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Indian Journal of Anatomy	Bi-monthly	8500	8000	664	625
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Indian Journal of Anesthesia and Analgesia	Monthly	7500	7000	586	547
Indian Journal of Biology	Semiannual	5500	5000	430	391
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Indian Journal of Communicable Diseases	Semiannual	8500	8000	664	625
Indian Journal of Dental Education	Quarterly	5500	5000	430	391
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International Physiology	Triannual	7500	7000	586	547
Journal of Animal Feed Science and Technology	Semiannual	78500	78000	6133	6094
Journal of Cardiovascular Medicine and Surgery	Quarterly	10000	9500	781	742
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Journal of Geriatric Nursing	Semiannual	5500	5000	430	391
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## Clinical Assessment of Absence of Palmaris Longus Muscle in Marathwada Region

Syed Abrullah Hussaini<sup>1</sup>, Anuja Govindrao Deshmukh<sup>2</sup>

### Abstract

*Introduction:* Palmaris longus is a small vestigial muscle with long tendon and short belly. It is phylogenetically retrogressive. It may be absent in 15 % of individuals. Palmaris longus used as a popular tendon graft. *Aim:* The present study is done to assess absence of palmaris longus unilaterally or bilaterally by using simple clinical tests in both sexes on both sides. *Method:* We examined 200 subjects for the presence or absence of palmaris longus. Standard clinical tests were used to determine the presence or absence of palmaris longus tendon. Observations were analyzed by statistical method. *Result:* The study showed Palmaris longus was absent in 11 (5.5%) males and 9 (4.5%) females unilaterally. It was absent in 7 (3.5%) males and 4 (2%) females on left side. Chi square test was 0.073 and P value was 0.39 ( $P < 0.5$ ). *Conclusion:* In present study we conclude that Palmaris longus was absent 10 % unilaterally and 6% bilaterally. Absence was more on left side than right side.

**Keywords:** Palmaris Longus; Tendon; Graft.

### Introduction

Palmaris Longus is one of the most variable and most superficial flexor muscle of forearm. It is a slender, fusiform, spindle shaped muscle medial to flexor carpi radialis. As the tendon crosses the flexor retinaculum superficially it broadens out to become a flat sheet which is incorporated into the palmar aponeurosis.

The palmaris longus is restricted to the mammals and is best developed in species using the forelimb for weight bearing and ambulation. It is the most desirable tendon in reconstructive surgery like total maxillectomy, ptosis correction, total mandible and chin reconstruction. It is the first choice donor tendon as it fulfills the necessary requirements of length, diameter and availability. It can be used without

producing any functional deformity. It is considered to be the ideal choice for tendon graft [1].

When one take a closer look at the Palmaris Longus tendon its superficial location makes the process of harvesting easier and these makes the procedure less complicated and safer. Palmaris Longus is also said to be a dispensable tendon, absence of which will not affect the function of the wrist significantly.

The advantages of using the Palmaris Longus muscle in reconstructive surgery, include that it is expandable, it has a nonessential function, readily available and easy to harvest. The presence of the Palmaris Longus is easily determined by preoperative examination.

The Palmaris Longus is a popular tendon graft, used in various reconstructive surgeries [2]. It is often described as most variable muscle in human body and is phylogenetically classified as a retrogressive muscle i.e muscle with short belly and long tendon. Palmaris longus muscle has little functional use in human but has a great significance when used as a donor tendon.

### Aim

The present study is done to assess absence of palmaris longus unilaterally or bilaterally by using simple clinical tests in both sexes on both sides.

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## Material and Methods

We examined 200 subjects (100 male and 100 female) for the presence or absence of Palmaris Longus in relation with visualization of its tendon. Healthy subjects between 18 to 50 years were randomly selected. Subjects with congenital or acquired abnormalities of hand were excluded from the study. Procedure was explained to each subject and written consent was taken for the same. Study was approved by Ethical committee of our institute.

### *Clinical tests which were done*

1. Standard Schaeffer's test [3]- Each subject was asked while the forearm in supination to oppose the thumb and little finger and flex the wrist. If the palmarislongus tendon present then it will form a protuberance under the skin. (Figure 1). If the tendon was not seen or palpable then 3 additional tests were done to confirm the absence.



Fig. 1: Standard Schaeffer's test



Fig. 2: Mishra's 1st test



Fig. 3: Mishra's 2<sup>nd</sup> test



Fig. 4: Pushpakumar's two - finger sign test

2. Mishra's 1<sup>st</sup> test [4]- Subject was asked to do passive hyperextension of fingers at metacarpophalangeal joints with active flexion of wrist (Figure 2).
3. Mishra's 2<sup>nd</sup> test - Subject was asked to do abduction of thumb against resistance with slight palmar flexion of wrist (Figure 3).
4. Pushpakumar's two - finger sign test [5]- Subject was asked to do full extension of index & middle finger with apposed thumb over medial two fingers (Figure 4).

If the tendon was not seen or not palpated then it was considered as absence of palmarislongus tendon. We observed absence of palmarislongus muscle on both side.

Our Observations were analyzed by statistical method using chi square test and p- value was calculated.

**Observation & Result**

We found following observations in our study

Table 1 shows that Palmaris Longus was present in 181 upper extremities in male and 175 upper extremities in female subjects.

Palmaris Longus was present in 85 male subjects and 83 female subjects subject bilaterally.

Unilateral absence of Palmaris Longus was found in 11 male subjects (5.5%) and 9 female subjects (4.5%). Bilateral absence of Palmaris Longus was in 4 male subjects (2%) while it was in 8 female subjects (4%).

Overall absence of Palmaris Longus was in 32 subjects (16%). Out of which it was absent unilaterally in 20 subjects (10%) and bilaterally in 12 subjects (6%).

Chi-square statics was 1.4139. P value was calculated 0.2344 which is not significant.

Table 2 shows that Palmaris Longus was absent on right side in 4 male subjects (2%) and in 5 female Subjects (2.5%). Palmaris Longus was absent on left side in 7 male subjects (3.5%) and in 4 female subjects

**Table 1:** Presence and absence of Palmaris Longus in both genders

	PL present in		PL absent in	
	Males	Females	Males	Females
U/L	181	175	11	9
B/L	85	83	4	8

**Table 2:** Unilateral absence of Palmaris Longus in both the genders

U/L absence	Male Subjects	Percentage %	Female Subjects	Percentage%	Overall Subjects	Percentage%	P value
RT	4	2	5	2.5	9	4.5	0.39073
Lt	7	3.5	4	2	11	5.5	

**Table 3:** Comparison of the unilateral and bilateral agenesis of Palmaris Longus muscle in living subjects

Sr. No.	Authors	Year	U/L A	B/L A	Remark
1.	Thompson et al	2001	16%	9%	U/L A>B/L A
2.	Sandeep et al	2006	3.30%	1.20%	U/L A>B/L A
3.	Roohi et al	2007	6.40%	2.90%	U/L A>B/L A
4.	Kapoor et al	2008	9.20%	8%	U/L A>B/L A
5.	Pawan Agarwal	2010	16.90%	3.30%	U/L A>B/L A
6.	L. A.Enye, et al	2010	8%	4.6%	U/L A>B/L A
7.	Mirela Eric et al	2010	21.6%	9.5%	U/L A>B/L A
8.	James W M Kigera et al	2011	3.3%	1.1%	U/L A>B/L A
9.	Faisal Nazeer Hussain	2012	16.7%	7.75%	U/L A>B/L A
10.	D K Sharma	2012	10%	6.25%	U/L A>B/L A
11.	Sangeeta et al	2013	6.5%	9.5%	B/L A>U/L A
12.	Deepti O Kulkarni et al	2014	15%	8.33%	U/L A>B/L A
13.	Present study	2014	10%	6%	U/L A>B/L A

**Table 4:** Comparison of the unilateral agenesis of Palmaris Longus muscle in living subjects

Sr. No.	Authors	Year	Rt A%	Lt A %	REMARK
1	Reimann et al	1994	4.7%	3.6%	Rt A >Lt A
2	Sandeep et al	2006	1.7%M	0.8%M	Lt A>Rt A
			0.5%F	3.3%F	
3	Kapoor et al	2008	3%	6.2%	Lt A>Rt A
4	Godwin O Mbaka	2009	2.4%	3.4%	Lt A>Rt A
5	Mirela Eric et al	2010	8.6%	13%	Lt A>Rt A
6	Pawan Agarwal	2010	7.17%M	12.30%M	Lt A>Rt A
			4.21%F	10%F	
7	James W M Kigera et al	2011	1%	2.6%	Lt A>Rt A
8	D K Sharma	2012	5.25%	4.75%	Rt A >Lt A
9	FarivarAbdolahzadehLahiji	2013	10.2%	5.9%	Rt A >Lt A
10	Deepti O Kulkarni et al	2014	5.5%	6%	Lt A>Rt A
11	Present study	2014	4.5%	5.5%	Lt A>Rt A

(2%). Palmaris Longus was absent on right side in 4 male subjects (2%) and in 5 female subjects (2.5%).

Chi-square statics was 0.7367. P value was calculated 0.39073 which is not significant.

## Discussion

Palmaris Longus is a small vestigial muscle which is phylogenetically retrogressive muscle. It has short belly and long tendon. Palmaris Longus may be absent in 15% individuals. It is the most desirable tendon in reconstructive surgery. It is also the first choice donor tendon as it fulfills the necessary requirements of length, diameter and availability and can be used without producing any functional deformity.

In carpal tunnel syndrome or arthritis, identification of palmarislongus tendon is useful during administration of drugs to relieve pain & median nerve wrist block. The most common variation found is agenesis of palmarislongus muscle. Its absence means losing potential site for reconstructive surgeries. Schaeffers test was first to be used and considered as a standard test. But it is difficult to demonstrate the tendon by this test then combinations

of tests were found to be useful. As palmarislongus is a wrist flexor, tensor of palmar aponeurosis and abductor of thumb (as sends slip to abductor pollicis brevis), test which help in wrist and finger flexion, thumb abduction and apposition help to make the tendon of palmarislongus prominent.

We compared our findings with the previous studies.

In the present study we found unilateral agenesis of Palmaris Longus more common than bilateral agenesis. Our findings correlated with all the authors except Sangeeta et al who found bilateral absence to be more than unilateral.

Findings of the unilateral and bilateral agenesis of Palmaris Longus muscle in living subjects of our study were similar to the authors in Table 3.

Table 4 shows that in the present study we found unilateral agenesis of Palmaris Longus to be more common on left side than on right side.

The findings of Reimann et al, DK Sharma and FarivarAbdolazadeh Lahiji did not correlate with the present study.

Table 5 shows that in the present study agenesis of Palmaris Longus was more common in female than in male subjects and these findings

**Table 5:** Comparison of agenesis Palmaris Longus muscle in both the genders

Sr. No.	Authors	Year	Male	Female	Remark
1	Sandeep et al	2006	4.2	4.8	F>M
2	Roohi et al	2007	5.8%U/L 1.3%B/L	7.1%U/L 4.4%B/L	F>M
3	L. A.Envy, et al	2010	9.5%	13.95%	F>M
4	Pawan Agarwal	2010	19.48%U/L 5.12% B/L	14.21%U/L 1.6%B/L	M>F
5	James W M Kigera et al	2011	4.9%	3.9%	M>F
6	D K Sharma	2012	8.5%	7.75%	M>F
7	Osonuga	2012	1.3%	1.8%	F>M
8	Deepti O Kulkarni et al	2014	10.53%	19%	F>M
9	Present study	2014	7.5%	8.5%	F>M

correlated with the findings of Sandeep et al, Roohi et al, LA Envy et al, Osonuga and Deepti Kulkarni et al. Pawan Agrawal, James WM Kigera et al and DK Sharma found agenesis of palmarislongus more common in male than in female subjects.

## Conclusion

Absence of palmarislongus is more common in female and unilateral absence is more than bilateral. There was no stastical association between absence of palmaris longus & gender, body sides. Knowledge

about the frequency of its absence and the most effective test for detecting its absence may be highly relevant in preoperative work up when surgical intervention involving forearm or specially tendon transfer is being considered.

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# Study of Different Parameters for Sex Determination of Human Skull

Shubhangi Ghule<sup>1</sup>, Bhushan Vitore<sup>2</sup>, Manoj Ambali<sup>3</sup>, Amrut Mahajan<sup>4</sup>

## Abstract

**Introduction:** Identification of skeletal remains plays a major role in forensic medicine. Sex determination is the most important and initial step in individual identification. Almost all bones of the human skeleton show some degree of sexual dimorphism. However, skull and pelvis are used to permit the diagnosis of sex with high accuracy. The skull is important in this regard as it resists adverse environmental conditions over time. The present study aims to determine sexual dimorphism in 200 skulls (100 male and 100 female). **Method:** Adult human dry skull of known sex (100 male and 100 female) were obtained from different medical colleges of Maharashtra. The Parameters like weight, maximum skull length, maximum skull breadth, maximum bizygomatic diameter were studied. **Result:** Mean values of all parameters are more in males than in females. **Conclusion:** Amongst the parameters, maximum bizygomatic diameter is more reliable for determination of sex with 95% accuracy by using the demarcating point.

**Keywords:** Sexual Dimorphism; Skull; Parameters.

## Introduction

Sex determination is major challenge for forensic anthropologist in the medicolegal context. Anthropological knowledge of human osteology is one of the important step in identification of age, sex, living stature and ancestry [1]. According to Krogman [2], the degree of accuracy in sexing adult skeletal remains is 100% when entire skeleton was present; pelvis alone 95%; skull alone 92%; pelvis plus skull 98%; long bones 80%; long bone plus pelvis 98%. Sexual differences are marked in pelvis and skull in all population [3]. Traditionally skull is most studied bone in physical anthropology [2]. Traditional studies by non-metrical methods were not reliable. So morphometry and statistical methods were introduced [4]. The aim of the present study to

determine sexual dimorphism of skull by multivariate analysis of anthropometric data which will be helpful in anthropometric and medicolegal studies.

## Materials and Methods

This study was conducted on 200 adult skulls of known sex (100 male and 100 female) collected from different medical colleges of Maharashtra. Ethical clearance was taken from the institutional ethical review committee before the initiation of the study. The following measurements were taken after placing the skull in Frankfurt's horizontal plane. Instruments used are sliding vernier caliper, spreading caliper, scale, weighing machine.

The following parameters used for the study are:

**Weight-** It was taken by weighing machine. It was recorded in grams.

**Maximum skull length (Figure 1) -** Maximum distance between the glabella and opisthocranium. It was measured with spreading caliper. It was recorded in millimeters.

