assessed the arches of foot using MatScanPedo barographic device among 386 women and 214 men and found 17% flat foot in men and 20% in women. The present study reports that the prevalence of PP and PC according to the newly designed podoscope was 34.13% (39.0% in women and 28.8% in men), as shown in Table 4. The difference between the above-mentioned studies and the present study is that none of the studies have reported about the grading or classification of PP and PC, but the present study a grading system of both PP and PC was established, as shown in Tables 3 and 4 and Figures 6 and 7.

Table 1: Characteristics of subjects (Mean±SD)

Gender	Mean±SD		
	Age	Height (cm)	Weight (kg)
Men	31.6±9.3	178±3.6	78.6±10.3
Women	28.4±7.6	162±4.4	65.2±8.2

SD: Standard deviation

Table 2: Normative values of newly proposed parameters - Plantar surface area

Different Types of arches	% of contact area
NA	61%-79%
PP	80%-100%
Grade I	80%-90%
Grade II	91%-100%
Grade III	100% with protrusion
PC	<61%
Grade I	51%-60%
Grade II	41%-50%
Grade III	21%-40%

NA: Normal arch, PP: Pes planus, PC: Pes cavus

Pourghasem *et al*.[33] evaluated the relation between the severity of flatfoot and obesity among 653 males and 505 females between the age group of 6 and 18 years using the Dennis method of classification and reported that the prevalence of flatfoot was 17.5% in boys and 14.5% in girls. Chougala *et al*.[34] examined and graded the flatfoot among 228 subjects, based on body mass index using the Dennis method of classification of flat foot and revealed that 44.2% had flat arch foot. The contrast between the present study and studies of Pourghasem *et al.* and Chougala *et al.* shows that they have used a Dennis method for classifying the flat arched foot, Chang *et al*., Abousayed *et al*. and that the exact prevalence of flat foot is unknown due to deficit of exact criteria for defining flat foot, and a new method should be established based on the anatomical perspective to classify

Table 3: Association between height, foot length and TPSA in women (*n*=208)

Height (cm)	Foot length (cm)												Total
	15-20				21-25				26-30				
	TPSA												
	140-180				140-180				140-180				
	140-150	151-160	161-170	171-180	140-150	151-160	161-170	171-180	140-150	151-160	161-170	171-180	
145-154	1	1	1	0	0	16	1	0	0	0	0	0	20
155-164	16	13	1	0	6	51	31	0	0	1	0	0	119
165-174	0	0	0	0	1	16	36	2	0	1	11	2	69
Total	33				160				15				208

TPSA: Total plantar surface area

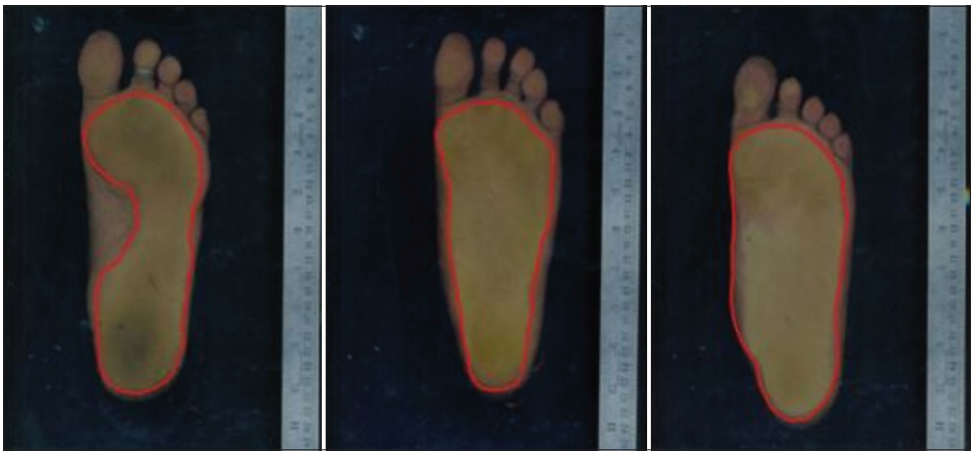

Figure 8: Grades of pesplanus classified based on newly proposed parameters

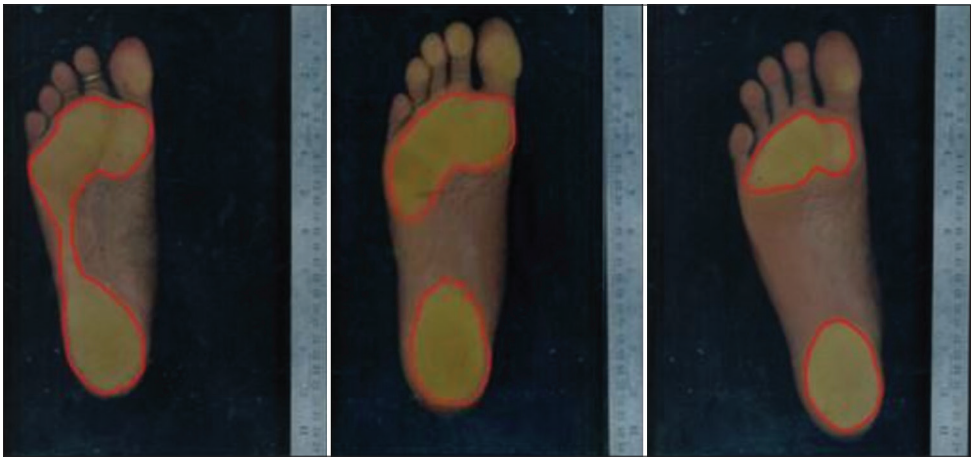

Figure 9: Grades of pescavus classified based on newly proposed parameters

the arches of the foot. Dennis method involves image representation and plotting lines in the footprint. The authors propose the above parameters based on the anatomical and biomechanical configuration of arches of the foot be used for detailed grading of abnormality of arches of foot.

Existing parameters versus newly proposed parameter plantar surface area (PSA)

The morphometry of the foot was studied by using indices, lines, and angles called as foot print parameters. CI, SI,and AA are some of the parameters used by the researchers to assess the integrity of arches of the foot.[35,36] Foot print parameters are basically calculated by lines and angles in some particular areas such as forefoot, midfoot, and hindfoot and not with the entire surface, so there are many areas which are left unmeasured, as shown in Figures 1 and 2. Therefore, these parameters are only capable of diagnosing whether it is a normal, flat, or high arched foot; hence, these parameters are unable to grade the severity of PP and PC.

Table 4: Association between height, foot length and TPSA in men (*n*=208)

Height (cm)	Foot length																		Total
	15-20				21-25				26-30				31-35						
	TPSA																		
	150-190				150-190				150-190				150-190						
	150-160	161-170	171-180	181-190	150-160	161-170	171-180	181-190	150-160	161-170	171-180	181-190	150-160	161-170	171-180	181-190			
155-164	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0			1
165-174	0	1	0	0	48	16	0	0	15	19	11	1	0	0	0	0			111
175-184	0	0	0	0	1	1	1	0	0	17	20	5	0	0	9	40			94
185-195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2			2
Total		1				68				88				51					208

TPSA: Total plantar surface area

Table 5: Distribution of NA,PP,PC based on gender

Gender	NA	PP	PC	Total
Female	126	47	35	208
Male	148	41	19	208
Total	274	88	54	416

NA: Normal arch, PP: Pes planus, PC: Pes cavus

The newly proposed PSA index was derived based on the individual's height, foot length, and the PSA, as shown in Tables 3 and 4. The parameters are based on the calculation of the entire plantar surface of the foot; PSA index covers the measurement of whole plantar surface of the foot, and no areas remains unmeasured, as shown in Figures 3-5. Therefore, the PSA index is capable for finding whether it's normal arch foot, PP or PC, as well as it also reveals the grading of PP and PC based on the severity Figures 6 and 7. Variability was present practically in each and every stage of this research process, the existing diagnostic tests were modified and updated in the current study by new parameters PSA index to confirm the presence or absence and to grade the PP and PC.

The existing parameters can be used only to assess or differentiate the normal and abnormal arches of foot. Witana *et al*.[37] used 3D scanner to assess the morphometry of 16 participants for the purpose of the preparing the foot orthotics. Similarly, with the available measurements of the newly proposed PSA index, it can be utilized for assessing the arches of the foot, to record the prognosis of PP and PC during the treatment and also it will be useful for manufacturing footwear and orthotics.

Conclusion

The present study has developed a newly-designed podoscope and established a newly proposed parameter (PSA) index and analyzed the prevalence of normal, flat, and high arch foot between the age group of 21–50 years. In this study, gender-wise normative value for new parameters PSA index was proposed under influence of height and foot length. The device was designed in a portable manner so it can be carried easily by a single person to any places, which allows to diagnose or to collect data in the rural and under-served areas without any cost. The podoscope and the newly proposed PSA index were designed in a simplified manner so it does not require a technical person to handle it. The outcome acquired by this study will be helpful for accurate diagnosis and to record the prognosis during the treatment of PP and PC, it will be also helpful in the field of orthopedics.

Acknowledgment

I thank R.Mohanasankari for helping in preparing this manuscript.

Table 6: Existing parameters shows only the different types of arches of foot, but newly proposed parameter (PSA) shows the grades of PP and PC in women

Different types of arches	Existing parameters	Newly proposed parameters (PSA)					
		F 1	F 2	F 3	H 1	H 2	H 3
NA	126	0	0	0	0	0	0
PC	35	0	0	0	15	7	13
PP	47	18	10	19	0	0	0
Total	208	18	10	19	15	7	13

NA: Normal arch, PC: Pes cavus, PP: Pes planus

Table: 7 Existing parameters shows only the different types of arches of foot, but newly proposed parameter (PSA) shows the grades of PP and PC in men

Different types of arches	Existing parameters	Newly proposed parameters (PSA)					
		F 1	F 2	F 3	H 1	H 2	H 3
NA	148	0	0	0	0	0	0
PC	19	0	0	0	14	4	1
PP	41	10	19	12	0	0	0
Total	208	10	19	12	14	4	1

NA: Normal arch, PC: Pes cavus, PP: Pes planus

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Original Article

Comparison of Maceration Techniques for Retrieval of Bones

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Abstract

Introduction: Learning osteology is an essential part of anatomy curriculum. However, recently, there has been a scarcity in the availability of bones for teaching in India. The present study was conducted to compare four different maceration techniques and find the most suitable method to procure bones from an embalmed cadaver. The present study was conducted on dissected human cadavers made available from the department of anatomy. **Material and Methods:** For the first three methods, after dissection, the cadavers were buried in the burial section of the department for 2 years. The bones were washed after excavation. In the first method, detergent was used; in the second, quick lime was used; and in the third, hydrogen peroxide was used. In the fourth method, parts were not buried. The dissected parts were defleshed manually. The bones were freed from the joint. A paste was made using baking soda and 30% hydrogen peroxide. This was applied and bones were kept covered for 24 h. All four methods were compared. **Results:** Based on time required to macerate, ease of soft-tissue removal and complete procurement with minimal damage, the method using 30% H_2O_2 was the best. For smaller specimens, the new method of applying a paste of baking soda and H_2O_2 was very effective. The time consumed was very less. **Discussion and Conclusion:** Maceration using 30% H_2O_2 gave the best result. New method tried is time-saving and useful for small specimens. Soft tissue was removed easily with no/minimal damage to the bone.