**Maximum skull breadth (Figure 2) -** Maximum transverse breadth at the level of parietal eminences. It was measured by sliding vernier caliper. It was recorded in millimeters.

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Fig. 1:



Fig. 2:



Fig. 3:

Maximum bizygomatic diameter (Figure 3)- width between lateral surfaces of two zygomatic arches. It was measured with sliding vernier caliper. It was recorded in millimeters.

After completing measurements, Mean, standard deviation, t value, p value were calculated for each parameter. Demarcating points (D.P.) were obtained for each parameter and also the percentage of bones crossed the demarcating points were obtained. To determine the demarcating point that is the point which will find whether the skull is of male or female,  $\text{mean} \pm 1.96 \text{ SD}$  (standard deviation) range was obtained. Considering the range of male, female demarcating point was determined while considering the range of female, male demarcating point was determined.

**Determination of Demarcating Point:** Mean and standard deviation were calculated for each parameter of both the sexes. Using these values 'calculated range' was arrived at by the formula ' $\text{mean} \pm 1.96 \text{ SD}$ '.

For a given male, calculated range of 'p to q' and female calculated range 'r to s', values of 'p' (minimum in male range) and 's' (maximum in female range) were chosen as 'demarcating points' for females and males respectively. According to Jit and Singh (1966), [5] skull with measurement lesser than 'p' was identified as female skull and greater than 's' as male skull.

When the formula " $\text{mean} \pm 3\text{SD}$ " was applied, very less percentage of bones could be sexed correctly. So we apply the formula " $\text{mean} \pm 1.96\text{SD}$ ".

## Results

Parameters were studied and analyzed statistically using a standard computer program. The analyzed data was tabulated as follows -

Statistical analysis of the parameters shows p value for weight, maximum skull length, maximum skull breadth, and maximum bizygomatic diameter was less than 0.001, so these parameters were significant.

Table 1 shows that weight, maximum skull length, maximum bizygomatic diameter are more reliable in male skulls while in female skulls maximum bizygomatic diameter is more reliable for determination of sex with 95% accuracy when compared with other parameter by using the demarcating point.

Therefore we can conclude that amongst the parameters maximum bizygomatic diameter is more

**Table 1:** Statistical analysis of different parameters

Parameters	Gr	N	Mean	S.D.	Mean $\pm$ 1.96SD	D.P.	% of bones identified by D.P.	t value	p value
Weight	M	100	572.90	75.75	424.43-721.37	>623.78	23	7.209	<0.001
	F	100	502.35	61.95	380.92-623.78	<424.43	7		
Maximum skull length	M	100	171.04	6.85	157.62-184.46	>175.70	23	8.544	<0.001
	F	100	162.98	6.49	150.26-175.70	<157.62	15		
Maximum skull breadth	M	100	128.33	4.68	119.15-137.51	>132.64	15	6.588	<0.001
	F	100	124.12	4.35	115.60 - 132.64	<119.15	11		
Maximum bizygomatic diameter	M	100	125.11	4.04	117.20 - 133.02	>126.10	33	12.039	<0.001
	F	100	118.27	3.99	110.44 - 126.10	<117.20	24		

**Table 2:** Comparison between Previous and present study on weight.

Author's name	Males Mean	Females Mean	p. value	Statistical significance
Keen JA (1950) [6]	618	572	>0.05	Not significant
Deshmukh and Devershi (2006) [4]	526	494	>0.05	Not significant
Talokar SA and Lade SH (2015) [7]	511.79	500.32	0.054	Not significant
Present study	572.90	502.35	<0.001	Significant

**Table 3:** Comparison between Previous and present study on maximum skull length

Author's name	Males Mean	Females Mean	p. value	Statistical significance
Deshmukh and Devershi (2006) [4]	173	166	<0.001	Significant
Chimmalgi et al. (2007) [9]	171.51	165.57	<0.001	Significant
Zavando et al. (2009) [10]	184.09	178.81	<0.05	Significant
Talokar SA and Lade SH (2015) [7]	174.31	163.63	0.000	Significant
Saini R. and Saini V. (2016) [11]	180.6	171.4	0.000	Significant
Present study	171.04	162.98	<0.001	Significant

**Table 4:** Comparison between Previous and present study on maximum skull breadth

Author's name	Males Mean	Females Mean	p. value	Statistical significance
Deshmukh and Devershi (2006) [4]	131	127	<0.001	Significant
Zavando et al. (2009) [10]	140.86	137.66	0.040	Significant
Talokar SA and Lade SH (2015) [7]	133.05	124.85	0.000	Significant
Saini R. and Saini V. (2016) [11]	126.72	124.29	0.000	Significant
Present study	128.33	124.12	<0.001	Significant

**Table 5:** Comparison between Previous and present study on maximum bizygomatic diameter

Author's name	Males Mean	Females Mean	p. value	Statistical significance
Deshmukh and Devershi (2006) [4]	126	121	<0.001	Significant
Chimmalgi et al. (2007) [9]	126.75	119.08	<0.001	Significant
Zavando et al. (2009) [10]	127.02	119.67	<0.001	Significant
Saini R. and Saini V. (2016) [11]	125.07	116.86	0.000	Significant
Present study	125.11	118.27	<0.001	Significant

reliable in both male and female skulls for determination of sex.

## Discussion

Although adult skull shows a few non-metrical and metrical differences, there is paedomorphic tendency in human skull of either sex. Each parameter is discussed by comparing them with the findings of

previous workers. Present study correlates with findings of previous workers. Only the findings of present study on weight do not coincide with Keen JA study (1950) [6], Deshmukh and Devershi study (2006) [4], Talokar SA and Lade SH study (2015) [7]. According to them, weight is not a statistically significant parameter. But in present study, weight is found statistically significant. So present study on weight go in favour of Sahana [8]. According to sahana, size

and weight of skull is larger and heavier in male than in female. Tables 2-5 show comparative study of different workers.

### Conclusion

1. Mean values of all parameters are more in males than in females.
2. All parameters are statistically significant. ( $p < 0.001$ )
3. Amongst all parameters, maximum bizygomatic diameter is more reliable in both male and female skulls for determination of sex.

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## Light Microscopic Study of Developing Medulla of Fetal Adrenal Gland

Rucha Kulkarni

### Abstract

One hundred human foetuses having crown-rump length in the range of 7–36 cm and gestational age of 12–36 weeks were subjected to morphological and histological studies to understand and observe the developing medulla of foetal adrenal glands. It is observed that from week 12 to 14, medulla is not clearly demarcated and clusters of medullary cells are found in the foetal cortex. Towards week 38, we observe that the medulla is well organized and differentiated with phaeochromocytes and few ganglion cells clearly visible. The observations are important for clinicians to help in diagnosis of neuroblastomas.

**Keywords:** Medulla; Foetal Adrenal Glands; Neuroblasts; Phaeochromocytes.

### Introduction

The prominence of the adrenal glands in the foetus and in the new-born infant has been recognized for almost two centuries [1]. During the foetal life there is remarkable increase in the size of adrenal gland mainly due to presence of foetal or provisional cortex present between the medulla and thin rim of permanent cortex [2].

The adrenal medulla is functionally related to the sympathetic nervous system. It secretes the hormone epinephrine and norepinephrine in response to sympathetic stimulation. Alternatively, the adrenal cortex secretes an entirely different group of hormones called corticosteroids. In a broad sense, both the steroid hormones synthesized by the cortex and the catecholamines synthesized by the medulla mediate adaptive responses of the organism to a changing environment [3].

This makes it important to understand and observe the developing medulla. A gross examination of slices

of fresh human adrenal show the outer and broader yellowish zone of cortex as a result of the presence of lipids and a thin reddish brown structure, i.e. the medulla [4].

The adrenal gland develops from two components. During fifth week of development, mesothelial cells between root of the mesentery and the developing gonad begin to proliferate and penetrate the underlying mesenchyme and differentiate into fetal cortex of the adrenal gland. Shortly after second wave of smaller cells from mesothelium penetrates the mesenchyme surround fetal cortex, and later form the definitive cortex [5]. The neural crest cells from adjacent celiac ganglia [6] reach mediadorsal aspect of the primitive cortex and begin to invade it to comprise medulla. There is simultaneous development of venous sinusoids in medulla [7]. The origin of the adrenal medulla is involved with origin of a whole group of tissue masses of the same general type and potentialities i.e. chromaffin cells. Chromaffin cells are derived from the cells of sympathoadrenal lineage. In adrenal medulla these cells differentiate into small neuroblasts and larger phaeochromocyte [8].

Over the past two decades, routine prenatal ultrasound has significantly increased the rate of diagnosis of fetal neuroblastoma. More than 90% of these tumors arise in the adrenal gland, suggesting a link between perinatal tumors and the nodular collections of neuroblasts that are part of normal adrenal development [9].

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## Materials and Methods

The study was performed on one hundred normal human foetuses (71 male and 29 female) in developmental week 12 to week 36. The foetuses were obtained from Medical Termination of Pregnancies and spontaneous abortions from tertiary care hospital in Mumbai.

The menstrual histories provided by the mothers were taken into consideration. The crown rump length of the foetuses ranged from 7 cm to 36 cm. The foetuses were classified according to their gestational age into groups as Weeks 12–14, Weeks 15–16, Weeks 17–18, Weeks 19–20, Weeks 21–22, Weeks 23–24, Weeks 25–26, weeks 27–28, Weeks 29–30, Weeks 31–32 and Weeks 36–38.

### Preservation

In order to minimize post-mortem changes, the fetuses were immediately preserved by injecting formalin into the abdominal cavity. Subsequently, they were immersed in formalin solution. For identification, numbered tags starting from 1 were tied to their wrists. Normal growth of the fetus was ensured by taking different external measurements and ascertaining various parameters.

### Dissection and Fixation

The fetuses were dissected by taking vertical abdominal incision. Subsequently, the adrenals were removed along with the kidneys by blunt dissection. Immense care was taken during the separation of the right adrenal from the liver. The left adrenals were kept in small locked plastic pouches to differentiate from the right. Finally, the adrenals were stored in small bottles and were numbered.

Next, the large adrenals were cut into pieces with sharp razor blade. The capsule was not damaged in the process.

Finally, the tissues were fixed by immersing in SUSA solution [10] for 24–36 hours.

### Dehydration

First, the tissues were immersed in 50% alcohol solution for 6–8 hours. Next, they were transferred to 70% alcohol and allowed to stay in it overnight. Subsequently, the tissues were bathed in 90% alcohol for one hour and finally they were subjected to absolute alcohol for duration of one hour each. Lastly, the tissues were dried using filter paper.

### Clearing and Embedding

Post dehydration, the tissues were subjected to two–three xylene changes until they turned transparent.

Once the tissues were impregnated with xylene, they were embedded in melted paraffin at 58°–60° for duration of 5–6 hours. The paraffin blocks containing tissues were made using L-shaped molds. These blocks of paraffin were then numbered accordingly. Care was taken during the preparation of the tissues to ensure that the respective numbering was maintained.

### Sectioning

The numbered blocks of paraffin containing tissues were sectioned by microtome steel blade to a thickness of 4–5 μm. The sections were floated on warm water and transferred to glass slides which were rubbed with a drop of albumin. A drop of 70% alcohol was put on a glass slide to ensure spreading of the section.

Subsequently, the slides were numbered accordingly with diamond marker and kept in over for a few seconds to fix the section on slide.

### Slide Staining

Next, the slides were stained with Hematoxylin and Eosin stain. After the slides were stored in Koplins jar, the following procedure was undertaken:

1. First, two changes of xylene were given for a short period of time. Next, the slides were successively bathed in descending grades of alcohol starting from absolute alcohol (three momentary changes as absolute alcohol I, II, III) to 90% and 70% alcohol.

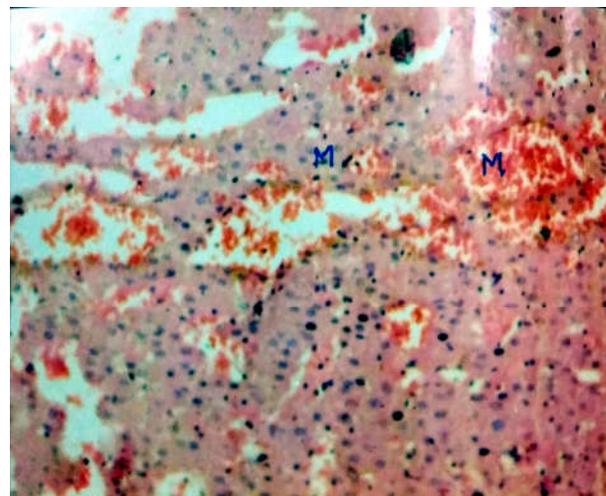


Fig. 1: Medulla showing formation of vascular pattern

2. The Koplins jars were kept under running water for 5–10 minutes. Then, the slides were stained with Hematoxylin for 10–15 minutes. After checking the intensity of staining under the microscope, the Koplins jars were kept under running water for 15 minutes,
3. Subsequently, Eosin was used as an acid dye for staining the slides for 3–5 minutes.

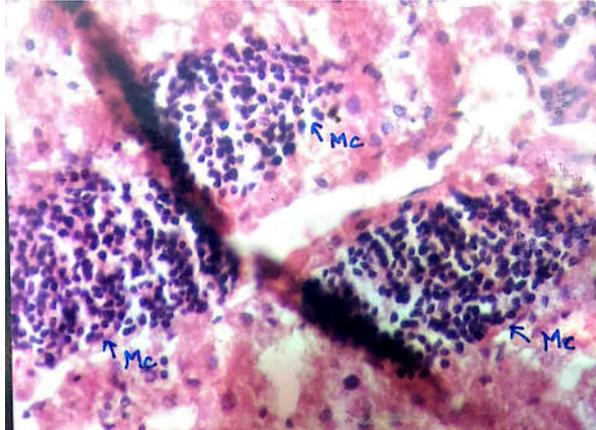


Fig. 2: Clusters of medullary cells Mc

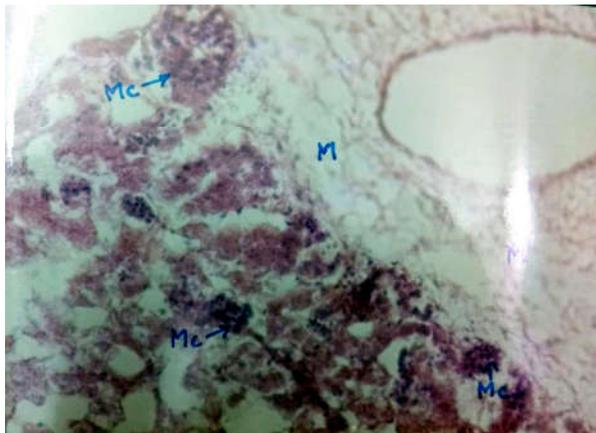


Fig. 3: Formation of connective tissue scaffolding M

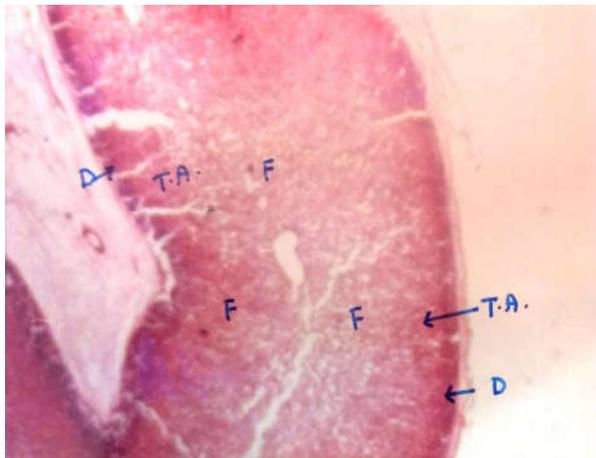


Fig. 4: Scanning view of adrenal gland at 23–24 weeks

4. After the Eosin staining, the slides were transferred from absolute alcohol I to II and III and then kept in xylene.
5. Using DPX mount, the coverslips were added. The slides were then cleaned and readied for the microscopic study.

The slides were then examined under the microscope to study the developing medulla of fetal adrenal gland under various stages. Histological slides of adrenal glands from each group were photomicrographed using trinocular Nikon microscope.

### Observations and Discussion

#### Weeks 12–14

The medulla at this stage is not clearly demarcated. Clusters of medullary cells are found in the foetal cortex and the cells are small and basophilic in nature.

#### Weeks 15–16

The cortico-medullary junction is not clear. However, the medulla showed the formation of medullary sinusoidal vascular pattern. This suggests that medullary vascular pattern is developed prior to the migration and settling of the medullary cells in their definitive positions in the medulla.

#### Weeks 17–18

Clusters of the medullary cells are seen in the deeper part of fetal cortex as depicted in Figure 2. The cells are small and basophilic. We observe that the nuclei of most of the cells are dark. Very few cells nuclei are pale with visible nucleoli.



Fig. 5: Mc- Medullary cells

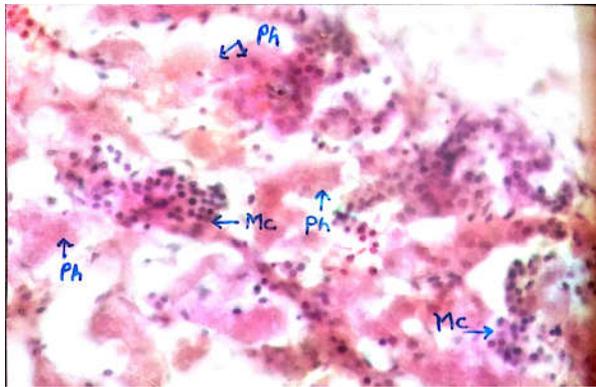


Fig. 6: Clusters of small basophilic cells Mc- neuroblasts



Fig. 7: Phaeochromocytes Ph, with granular cytoplasm and vesicular nucleus.

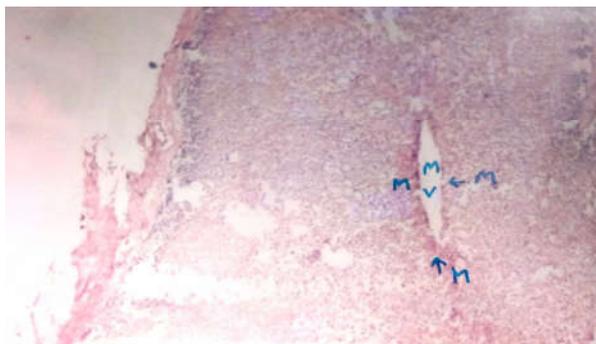


Fig. 8: Well organized medulla, M- Medulla, Mv- Medullary vein

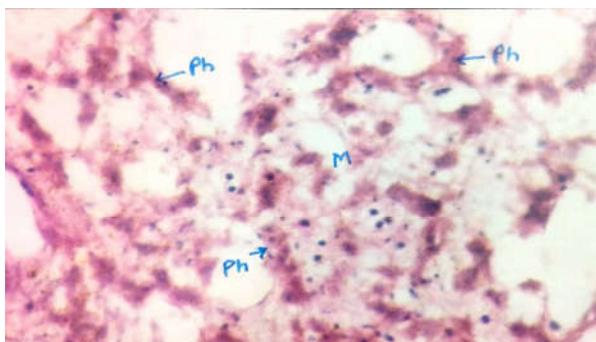


Fig. 9: Formation of groups of basophilic cells around sinusoids

Weeks 19–20

Medullary islands of small basophilic cells have increased in number and scattered. Some of them are present towards the medullary vein.

Weeks 21–22

Medulla does not reveal any change.

Weeks 23–24

The connective tissue scaffolding of medulla is formed. Clusters of medullary cells are ready to migrate as seen in Figure 3.

We observe two types of cells

1. Cells are large and lightly stained.

Nucleus is vesicular and Cytoplasm is granular as shown in Figure 7.

These can be called as phaeochromocytes.

2. Clusters of small basophilic cells are neuroblasts as depicted in Figure 6.

These clusters along with phaeochromocytes have arranged themselves around well formed sinusoids (Figure 5 and 6).

Weeks 25–28

Medulla does not reveal any changes during this period.

Weeks 29–30

Medulla is now well organized as shown in Figure 8. Clusters of small basophilic cells are not seen as they are mingled with few phaeochromocytes (Figure 9) and are forming groups around sinusoids.

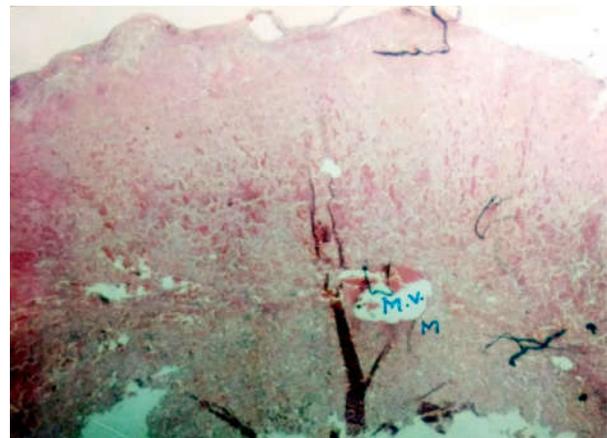


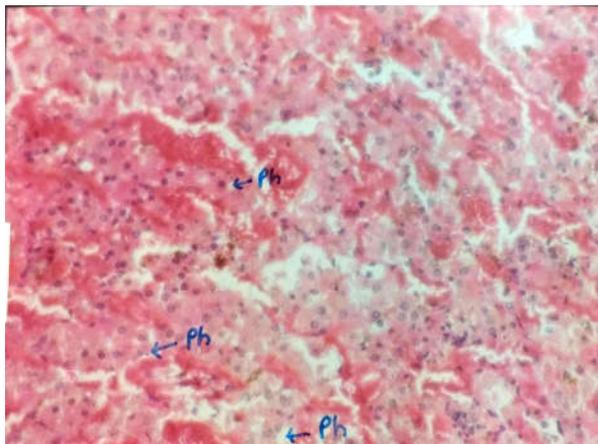
Fig. 10: Organized and differentiated medulla. Mv: medullary vein. M: medulla

*Weeks 31–32*

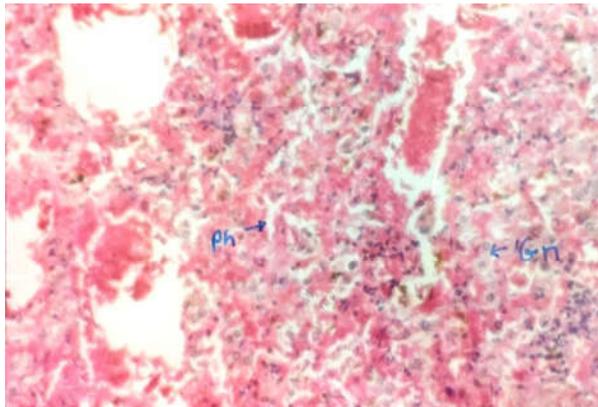
No changes are visible in the medulla.

*Weeks 36–38*

Medulla is well organized and differentiated (Figure 10). We can observe the phaechromocytes (Figure 11) and few ganglion cells (Figure 12).



**Fig. 11:** Phaechromocytes can be observed. Ph: phaechromocytes



**Fig. 13:** Phaechromocytes - Ph, Ganglion cells-Gn

### Conclusion

A prospective study of one hundred human fetuses is done (71 males and 29 females) ranging from 7 cm to 36 cm in crown-rump length and in gestational

period of 12 to 36 weeks. In this study, we observe the developing medulla of the fetal adrenal gland. It is clearly seen that in the initial weeks, the medulla is not clearly demarcated, however, from the 15<sup>th</sup> week we can see the formation of medullary cells. Subsequently, the connective tissue scaffolding of the medulla is fully differentiated at 23 to 24 weeks of gestation. The neuroblasts (small darkly staining basophilic medullary cells) in the form of clusters migrate from the deeper part of fetal cortex to the medulla but don't settle in the medulla till the medullary sinusoidal pattern is well organized.

Moreover, the phaechromocytes are differentiated and can be identified at 23 to 24 weeks of gestation. Finally, this knowledge of normal development of adrenal medulla will help clinicians in diagnosis of conditions such as fetal neuroblastoma.

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## Study of Variations in the Origin of Profunda Femoris Artery and Internal Diameter of Femoral Artery in Human Cadavers

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### Abstract

**Introduction:** Profunda femoris artery is the largest deep branch of femoral artery, provides the principal supply to the extensor, adductor and flexor muscles of the thigh. This large artery arises from the posterolateral side of the femoral artery about 3.5-5cm from the mid-inguinal point. The study of the femoral artery and its branching pattern has been a great interest among the anatomists and the surgeons because of its major implication in the clinical as well as radiological interventions. **Material and Methods:** In the present study, hundred formaldehyde embalmed cadavers without malformations were dissected and site and level of origin of the profunda femoris artery in relation to the midpoint of the inguinal ligament from the femoral artery studied, also the internal diameter of femoral artery measured by dissection method. **Results:** Profunda Femoris Artery originated on right side in 46% cases and 44% on left side from the posterolateral aspect. The average distance of origin of Profunda Femoris Artery from Midpoint of Inguinal Ligament on right side was observed to be 4.45 cm while on left side was observed to be 4.69cm. The mean value of Internal Diameter of Femoral Artery was found to be 7.46 mm in males and 6.33 mm in females on right side and 7.43 mm in males and 6.29 mm in females on left side. **Conclusion:** Most common site of origin of profunda femoris artery was observed to be the posterolateral aspect of the femoral artery. Variations seen in the form of posterior and lateral origins. The average distance of origin of profunda femoris artery was observed between 4-5cm. In the present study 3 cases of high origin of profunda femoris artery observed. The advantage of such a high origin of profunda femoris artery is that it can be used for catheterisation and further investigation of any arterial system of the body. Gender wise comparison of mean value of internal diameter of femoral artery on both sides showed statistically highly significant difference.

**Keywords:** Femoral Artery; Inguinal Ligament; Profunda Femoris Artery.

### Introduction

The big horizon of interventional radiology opens new avenues for the study of variations of the course of the profunda femoris artery [1]. In Homo sapiens, the main stem artery supplying arterial branches to deep structures of the proximal thigh and hip joint is the profunda femoris artery (deep femoral artery) [2].

It is the largest deep branch of femoral artery. It is the principal artery to supply to the extensor, adductor and flexor muscles of the thigh [3]. This large artery arises from the posterolateral side of the femoral artery about 4-5cm below the inguinal ligament [4].

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Femoral artery is the continuation of the external iliac artery and enters the femoral triangle behind the inguinal ligament midway between the Anterior Superior Iliac Spine and the symphysis pubis [5]. This is the point where its pulsations can be felt. This location is also used for the femoral catheterization [6].

The study of the femoral artery and its branching pattern has been a great interest among the anatomists and the surgeons because of its major implication in the clinical as well as radiological interventions [7].

It is used for investigation of any arterial system in the body and for various clinical procedures like coronary angioplasty. In addition to those the femoral artery at the femoral triangle is directly opened at the origin of the profunda femoris artery for femoral embolectomy in lower limb arterial thrombo embolism [8]. The profunda femoris artery is used for arteriography, ultrasound and Doppler imaging, digital subtraction angiography and magnetic resonance imaging [9].

Since the advent of interventional radiology, the methods of investigation of the cardiac patients have taken a big leap towards this end. Femoral arteriography

is the main line for investigation in peripheral occlusive arterial diseases and in diagnosis of suspected congenital anomalies [1]. Femoral artery is also used for the procedure called embalming for the disinfection and preservation of cadavers by injecting the embalming fluid from femoral artery [10]. As the femoral arteries are commonly used for these procedures, the internal diameter and as well as the origin of the profunda femoris artery are of clinical significance in the procedures used for diagnosis [1].

#### *Aims & Objectives*

1. To determine site of origin of Profunda Femoris Artery.
2. To determine the distance of origin of Profunda Femoris Artery from the midpoint of the inguinal ligament.
3. To determine the internal diameter of Femoral Artery.
4. To compare the obtained results with those of other studies.

#### **Material and Methods**

##### *Source of Data*

The present study was carried out on fifty (50) formalin embalmed cadavers allotted to the undergraduate students for dissection in the Department of Anatomy, at Government medical colleges. Among these there were thirty (30) males and twenty (20) females.

##### **Dissection Method**

A series of 100 femoral triangles in 50 human cadavers were dissected (30 males and 20 females). The femoral artery and the profunda femoris artery were identified, their origin and course studied. The mode of origin of profunda femoris from the femoral artery was studied. The distance of origin of the profunda from the midpoint of the inguinal ligament was measured in millimeters with digital vernier calliper (Figure 1).