Keywords: *Baking soda, bones, embalmed, hydrogen peroxide, maceration, quick lime*

Introduction

Learning osteology is an important part of the anatomy curriculum. While modes such as computer applications, textbooks, and plastic models help students to learn how the human body works, there is virtually no substitute for the use of authentic human tissue. Human bones are unsurpassed in the ability to provide three-dimensional instruction in osteology as well as understanding the soft-tissue insertion and the course of neurovascular structures.[1] The normal variations in the human anatomy cannot be adequately reproduced in software, illustrations, or models. Even photographs, while useful as documentation, cannot replace the tactile appreciation of bone. While nonhuman remains are readily available, without access to human skeletal resources, a comparative study is impossible.[2]

Recently, there has been a scarcity in the availability of bones for teaching in India. The demand of dry human bones for students of medicine, dentistry, physiotherapy, and allied sciences is increasing enormously. The supply is scarce. Hence, a solution must be found to meet the demand as the supply dwindles. Retrieval of the skeleton from the dissected cadavers may be a choice. Currently, underutilized sources of human skeletal material from the preserved tissue offer a solution.[2]

The retrieval of bones and removal of all soft tissue is called maceration. Various maceration techniques exist in the literature. All maceration techniques aim at removing the soft tissue from the bone. In general, several steps are required: the complete removal of all soft tissue and the processes to degrease the bone and then whiten it. Initially, as much soft tissue as possible is physically removed. This includes skinning, gutting, and usually, disarticulation in order for the bone to macerate at a more reasonable pace. In general, these techniques fall into the following categories: boiling, using chemicals or burying or using dermestid beetles.[3] Retrieval of bones from formalin-fixed cadavers is difficult. No formal

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standards of maceration exist. Traditional methods are tedious and time-consuming. There is a practical need for research with fixed specimens. Producing dry skeletons without bone modification from preserved tissue must be exact, as they do not macerate easily.

Therefore, a study was planned to evaluate the different methods to procure bones in terms of efficiency, effectiveness, and destructiveness. The purpose of this study is to use various methods and find the most suitable method in terms of time consumed, ease of access, and complete procurement of bones from embalmed cadavers.

Material and Methods

The study was carried after taking clearance from the Institutional Ethics Committee. The study was conducted on dissected human cadavers made available from the department of anatomy, of a reputed medical college. Universal precautions were observed while handling tissue and chemicals. Four different methods were employed and were compared. For the first three methods, after dissection, the cadavers were buried in the burial section of the department for 2 years. The cadavers were excavated after 2 years. The bones were washed.

In the first method, after excavation, the bones were dipped in detergent for 24 h. Any remaining soft tissue was removed manually using a brush. The bones were washed and dried.

In the second method, bones were dipped in a quick lime solution. Then, they were washed and dried.

In the third method, after excavation, the bones were dipped in detergent for 24 h. Bones were then chemically treated with hydrogen peroxide. Two liters of 30% H_2O_2 were dissolved in 15 L water. The bones were dipped and left covered for 24 h. They were then washed and dried in sun.

In the fourth method, the dissected parts were defleshed. They were not buried. Bones were freed from the joint. A paste was made using 100 g baking soda and 30% H_2O_2. This paste was applied on the bones and left covered for 24 h. Next day, they were washed and dried. The methods were compared on the basis of time required for maceration, ease of soft-tissue removal, and complete procurement or minimal damage to bone tissue.

Observations

The following observations were made.

Method 1 use of detergent

Time to macerate – More than 2 years.

Ease of access to remove soft-tissue cleaning was effective. Bones had dark color. Soft tissue could not be removed from the ends and had to be removed manually.

Destructiveness – No damage to bone. Bones were darker.

Method 2 use of quick lime

Time to macerate – More than 2 years.

Ease of access to remove soft tissue cleaning was not effective. There was a chalky deposit on the bones [Figure 1]. The remnants of ligaments and tendons were not softened. The tissue was not removed.

Destructiveness – No damage to bone. Soft tissue was not removed There was a deposit on the bone.

Method 3 use of hydrogen peroxide

Time to macerate – More than 2 years.

Ease of access to remove soft-tissue cleaning was effective. Bones had lighter tone. Only some of the bones needed brushing to look completely clean [Figures 2 and 3].

Destructiveness – no damage to bone. Bones were lighter toned looked visually appealing to touch.

Method 4 use of baking soda and hydrogen peroxide – no burial

Time to macerate – The whole procedure took less than a week. In the previous three methods, the cadaver was buried the bones excavated which usually took 2 years.

Ease of access to remove soft tissue – most of the tissue comes off easily. Some tissue had to be removed manually using scalpel.

Destructiveness – no damage to bone. The bones were clean having lighter tone [Figure 4].

Results

The advantages and disadvantages of various methods are tabulated in Table 1.

Figure 1: Femur head showing chalky deposit of quick lime

Based on time required to macerate, ease of soft-tissue removal and complete procurement with minimal damage, the method using 30% H_2O_2 was the best. The chemicals are easily available and fairly inexpensive. For smaller specimens, the new method of applying a paste of baking soda and H_2O_2 was very effective. The time consumed was very less. No burial was required. Thus, we can conclude that the method using hydrogen peroxide can be used conveniently to procure full skeletons from dissected cadavers.

Figure 2: Sacrum removed after 2 years of burial

Figure 3: Sacrum after treatment with H_2O_2

Figure 4: Bones treated with paste of baking soda and H_2O_2

Discussion

The need for the use of authentic osteological specimens for students as well as professionals in established fields and in new burgeoning disciplines has rapidly increased over the past several decades. Philip Tobias emphasized the importance of human skeletons for the teaching of human anatomy, including dental anatomy for students of medicine, dentistry, physiotherapy, occupational therapy, nursing, and pharmacy as well as students of comparative anatomy, primatology, and general morphology.[4] The number of new fields that rely on access to this learning material has astronomically increased and expanded. Forensics, DNA research, and molecular biology are but a few worth mentioning.[2]

To meet the increasing demand of bones in the department necessitated experimenting with various maceration procedures. In the present study, four methods were chosen for this purpose seeing the feasibility, expenses, and other factors. Although boiling of bones is time-tested procedure, it was not preferred due to obnoxious fumes and environmental hazards. Because of this disadvantage, it cannot be carried at all places.

Based on the time required to macerate, ease of soft-tissue removal, and complete procurement with minimal damage, the method using 30% H_2O_2 was the best. The chemicals are easily available and fairly inexpensive. Many bones can be macerated together. A single trained person can do the entire procedure. Earlier studies also concluded this method as an efficient method.[5] Burial is necessary, and bones were kept buried for 2 years. This time for burying can be reduced by burying the bones near the surface in the superficial soil.[6]

For smaller specimens, the new method of applying a paste of baking soda and H_2O_2 was very effective. The time consumed was very less. No burial was required. Complete knowledge and training are required to deflesh the bones and disarticulate them from the joints.

Snyder, Burdi, and Gaul introduced a method of skeletal preparation that involved a quick-acting formula they named anti-formin, prepared by combining sodium carbonate and bleaching powder.[6] Contemporary scholars caution against the guaranteed destructive properties of bleaching products.[7-10] The use of bleaching powder in skeletal processing has been shown to destabilize bone structure well after the removal from the solution.[7,9,10] Sodium hypochlorite is effective at removing fat and whitening specimens but researchers cautioned that the resultant bone will be flaky and may crumble to dust.

Table 1: Showing Advantages and Disadvantages of various methods used in maceration

Method	Advantages	Disadvantages
Use of Detergent	Fairly Inexpensive	Time Consuming
	Requires Minimal Training	Requires Manual Extraction
Use of Quick Lime	nil	Time consuming
		Removal Of soft Tissue impossible
		Could not break ligaments, tendons
		Chalky deposit on Bones
Use of Hydrogen Peroxide	Fairly Inexpensive	Time Consuming
	Requires Minimal Training	
	Effective Cleaning	
	Visually appealing Lighter Coloured Bones	
	No damage to Bones	
	Lot of Bones can be Done together	
No Burial Use Of Hydrogen peroxide and Baking Soda Paste	Process takes less than a week	Requires Extensive knowledge
	Fairly Inexpensive	Can be done only on small specimens
	Effective Cleaning	
	Visually appealing Bones	
	No damage to Bones	

As an alternative to sodium hypochlorite, hydrogen peroxide has been suggested in the literature.[8,11] Sodium bicarbonate may be used to soften proteinaceous materials. When comparing which chemical proved the easiest to deflesh in the shortest amount of time, sodium bicarbonate came in the first place in all trials.[2-8] Thus, a combination of sodium bicarbonate and hydrogen peroxide was tried gave us fast and effective cleaning. This method requires the help of trained person to deflesh and disarticulate the bones. The reagents are easily available. It is very fast. No burial is required. This method may be difficult to be applied on the axial skeleton. It can be the method of choice for small dissected specimens.

Conclusion

Maceration using 30% H2O2 gave best result New Method tried is time saving and useful for small specimens. Soft tissue was removed easily with no/minimal damage to the bone skeleton. It can be the method of choice for small dissected specimens. The methods described here are easy to perform and will help medical colleges to procure bones from preserved tissue.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Original Article

A Cadaveric Study on Subclavius Posticus Muscle

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Abstract

Introduction: Subclavius posticus muscle (SPM) is a rare anomalous muscle that traverses from costal cartilage of first rib posterolaterally to superior border of scapula. The aim of the study was to study the prevalence of SPM in adult cadavers. **Material and Methods:** Fifty upper limbs from embalmed cadavers allotted for routine dissection practical for first MBBS students were used for the study. There were twenty male and five female cadavers, with ages ranging from 60 to 80 years, specimens of both sides were used. **Results:** The SPM was found in seven cases out of fifty cases, two on left, and five on the right side of pectoral region. **Discussion and Conclusion:** The presence of variant SPM could be a predisposing causative factor of thoracic outlet syndrome.

Keywords: *Coracoid process of scapula, subsclavius posticus muscle, thoracic outlet syndrome*

Introduction

The anatomical variations in the anterior thoracic region has been well documented in literature but paid scant attention to a small muscle subclavius posticus which is a predisposing factor for thoracic outlet syndrome. The present study was aimed to scrutinize this muscle particularly its attachments.

Subclavius posticus originates from first costal cartilage, gets inserted into upper margin of coracoid process of scapula, and is innervated by nerve to subclavius or suprascapular nerve or phrenic nerve.[1]

It is speculated that the muscle might develop from an analage of the hypobranchial musculature near and/or in the junctional region between the hypobranchial and the pectoral regions of the body trunk. The region might phylogenetically and ontogenetically, concomitantly with the development of the heart and lungs, undergo remarkable changes, to which variations of this muscle, and its innervation could be attributed.[2]

Material and Methods

Inclusion criteria

All the cadavers available during the study period were included in the study.

Exclusion criteria

Deformed axillae were excluded from the study.

Fifty upper limbs from embalmed cadavers allotted for dissection over a period of 3 years (2017–2019) were used for the study. Twenty male and five female cadavers were studied with ages ranging from 60 to 80 year. Specimens of both sides were used.

The axillary region was dissected and exposed according to the methods described in Cunningham's Manual of Practical Anatomy.[3] Detailed dissection of subclavius posticus muscle (SPM) was done. Pattern of muscular attachments, innervations were examined, recorded, and photographed. Total length of the muscle and maximum width were measured.

Results

The overall incidence was 14%. The SPM was found in seven cases out of fifty cases, two on left and five on right.

In all the cases, SPM took origin from superior surface of first costal cartilage. The insertion and nerve supply in our study is depicted in the tabular format [Table 1]. The muscle coursed dorsolaterally beneath the clavicle crossing the axillosubclavian vessels and cords of brachial plexus. Photographs of dissected SPM have been included in [Figures 1-5].