A segment of 5 cm of the femoral artery (vessel) is cut just below the midpoint of the inguinal ligament. Then a vertical nick is given to the vessel and extended throughout the length vertically. This vessel is kept on an even surface and spread out.

Now, near the proximal end of the vessel horizontal length is measured from the inner side of the vessel by spreading a thread over that end horizontally (Figure 2). Two points were marked on the thread at the ends. Then this distance between the two points on the thread is measured by digital vernier caliper (Figure 3).

This gives the circumference (C) of the vessel.

$$C = 2\delta r$$

r denotes radius and  $2r = D$

D denotes diameter of the vessel

As this distance is measured from inner side of vessel, this diameter D denotes the internal diameter of the vessel.

Now,  $C = \delta D$

Or internal diameter  $D = C \div \delta$

Where  $\delta = 3.14$

So  $D = C \div 3.14$

So by this method, internal diameter of the vessel is measured. The variations in the branching pattern were noted, photographs taken with a digital camera. The observations were tabulated and analyzed.

##### *Study design*

Observational study

##### *Study setting*

Dissection hall, Department of Anatomy

##### *Study duration*

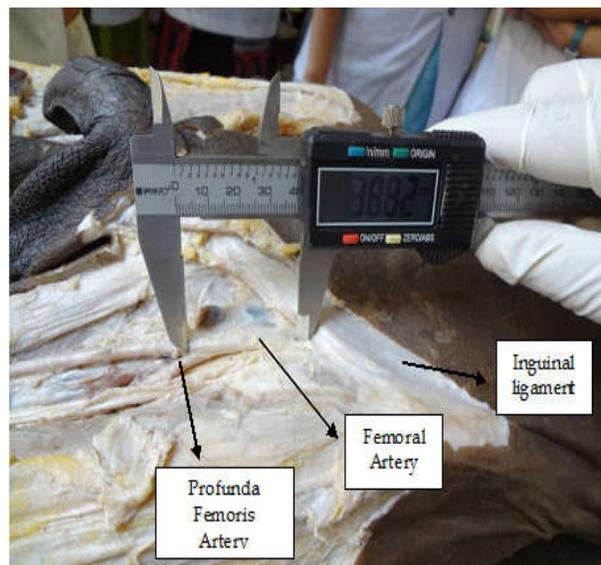
January 2012 to December 2013.

##### *Study sample size*

100 femoral triangles.

##### *Study subjects*

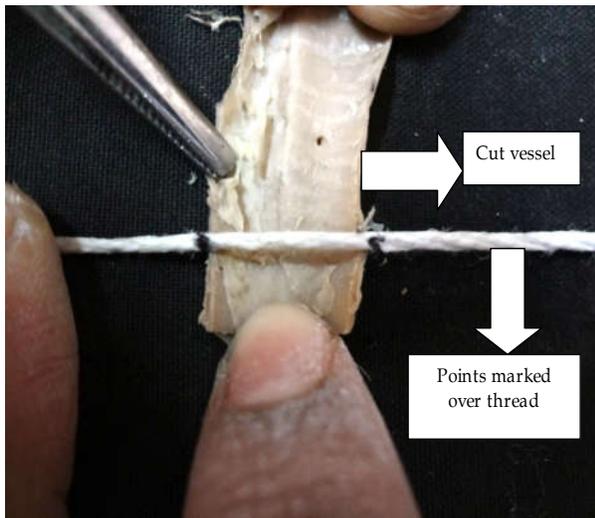
Human cadave



**Fig. 1:** Measurement of distance of origin of Profunda femoris artery from midpoint of inguinal ligament

### Data Analysis

1. Data entry:- It was done using Microsoft excel 2007.
2. Statistical Analysis:
  - a. Descriptive statistics (Percentage, Mean, Median and Standard deviation) was used to summarize baseline characteristics of the study subjects.
  - b. Various data obtained from dissection of human cadavers and variations were noted.
  - c. Data was analysed using STATA VERSION-10 statistical software.
  - d. Chi square test, Unpaired t-test used to analyse data.



**Fig. 2:** Measurement of internal diameter of femoral artery: howing near the proximal end of the vessel horizontal length is measured from the inner side of the vessel by spreading a thread over that end horizontally and two points are marked on thread at the ends



**Fig. 3:** Measurement of internal diameter of femoral artery: Distance between the two points on the thread is measured by digital vernier caliper

### Observation and Results

In most of the cases, site of origin of the Profunda Femoris Artery was from the posterolateral aspect of the Femoral Artery, in 46% on right side and 44% left side. The site of origin of Profunda Femoris Artery between the right and left sides, showed statistically non significant difference by chi square test

The site of origin of Profunda Femoris Artery between the right and left sides in males showed statistically non significant difference by chi square test. On both sides it arose most commonly from posterolateral aspect in males i.e. 43.33% on right side and 36.67% on left side.

In females also it showed statistically non significant difference by chi square test. On both sides it arose most commonly from posterolateral aspect i.e. 50% on right side and 55% on left side.

Distance of origin Profunda Femoris Artery from midpoint of inguinal ligament was recorded most commonly in the range of 4.1-5cm on both sides.

The average distance of origin of Profunda Femoris Artery from Midpoint of Inguinal Ligament on Right side was observed to be 4.45cm whereas on left side 4.69cm.

The comparison of mean of distance of origin of Profunda Femoris Artery from Midpoint of Inguinal Ligament on Right And Left side showed statistically non significant difference by unpaired t-test.

The internal diameter of Femoral Artery was recorded in the range of 7.1-8 cm in 70% cases on right side and 73.33% cases on the left side.

Whereas in females 70% of the cases on right side and 75% cases on the left side in the range of 6.1-7 cm.

The mean value of Internal Diameter of Femoral Artery was found to be 7.46 mm on right side and 7.43 mm on left side in males.

In females the mean value was found to be 6.33 mm on right side and 6.29 mm on left side.

The mean value of comparison of internal diameter of the male subjects between right and left legs showed statistically non significant difference by unpaired t-test.

Similarly in females too the mean value of comparison of internal diameter between right and left legs showed statistically non significant difference by unpaired t-test.

The mean value of Internal Diameter of Femoral Artery was found to be 7.46 mm in males and 6.33 mm in females on right side.

**Table 1:** Distribution of site of origin for Profunda Femoris Artery

	LA	PL	PO	P-Value	Chi. Sq.
Right	10(20%)	23(46%)	17(34%)	0.9657, NS	0.069 df=2
Left	11(22%)	22(44%)	17(34%)		

**Table 2:** Distribution of site of origin of Profunda Femoris Artery separately among males and females

	Male (30)		Female (20)	
	Right	Left	Right	Left
LA	8 (26.67%)	9 (30%)	2 (10%)	2 (10%)
PL	13 (43.33%)	11 (36.67%)	10(50%)	11(55%)
PO	9 (30%)	10 (33.33%)	8 (40%)	7 (35%)
P-VALUE	0.87, NS		0.94, NS	
Chi square	0.2781 df=2		0.1143 df=2	

**Table 3:** Showing Distribution of distance of origin of Profunda Femoris Artery from midpoint of inguinal ligament

Distance(cm)	Right	%	Left	%
0-1	2	4	1	2
1.1-2.0	1	2	2	4
2.1-3.0	2	4	2	4
3.1-4.0	6	12	6	12
4.1-5.0	23	46	21	42
5.1-6.0	11	22	13	26
6.1-7.0	5	10	5	10
Total	50	100	50	100

**Table 4:** Comparison of distance of origin of Profunda Femoris Artery Midpoint of Inguinal Ligament on Right and Left side

	Right	Left
Mean	4.45	4.69
SD	1.22	1.26
Median	4.3	4.8
SEM	0.1725	0.1796
T-Value	0.9799 df=98	
P-Value	0.3296, NS	

**Table 5:** Comparison of distance of origin of Profunda Femoris Artery from Midpoint of Inguinal Ligament separately among males and females

	Male		Female	
	Right	Left	Right	Left
Mean	4.53	4.84	4.33	4.47
SD	1.29	1.35	1.12	1.12
Median	4.35	5.0	4.3	4.75
SEM	0.2362	0.2477	0.2507	0.2510
Range	1-6.9	1-6.8	1-6.6	1.9-6.8
P-Value	0.9057 NS		0.6850, NS	
T-Value	0.9057 df=58		0.4087 df=38	

**Table 6:** Distribution of Internal Diameter of Femoral Artery among the study group

In mm.	Male(30)		Female(20)	
	Right	Left	Right	Left
4.1-5.0	2 (6.67%)	1 (3.33%)	2(10%)	2 (10%)
5.1-6.0	1 (3.33%)	2 (6.67%)	3 (15%)	2 (10%)
6.1-7.0	3(10%)	3 (10%)	14 (70%)	15(75%)
7.1-8.0	21(70%)	22 (73.33%)	1 (5%)	1 (5%)
8.1-9	2 (6.67%)	1(3.33%)	0(0)	0 (0)
9.1-10	1(3.33%)	1(3.33%)	0(0)	0(0)

**Table 7:** Comparison of Internal Diameter of Femoral Artery between right and left side in males and females

	Male		Female	
	Right	Left	Right	Left
Mean	7.46	7.43	6.33	6.29
SD	0.97	0.93	0.6898	0.6932
Median	7.6	7.50	6.500	6.500
SEM	0.1781	0.1703	0.1543	0.155
Range	5-9.9	4.8-9.8	4.8-7.4	4.8-7.3
T-Value	0.1082 DF= 58		0.1601 DF=38	
P-Value	0.9142, NS		0.8737, NS	

**Table 8:** Gender wise comparison of Internal Diameter of Femoral Artery

	Right		Left	
	Male	Female	Male	Female
Mean	7.46	6.33	7.43	6.29
SD	0.97	0.68	0.93	0.69
Median	7.6	6.5	7.5	6.5
SEM	0.1781	0.1543	0.1703	0.1550
T value	4.494 DF= 48		4.674 DF= 48	
Range	5-9.9	4.8-7.4	4.8-9.8	4.8-7.3
P-Value	0.0001, HS		0.0001, HS	

The mean value of Internal Diameter of Femoral Artery was found to be 7.43 mm in males and 6.29 mm in females on left side.

Gender wise comparison of mean value of internal diameter of femoral artery on both sides showed statistically **highly significant** difference by unpaired t-test.

This shows that male femoral artery have significantly larger diameter than female femoral artery.

### Discussion

Profunda Femoris Artery is the main source of blood supply in the thigh region. It has an important role in arteriography, ultrasound, doppler imaging, digital subtraction angiography and MRI [11].

In the recent era, profunda femoris is being used for haemodialysis other than femoral artery.

Damage to this artery can cause life threatening complications. It is an important branch of Femoral Artery which is commonly used for catheterization in interventional radiology. So clinicians and surgeons must be aware of normal anatomy and variations in this region.

Anatomical variations reported at the level of the division of the femoral artery can be explained as follows. In the lower animals, the profunda femoris artery is a branch of the internal iliac artery. During course of evolution, the origin shifted distally from

the femoral artery. Ontogeny repeats phylogeny. Hence, developmental arrest at different stages may lead to anatomical variations related to the division of the femoral artery [12].

Vaas F [13] reported that the profunda femoris artery acts as a collateral vessel in the occlusion of the femoral artery and for this important function, it has to have a large caliber, which can be explained based on the aforementioned comparative anatomy.

### Variations in the arterial patterns may be due to [14]

1. Divergence in the mode and proximodistal level of branching.
2. Presence of unusual compound arterial segments.
3. Aberrant vessels that connect with principal vessels, arcades or plexuses.
4. Vessels that occupy exceptional tissue planes (e.g. superficial fascia instead of sub fascia).
5. Have unsuspected neural myological or osteoligamentous relationships based on the aforementioned comparative anatomy.

Many workers have reported variability in the origin and branching pattern of Profunda Femoris Artery still, combined study on the anatomical variations of the origins of the profunda femoris, and internal diameter of femoral artery is rare in literature. Hence, present work was undertaken on cadavers to study.

*Site of origin of the Profunda Femoris Artery*

Dixit DP [7] et al 2001, did cadaveric study and found that the profunda femoris artery originated from the posterolateral aspect of the femoral artery in 17 out of 48 cases i.e. 35.41% and from the posterior aspect in 15 out of 48 cases i.e. 31.25%.

Samarawickrama MB [15] et al 2009, observed that profunda femoris artery originated from either posterior (12/26) i.e. 46.15% cases, posterolateral (8/26) i.e. 30.76% or lateral (6/26) i.e. 23.07% aspect of the common femoral artery.

Prakash [12] et al 2010, in a cadaveric observed that 32 out of 64 (50%) extremities, the profunda femoris artery originated from the postero-lateral aspect of the femoral artery; whereas it originated from the posterior aspect in 30 out 64 (46.9%) specimens.

Daksha D [16] et al 2011, dissected 228 lower limbs. The profunda femoris originated from the posterolateral aspect of femoral artery in 96 cases i.e. 42.1%, from the posterior aspect in 68 cases i.e. 28.5%, from lateral side in 43 cases i.e. 18.8%.

Thitilertdecha S [17] et al 2012, observed that PFA was found mostly separated from posterior aspect of FA in 100 cases (44.64%) followed by posterolateral aspect in 68 cases (30.36%), from lateral aspect in 48 cases (21.43%).

In the present study, site of origin of the Profunda Femoris Artery was from the posterolateral aspect of the Femoral Artery in 46% on right side and 44% left side. So the Profunda Femoris Artery originated commonly from the posterolateral aspect of the Femoral Artery on both sides. The site of origin of Profunda Femoris Artery between the right and left sides, showed statistically non significant difference.

The findings of the present study were similar with the findings of the study conducted by the Dixit, D.P. et al (35%), Prakash et al (50%), and Daksha Dixit 2011 (42.1%) et al. Marina et al also found most common site as posterolateral aspect. However when compared with the findings of MB Samarawickrama et al, Siriporn Thitilertdecha et al, it indicated differences. They found most common site from the posterior aspect of the Femoral Artery which was 46.15% and 44.15% respectively. These differences may be due to various ethnic origins.

*Distance of origin of Profunda Femoris Artery from midpoint of inguinal ligament*

Siddharth P [9] et al 1985, dissected 100 legs and observed: The deep femoral artery originates a median distance of 4.4 cm from the inguinal ligament.

Dixit DP [7] et al 2001, observed that the distance of origin of profunda femoris from the midpoint of the inguinal ligament on the right side was mostly between 41 and 52 mm whereas on the left side it was between 46 and 54 mm.

Baptist M [18] et al 2007, observed that the distance of origin of profunda femoris artery on the right side, was observed to be commonly between 30 - 40 mm (40% cases). On the left side also it was 30-40 mm (35% cases).

Nachiket S [19] et al 2009, during routine dissection of a middle aged male cadaver, an unusual origin of the deep artery of thigh was observed bilaterally.

It arose from the femoral artery less than 1 cm distal to the inguinal ligament. On both sides, its diameter was greater than that of the femoral artery.

Prakash [12] et al 2010, observed that the median distance of separation of the profunda femoris artery from the femoral artery was 4.2 cm distal to the midpoint of the inguinal ligament.

Thitilertdecha S [17] et al 2012, observed that the average distance was 34.6mm (37.68 mm in males and 31.54mm in female). Moreover, there were 36.22mm on the right and 33mm on the left.

Mamatha H [20] et al 2012, observed that the PFA originated at about 4.5 cm from the mid-inguinal point and got the results like higher origin of the profunda femoris artery in one specimen.

Shiny Vinila BH [21], et al 2013, observed that the mean distance of origin of profunda femoris artery was observed as 4.13cm and standard deviation was observed as 0.80cm.

Anwer D [22] et al 2013, observed that the average distance of origin of profunda femoris from the midpoint of inguinal ligament was found to be 37.12mm.

In the present study the Profunda Femoris Artery originated commonly from a distance of 4-5 cm. from the midpoint of inguinal ligament. The average distance on right side was found to be 4.45 mm whereas on left side 4.69 cm. The comparison of mean value of distance of origin of Profunda Femoris Artery from the midpoint of Inguinal Ligament on Right and Left side showed statistically non significant difference.

These findings are comparable with findings of Siddharth et al, Dixit et al, Prakash et al, Mamatha H. et al, Shiny V et al, Suthar K. et al 2013.

However, Firdose sultana et al, Siriporn Thitilertdecha et al and Danish Anwer et al 2013 got average distance in the range of 3-4cm which is less

than the present study. These differences may be due to differences in various ethnic origins. Still the findings are nearer to the present study.

Nachiket S. 2009 observed origin of profunda femoris from less than 1 cm distal to the inguinal ligament. In the present study such findings observed in 3 legs.

The advantage of such a high origin of profunda femoris artery is that it can be used for catheterisation and further investigation of any arterial system of the body.

#### *Internal Diameter of Femoral Artery*

Sandgren T [23] et al 1999, stated that male subjects have larger arteries than female subjects this is related to age, body size, and sex after investigating on 122 healthy volunteers (59 male, 63female) by echo-tracking B-mode ultrasound scan.

Schnyder G [24] et al 2001, assessed the angiographic size of the common femoral artery (CFA) and the influence of demographics and comorbidities. Consecutive CFA angiograms (n = 200) were prospectively analyzed. CFA diameter was  $6.9 \pm 1.4$  mm. By multivariate analysis, only diabetes ( $P < 0.001$ ), female gender ( $P < 0.0005$ ), and small body surface area ( $P < 0.01$ ) predicted small vessel size.

Minami T [25] et al 2006, observed that men had significantly larger arterial diameters than women for femoral artery ( $9.8 \pm 1.5$  vs.  $7.2 \pm 1.7$  mm,  $P < 0.001$ ) arteries an ultrasound study.

Baptist M [18] et al 2007, observed that on the left side 70% cases were in the range of 7.1 to 8.0 mm and 75% cases on the right side were in the range of 7.1-8.0 mm.

Shiny Vinila BH [21] et al 2013, observed that the average internal diameter of femoral artery was observed as  $7.02 \pm 0.85$  mm.

In the present study, the internal diameter of Femoral Artery was recorded in the range of 7.1-8 cm in 70% cases on right side and 73.33% cases on the left side. Whereas in females 70% of the cases on right side and 75% cases on the left side in the range of 6.1-7 cm.

The mean value was found to be 7.46 mm on right side and 7.43 mm on left side in males.

In females the mean value was found to be 6.33 mm on right side and 6.29 mm on left side.

Gender wise comparison of mean value of internal diameter of femoral artery between males and females showed statistically significant difference on right side as well as on left side.

Findings of present study are comparable with findings of the above studies however Taro et al got larger diameter of femoral artery than the present study. This difference may be due to different method of study by Taro et al and the different ethnic origins between the two study group.

This shows that male femoral artery have significantly larger diameter than female femoral artery.

#### **Summary**

The results of above observations were summarized as,

1. The site of origin of the Profunda Femoris Artery was observed to be from the posterolateral aspect of the Femoral Artery most commonly.

It originated on right side in 46% cases and 44% on left side from the posterolateral aspect, from the posterior aspect in 34% on both sides and from the lateral aspect in 20% on right side and 22% on left side

The site of origin of Profunda Femoris Artery between the right and left sides, of the study group showed statistically non significant difference.

The site of origin of Profunda Femoris Artery between the right and left sides in males showed statistically non significant difference. On both sides it arose most commonly from posterolateral aspect.

In males 43.33% on right side and 36.67% on left side.

In females also it showed statistically non significant difference. On both sides it arose most commonly from posterolateral aspect i.e. 50% on right side and 55% on left side.

2. Distance of origin of Profunda Femoris Artery from midpoint of inguinal ligament was recorded most commonly in the range of 4.1-5cm on both sides.

- The average distance of origin of Profunda Femoris Artery from Midpoint of Inguinal Ligament on right side was observed to be 4.45 cm while on left side was observed to be 4.69cm.

The comparison of mean distance of origin of Profunda Femoris Artery from Midpoint of Inguinal Ligament on Right And Left side showed statistically non significant difference.

The mean distance of origin of Profunda Femoris Artery from Midpoint of Inguinal Ligament on right side was observed to be 4.53 cm and on left side 4.84cm in males.

In females it was observed to be 4.33 cm on right side and on left side 4.47cm.

The comparison of mean distance of origin of Profunda Femoris Artery from Midpoint of Inguinal Ligament separately for males and females on Right And Left side showed statistically non significant difference

3. The internal diameter of Femoral Artery was recorded in the range of 7-8 cm in 70% cases on right side and 73.33% cases on the left side.

Whereas in females 70% of the cases on right side and 75% cases on the left side in the range of 6-7 cm.

The mean value of Internal Diameter of Femoral Artery was found to be 7.46 mm on right side and 7.43 mm on left side in males.

In females the mean value was found to be 6.33 mm on right side and 6.29 mm on left side.

The comparison of mean value of internal diameter of the male subjects between right and left legs showed statistically non significant difference

Similarly in females too it was non significant.

The mean value of Internal Diameter of Femoral Artery was found to be 7.46 mm in males and 6.33 mm in females on right side. The mean value of Internal Diameter of Femoral Artery was found to be 7.43 mm in males and 6.29 mm in females on left side.

Gender wise comparison of mean value of internal diameter of femoral artery on both sides showed statistically highly significant difference.

This shows that male femoral artery have significantly larger diameter than female femoral artery.

## Conclusion

Profunda femoris artery is an important artery of the thigh and the largest branch of femoral artery. It originates from the femoral artery on the posterolateral aspect commonly. Alteration in the developmental pattern of the axial or Ischiadic artery is the main cause for the anatomical variations in lower limb arteries. The knowledge of these variations is of importance during surgical and radiological procedure to avoid any catastrophic complications.

*In the present study;*

1. Most common site of origin of profunda femoris artery was observed to be the posterolateral aspect of the femoral artery. Variations seen in the form of posterior and lateral origins.

2. The knowledge of the site of origin of profunda femoris artery is important while performing clinical procedures in the femoral region and hip joint replacement and also for avoiding iatrogenic arteriovenous fistula or severe secondary haemorrhage while performing femoral artery puncture.
3. The average distance of origin of profunda femoris artery was observed between 4-5cm.
4. In the present study 3 cases of high origin of profunda femoris artery observed. The advantage of such a high origin of profunda femoris artery is that it can be used for catheterisation and further investigation of any arterial system of the body
5. The internal diameter of the femoral artery was observed significantly more in males than females.
6. The knowledge of the internal diameter of femoral artery at the femoral triangle is useful to surgeons and interventional radiologists as this artery is used in certain clinical procedures like cardiac catheterization, trans-arterial chemo embolization in the treatment of malignancy, arteriography in peripheral vascular diseases.

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## A Morphometric Analysis of Suprascapular Notch & its Clinical Significance in East Godavari Region

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### Abstract

The suprascapular notch is present along the superior border of the scapula and is converted into a foramen by the ossification of the superior transverse scapular ligament which joins the two corners of the notch. This particular notch allows the passage of the suprascapular nerve to the suprascapular fossa and is responsible for the motor nerve supply to the surrounding muscles. There are variations in the shape of the notches. Just below the superior transverse scapular ligament passes the anterior coracoscapular ligament which also ossifies in some cases. The ossification of these two ligaments leads to narrowing of the suprascapular notch and converting it to a foramen. This is one of the important causes of the suprascapular nerve entrapment. The knowledge of the morphometric details of the suprascapular notch is very promising in understanding the cause of the suprascapular nerve entrapment & its subsequent treatment. The present study was conducted using 69 dried scapulae in the GSL Medical College Rajahmundry. Various morphometric parameters of the suprascapular notch were measured & grouped into 6 types based on Rengachary's studies. In this study type III is the commonest (36%) followed by type II (35%), type I (10%), type IV (7%) and type V (7%). Only 5% of the scapulae presented with the complete ossification of the suprascapular ligament converting the notch into a foramen. The knowledge of the variation in the occurrence of the suprascapular notch and their association with the cause of the suprascapular nerve entrapment has drawn the attention of many surgeons enabling them for the proper diagnosis and its treatment.

**Keywords:** Superior Transverse Scapular Ligament; Anterior Coracoscapular Ligament; Suprascapular Notch; Suprascapular Nerve Entrapment.

### Introduction

The scapulae is a triangular bone lying over the posterolateral aspect of the chest wall providing wide area for muscular attachments and helping in various movements around the shoulder. The suprascapular notch is a notch present along the superior border of the scapula close to the roots of coracoid process at the lateral end. This notch varies in shapes and sizes. The notch is bridged by the superior transverse scapular ligament (suprascapular ligament) which is attached laterally to the roots of the coracoid process. Sometimes this particular ligament will undergo

partial or complete ossification converting the notch into a foramen. The foramen formed by the bridging of the suprascapular ligament will transmit the suprascapular nerve whereas the suprascapular vessels pass backwards above the ligament [19].

The anterior coracoscapular ligament is present just below the superior transverse ligament and it may undergo ossification in some cases [2].

For the above mentioned reason the suprascapular notch or foramen serves as an important landmark of the suprascapular nerve while performing various arthroscopic procedures [4]. The variations in the morphological parameters of the suprascapular notch is one of the leading causes of the suprascapular nerve entrapment [8,9]. The suprascapular nerve entrapment will present as pain in the posterolateral region of the shoulder, weakness in the arm with difficulty in movements mainly for the external rotation and abduction, also presents with atrophy of supraspinatus and infraspinatus muscles [1,5]. This syndrome is mostly seen in individuals with repetitive and forceful overhead movements like weight lifters, volleyball players as well as it affects

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certain group of people who are involved with works involving abduction and external rotation [8,9,14].

The detailed morphometric knowledge of the suprascapular notch has gained much of an interest to surgeons allowing them to justify as one of the important causes of nerve entrapment and can be applied for its treatment [3,21].

### Material and Methods

The present study was undertaken on 69 washed and dried human scapulae in the Department of Anatomy G.S.L Medical College Rajahmundry. Age and sex were not considered. Bones with deformed surfaces and broken bones were excluded from the study. Each scapulae was grossly examined, analysed and measured using Vernier calliper & classified according to study brought forward by Rengachary et al [15]. According to him the suprascapular notch was classified into 6 groups by measuring the morphological details of the notch [15].

The following measurements were taken in the study-

1. Superior transverse diameter (STD) – horizontal distance between the superior edges of the notch on the superior border.
2. Maximum depth (MD) – distance between the upper border to the lower point of the suprascapular notch.
3. Middle transverse diameter (MTD) – horizontal distance between the two lateral walls of SSN at the midpoint of Maximum depth.

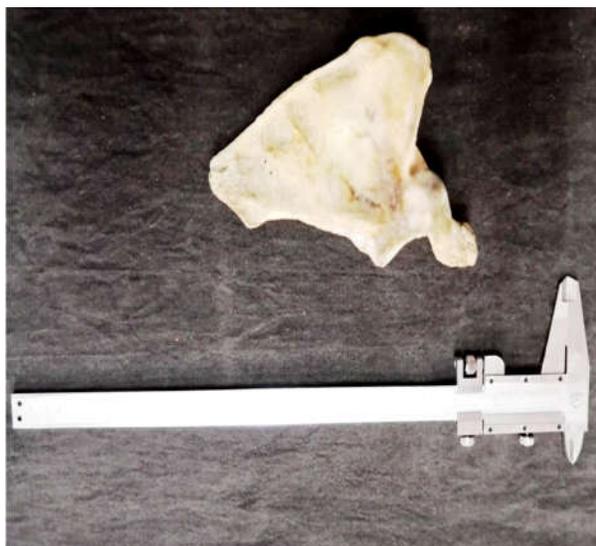


Fig. 1: All measurements taken with the help of Vernier calliper.

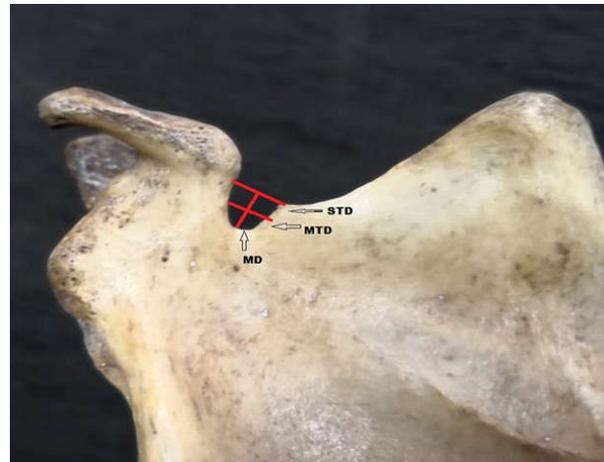


Fig. 2: Measurement of STD, MTD & MD

According to Rengachary et al Suprascapular notch can be classified into 6 types:

Type I - absence of notch.

Type II – wide blunted V shaped notch.

Type III – symmetrical and U shaped notch with parallel lateral margins.

Type IV – small V shaped notch.

Type V – U shaped notch with partial ossification of medial part of suprascapular ligament.