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Table 1: Observations of subclavius posticus muscle in our study

Specimen number	Insertion	Nerve supply	Total length (cm)	Maximum width (cm)
SPM 1	Root of coracoid process of scapula	Direct branch from fused cords of brachial plexus	12.5	1
SPM 2	Root of coracoid process of scapula	Suprascapular nerve	14.4	1.2
SPM 3	Root of coracoid process of scapula	Nerve to subclavius	13.2	1.1
SPM 4	Root of coracoid process of scapula	Suprascapular nerve	13.3	1.2
SPM 5	Root of coracoid process of scapula	Nerve to subclavius	15.5	1.3
SPM 6	Root of coracoid process of scapula	Suprascapular nerve	14.6	1.2
SPM 7	Coracoid process, superior transverse ligament	Suprascapular nerve	12.7	0.8

SPM: Subclavius posticus muscle

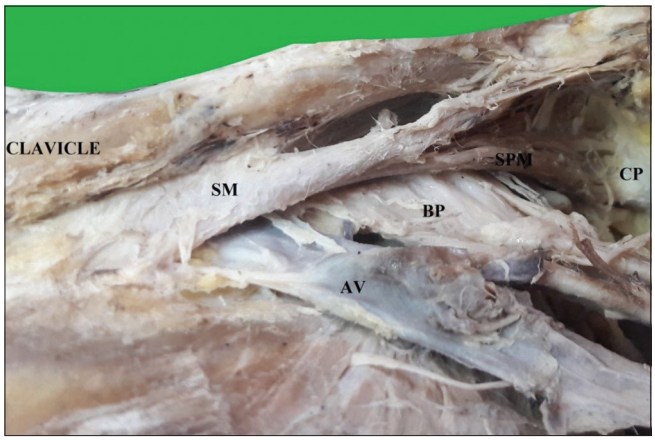

Figure 1: Left infraclavicular region (subclavius posticus muscle 1) before removal of clavicle

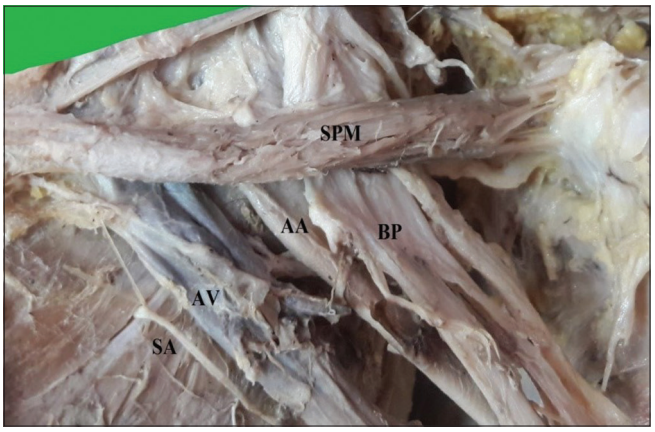

Figure 2: Superior view (subclavius posticus muscle 1). After removal of clavicle

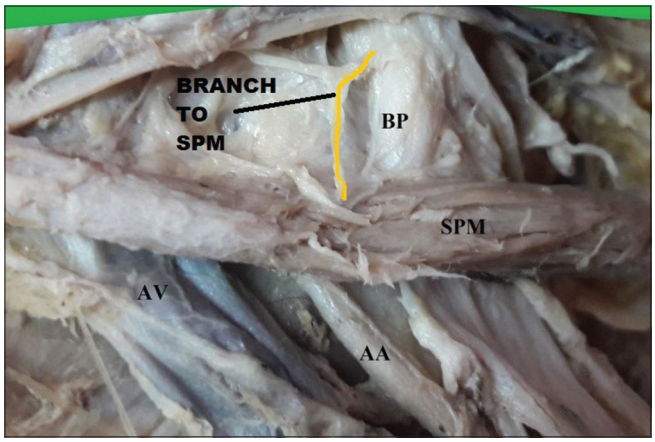

Figure 3: Showing nerve supply (subclavius posticus muscle 1)

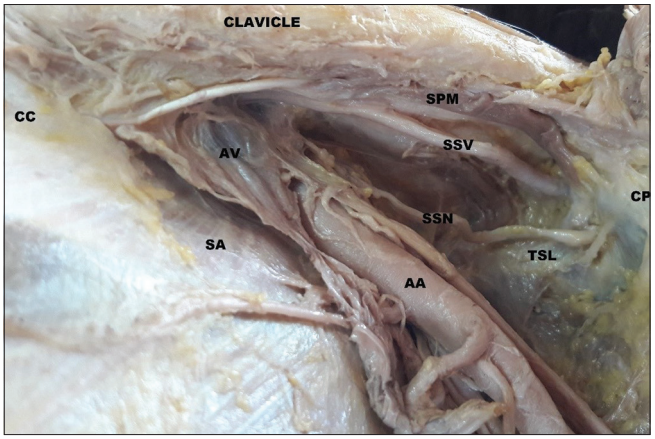

Figure 4: Left subclavius posticus muscle, inserted into coracoid process and transverse scapular ligament (subclavius posticus muscle 7)

Among seven specimens one received innervation from a direct branch from brachial plexus, in which all three cords were united, four from suprascapular nerve, and two from nerve to subclavius.

The length of subclavius posticus ranged from 12.5 cm to 15.5 cm and breadth of the muscle ranged between 0.8 cm and 1.3 cm. The maximum width of muscle was found to cross the neurovascular bundle. A comparison of the measurements have been given in Table 2.

All the muscular components in axillary and scapular regions were normal.

Discussion

Eisler reported a muscle in 1912, termed by Rosenmuller as SPM, which arose from first costal cartilage and inserted into the coracoid process or upper margin of the scapula.[4]

The incidence of SPM in Japanese was 8.9% and 36% in Thais, as compared to 14% in our study, all the studies were done on cadavers.[5]

Piyawinijwong and Sirisathira describe the classification of subclavius muscle according to its insertion, in which muscles in Type II–IV corresponds to SPM [Table 3]. Prevalence of SPM Type II in a study conducted in Thais was 17.97%, but in our study, it is 12%, SPM Type III in Thais was 15.62%, and in our study, it is 2%.[5]

Table 2: Comparison of measurements of subclavius posticus muscle observed by various authors

Measurements	Length (cm)	Maximum width (cm)
Singal *et al.*	11.5	1.1
Shetty *et al.*	16.6	-
Present study	12.5-15.5	0.8-1.3

Table 3: Classification of subclavius muscle according to its insertion[5]

Type	Site of insertion
I	Shallow groove on inferior surface of clavicle
II	Conoid ligament and root of coracoid process
III	Conoid ligament, coracoid process and the superior transverse ligament
IV	Conoid ligament and coracoid process, superior transverse ligament and the superior border of the scapula overlapping to the insertion of the inferior belly of omohyoid muscle

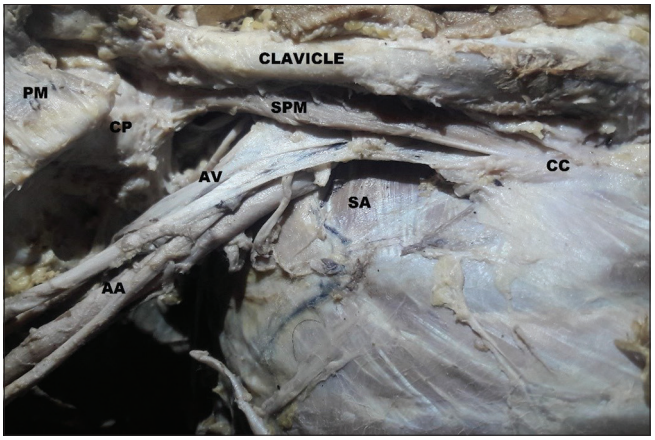

Figure 5: Superior view of right subclavius posticus muscle 3

Table 4: Subclavius posticus muscle as described in various studies

Author/year	Attachment to first rib	Attachment to scapula		Nerve supply
Present study, 2019	Costal cartilage of first rib	Type II Type III	6-root of coracoid process of scapula 1-coracoid process, superior transverse ligament	1 - Direct branch from fused cords of brachial plexus 4 - Suprascapular nerve 2 - Nerve to subclavius
Muellner *et al.*, 2015 MRI	Medial aspect of first rib	Superior border of scapula near base of coracoid process		-
Cogar *et al.*, 2015 MRI	Superolateral cartilageous part of first rib	Superior border of scapula		Suprascapular nerve
Piyawinijwong S and Sirisathira N, 2010	Costal cartilage of first rib	Type II-Type III -Type IV	Root of coracoid process Coracoid process, superior transverse ligament Coracoid process, superior transverse ligament, superior border of scapula	-
Singhal *et al.*, 2007	Costal cartilage of first rib	Upper border of scapula lateral to inferior belly of omohyoid muscle		Suprascapular nerve
Shetty *et al.*, 2006	Costal cartilage of first rib	Medial margin of suprascapular notch medial to inferior belly of omohyoid and laterally blends with the capsule of acromioclavicular joint		Nerve to subclavius
Kutoglu *et al.*, 2005	Costal cartilage of first rib	Upper border of scapula lateral to inferior belly of omohyoid muscle		Suprascapular nerve
Sarikcioglu *et al.*, 2001	Costal cartilage of first rib	Superior angle of scapula		Suprascapular nerve
Forcada *et al.*, 2001	Costal cartilage of first rib	Upper margin of scapula and transverse scapular ligament		Suprascapular nerve
Akita *et al.*, 2000	Costal cartilage of first rib	Superior margin of scapula just mediocaudal to inferior belly of omohyoid muscle		Nerve to inferior belly of omohyoid, accessory phrenic nerve (in 1 case), nerve to subclavius
Akita *et al.*, 1996	Costal cartilage of first rib	Upper margin of scapula		Nerve to subclavius

MRI: Magnetic resonance imaging

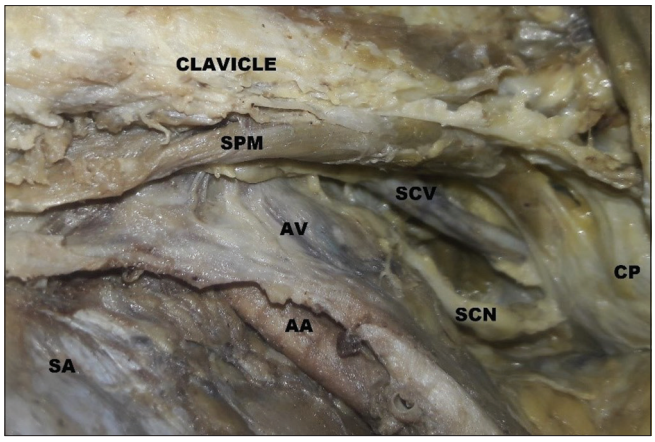

Figure 6: Left subclavius posticus muscle, inserted into coracoid process (subclavius posticus muscle 4)

Relationship to structures at the root of neck stated by previous authors as well as in our study was superficial to subclavian vessels and brachial plexus. The comparison of attachments and nerve supply as observed by various authors are depicted in Table 3.[2,5-8]

Akita *et al.* described SPM as an aberrant muscle between inferior belly of omohyoid and subclavius muscle. They reported a common matrix for these muscles. Accordingly, the matrix is divided into three parts and middle part becomes the aberrant muscle.[9] Table 4 gives a summary of results of SPM of present study in relation to results of various other studies.

Cogar *et al*. presented a case of an athlete with suprascapular nerve compression associated with subclavius posticus diagnosed by magnetic resonance imaging (MRI). Symptoms were relieved and function was restored by decompression of the nerve and excision of the anomalous muscle.[7]

Conclusion

The presence of SPM could be a predisposing causative factor of thoracic outlet syndrome, suprascapular nerve compression. Radiologists and surgeons should be aware of this muscle. High-resolution MRI examination is recommended in such suspected cases. A band of nonenhancing tissue stretching from the first costal cartilage to the superior angle of scapula, isointense to the adjacent muscles in the presence of a normal subclavius muscle are the classical MRI features of SPM.[10]

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Conflicts of interest

There are no conflicts of interest.

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Original Article

Anatomical Variations in Scapula: A Study with Correlation to Gender and Side

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Abstract

Introduction: Anatomical variation is defined as the normal flexibility in the topography and morphology of body structures. The present study was planned to study anatomical variations in dry scapula of North Indian population and their comparison between males and females on both sides. **Material and Methods:** The study was performed at the Department of Anatomy, PGIMS, Rohtak, on fifty pairs of human scapulae, out of which thirty were males and twenty were females. Various anatomical variations were noted such as sulcus for circumflex scapular artery, costal facets, horizontal inferior border, scapular foramina, and facet on inferior surface of acromion process. Morphological types of tip of acromion process, inferior surface of acromion process, and superior border of scapula were studied. These parameters were compared in both sexes on both the sides. **Results:** Majority of the anatomical variations were common in females in comparison to males. **Discussion and Conclusion:** Knowledge of the anatomical variations of scapula is the key to a successful outcome in the clinical setting.

Keywords: *Anatomical, costal, morphology, topography*

Introduction

The scapula is a large, flat, and triangular bone which lies on the posterolateral aspect of the chest wall, covering parts of the second to seventh ribs. It has costal and dorsal surfaces; superior, lateral, and medial borders; inferior, superior, and lateral angles; and three processes, the spine, the acromion, and the coracoid process.[1]

Anatomical variation is defined as the normal flexibility in the topography and morphology of body structures.[2] Not many anatomical variations have been reported in scapula, yet some of these variations have got clinical significance.

Typically, the anterior surface of the scapula is smooth and articulates indirectly with the posterior thoracic wall through the scapulothoracic joint. The anterior surface of the scapula has sometimes been reported to have distinct synovial articulations with the ribs that restrict its motion. This has been reported occurring near the inferior angle, superior angle, and superior border of the scapula. Fontan described a pair of scapulae, which possessed two costal facts each. They articulated with the posterior surfaces of the third and seventh ribs, respectively, and had associated with them both a capsule and synovial membrane.[3]

The supraspinous and infraspinous fossae are located on the posterior aspect of scapula, and the bone in this region can become quite thin. Hence, the incidence of scapular foramina is more in these fossae.[3]

Increased degenerative changes are associated with increased length of the acromion, and length is in turn related to the shape of the acromion. The longest specimens are "cobra" shaped with a mean length of 6.2 cm. The shortest specimens are "square tipped" with a mean length of 5.2 cm.[4]

The superior border of scapula is the most variable of the scapula's borders. It can appear horizontal, moderately oblique, markedly oblique, deeply saddle shaped, concave or semilunar, and wavy.[3]

Although nearly all possible human anatomical variations have been reported and cataloged, their combinations continue to arouse interest. Second, there appear to be ethnic differences in the frequency of these variations. Consequently, there

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is a need for continuous appraisal for emphasis and to encourage anatomists and clinicians to beware of their existence. Unfortunately, continuous appreciation of variations is being undermined by current trends in the undergraduate medical training characterized by reduced exposure to dissection and dissected specimens, increased use of plastic bones, computer-generated images, loss of experienced teachers, especially those who are medically trained, and loss of morphological approach.[5]

Since there is dearth of literature regarding the anatomical variations of scapula in North Indian population, so, the present study was planned to study these anatomical variations in dry scapula of North Indian population and their comparison between males and females on both sides.

Material and Methods

The present study was conducted on fifty pairs of dry human scapulae in the Department of Anatomy at our institution in the year 2017–2018. Out of fifty pairs, thirty belonged to males and twenty were of females. Gender determination of scapulae was done on the basis of bone register maintained in our department. In our department, complete skeleton is procured by maceration and is then numbered. Hence, gender of all the scapulae was known to us. Bones with clear and intact features were included in this study. The various anatomical variations taken into consideration are as follows:

Sulcus for circumflex scapular artery

Its presence or absence was noted on dorsal surface of lateral border of scapula [Figure 1a].

Costal facets

The presence or absence of costal facets for ribs was noted on superior border and inferior angle of scapula[3] [Figure 1b].

Presence of inferior border of scapula

Its presence or absence was noted down [Figure 2a].

Figure 1: (a) Sulcus for circumflex scapular artery (arrow); (b) Costal facet along horizontal superior border (red arrow) and scapular foramen at root of spine (black arrow)

Scapular foramina

The presence or absence of scapular foramina other than suprascapular foramen was noted [Figure 1b].

Inferior surface of acromion process

The inferior surface of anterior third of acromion process was classified into rough and smooth types as suggested by Paraskevas *et al*.[6] and their incidence was noted down [Figure 2b].

Facet on the inferior surface of acromion process

The presence or absence of accessory facet on the inferior surface of acromion process other than the clavicular facet on medial border of acromion process was noted down [Figure 2b].

Tip of acromion process

The tip of acromion process as viewed from superior surface was classified into cobra, square, and intermediate types as suggested by Edelson and Taitz[4] and their incidence was noted down [Figure 3a-c].

Superior border of scapula

The superior border of scapula was classified into horizontal, moderately oblique, markedly oblique, saddle-shaped, and wavy types as suggested by Hrdlička[7] and their incidence was noted down [Figures 1b and 4a-d].

Data obtained were compared in males and females on both sides.

Results

Sulcus for circumflex scapular artery

The sulcus for circumflex scapular artery was observed in 60/100 scapulae, out of which 32/60 were in males, 28/40 in females, 27/50 on right side, and 33/50 on left side [Table 1].

Figure 2: (a) Presence of inferior border of scapula (marked with red line). (b) Rough inferior surface of acromion process with an accessory facet in addition to clavicular facet (arrow)

Figure 3: Tip of acromion process; (a) Cobra type; (b) Intermediate type; (c) Square type tip

Figure 4: Superior border of scapula; (a) Moderately oblique; (b) Markedly oblique; (c) Saddle shaped; (d) Wavy

Costal facets

The costal facets were observed in 2/100 scapulae, out of which 2/40 were in females and 2/50 on right side, whereas no costal facet was observed in males and on left side. Both costal facets were observed in females on right side on superior angle of scapula [Table 1].

Presence of inferior border of scapula

The inferior border was observed in 12/100 scapulae, out of which 7/60 were in males, 5/40 in females, 6/50 on right side, and 6/50 on left side [Table 1].

Scapular foramina

The scapular foramina were observed in 5/100 scapulae, out of which 2/60 were in males, 3/40 in females, 4/50 on right side, and 1/50 on left side. Out of five scapular foramina observed, three were present in infraspinous fossa, one in supraspinous fossa, and one at root of spine [Table 1].

Inferior surface of acromion process

The inferior surface of anterior third of acromion process was found smooth in majority of the scapulae (51/100), followed by rough surface (49/100). The rough surface was more prevalent in males and on right side, whereas the smooth surface was more prevalent in females and on left side [Table 1].

Facet on the inferior surface of acromion process

The accessory facet on the inferior surface of acromion process other than the clavicular facet on medial border of acromion process was observed in 14/100 scapulae, out of which 5/60 were in males, 9/40 in females, 7/50 on right side, and 7/50 on left side [Table 1].

Tip of acromion process

The most common type of tip of acromion process found was square type (42/100), followed by intermediate and cobra types, i.e., 40/100 and 18/100, respectively. The same pattern was observed in females and on right and left sides except in males, in which intermediate type was predominant, followed by square and cobra types [Table 1].

Superior border of scapula

The most common type of superior border of scapula found was horizontal type (40/100), followed by moderately oblique (27/100), markedly oblique (15/100), saddle-shaped (12/100), and wavy (6/100) types. The same pattern was observed in males and on right and left sides except in females, in which the pattern observed was horizontal > moderately oblique > wavy > markedly oblique > saddle shaped [Table 1].

Discussion

Anatomical variations in scapula are not so frequent, but if present, may prove to be clinically significant.

Sulcus for circumflex scapular artery

In a study on French scapulae, Vallois found the sulcus in 64% of scapulae on the right side and 61.7% of scapulae on the left side.[8] In the present study, we found the sulcus in 54% on the right side and 66% on the left side. Our findings are near to the findings of Vallois.

Costal facets

Vallois found 13 costal facets in 180 (7.2%) scapulae.[8] Gray found costal facets in 64 of 1152 (5.55%) scapulae.[9] In the present study, we found the costal facets in 2% of scapulae.

Presence of inferior border of scapula

To the best of our knowledge, no previous study was found on inferior border.

Scapular foramina

The defects due to scapular foramina can be seen radiographically and remain unchanged over time. They are problematic if the resulting radiolucency is mistaken for a lesion of the lung.[3] Gray studied 1152 scapulae with 28 possessing foramina, i.e., 2.4%.[9] In the present study, we found the scapular foramina in 5% of scapulae.

Inferior surface of acromion process

Paraskevas *et al*.,[6] Singh *et al*.,[10] and Gupta *et al*.[11] found that the inferior surface of the anterior third of the acromion process was smooth 42%, 55.8%, and 10% of scapulae, respectively, and rough in 57.9%, 44.2%, and 90% of scapulae, respectively, whereas in our study, the inferior surface anterior two-third was smooth in 51% and rough in 49% of scapulae.

Facet on the inferior surface of acromion process

Gray reported 240 (20.8%) facets on the inferior surface of acromion process in 1152 scapulae.[9] In the present study, the accessory facet on the inferior surface of acromion process other than the clavicular facet on medial border of acromion process was observed in 14% of scapulae.

Tip of acromion process

Comparison with previous studies is done in Table 2.

Superior border of scapula

To the best of our knowledge, no previous study was found on types of superior border of scapula.

Conclusion

Clinical awareness of known and newly discovered anatomical variations, which can be achieved through a frequent review of the pertinent literature in specialized journals, is the key to a successful outcome in the clinical setting.

Table 1: Number (percentage) of anatomical variations in scapula in males and females on both sides

Observation	Males (*n*=60)		Females (*n*=40)	
	Right, *n* (%)	Left, *n* (%)	Right, *n* (%)	Left, *n* (%)
Sulcus for circumflex scapular artery	13 (21.7)	19 (31.7)	14 (35)	14 (35)
Costal facets	0	0	2 (5)	0
Presence of inferior border of scapula	3 (5)	4 (6.7)	3 (7.5)	2 (5)
Scapular foramina	1 (1.7)	1 (1.7)	3 (7.5)	0
Inferior surface of acromion process				
Rough	19 (31.7)	14 (23.3)	7 (17.5)	9 (22.5)
Smooth	11 (18.3)	16 (26.7)	13 (32.5)	11 (27.5)
Facet on inferior surface of acromion process	3 (5)	2 (3.3)	4 (10)	5 (12.5)
Tip of acromion process				
Square	12 (20)	11 (18.3)	9 (22.5)	10 (25)
Intermediate	13 (21.7)	14 (23.3)	7 (17.5)	6 (15)
Cobra	5 (8.3)	5 (8.3)	4 (10)	4 (10)
Superior border				
Horizontal	12 (20)	10 (16.7)	11 (27.5)	7 (17.5)
Moderately oblique	10 (16.7)	7 (11.7)	4 (10)	6 (15)
Markedly oblique	4 (6.7)	7 (11.7)	2 (5)	2 (5)
Saddle shaped	4 (6.7)	5 (8.3)	1 (2.5)	2 (5)
Wavy	0	1 (1.7)	2 (5)	3 (7.5)

Table 2: Comparison of types of acromion in different regional and international population

Population groups	Authors	Type of acromion process
Turkish	Coskun *et al*.[12]	Intermediate type>cobra type>square tipped
Egyptian	El-Din and Ali[13]	Intermediate type>square tipped>cobra type
Maharashtra	Wasavade and Yadav[14]	Intermediate type>square tipped>cobra type
Turkish	Boyan *et al*.[15]	Intermediate type>cobra type>square tipped
North Indian	Present study	Square tipped>intermediate type>cobra type

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Original Article

Biotherapeutic Sufficiency of Virgin Coconut Oil on Paraquat-Mediated Reproductive Dysfunction

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Abstract

Introduction: Paraquat (PQ) affects male reproductive health with the risk of infertility. Virgin coconut oil (VCO) has antioxidative and fertility properties. Thus, the histology of the testis and seminal vesicles, spermatic indices, testosterone, malondialdehyde (MDA), and superoxide dismutase level in Wistar rats exposed to PQ and treated with VCO was investigated. **Material and Methods:** Twenty-four rats (150–200 g) were divided into groupings (A-D) with six rats per group. Control (Group A) had a daily dose of 5 ml/kg of normal saline (NS) throughout the experimental period of 24 days. Group B received NS and oral dose of 12.75 mg/kg of PQ at the last 3 days of the experiment. Groups C and D were treated with 5 ml/kg and 10 ml/kg of VCO, respectively, for 21 days before PQ. The rats were then sacrificed. Blood samples were collected for biochemical analysis and the organs were harvested for histology. **Results:** There was no significant rise in MDA except in Group B. Groups C and D had significant decreases in sperm cells with unconventional pinhead, contrasting difference in active motile cells and testosterone when compared to Group B ($P < 0.05$). Normalcy in sperm count and a decrease in sperm cells with headless tails were only seen in Group C ($P < 0.05$). Histological evaluations showed minimal damage in VCO-treated groups. **Discussion and Conclusion:** VCO has a promising effect against PQ by modulating the activities of its free radicals in a dose-dependent manner.