Type VI – completely ossified suprascapular ligament forming foramen.

In the present study morphometric details of type II, type III, type IV and type V were taken into consideration as in type I the suprascapular notch was significantly absent and in type VI due to presence of complete ossification of the ligament the measurement could not be taken.



Fig. 3: Type I - No suprascapular notch



Fig. 4: Type II - V Shaped suprascapular notch

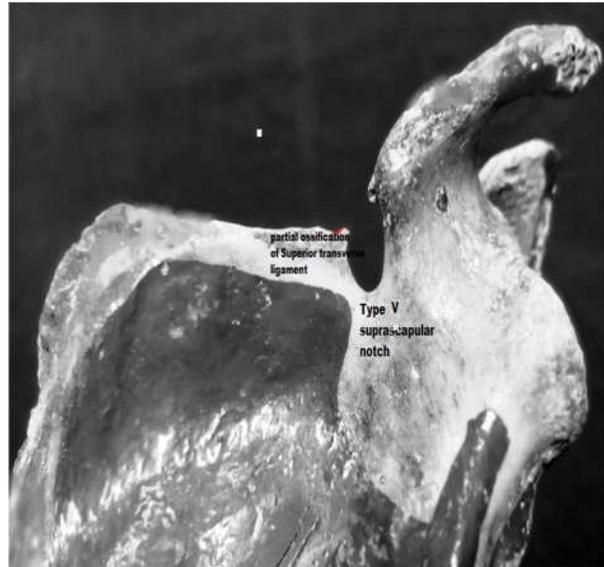


Fig. 7: Type V - partial ossification of suprascapular ligament.



Fig. 5: Type III - U shaped suprascapular notch



Fig. 8: Type VI - complete ossification of suprascapular ligament forming suprascapular foramen



Fig. 6: Type IV- small v shaped suprascapular notch

### Results

In the present study, 69 dried scapulae were observed and the morphometric measurement of the suprascapular notch was taken. Based upon Rengachary et al studies, the suprascapular notch was classified into 6 types.

Morphological analysis and measurement of the suprascapular notch in this study depicts that type III is the commonest (36%) followed by type II (35%), type I (10%), type IV (7%) and type V (7%). Only 5% of the scapulae presented with the complete ossification of the suprascapular ligament converting the notch into foramen.

**Table 1:** Various types of suprascapular notch in the present study

S. No	Type	Total%	Number
1.	Type I	10%	7
2.	Type II	35%	24
3.	Type III	36%	25
4.	Type IV	7%	5
5.	Type V	7%	5
6.	Type VI	5%	3

**Table 2:** Morphometric measurement of the suprascapular notches

S. No.	Side	Type	STD(mm)	MD(mm)	MTD(mm)
1.	L	Type II	10	8	7
2.	R	Type III	9	6	7
3.	L	Type III	12	4	9
4.	R	Type V	7.6	8.1	8
5.	L	Type III	10	4	8
6.	R	Type III	12	7	13
7.	L	Type III	11	7	8
8.	R	Type III	12	8	8
9.	L	Type IV	7.2	4.1	5.7
10.	R	Type I	-	-	-
11.	L	Type IV	7.5	4.8	5.3
12.	L	Type I	-	-	-
13.	L	Type VI	-	-	-
14.	R	Type III	11.5	7.9	8.9
15.	R	Type III	10.9	7.5	8.1
16.	R	Type III	12.1	6.9	7.9
17.	L	Type III	10.5	7.3	8.2
18.	R	Type II	13.7	6.7	9.8
19.	R	Type III	11.1	8.6	7.9
20.	R	Type III	10.6	8.1	7.8
21.	R	Type III	11.7	7.9	7.7
22.	L	Type III	10.2	8.2	7.9
23.	L	Type III	11.6	8.7	7.5
24.	R	Type VI	-	-	-
25.	R	Type II	13.9	6.7	10.1
26.	L	Type II	13.1	7	9.8
27.	R	Type III	11.6	8.7	7.5
28.	R	Type II	14.1	7.2	9.5
29.	L	Type II	12.9	6.9	9.6
30.	L	Type II	14.3	7.5	10
31.	R	Type I	-	-	-
32.	R	Type II	12.8	6.9	9.8
33.	L	Type II	13	7.6	9.2
34.	L	Type II	12.9	6.6	10.2
35.	R	Type IV	8.3	5.5	4.5
36.	R	Type II	13.5	6.9	9.7
37.	L	Type II	13.9	7.5	10
38.	R	Type II	13.4	6.8	9.7
39.	L	Type III	11.6	8.7	7.5
40.	R	Type II	12.8	6.9	9.7
41.	R	Type II	11.9	7	10.2
42.	R	Type II	13.8	7.3	9.8
43.	L	Type II	12.9	6.7	10.4
44.	L	Type I	-	-	-
45.	R	Type II	13.8	7.1	9.8
46.	L	Type V	8.7	7.5	7
47.	R	Type II	12.9	7.3	9.8
48.	R	Type II	13.2	6.9	10.6
49.	L	Type III	11.3	8.8	7.8
50.	R	Type I	-	-	-
51.	R	Type II	13.8	6.5	9.9
52.	L	Type II	14.1	7.3	10.2

53.	R	Type VI	-	-	-
54.	L	Type V	8.9	9.1	7.5
55.	R	Type IV	8.1	5.2	4.7
56.	R	Type III	11.7	8.5	7.7
57.	L	Type II	12.8	7.2	9.5
58.	L	Type III	11	8.7	7.9
59.	R	Type III	10.9	8.5	7.5
60.	L	Type IV	8.2	4.9	4.7
61.	R	Type III	11.6	8.6	7.8
62.	L	Type V	8.7	9	7.5
63.	L	Type III	11.3	9.1	8.1
64.	R	Type III	10.9	8.6	7.5
65.	L	Type II	12.9	6.8	9.5
66.	L	Type I	-	-	-
67.	R	Type III	11.2	8.3	7.7
68.	R	Type V	8.9	9	7.6
69.	L	Type I	-	-	-

**Table 3:** Comparison of present study with previous one showing different type of suprascapular notches.

Researches	Notch					
	Type I	Type II	Type III	Type IV	Type V	Type VI
Rengachary et al	8%	31%	48%	3%	6%	4%
Sangam M et al	21%	8%	59%	2%	5%	1%
Sinkeet et al	22%	21%	29%	5%	18%	4%
Muralidhar	21.15%	8.65%	59.61%	2.88%	5.76%	1.93%
Natsis et al	8%	31%	48%	3%	6%	4%
Paolo Albino	12.4%	19.8%	22.8%	31.1%	10.2%	3.6%
Present study	10%	35%	36%	7%	7%	5%

## Discussion

Various studies has been conducted by number of researches pointing the occurrence of different shapes of the suprascapular notch and the partial or complete ossification of the superior transverse ligament STSL converting the notch into a foramen. Micha Polguje al presented a study showing the coexistence of the suprascapular notch and suprascapular foramen supported by radiological data [13]. Similarly Natsis et al founded in 1% of cases the coexistence of the suprascapular notch and the foramen with complete ossification of Anterior coracoscappular ligament [11]. The presence of ossified anterior coracoscappular ligament was described as a bonybridge that divides the notch reducing the area of passage of suprascapular nerve (36%) [17]. Here only 2 cases were reported with the similar features. The presence of the partial or complete ossification of the superior transverse scapular ligament and anterior coracoscappular ligament were responsible for narrowing of the suprascapular notch and converting it to a foramen thereby causing Suprascapular nerve entrapment.

In the present study of 69 dried scapulae, only 5% of cases presented with the complete ossification of the superior transverse ligament converting the notch

into foramen ,which is close to the studies done by Rengachary et al 1976 (6%), Natsis et al 2007 (4%) and Sinkeet et al 2010 (4%) [11,15,18]. Only 7% of the cases presented with partial ossification of the superior transverse ligament ,this was nearly similar to studies done by Rengachary et al (6%) and Muralidhar (5.76%) [10,15]. Absence of the notch was found to be in 10% of cases which is very low as compared to the study brought up by Sinkeet et al (22%) and Sangam M et al (21%) [16,18]. Various studies by different researches showed that type 3 was the commonest type. In the present study 36% of cases were of type III followed by type II that accounts for 35% which was supported by the studies done by Rengachary et al, Natsis et al, Paolo Albino et al. [11,12,15]. The fact that type IV- small v shaped notch has a narrow area for the passage of the suprascapular nerve leading to its entrapment was supported by the studies done by Dunkelgrun et al [6].

## Conclusion

As the suprascapular nerve entrapment is most frequently associated with the narrower suprascapular notch and formation of suprascapular foramen due to the ossification of the superior transverse scapular and anterior coracoscappu-

larligament. The Knowledge of types of the suprascapular notch would be helpful for understanding the cause of the suprascapular nerve entrapment supported by various radiological modalities and subsequent treatment.

### Abbreviations

STD - Superior transverse diameter

MD - Maximum depth

MTD - Middle transverse diameter

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## Variations among Foramen Transversarium in Cervical Vertebrae and its Clinical Significance

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### Abstract

*Aim:* To study the variations of Foramen Transversarium in cervical vertebrae and to analyze their morphological features with emphasize on their embryological and surgical importance. *Material and Methods:* The study included human cervical vertebrae which were procured from the dry bone collections of Department of Anatomy, Andaman & Nicobar Islands Institute of Medical Sciences, Port Blair and Sri Lakshmi Narayana Institute of Medical Sciences, Pondicherry. The age and sex were not known. The foramina transversaria of all the vertebrae were studied for shape, size and for presence of accessory foramina. *Results:* Significant number of bones with shape variations, size variations and many accessory foramen transversarium were found. The incidence of accessory foramen transversarium appears to be very high. One unilateral Arcuate canal (posterior arch canal) was identified. No incidence of three foramen and absence of foramen. *Conclusion:* Variations in number and position of foramen transversarium is important for interpreting the CT and MRI scans and essential while performing complex surgical procedures. Their morphological knowledge is clinically important since the course of the 2<sup>nd</sup> and 3<sup>rd</sup> part of vertebral artery may be distorted. These variations may be one of the causes for complaints like headache, migraine and fainting episodes due to vertebral artery compression.

**Keywords:** Foramen Transversarium; Cervical Vertebrae.

### Introduction

Foramen transversarium is the foramen present in the lateral masses of all cervical vertebrae. It is present on both sides. It is one of the typical characteristic features of cervical vertebrae. Foramen transversarium of typical cervical vertebra transmits 2<sup>nd</sup> part of vertebral artery, plexus of sympathetic nerves and vertebral veins [1].

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Any variation in the dimensions of foramen transversarium can cause many clinical symptoms. Second part of vertebral artery passes through foramina transversaria is the most mobile part of artery during neck movements. Vertebral artery supply areas of brain stem responsible for vital functions, Cerebellum responsible for coordination, Occipital lobes responsible for sense of vision and upper 6 segments of spinal cord [2]. This implies its importance [2]. Sympathetic nerve plexus derived from cervico-thoracic sympathetic chain are passing along the foramen transversarium. In case of injury to these nerve plexus leads to Horner's syndrome with symptoms like ptosis, myosis, anhidrosis, enophthalmos etc. [2].

The vertebral veins formed from the internal venous plexus and veins of suboccipital triangle, passes along the foramen transversarium, emerges out of sixth cervical vertebra, descends anterior to the subclavian artery and terminates into the brachiocephalic vein [1].

### Embryological Considerations

The foramen transversarium is formed by the fusion costal element to the body and the true transverse process of the vertebra. The vertebral vessels and nervous plexus are caught between these two bony parts. Costotransverse bar - a thin plate of bone connecting the rib element to the original transverse process; closes the foramen transversarium in the lateral aspect [3,4].

Variations of foramen transversarium in cervical vertebrae are common and various reports says that hypoplastic, duplicated, triplicated and accessory foramina transversaria are the variant varieties [5,6,7]. Such anatomical variations may lead to a different path or extra osseous path for the contained structures [5]. Accessory foramina transversaria can be due to a duplicated vertebral artery or it may be formed from a fenestration at that level in the vertebral artery [6].

Variations of the foramina transversaria can affect the course of vertebral vessels and nerves, which can attribute into various clinical pathological symptoms. A good knowledge of the anatomy and variations of these foramina will benefit clinical diagnosis and treatment of such symptoms. So we have taken this study to estimate the type and incidence of structural as well as numerical variations in foramen transversarium among typical and atypical cervical vertebrae.

### Material and Methods

The study included human cervical vertebrae which were procured from the dry bone collections of Department of Anatomy, Andaman & Nicobar Islands Institute of Medical Sciences and Sri Lakshmi Narayana Institute of Medical Sciences, Pondicherry. The age and sex were not known. The foramina transversaria were examined from both sides of all the vertebrae. Difference in shape and number of all foramina transversaria were noted. Right and left foramina of same vertebrae compared for size difference.

### Observations

All the foramina transversaria of 534 cervical vertebrae were examined carefully. Among them, 351 were typical cervical vertebra (C3, C4, C5 and C6) and 183 were atypical (74 atlases, 59 axes and 50 C7-vertebra prominence). The age and sex of the bones were not known. Many foramina transversaria were showed shape variations, partially formed accessory

notch and fully separated accessory foramen. Accessory Foramen transversarium and one posterior arch canal were identified.

Firstly in shape, about 60% of the foramina transversaria showed circular type (Figure 1A) and 15% of the foramina transversaria showed elliptical type (Figure 1B).

### FT Notch

Notch like extensions are seen in many foramina transversaria, hence we named such extensions as FT notch. This can be also referred to as partial accessory foramen.

About 7% of the total foramina transversaria showed unilateral right sided FT notch (Figure 1C 1-3).

### Accessory Foramen

Accessory foramen means additional to the already existing foramen. The smaller foramen is considered as accessory to the larger foramen. About 21% of the cervical vertebrae showed accessory foramen in FT. They can be subdivided into unilateral and bilateral. Among the unilateral type many variations are identified such as unilateral right, unilateral left, posteriorly placed accessory, anteriorly placed accessory, equally divided FT etc. Only one vertebra had bilateral accessory foramina and they are placed posteriorly.

About 16 specimen showed Unilateral Left accessory foramen Figure 2A & Figure 2B.

Unilateral right Accessory and unilateral left FT notch were present in three vertebrae (Figure 2C)

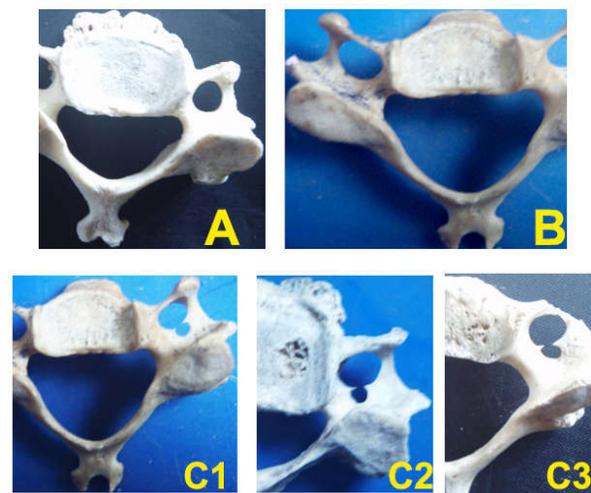


Fig. 1A: Circular type Foramen Transversarium. 1B: Elliptical type Foramen Transversarium. C1: FT Notch - Unilateral Right sided. C2: FT Notch - Unilateral Right sided. C3: FT Notch - Unilateral Right sided

### Variations in position of accessory foramen:

About 4 cervical vertebrae showed accessory foramen in posterior aspect of foramina transversaria. (Figure 2D)

Two cervical vertebrae showed accessory foramina in anterior aspect of Foramen transversarium. (Figure 3A)

One cervical vertebra showed equally divided Foramen transversarium (Figure 3B).

One cervical vertebra showed bilateral posteriorly placed accessory foramen (Figure 3C).

One atlas vertebra showed unilateral right sided arcuate foramen (Figure 3D).

### Discussion

Das and Kapur [8] studied 132 specimens and reported unilateral as well as bilateral presence of double foramina transversaria, only in two cervical vertebrae.

In contrast, Taitz et al [4] from a study comprises 480 cervical vertebrae, observed the doubling of foramina transversaria in 34 cases. Of these, only 6 vertebrae had foramen transversarium of equal size, while the others had foramina of very small dimensions. They also observed triple foramina transversaria in one vertebrae and absence of foramen in 4 cases. The triple foramina transversaria is a very rare variation. It may be the result of double rib bone element on the same side fusing to the original transverse process, resulting in unusual number of foramina. Therefore, the vertebra with triple foramina transversaria shows two costal bars instead of one [4]. Shaarawy et al. observed that the accessory foramina transversaria were most common at the lower cervical vertebrae (C5, C6 and C7), mostly in C6 [9]. In the present study also the foramina were seen at C6 and C7.

The posterior arch of the atlas contains a groove for the third part of vertebral artery variable in size and depth [10]. In some cases this groove can be bridged by ossified part of bone called posterior ponticulus (Latin for bridge). Atlas bridges, also called ponticles, are bony outgrowths occurring on the atlas vertebra over the third segment of the vertebral artery, converting its groove into a sulcus, incomplete or complete foramen [11]. The canal thus formed over the posterior arch of the atlas is called as "arcuate foramen" and by an eponym "Kimmerle's anomaly" since Kimmerle was an early describer of this structure [12]. Other names are: "foramen sagittale", "foramen atlantoideum", "foramen retroarticulare superior", "canalis vertebralis", "retrocondylar vertebral artery" [13].

The arcuate foramen has been reported to play a role in problems like migraine and vertebrobasilar artery stroke [14,15] and the incidence of the arcuate foramen range from 1.14% to 18% depending on the study [15-19]. Seven patients out of nine were identified to have arcuate foramen and they were subjected to vertebral angiograms. Results showed that the vertebral artery passing through the arcuate foramen was constantly under stress and leads to arterial dissection and occlusion. The presence of an arcuate foramen is having strong relation to tethering of the vertebral artery and dissection from repetitive trauma with movement of the neck [14]. The complete

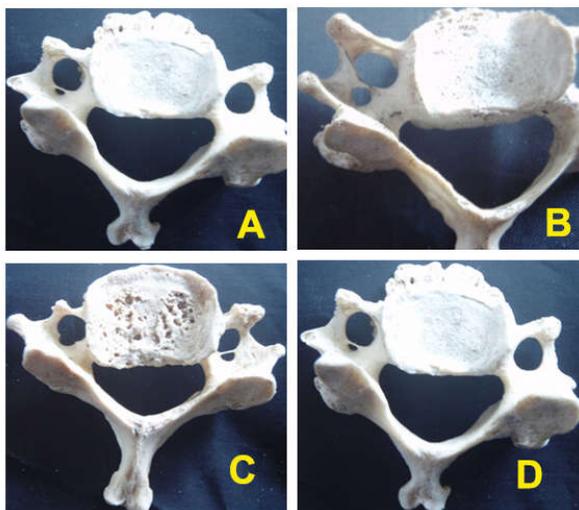


Fig. 2A: Unilateral Left Accessory. 2B: Unilateral Left Accessory. 2C: Unilateral Right Accessory and left FT notch. 2D: Posteriorly placed accessory foramen

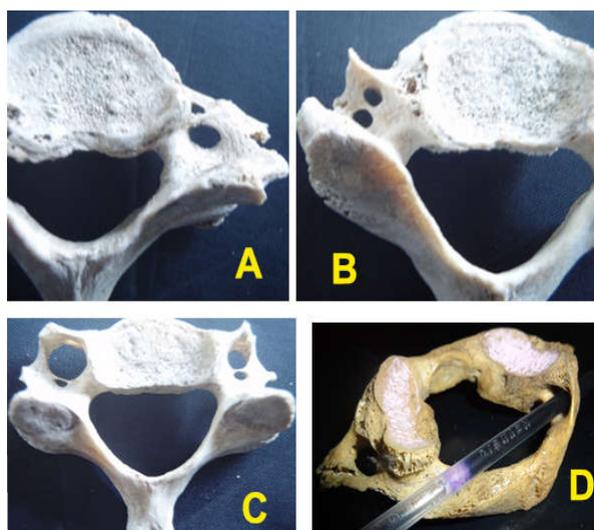


Fig. 3A: Anteriorly placed accessory foramen. 3B: Equally divided Foramen Transversarium. 3C: Bilateral posteriorly placed accessory foramen. 3D: Atlas showing Unilateral Right arcuate foramen

arcuate foramen is significantly more common in males. The partial foramen is commonest in white females. The rate of occurrence seems independent of age [17]. Bundi et al. reported the presence of retro-articular canal in 14.6% and 13.6% on the right and left sides respectively [11].

Occurrence of atlas bridges especially complete and incomplete ones predispose to vertebrobasilar insufficiency and cervicogenic syndromes especially in neck movements. The observation of atlas bridge foramina proposes that they are an important cause of vertebral artery compression [20].

The formation of vertebral artery is by the fusion of longitudinal anastomoses found in between cervical intersegmental arteries. The cervical intersegmental arteries are the branches of the primitive dorsal aorta. These intersegmental arteries eventually disappear, except the seventh artery. The seventh artery forms the proximal portion of the subclavian artery, including the beginning of the vertebral artery [21] Sim et al. [22], described that some portion of the primitive dorsal aorta may not regress along with the two intersegmental arteries which connect the vertebral artery. This arrangement may lead to double origin and duplication of the vertebral artery. The duplication is thought to represent the failure of controlled regression of two intersegmental arteries and a segment of the primitive dorsal aorta. Bilateral occurrence of these failures is the etiology behind bilateral duplication of the vertebral artery [21].

Numerous surgical procedures such as screw and plate fixation, laminar clamping and wiring in between spinous process are being done to overcome the instability of the cervical vertebral column, atlantoaxial complex or occipitocervical junction. Transpedicular and transarticular fixation of screws are also being done widely in recent year in order to stabilize the cervical column. Any mistake done during pedicle screwing will cause severe injury on adjoining important structures like the spinal cord, nerve roots and vertebral arteries [23].

Our study may provide information for the surgeons to determine the safe site of entry and trajectory for the screw implantation and also to avoid injuries to vital structures while operating around axis. Dimensions of axis vertebral foramen transversarium are important and act as a useful guide in the estimation of dilation of vertebral artery. The vertebral artery and the basilar artery contribute blood supply not only to the brain but to inner ear also and their compression may lead to irritation of sympathetic plexus, manifested not only by neurological symptoms but also by labyrinthine or hearing disturbances. To determine accurate

placement of a screw in the area of any deformity resulting from fracture or partial subluxation, ideal drill angle for transpedicular screw placement is required. Therefore careful anatomic reduction is essential.

## Conclusion

Features of the atlas vertebra must be familiar before any spinal surgeries such as transpedicular screw fixation, transarticular screw fixation, interspinous wiring, and interlaminar clamp. In the present study significant number of variations among foramina transversaria were found. The incidence of accessory foramen transversarium appears to be very high. One unilateral Arcuate canal (posterior arch canal) was identified. These information will be helpful in avoiding and reducing complications such as vertebral artery injury, spinal cord injury during spine surgeries. For neurosurgeons and radiologists, the surgical anatomy of these variations is important for interpreting the CT and MRI scans and essential while performing complex surgical procedures. Their morphological knowledge is clinically important since the course of the 2<sup>nd</sup> and 3<sup>rd</sup> part of vertebral artery may be distorted. These variations may be one of the causes for complaints like headache, migraine and fainting episodes due to vertebral artery compression.

## Conflicts of Interest

None

## Key Messages

Variations among foramen transversarium can affect the normal course of its contents and leads to complaints like headache, migraine and fainting episodes due to vertebral artery compression.

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## Estimation of Stature among Tribal Males from the Measurements of Foot Breadth in Udaipur District of Rajasthan

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### Abstract

*Background:* Estimation of stature has a very significant role to play in forensic anthropometry for personal identification. *Objective:* To discover out the correlation among proportions of feet with stature in tribals of Udaipur district in Rajasthan (India). *Material and Methods:* The present study was conducted on a total number of 481 male tribals of Udaipur district by using standard anthropometric techniques. *Results:* There was a correlation between height and foot breadth in Tribals of Udaipur and found correlation coefficient ( $r$ ) as 0.0240 for right foot and for left foot it was 0.0238. *Conclusion:* Linear regression equations were deduced in males out of which lowest standard error of estimate was experienced in combined foot breadth of males.

**Keywords:** Stature; Foot Breadth; Regression Equations.

### Introduction

Anthropometry is an important tool of physical anthropology for obtaining different measurements like stature on the living as well as dead (skeleton and skeletal remains) of man using scientific method. Physical anthropologists mainly deal with study of human origin and evolution of human beings. They also deal with study of different races in various parts of the world. Stature estimation has a very important role to play in forensic anthropometry for personal identification. Even anatomists and anthropologists apart from forensic experts have shown keen interest in estimating the height of an individual/stature by measuring different parts of body like hand length, foot length. Previous researchers have established a very well defined relationship between height of individual and different parts of body like head, trunk and lengths of upper and lower limb. Important differences / variations between various ethnic groups have been studied in detail by comparing relationship between body segments and this has also

been shown to be related to life style and locomotion.

Prediction of dimensions of body segments is useful in many areas of modern science for example in growth and decay the relationship between body segments is used in assessing normal growth as well as in people suffering from specific syndromes. The relationship between proportions and various body segments especially of long bones of limb (femur) have been most widely studied. The biological profile of an individual like inherent traits such as age, sex, ethnicity and stature can be determined with the help of anthropometry. For example, it has been proved that stature can be estimated from a shoe left at the scene of a crime. Similarly the stature of a victim can be estimated when a part of body, such as a long bone, or hand, is all that remains (Santosh K. 2014) [1]. Forensic anthropology is a branch of physical anthropology which interacts with other disciplines pertaining to the understanding of crime and its investigations. The biological profile of an individual is an inherent traits such as age, sex, ethnicity and stature can be determined with the help of anthropometry (A.I. Numan, 2013) [2].

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### Materials & Method

#### Source of Data

Sample will be drawn from the tribal community in Udaipur district. The study has been conducted

on 481 tribals males. Bhil, Meena, Damors, Sahariyas, Gaduliya lohars, Garsias were the tribals of the Udaipur.

the wall and hands hanging down on the sides. Measuring tape was kept fixed on wall and height is recorded.

*Instruments Used*

- Sliding calipers will be used for the measurements of feet.
- Measuring tape will be used for vertical height measurement.

**Inclusion Criteria**

Healthy males of age group 20-30 years.

**Exclusion Criteria**

- Males having physical deformity affecting stature, hands and feet will be excluded from the study.
- Age 18 to 32 years.

**Statistical Analysis**

The data obtained will be subjected to statistical analysis to derive the mean, standard deviation, correlation coefficient, regression coefficient. For testing the level of significance t test will be applied.

*Stature*

It is the vertical distance between the highest point on vertex and the floor. The subject will be made to stand barefoot in an erect posture against a wall with the foot close together, buttocks and occiput touching

*Foot breadth*

It is the distance between the most prominent point on medial aspect of head of first metacarpal and most prominent point on lateral aspect of head of fifth metatarsal.

*Observations*

The following observations were tabulated after statistical analysis:

The age of the study population ranged between eighteen and thirty two years for males. Table 1.shows the distribution of age in the study population. The mean age of males was 24.688 years.

Table-II Shows descriptive statistics for height and weight various parameters studied in males. The average stature of males was 1613.457±72.096 mm and ranged between 1426 to 1800 mm.

Table 3 shows Foot Breadth measured approximately 89 mm & ranged between approximately 70 to 104 mm in males.

To assess the statistical differences between the observations of right and left Foot Breadth in males, paired sample t test was performed and thus null hypothesis was rejected. The Foot Breadth in males was highly significant of right and left sides. There is a high correlation between right & left side Foot Breadth of males as observed in Table 4.