Keywords: *Fertility, oxidative stress, paraquat, reproductive health, virgin coconut oil*

Introduction

Adverse male reproductive health from varying toxicities has been intimately related to infertility.[1] The testis, seminal vesicle, and epididymis are affected sites that are prone to pathological changes since they contribute to mammalian reproducibility.[2] It is believed that fertility challenges are apparently worrisome, especially in societies where birth expectancies are high. Certain agrochemicals like paraquat (PQ) under different trade names are used as a better alternative to manual weeding for their efficacy.[3] However, their usages posit dangers to the reproductive function as reported elsewhere.[4] Redox cycling and intracellular oxidative stress has been implicated in the mechanism of PQ-mediated toxicity.[5,6] Oxidative stress is an important factor that affects the development of male fertility because of very high rate of cell division and mitochondrial oxygen consumption in testicular tissues.[7] The associated health risks from PQ toxicities result from accidental ingestion and dermal exposures with the intensity of toxicities being dependent on dose.[8,9] Currently, there are no antidotes for the treatment of PQ poisoning and therapeutic management is mostly supportive and directed toward changing the disposition of the poison.[10] Development of an efficient antioxidant therapy from novel compounds of plant origin may provide the necessary antidote that could attenuate the toxic effects of PQ on reproductive function due to their presumptive adequacies. Virgin coconut oil (VCO) is a plant product consumed as a dietary food. Unlike ordinary coconut oil, VCO is enriched with more polyphenols, tocopherols, sterols, and squalene.[11] Perhaps, this suggests why it has continued to capture recent interest as an antioxidant.[12] From the foregoing premise, it became germane to explore the efficacies of dietary supplementations of VCO on the male reproductive organs in circumstances of PQ toxicity.

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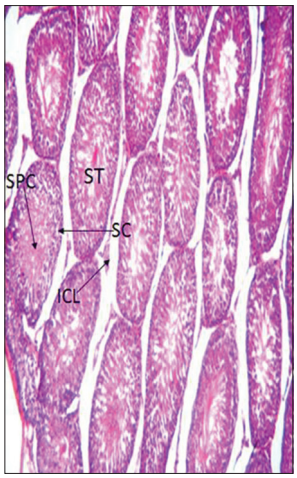

Figure 1 : Micrograph of control section of the testis show normal architecture with well clustered and numerous convoluted seminiferous tubule (ST) lined by sertoli cell (SC), well-nourished spermatogenic cells (SPC). H & E x400

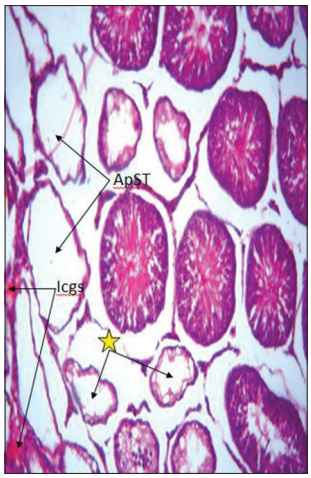

Figure 2 : Micrograph of section of the testis administered with paraquat only (Group B) shows Apoptotic Seminiferous Tubules (ApST), Shrinked and Unevenly spaced Seminiferous Tubules (marked by yellow star), Interstitial clogs (Icgs) H & E x400

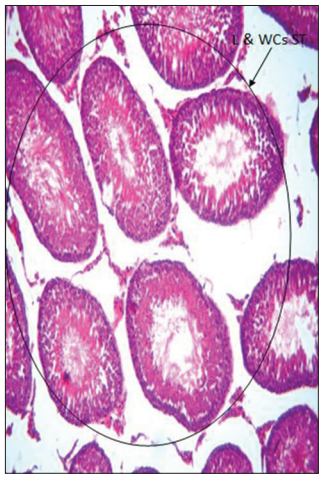

Figure 3 : Micrograph of section of the testis pre-treated with low dose VCO for 21 days before paraquat administration (Group C) shows nourished, large and well clustered Seminiferous tubules (L & WCs ST) with preserved spermatogenic appearance. H & E x400

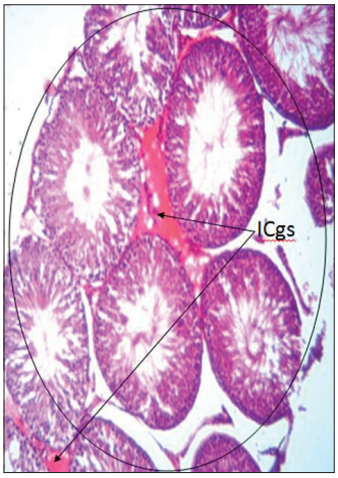

Figure 4 : Micrograph of section of the testis pre-treated with high dose VCO for 21 days against paraquat toxicity (Group D) shows Nourished, larger sized and Well clustered seminiferous tubules with preserved spermatogenesis except for mild presence of vascular and interstitial clogs (Icgs) H & E x400

Material and Methods

Fresh mature coconuts numbering thirty (30) were gotten from a coconut farm situated in Ikwo Local Government Area of Ebonyi State, Nigeria.

Plant preparation and extraction

The coconut shells were removed and the fleshy endosperms were crushed into a viscous slurry. Five hundred ml of water was added to the slurry obtained and squeezed through a fine sieve to obtain coconut milk. The resultant coconut milk was left for about 24 h to facilitate the gravitational separation of the emulsion.[13,14] Extraction of VCO was done by adopting a modified wet extraction method described in a previous study.[15] The oil on the top layer was scooped, de-moisturized, and filtered through a fine sieve. It was then stored at room temperature for the experiment.

Preparation of the reproductive toxin

PQ dichloride used as the toxicant was purchased under the trade name Paraeforce, a product of Nanjing Redsun Biochemical Company Ltd. The working solution was constituted within a fume cupboard. 2.5 ml of the stock solution (concentration of 200 g/L) was diluted in 400 ml of distilled water, shaken, and left to stand for some minutes before use.

Experimental animals

Twenty-four (24) Wistar rats (150 g–200 g) were purchased and housed in the Animal Facility of Alex Ekwueme Federal University Ndufu Alike Ikwo, Ebonyi State (AE-FUNAI), Nigeria. The animals were kept in well-ventilated cages under standard conditions. They were

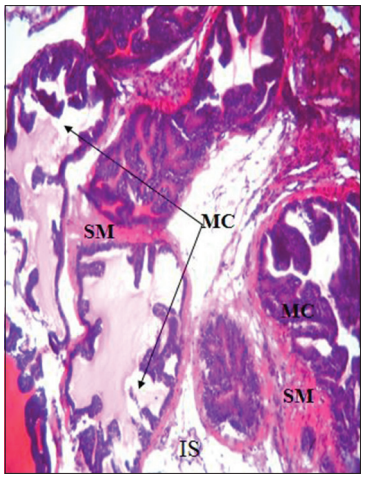

Figure 5 : Micrograph of Control section of Seminal vessicle (Group A) shows healthy appearance such as numerous convolutional Mucosal folds (MF) with mucosal crypts (MC) and secretory activity, Interstitial spaces (IS), presence of well dispersed smooth muscles (SM) of (x400)(H/E)

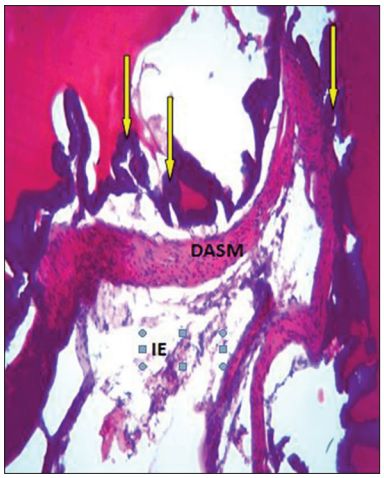

Figure 6 : Micrograph of Seminal vesicle (Group B), show severe alteration of the mucosal foldings (marked by arrows), disoriented and Atrophied Smooth Muscles (ASM), Interstitial Erosion with associated lymphocytic infiltration. H & E x400

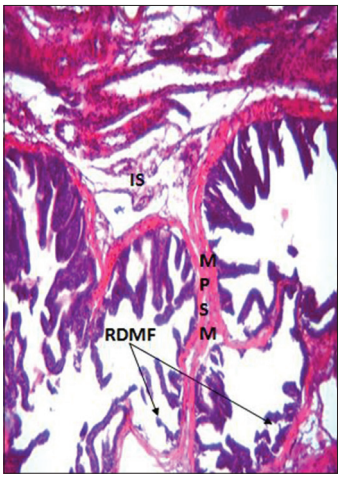

Figure 7 : Micrograph of Seminal vesicle pre-treated with 5ml/kg VCO before paraquat (Group C) show reduced and distorted folding (RDMF) of the mucosal gland, a moderately preserved smooth muscle mass (MPSM) around the gland as well as mild damage to the Interstitium. H & E x400

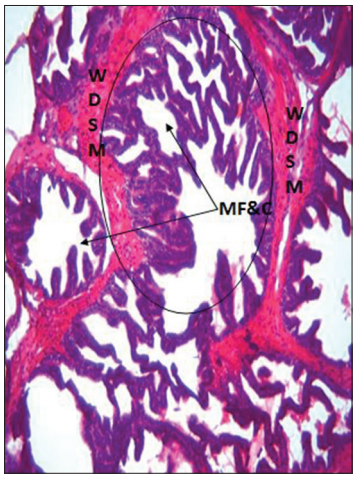

Figure 8 : Micrograph of Seminal vesicle pre-treated with 10ml/kg VCO before paraquat (Group D) show improved architecture with well-defined and finely dispersed smooth muscle (WDSM), enveloping the abundant and better organized mucosal folding and cryptic formation. H & E x400

fed with rat pellet and drinking water *ad libitum*. Their weights were taken by the aid of an electronic weighing balance during acclimatization and for the duration of the experiment. Acclimatization period was for 1 week and the experiment lasted for 24 days.

Induction of toxicity

Target organs were induced with toxicity through oral administration of 12.75 mg/kg bwt of PQ chloride. This dose represents 11.20% of the reported oral LD_{50} of PQ in male Wistar rats.[16]

Dose determination of virgin coconut oil and administration route

An oral dose of 5 ml/kg of VCO with reported health benefit served as the low dose for this present study. A high oral dose of 10 ml/kg of VCO being twice the low dose was equally used in this study. These administered doses were considered safe as the calculated percentages lie below the limit of the established oral LD_{50} of VCO.[17]

Experimental design

The animals were randomly assigned into six groups of four rats each. Group A served as control that received a daily dose of 5 ml/kg bwt of normal saline (NS) throughout the experimental duration. Group B served as the positive control that received NS as vehicular medium and 12.75 mg/kg bwt of PQ on the last 3 days of the experiment. The animals in Group C were pretreated with 5 ml/kg bwt of VCO for 21 days followed with a toxic dose of PQ. Group D animals were equally pretreated with

Table 1: Testosterone, SOD and MDA level.

	GROUP A	GROUP B	GROUP C	GROUP D
MDA	1.15±0.67	2.94±0.07*	2.60±0.33	2.20±0.03
SOD	13.33±2.10	11.66±0.80	4.85±2.05	16.05±1.76[a]
TESTOSTERONE	5.60±1.17	3.40±0.20**	4.96±0.56	6.65±1.20[a]

Group A (control); Group B (Paraquat only); Group C (5ml VCO+PQ); Group D (10ml VCO+PQ); *=significant at $P<0.05$.The values are the means±SD. $n=6$ in each group. [a, b] represent significant increases or decreases respectively at $P<0.05$ when the values are compared with positive control (Group B). *,** represent significant increases or decreases respectively at $P<0.05$ when values are compared with the negative control (Group A).

Table 2: Sperm Morphology

SPERM MORPHOLOGY	GROUP A	GROUP B	GROUP C	GROUP D
Round Head	0.67±0.33	2.00±1.00	0.75±0.47	1.33±0.33
Pin Head	1.00±0.00	5.50±0.50*	1.50±0.50[b]	0.67±0.33[b]
Headless tail	2.00±1.00	5.50±1.50*	1.50±0.28[b]	2.33±0.66
Bent Mid-Piece	1.33±0.33	1.50±0.50	1.50±0.28	2.00±1.00
Coiled Tail	0.33±0.33	1.00±0.00	0.50±0.28	1.00±0.57

Group A (control); Group B (Paraquat only); Group C (5ml VCO+PQ); Group D (10ml VCO+PQ); *=significant at $P<0.05$.The values are the means±SD. $n=6$ in each group. [a, b] represent significant increases or decreases respectively at $P<0.05$ when the values are compared with positive control (Group B). *,** represent significant increases or decreases respectively at P<0.05 when values are compared with the negative control (Group A).

Table 3: Sperm Motility and Count.

Sperm parameter	GROUP A	GROUP B	GROUP C	GROUP D
Active Motility (%)	38.33±7.26	12.50±7.50**	30.00±10.21[a]	38.33±8.33[a]
Sluggish Motility (%)	21.66±1.66	35.00±25.00*	23.75±2.39[b]	25.00±7.64[b]
No motility (%)	40.00±5.77	52.50±32.50*	43.75±9.21[b]	36.66±6.66[b]
Sperm count (X106)	54.33±5.24	37.00±6.00**	54.75±1.18 [a]	48.33±1.85

Group A (control); Group B (Paraquat only); Group C (5ml VCO+PQ); Group D (10ml VCO+PQ); *=significant at $P<0.05$.The values are the means±SD. $n=6$ in each group. [a, b] represent significant increases or decreases respectively at $P<0.05$ when the values are compared with positive control (Group B). *,** represent significant increases or decreases respectively at $P<0.05$ when values are compared with the negative control (Group A).

a high dose of VCO for 21 days before toxic administration of PQ.

Animal sacrifice and sample collection for biochemical evaluations

At the end of the experiment, the animals were fasted overnight, anesthetized with diethyl ether. Following a simple cardiac puncture, blood samples were collected into plain tubes and centrifuged at 3000 rpm for 10 min using a tabletop centrifuge (P/C 03). The sera were separated and stored in aliquots at −25°C for biochemical assays of testosterone, superoxide dismutase (SOD), and malondialdehyde (MDA) using commercially available Analyse Gold Kits. The pelvic area was quickly and carefully incised. The testis and seminal vesicles were harvested, blotted on filter paper, and fixed in formal saline for routine histology.

Semen collection and evaluation of sperm parameters

Prior to fixing the testis, the caudal tip of the epididymis was excised and placed into a Ringer's physiological saline solution. The tissue was minced and left for a few minutes to liberate the spermatozoa into the solution. Sperm count procedure and determination of morphological defect in sperm were done according to an earlier descriptive method.[18] Sperm motility was evaluated following a small drop of semen on a warmed slide, mixed with one drop of warm sodium citrate, and covered with a glass slip. The percentage of sperm cells in a unidirectional progressive movement over a field on a slide was observed, using a research light microscope as previously described.[19] Sperm motility was classified as highly motile sperm (sperms that could be seen to cross the field of view very quickly), slightly motile sperms, and nonmotile sperms. Morphological defects in sperms were classified accordingly.[20,21] In general, all values were expressed as percentages of normal sperm.

Estimation of testosterone level

This was done using the Testosterone AccuBind™Microplate EIA test system following a descriptive procedure.[22]

Estimation of malondialdehyde and superoxide dismutase

The amount of lipid peroxidation using MDA was estimated following an earlier descriptive method.[23] Quantification of SOD was determined in line with known descriptive techniques.[24]

Ethical approval

Guidelines relating to National Institutes of Health Guide for the Care and Use of Laboratory animals (NIH Publications No. 8023, revised 1978) were adhered to.[25]

Data analysis

The data obtained in this present study were subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS) software, manufactured by IBM, Chicago, USA version 23. Values were expressed as mean ± standard deviation for the groupings. Differences in the mean between the groups were analyzed using one-way ANOVA. Statistical significance was considered at $P \leq 0.05$.

Results

Comparing the groups [Table 1], there was a significant difference in MDA level between groups that received only PQ (Group B) and control group (Group A) ($P \leq 0.05$). SOD was significantly increased in high-dose VCO pretreatment group when the mean value was compared with Group B ($P \leq 0.05$). Testosterone level decreased significantly in Group B when the mean value was compared with control ($P \leq 0.05$). However, there was a significant increase in testosterone hormone in high-dose VCO pretreatment group when compared to Group B ($P \leq 0.05$).

Sperm morphology showed that among all the abnormalities observed, there was a significant difference in sperm cells presented with pinheads and headless tails between control and Group B ($P \leq 0.05$). Although there was also a decrease in pinhead sperm cells of Group D, only low-dose VCO pretreatment group (Group C) had significantly decreased number of sperms with headless tail and pinheads when values were compared with Group B ($P \leq 0.05$). A detailed comparison is given in Table 2.

Differences in the sperm motility and sperm count were observed between the respective groups [Table 3]. Group B had a significantly lowered sperm count when compared with control ($P \leq 0.05$). Contrastingly, the sperm count was significantly preserved when a comparison was made between Groups B and C ($P \leq 0.05$). The result further showed that sperm motility was not significantly affected in both Groups C and D as otherwise seen in Group B when their mean values were compared.

Histological micrographs

The result of the histology showed that sections of the testis from the Control had normal tissue architecture with numerous and well-organized seminiferous tubules lined spermatogenic cells with normal progression of spermatogenesis [Figure 1]. PQ administration resulted in loss of seminiferous tubules, resorption in the mass of sertoli cells, and spermatogenic cell series with possibilities of an arrest of spermatogenesis [Figure 2]. However, pretreatment with VCO showed an appreciable protection against the adverse effect of PQ in a dose-dependent fashion [Figures 3 and 4]. Micrographs of the seminal vesicle of control (Group A) showed normal convoluted mucosal folds with mucosal crypts and secretory cells, interstitial spaces, and smooth muscles [Figure 5]. In contrast, micrographs of Group B [Figure 6] administered with PQ only showed severe fragmentations of mucosal folds and other deleterious effects on the seminal vesicle. Mild-to-moderate damage was observed in the histoarchitecture of Group C [Figure 7] and Group D [Figure 8] pretreated with 5 ml and 10 ml/kg VCO, respectively.

Discussion

PQ is a toxic agent that affects bodily organs on environmental and occupational exposures.[26] Establishing its reproductive toxicity and providing a potential biotherapy are central to the priority setting of this study. According to the WHO (2010), the preliminary basis for ascertaining male infertility is through clinical evaluation of sperm concentration, morphology, and motility.[27] It is believed that the uptake of reactive metabolites of PQ via processes of ionic mimicry into the tissues critically interferes with the molecular and genetic transcription factors like the HSF2 and OVOL1 expressed in germ cells as well as WT1, RHOX5, and SOX8 expressed in sertoli cells for regulating the development and maturation of sperm cells. The sluggish and nonmotility of the sperms could be due to impairment in the production of sufficient Adenosine triphosphate (ATPs) hat would have otherwise facilitated propulsive movements. Although sperm count and sperm motility are regarded as the first and most important predictors of fertility than sperm morphology, primary morphological defects like acephalic sperms are associated with decreased fertility.[28,29] Therefore, these sperm cells cannot initiate the acrosome reaction step of fertilization process. This impairment has earlier been associated with disorders in the spermiogenic epithelium which occur in testicular degeneration.[30] The low sperm count, vast depth of nonmotile sperm, and morphological abnormalities mediated by sublethal exposure to PQ without treatment are clear evidence that it could cause a rapid progression to infertility. This finding agrees with an earlier report on the hazards of PQ to sperm.[31]

Histological evaluations of the testis and seminal vesicle in the group exclusively exposed to PQ also corroborate

its adverse effect. Besides forming the blood–testis barrier, the sertoli cells otherwise called "nurse" cells respond to FSH to promote spermatogenesis. The degenerated mass of the sertoli cells lining the empty seminiferous tubules may point toward the germ cell aplasia or Del Castillo syndrome. The genomic integrity of these spermatogenic cells may be compromised since reactive oxygen species (ROS) have been reported to affect spermatogonia DNAs.[32,33] These findings agree with a similar report that PQ is genotoxic as well as cytotoxic in germ cells.[34] Furthermore, the severe spermatogenic arrest observed could be linked to the diminished level of testosterone since the primary role of the male steroid hormone is in spermatogenesis. This finding agrees with a previous report that PQ toxicity alters testosterone levels.[35,36] The mucosal folds and glands of the seminal vesicle are composed of granular epithelia cells that are active in protein synthesis.[37] Impairment of protein synthesis and channel blockage via PQ-mediated damage will affect the general integrity and functionality of the tissue. The atrophied smooth muscle may suggest impairment in the rhythmic contraction of the muscle to release abundant seminal fluid rich in fructose and prostaglandin that nourishes the sperm cells as they move into the ejaculatory duct during ejaculation.[38] By implication, there is a diminished level or absence of factors that increase sperm motility, factors that suppress the immune response in the female reproductive tract against semen, and factors that clot and then liquefy semen in the vagina. These events culminate in the progression of infertility.

Testicular tissues are susceptible to oxidative stress damage because they have comparably higher levels of unsaturated fatty acids than other tissue. Intense oxidation of lipid membrane is due to increased ROS.[39] This alters the structure, function of the cell membrane, and inadvertently disposes cellular organelles to functional impairment.[40] In the present study, the high lipid peroxidation could be attributed to the excessively generated ROS from PQ in oxidative stress. This lends credence to a previous report on the basis of PQ-mediated damage.[41] The surge in the activity of SOD as seen in VCO high-dose pretreatment group is a pointer toward oxidative stress as it suggests the adaptive responses of the antioxidant in mopping up excess free radicals. This finding in tandem with a previous report on intracellular events associated with oxidative stress.[42]

The minimal damage in the histology of the testis, seminal vesicle, sperm, and biochemical parameters after pretreatments with VCO could be attributed to its tocopherols, polyphenols, and phenolic compounds like p-coumaric acid, protocatechuic acid, vanillic acid, ferulic, caffeic acid, and lauric acid.[43,44] Being quite profound in the VCO low-dose group, it is believed that these biologically active ingredients are present in proportions that do not distort the cellular homeostatic balances. They may aid to considerably forestall rapid depolarization of the seminiferous membrane for intracellular uptake of reactive metabolites of PQ that could affect sperm development. Consequently, the chances of an occurrence of a progressive nonobstructive azoospermia may be halted since the structural organization and functional role of the sertoli cells, Leydig cells, seminiferous tubules, and accessory organs of reproduction were relatively sustained. This finding appears novel as it demonstrates the benefit of VCO on the seminal vesicle. It may also be related to documented evidences on the benefits of VCO on the testis, as well as other reproductive indices in a dose-dependent fashion.[45,46]

Conclusion

Reproductive toxicity caused by PQ has remained a health risk of major concern in various populations, especially in West Africa. The treatment options when available are usually expensive and few. VCO has shown a more beneficial effect on male fertility and reproduction at low dose by impacting positively on the functionality of the testicular tissue and seminal vesicle in the release of fluid during ejaculation. This could be attributed to its naturally occurring constituents. Thus, harnessing and developing the pharmacologically active ingredients as therapeutic supplements may protect and promote the reproductive health from adverse risks associated with PQ.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Case Report

Sternalis and Transversus Thoracis Muscles: An Anatomical Variation and Its Clinical Implications

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Abstract

An unusual muscle was discovered during the dissection of the presternal and pectoral regions, which, according to Jelev classification, can be considered a sternalis muscle. The identified right sternalis muscle has a common origin with the sternal head of the right sternocleidomastoid muscle and then splits in two bellies, the right one, much longer, which inserts on the right 2nd–5th costal cartilages, and the left one which inserts on the 2nd–3th left sternocostal joints. The sternalis muscle was associated with a very poor developed right transversus thoracis muscle. The study is important for the anatomists and more important for the clinicians, as this muscle's presence may cause diagnostic errors in the pectoral region.

Keywords: *Anatomy, muscle anomaly, pectoral region, sternalis muscle, transversus thoracis muscle*

Introduction

In literature, the sternalis muscle was reported as a uni- or bilateral parasternal muscle, located between the superficial fascia of the anterior thoracic wall and the pectoral fascia. The origin is on the manubrium of the sternum, sternocleidomastoid fascia, pectoralis major, the upper ribs, and their costal cartilages and insertion on the lower ribs and their costal cartilages, the rectus abdominis sheath, and the aponeurosis of external oblique muscle.[1] Transversus thoracis also called sternocostalis or triangularis sternae,[2] was classically described as four to five slips, which spreads on the internal surface of the anterior thoracic wall. Its origin is on the xiphoid process, inferior part of the sternum, and the adjacent costal cartilages and insertion on the 2nd–6th costal cartilages.[3]

According to Jelev *et al*., in 44.2% of cases, the transversus thoracis muscle was asymmetrical.[3] Sternalis muscle may occur as an isolated supernumerary muscle or associated with other anterior thoracic wall unusual muscles, such as the chondroepitrochlearis muscle, pectoralis quartus, and pectoralis minimus. To the best of our knowledge, the association between sternalis and the transversus thoracis muscle anomaly have not been reported before.

Most of the studies regarding sternalis muscle were anatomical studies performed by cadaveric dissection; that's why such an accessory muscle's clinical significance is controversial. The sternalis muscle was frequently discovered on magnetic resonance or computed tomography imaging, showing its importance among surgeons because it may cause diagnostic errors in the pectoral region[4] and may be used in breast reconstruction.[5]

Case Report

The purpose of the present study is to describe a rare anatomical variant of the sternalis muscle, associate with a variation of the transversus thoracis muscle, significant for anatomists, but much more important for clinicians.

During the routine dissection studies for medical students in the presternal and pectoral regions', a unilateral variant of the sternalis muscle was found located on the right side in a 60-year-old male formalin-fixed cadaver. This muscle takes origin on the sternum's manubrium's anterior surface by a common tendon with the sternal head of the sternocleidomastoid muscle. It then splits into two flat bundles, right and left, their direction being

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perpendicular to the major pectoralis muscle. Pectoralis major muscles were normally placed. The right bundle measured 8 cm in length, and 1.4 cm at its broadest part, runs craniocaudally, parasternal, and inserts on the costal cartilages at the 2nd–5th rib level. The left flatband, measured 2 cm in length, had a craniocaudal trajectory on the sternum's anterior surface, across the midline, becoming parasternal and inserted on the 2nd–3th left sternocostal joints [Figure 1].

At the same time, the dissection revealed a very poorly developed transversus thoracis muscle on the right side and a very well-developed transversus thoracis muscle on the left side [Figure 2].

A drawing was made to reveal the present case [Figure 3].

Discussion

Cabrolius first reported the sternalis muscle in 1604,[6] when he found a longitudinal band-like muscle situated superficial to the sternum. Because of its relations, the muscle was called "parasternalis" or "rectus sterni muscle," "sternalis brutorum" or "episternalis," "rectus thoracicus superficialis," "rectus sternalis," or "mystery" muscle.[1,7,8]

Many authors investigated the sternalis muscle in different populations and appeared to be present in 8% of the cases.[9] Due to its peculiar morphological position, it has produced a literature of its own.[10] Its nerve supply is variable, by the pectoral nerves or by the intercostal nerves.[1] Although its function is still unknown, most of the authors agreed that it might participate in the chest and shoulder joint movements, such as elevating the lower part of the chest and acting as an accessory inspiratory muscle.[1] The transversus thoracis represents the primary muscle of breathing in dogs, but in humans is an accessory muscle for respiration, supporting the active expiration by drawing down the costal cartilages.[2] The intercostals nerves innervate it.

According to Huntington,[10] the sternalis is always innervated by the anterior thoracic nerves, and hence neurologically, it belongs to the pectoralis group muscles. He reported three hypotheses regarding the derivation of the sternalis muscle: Turner's hypotheses describing the sternalis as a reversional persistent remnant of the thoracic cuticular muscle; Cunnigham's hypotheses describing the sternalis as a displaced and rotated segment of the pectoralis major muscle; Eisler's hypotheses describing the direct derivation of the sternalis from the pectoralis major due to an atypical widening of the ventral parts of intercostal spaces. Huntington[10] classified the sternalis in three types: well-developed sternalis coexisting with pectoralis major anomalies; a slender form of the sternalis muscle with normal pectoralis major; sternalis muscle which presents a direct connection with pectoralis major. According to Sadler,[11] the myoblasts from thoracic and abdominal hypomeres split into three layers and a ventral

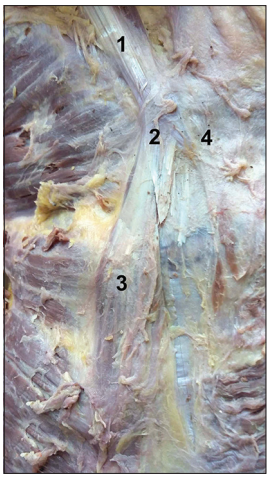

Figure 1: Dissection revealing the right sternalis. Anterior view. (1) Sternal head of the right sternocleidomastoid; (2 and 3) right belly of the sternalis ([2] fibrous part;[3] fleshy part); (4) left belly of the sternalis

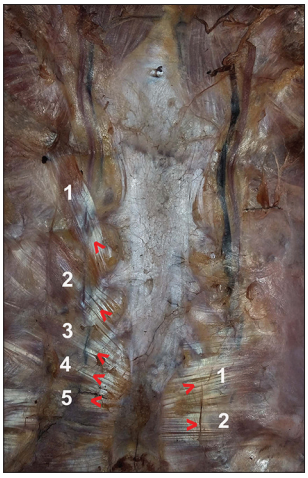

Figure 2: Dissection revealing the transversus thoracis. 1–5 (Red arrowhead). Left transversus thoracis; 1–2 (red arrowhead). Right transversus thoracis

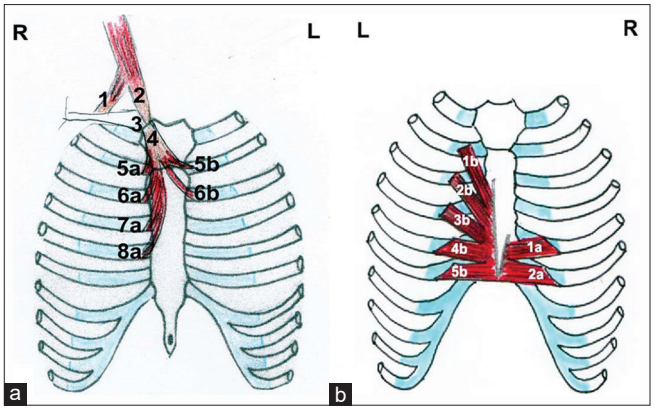

Figure 3: Drawing illustrated the right sternalis (a) and the transversus thoracis (b). (a) (1 and 2) Clavicular and sternal heads of the right sternocleidomastoid; (3) common origin of the right sternalis and sternal head of the right sternocleidomastoid; (4) sternalis muscle; (5–8 a). insertion of the right belly of the sternalis on the right 2nd–5th costal cartilages; (5–6 b). Insertions of the left belly of the sternalis on the 2nd–3th left sternocostal joints. (b) (1–2 a and 1–5 b) Right and left transversus thoracis

longitudinal column. The thorax's three layers consist of external intercostal, internal intercostal, and transversus thoracis muscle, and in the abdomen of internal oblique, external oblique, and transversus abdominis muscles. The longitudinal column is represented by the rectus abdominis muscle in the abdominal region, infrahyoid muscles in the cervical region, and disappears in the thoracic region or it may be found as the sternalis muscle. The embryological origin of the transversus thoracis muscle and the sternalis muscle associated with a very poorly developed transversus thoracis muscle may explain sternalis muscle presence like a "compensatory" muscle for the transversus thoracis.

According to the Jelev *et al*. classification,[1] the muscle that we found is located between the superficial fascia and pectoral fascia of the anterior thoracic region, originates on the sternum and inserts on the costal cartilages. Therefore, it can be considered sternalis muscle, Type II2 (one muscle and two simple asymmetric bellies). A well-developed muscular belly, like the right belly, in this case, associated with an anomaly of the right transversus thoracis muscle, can be regarded as a "symptomatic" sternalis muscle.

Conclusions

We report a variant of sternalis muscle, associate with a variation of the transversus thoracis muscle, important for anatomists, but much more significant for clinicians. Its presence may interfere with the proper positioning of the breast implants, cause changes in the electrocardiogram and pain in the pectoral region, or misdiagnosed as a tumor or a lesion in the anterior chest wall.

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Conflicts of interest

There are no conflicts of interest.

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Case Report

A Unilateral Anomalous Muscle with an Uncommon Nerve Supply Interconnecting the Biceps Femoris and the Gastrocnemius

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Abstract

This case study describes the morphology and embryology and hypothesizes the muscle action based on the morphology of an anomalous muscle that extends from the long head of the biceps femoris to the medial head of the gastrocnemius muscles. It has an uncommon nerve supply via the medial sural cutaneous nerve which is mainly sensory in humans. This variation is different from other similar variations involving the gastrocnemius and biceps femoris muscles. The case report will be of benefit to diagnosis, clinical training, and surgical procedures as well as contribute to knowledge on the type of nerve fiber carried by the medial sural cutaneous nerve or its components.

Keywords: *Anomalous muscle, biceps femoris, gastrocnemius, medial sural cutaneous nerve, tensor fascia suralis, third head of gastrocnemius*

Introduction

The most common variation of the gastrocnemius is the presence of an additional head that inserts into the popliteal fossa. This is called the third or accessory head of the gastrocnemius muscle.[1-4] This abnormally placed muscle, with variable proximities to the popliteal artery or vein, may compress the popliteal vessels therefore causing problems that may require surgical interventions.[2-6] Another variation that often involves one or two hamstring (biceps femoris or semitendinosus) muscles is tensor fascia suralis or ischioaponeuroticus. This muscle usually arises from either or both hamstring muscles and then inserts by blending with the fascia of the leg.[7,8] The present case study describes the morphology and embryology and hypothesizes the function of the anomalous muscle based on its morphology and location. This muscle variation is rare and has an uncommon nerve supply via the medial sural cutaneous nerve.

Case Report

A 71-year-old male cadaver (from bequests/donation process) of South African of European ancestry was used during a routine dissection for the undergraduate medical students, permitted under the Human Ethics number: W-CJ-140604-1. After removing the skin and the deep fascia (fascia lata) to reveal the popliteal contents, a nerve-like structure initially thought to be a tibial nerve or its variant was observed in the fossa on the left leg. By tracing the tendon proximally and distally, the whole length of the anomalous muscle [Figure 1a – indicated by arrows] measuring approximately 43 cm in length became obvious. The anomalous muscle extended from the media side of the long head of bicep femoris to the medial head of the gastrocnemius muscles. For morphological description, the anomalous muscle [Figure 1a-c] had three observable and distinguishable parts – proximal, intermediate, and distal.

The proximal part, presumably the muscle origin about 17 cm from the ischial tuberosity [Figure 1b – indicated by no-colour filled arrows], was fleshy, flattened mediolaterally and had a muscle belly that was about 2 cm wide and 16 cm long. It attached to the bicep femoris via a tendinous aponeurosis and tapered distally to become tendinous (intermediate part) at about 33 cm from the ischial tuberosity. This part was supplied through intramuscular branches of the sciatic nerve innervating the bicep femoris.

The intermediate part [Figure 1a – indicated by white arrows] was tendinous and laid

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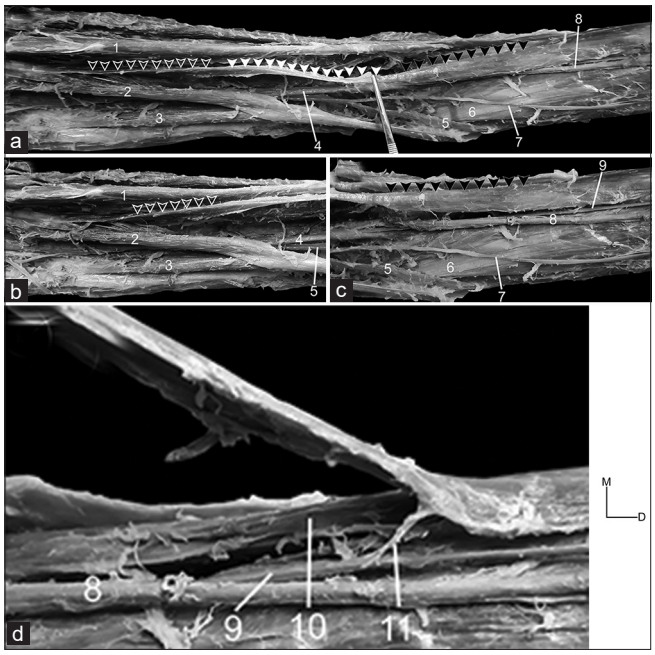

Figure 1: Photographs showing (a) the extent of the anomalous muscle (indicated by arrows) and its intermediate part (indicated by white arrows), (b) the proximal part with its muscle belly (indicated by no color – filled arrows) and (c) the distal part with its muscle belly ([c] – indicated by black arrows) on the posterior aspect of the lower limb. Photograph (d) shows a small muscular branch (11) from the medial sural cutaneous nerve (9) supplying the anomalous muscle. 1: Semitendinosus, 2: Long head of biceps femoris, 3: Short head of the biceps femoris, 4: Tibial nerve, 5: Common fibular nerve, 6: Lateral head of the gastrocnemius, 7: Lateral sural cutaneous nerve, 8: Small saphenous vein, 9: Medial sural cutaneous nerve, 10: Medial head of the gastrocnemius, 11: Small muscular branch from the medial sural cutaneous nerve, M: Medial, D: Distal

in line with the tibial nerve within the popliteal fossa. Its tendon was thick and strong, measured about 12 cm long. This tendon connected the two ends of the anomalous muscle (i.e. the two bellies). Distally, it deviated slightly to the medial side to attach to the muscle belly of the distal part (at about 45 cm from the ischial tuberosity).

The distal part had a muscle belly and flattened anteroposteriorly. It measured about 1.8 cm wide and 15 cm long [Figure 1c – indicated by black arrows]. It rested entirely on the medial head of the gastrocnemius with the medial sural cutaneous nerve and the small saphenous vein medial to it. Its fibers blended with the superficial fibers of the medial head of the gastrocnemius muscle (at about 60 cm from the ischial tuberosity) with no visible tendinous aponeurosis. This part was presumed to be the insertion of the anomalous muscle. On careful examination, this part received a small muscular branch from the medial sural cutaneous nerve [Figure 1d] which was positioned underneath the muscle belly.

Discussion

Several variations involving human skeletal muscles are common. These variations are often due to abnormalities during the embryonic development of skeletal muscles. All progenitor cells of the limb skeletal muscles are derived from the somites[9] which were initially formed after a series of migration and de-epithelization aided by several transcription factors.[10] Thereafter, the muscle masses undergo sequence of orientation, mitosis, lengthening, and delamination to form the individual muscles of the limbs.[9] It is thus believed that a failure in the sequence of events (for example incomplete delamination or disorientation) would result into variations sometimes seen in humans.[9,10]

Most variations do not always present with severe clinical problems; thus, they usually remain unnoticed. Some however cause serious problems to structures within the proximity of the muscle variation that may require surgical intervention.[2] A good example is the third head of the gastrocnemius muscle which may compress the popliteal neurovasculatures.[1-4,6] Morphologically, it is improbable that the intermediate tendon (or its other parts) of the present variation would have caused any clinical problems in the subject while he was alive despite its close proximity to the tibial nerve.

The tensor fascia suralis has no associated clinical problem. It could arise from either the semitendinosus or the biceps femoris or from both but ends as a tendon that blends with the fascia of the leg.[7,8] A similar variation was reported by Kumar and Bhagwat[11] which consisted a proximolateral (attachment on the medial side of the long head of biceps femoris), a proximomedial (attachment on the medial side of the semitendinosus), a middle (fleshy and tapered distally to form a somewhat "W" shaped intersection), and a distal part (fleshy and inserted between the two heads of gastrocnemius muscle). Another anomalous muscle arising from the medial side of the long head of the biceps femoris but fusing only with the semitendinosus has also been described.[12] A variation similar to the latter was also reported by Somayaji *et al*.,[13] but the muscle inserted superficially into the tendocalcaneus.

The present case differs morphologically from other variations in that the anomalous muscle only attached to the long head of the biceps femoris before blending superficially with the medial head of the gastrocnemius where it received a muscular branch from the medial sural cutaneous nerve – a striking feature of this anomalous muscle. The medial sural cutaneous nerve arises from the tibial nerve and it is the main trunk that forms the sural nerve. In addition, the sural nerve formation is highly variable; thus, it is often called a sural nerve complex.[14] Sural nerve transmits sensation from the skin on the posterolateral area of the lower third of the leg. However, the sural nerve may also carry motor fibers which are considered rare in humans.[14,15] This uncommon innervation of a muscle variation involving the gastrocnemius and biceps femoris has not been reported in

the literature. This is of clinical relevance in that surgeons need to investigate the complexity of sural nerve formation and the type of fibers (sensory or motor) it conveys before harvesting the nerve as an autograft. The sural, lateral, or medial sural cutaneous nerve could be harvested depending on factors such as the length of graft required and the complex nature of sural nerve formation.[15] In this scenario, for example, it would be the medial sural cutaneous nerve that would be spared. Other clinical relevancies are in research on nerve conduction studies as well as in nerve biopsy for diagnosing neuropathies of unclear underlying cause after conventional diagnostic assessments.[16]

It is reasonable to think that muscle variants may have no specific function (i.e. redundant muscle slip) because muscle variations often occur by accidents during development. Morphologically, this anomalous muscle could be said to have an origin (proximal end) and an insertion (distal end). The muscle belly thickness and the strong intermediate tendon signaled that this muscle when it contracts and acts together with other hamstrings would play a synergistic role during knee flexion. It must be emphasized that documenting the exact functions of muscle variations in cadavers may remain difficult, but their morphological features may provide cues for hypothesizing their action. Furthermore, the rarity of a variation or when present could be unnoticed due to no clinical problem that may warrant medical investigation.

Conclusion

This anomalous muscle is rare, and its uncommon innervation further shows that the medial sural cutaneous nerve carries motor fibers which may innervate an anomalous muscle when present. Awareness of such variation or its innervation will be of benefit during nerve conduction studies, diagnosis, and surgeries. It is also hypothesized that the anomalous muscle may have acted as a synergist during knee flexion.

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Conflicts of interest

There are no conflicts of interest.

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Prof. (Dr.) S. P. Tewari (October 1926 - May 2020): A Legendary Anatomist and teacher

We hereby pay our homage to the departed soul of Prof. (Dr.) S. P. Tewari who left us on May 17, 2020 at the age of 94 years, The anatomical fraternity was deeply saddened to hear the news of the passing away of Prof. (Dr.) S. P. Tewari, former Head of the Department of Anatomy, GSVM Medical College, Kanpur (UP). The loss is on twin counts, on the professional level as academician and teacher and as an excellent human being. Professor S P Tewari was born on October 01, 1926, in Lucknow (UP) and he did his premedical schooling from Lucknow. He did his MBBS from K G Medical College, Lucknow, and then, he joined state PMS services. His illustrious academic career began with the completion of MS (Anatomy) from K G Medical College, Lucknow, in the year 1961. After that, he joined as a lecturer in the Anatomy Department at BHU (Varanasi) and worked till 1966, then he joined in the Anatomy Department at GSVM Medical College, Kanpur, and worked till 1986, till his retirement as Professor and Head.

From the very beginning of his career as Faculty in Varanasi, he took interest in teaching and research. Known as a very caring, loving, and disciplined teacher to his undergraduate and postgraduate students, across the spectrum, he had two very different approaches in dealing with the students. At the undergraduate level, he would very much teach the basics of anatomy to the students, while he would look in depth in assessing the finer points at the postgraduate level. He had a special interest in Head and Neck anatomy and Cytogenetics. He was instrumental in establishing the cytogenetics laboratory in the Anatomy Department of GSVM Medical College, Kanpur (UP). He has many research papers in reputed national and international journals. He was an examiner in various medical colleges. Post retirement, he practiced as an infertility specialist in Kanpur till his demise and earned a good name in the society, offering patients the best medical care possible. Thanks to his concerned teaching as an academician and the care he provided as a fine human being to his students, spanning generations, they are spread across the globe, many of whom are professors and head of departments in various medical colleges. A huge chunk of our academic credentials goes in honor of this great teacher and a beloved human being. For all the students, his untimely departure will leave a huge vacuum in this field which is difficult to be filled in, in times to come.

He was known for the following characteristics: (a) He was a stickler for time, be it professional or personal. He

Prof. (Dr.) S. P. Tewari
October 1926 - May 2020: A Legendary Anatomist and teacher

firmly believed the age old saying that time and tide wait for no man. One should always be punctual. (b) He was a very disciplined man and was of the rock-solid opinion that inculcation of this practice coupled with hard work is the foundation for the development of life and there is no looking back once a person adopts this path. (c) He believed in divine saying that health is wealth. He was very health conscious, in tune of keeping which he was an ardent practitioner of meditation and yoga for over six decades. He would often mention that man should treat his body like a temple, if a person is able to take care of his health well, then, he can handle the other aspects seamlessly. One of the basic reasons of his excellent health was that he has a helping attitude toward everybody. He was a strict vegetarian. (d) He always maintained the highest standard of medical education and discipline in medical curriculum. (e) He was also financially helpful to economically weaker students but was very particular in maintaining his incognito status, of not making his presence felt. He believed that if a student comes to know the source that Professor Tewari has been behind the help, then, that would give rise to attachment. He was always detached from the result while only believing in the performance of karma.

At this juncture, may I remind all the colleagues that, while we all are saddened with the grief, but the occasion is more than apt for us to take the pledge to commit ourselves to raise the bar of medical education in India, to carry forward the legacy of Prof. S P Tewari.

He left behind his wife, a son Dr Satyendra Tewari who is a cardiologist (SGPGI Lucknow), and a daughter. I offer my heartfelt condolences to his family and pray god to give peace to his departed soul.

Vishram Singh

Department of Anatomy, Kasturba Medical College, Mangalore, MAHE, Manipal, Karnataka, India

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Erratum: *Examining the Antitumoral Effect of Cornelian Cherry (Cornus mas) in Ehrlich Ascites Tumor-induced Mice*

In the article titled "*Examining the Antitumoral Effect of Cornelian Cherry (Cornus mas) in Ehrlich Ascites Tumor-induced Mice*", published on pages *16-22*, Issue *1*, Volume *68* of Journal of the Anatomical Society of India,[1] *Figure 4* has been incorrectly published. The *figure* legend and figure number are correct. The correct *figure* is mentioned below:

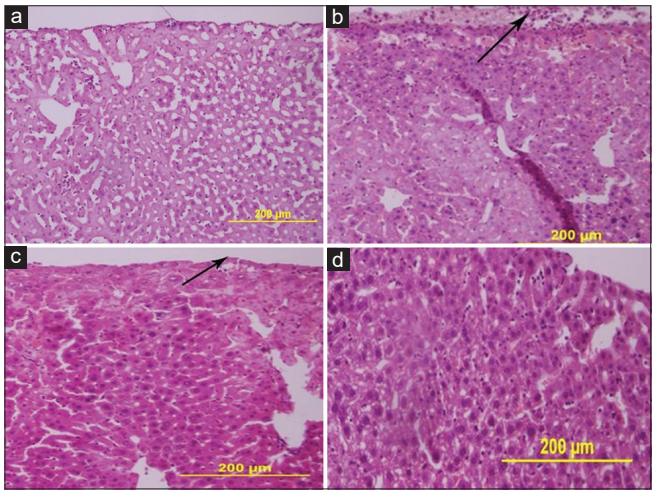

Figure 4

Reference

1. *Yilmaz S, Alpa Ş, Nisari M, Karatoprak GŞ, Doğanyiğit Z, Ülger H, et al. Examining the antitumoral effect of cornelian cherry (Cornus mas) in ehrlich ascites tumor-induced mice. J Anat Soc India 2019;68:16-22.*

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Books and Other Monographs

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