**Table 1:** Table showing distribution of age among study population in males

	Males
Number	481
Mean	24.688
Median	24.000
Std. Deviation	4.319
Range	14.000
Minimum	18.000
Maximum	32.000

**Table 2:** Descriptive Statistics of Height & Weight Studied in Males

Column	Size	Mean	Std. Dev	Std. Error	Range	Max	Min	Median
Height	481	1613.457	72.096	3.287	374	1800	1426	1621
Weight	481	56.89	11.495	0.524	46.07	88.13	42.06	53.29

**Table 3:** Descriptive Statistics of Right & Left Foot Breadth Studied in Males

Column	Size	Mean	Std. Dev	Std. Error	Range	Max	Min	Median
Male RFB	481	88.637	6.524	0.297	33.620	103.62	70	89.510
Male LFB	481	88.902	6.492	0.296	33.250	103.74	70.49	89.65

**Table 4:** Paired Samples t-Test & Pearson Correlation showing statistical difference between Right and Left Foot Breadth in Males

Paired Samples	t	DF	Sig.(2-tailed)	Pearson Correlation
Male Right Foot Breadth-Male Left Foot Breadth	17.181	480	.000**	.999**

\*\* Statistically Highly Significant at the Level (0.01 & 0.05)

**Table 5:** Correlation between the Stature and Right & Left Foot Breadth Parameters studied in Males

Parameters	Male Right Foot Breadth	Male Left Foot Breadth
Pearson Correlation	0.024	0.023
Sig.(2-tailed)	0.599	0.603

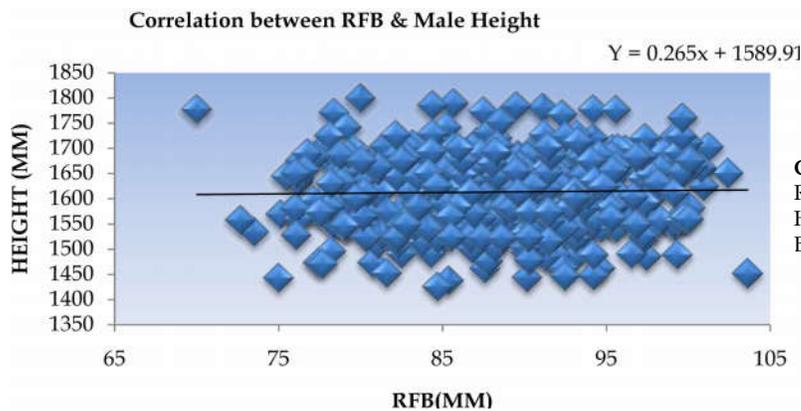
**Table 6:** Correlation between the Stature and combined Foot Breadth studied in Males

Parameters	Male Foot Breadth
Pearson Correlation	0.0239
Sig.(2-tailed)	0.601

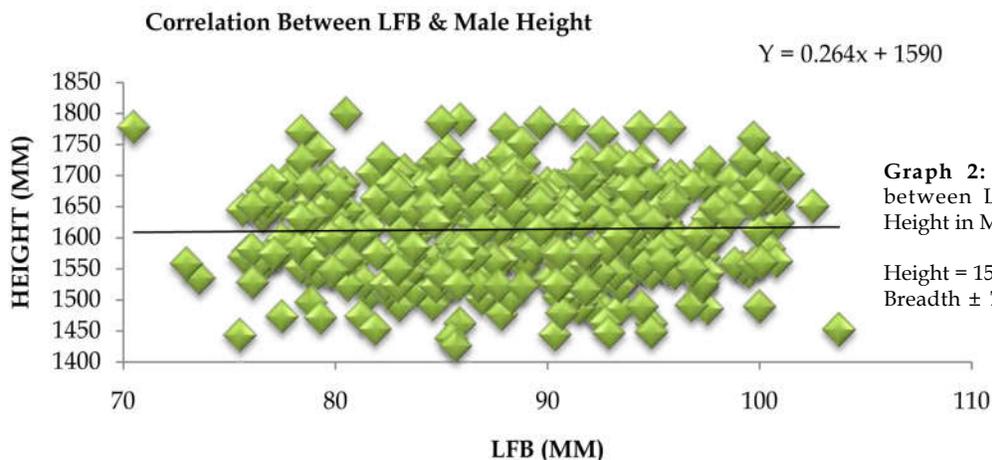
To assess the statistical differences between the observations of right and left Foot breadth in males, Pearson Correlation was performed. There is a low correlation between foot breadth of males of right and left sides with the stature as observed in Table 5.

There was a low correlation between foot breadths of males with the stature.

Graph 1 Shows Regression Formula. Value of constant is 1589.91, Regression coefficient is 0.265 and standard error is 72.151. There was positive but low correlation between height and Right Foot Breadth in males.

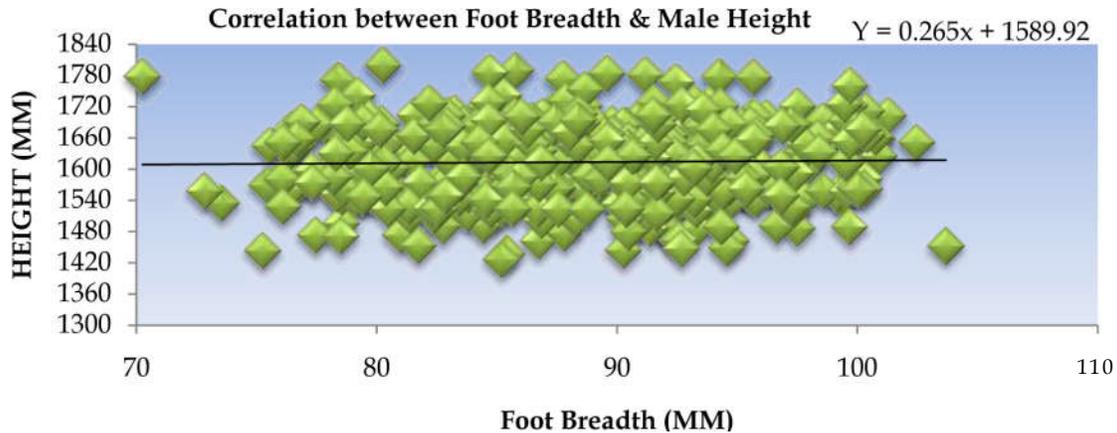


**Graph 1:** Showing Correlation between Right Foot Breadth and Height in Male  
 Height = 1589.910 + 0.265 × Right Foot Breadth ± 72.151



**Graph 2:** Showing Correlation between Left Foot Breadth and Height in Male

Height = 1589.971 + 0.264 × Left Foot Breadth ± 72.151



**Graph 3:** Showing Correlation between Foot Breadth and Height in Males  
 $HEIGHT = 1589.924 + 0.265 \times \text{Foot Breadth} \pm 72.151$

Graph-2 Shows Regression Formula. Value of constant is 1589.971, Regression coefficient is 0.264 and standard error is 72.151. There was positive but low correlation between height and Left foot breadth in males.

Graph-3 shows Regression Formula. Value of constant is 1589.92, Regression coefficient is 0.265 and standard error is 72.151. There was positive but low correlation between height and foot breadth in males.

## Discussion

In 2007 Bhavna and Nath S studied correlation between height and foot breadth in Male Muslims of Delhi and found correlation coefficient (r) as 0.383 in males. Lowest correlation was exhibited by foot breadth with highest error of estimate, should be used only in the absence of the other measurements of the lower limb.

In 2007 Krishan K and Sharma A studied correlation between height and Foot Breadth in Rajputs of Himachal 60 Jat Sikhs and found correlation coefficient (r) as 0.324 in males where as in females it was 0.323.

In 2010 Singh S, Hussain M and Rizvi SJ studied correlation between height and hand Foot Breadth in Volunteers of Aligarh and found correlation coefficient (r) as 0.31 in males where as in females it was 0.36. Coefficients was more positive in both the sexes combined as compared to those of male and female separately. Foot breadth and stature were better correlated in females as compared to that of males.

In 2011 Rani M et al. studied correlation between height and Foot Breadth in Students of Delhi and

found correlation coefficient (r) as 0.345 for right foot and r for left side was 0.413 in males where as in females it was 0.345 for right side and 0.358 for left side in females. The correlation coefficients between stature and foot dimensions were found to be positive and statistically highly significant.

In 2012 Shende S, Tirpude B and More S studied correlation between height and Foot Breadth in Students of Maharashtra and found correlation coefficient (r) as 0.44 for right foot and r for left side was 0.41 in males where as in females it was 0.29 for right side and 0.32 for left side in females. Foot breadth showed minimum correlation with stature in females.

In 2013 Singh JP et al. studied correlation between height and foot breadth in female volunteers of New Delhi and found correlation coefficient (r) as 0.379. Correlation coefficients of foot breadth were lower as compared to foot length measurements in females.

In 2014 Dayananda R, Babu U and Kiran J studied correlation between height and foot breadth in Medical Students and found correlation coefficient (r) as 0.375. The correlation between stature and all the foot measurements was found to be positive and statistically significant (p value <0.001).

In 2015 DR R et al. studied correlation between height and foot breadth in Medical students of Puducherry and found correlation coefficient (r) as 0.431 for right side in males and r for left side was 0.394 where as in females it was 0.464 for right side and 0.473 for left side in females. The correlation coefficients were higher in females than the males.

In the present study I noted the correlation between height and foot breadth in Tribals of Udaipur and found correlation coefficient (r) as 0.0240 for right foot and for left foot it was 0.0238 and for combined

foot breadth  $r$  was 0.0239 in males. In the present study the stature shows low correlation between the stature and foot breadth in males.

All the human beings on this earth belong to the same species i.e. *Homo sapiens*. They are not exactly alike in all their measurable traits; even genetically differ in so many respects. All traits tend to undergo change in many degrees from birth to death. In these traits changes in skeletal development depends on geographical regions.

The study is also in accordance with the fact that there are ethnic as well as racial variations in the dimensions of hands, digits, phalanges and foot. Thus, emphasizing the need to have normal values and range for the dimensions of hand length, hand breadth, middle finger digit length, middle finger proximal, middle and distal phalangeal length, foot length, foot breadth of both the sides (right and left) for different population as well as supporting the statement "There are no mean values,  $t$  values, correlation values and regression equations that is linear and multiple regression of the hands and foot that are valid for all population." It is suggested to carry on further studies on the other body parameters (eg: - ankle breadth, wrist breadth, ratio of fingers to the body length, length of lower limb, arm length, forearm length) to allocate for full anthropometric data for tribals of Udaipur district.

### Conclusion

In the present study following conclusions were derived these were:

1. In the males for right and left foot breadth a low correlation was shown.
2. From my study it was concluded that foot breadth in males can be used in stature estimation in tribal population of Udaipur district.

### Conflicts of Interests

None

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## A Study of Supratrochlear Foramen and Their Clinical Significance in a Teaching Hospital of Deccan Plateau

Divya Agrawal<sup>1</sup>, G.B. Sujatha<sup>2</sup>, V. Subhashini Rani<sup>3</sup>, Prafulla Kumar Chinara<sup>4</sup>

### Abstract

*Aim:* The supratrochlear foramen is an aperture or hole that is created when the bony septum between the olecranon fossa and coronoid fossa becomes perforated. The STF has achieved importance in recent years as its knowledge is useful for anatomists, anthropologists, orthopedic surgeons, and radiologists. The goal of our study was to determine the morphometric measurements of STF in the Andhra Pradesh population. *Materials & Methods:* The study was conducted on 135 humeri of unknown sex and age. The STF were measured using Vernier calipers and the measurements on both the sides were tabulated & statistically analyzed. A light source was used to determine the translucency of the septum. *Observations & Results:* The prevalence of STF in the present study is 22.96% and is more common on the left side. Majority of STF were oval (61.29%) followed by round apertures (32.25%). In the present study, the mean transverse diameter of the STF was 6.49mm and 6.35 mm, on left and right sides respectively while the vertical diameter was 4.88mm and 4.16mm on left and right sides respectively. *Conclusion:* STF is associated with narrow and shorter medullary canal and anterior angulation at the distal humerus. The knowledge of STF is very important for preoperative planning of intramedullary nailing for treatment of supracondylar fractures, especially following traumatic injuries and pathologic fracture.

**Keywords:** Supratrochlear; Foramen; Humerus.

### Introduction

The supratrochlear foramen is a small hole located above the trochlea of the humerus of several mammals. The supratrochlear foramen (STF) of the humerus has been neglected in standard anatomy and orthopedics books. It is an important and relatively common anatomic variation in the lower end of the humerus. A thin plate of bone called supratrochlear septum separates the olecranon fossa and coronoid fossa of the distal end of humerus. This bony septum may be opaque or translucent or in some cases it may be perforated to form a foramen called asepitrochlear foramen, supratrochlear aperture, septal aperture, intercondylar foramen, but is most commonly referred

to as supratrochlear foramen (STF) [1-3]. This foramen lies between the lateral and the medial epicondyles [4] at the lower end of humerus. Meckel in 1825 was the first person to describe the supratrochlear foramen [5].

STF are of varied shapes. They can be oval, round, triangular, sieve-like, and irregular [6,7]. Studies have shown that the humerus is not perforated in the embryonal stage [8]. The septum is present until 7 years of age, after which it is occasionally absorbed to form STF [9].

Many researchers have described it in dogs, cattle, rats, hyenas and other animals. They believe that it is produced due to the posture they adopt during tearing of food [10].

Supracondylar fractures account for 75% of all fractures in children [4].

STF is associated with narrow and shorter medullary canal and anterior angulation at the distal humerus.

The knowledge of STF is very important for preoperative planning of intramedullary nailing for treatment of supracondylar fractures, especially following traumatic injuries and pathologic

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fracture. In presence of supratrochlear foramen, antegrade route is better for intramedullary nailing than retrograde method [11,12]. Awareness of the various shapes and dimensions such as the transverse (TD) and vertical (VD) distance in which this foramen occurs may help avoid misinterpretation of radiographs [3].

**Materials and Methods**

The present study was carried out in the Department of anatomy, GSL Medical College & General hospital, Rajahmundry, Andhra Pradesh. Supratrochlear foramen was studied in 135 dried humeri of both sides of unknown sex and age. Only bones free of any pathological changes were included in the study. The bones were examined for the presence of supratrochlear foramen and their size and shape were determined. Vernier calipers was used to measure the vertical and horizontal diameters. A light source was used to determine the translucency of the septum.

**Observations and Results**

A total of 135 humeri free of any pathological changes were included in the study (Figure 1). There were 69 right and 66 left humeri out of which 10 had round supratrochlear foramen 19 had oval foramen and 2 had irregular STF (Table 1). Around 22 bones showed translucency (Table 2) in the region of



Fig. 1: Shows various shapes of supratrochlear foramen

Table 1:

Foramina	Right humeri (n=69)	Left humeri (n=66)
Round	4	6
Oval	8	11
Irregular	1	1

\*STF= supratrochlear foramen n=number of humeri

Table 2:

Foramina	Right humeri	Left humeri
Translucent septum	7	15
Peforated septum	1	6

Table 3A: Shows mean and standard deviation of transverse and vertical diameters of supratrochlear foramen

LEFT SIDE

Transverse diameter	Vertical diameter
Mean = 6.49mm	Mean = 4.88mm
S. D= 1.375	S. D=0.694
Variance =1.890	Variance =0.482
Standard error of mean=0.324	Standard error of mean=0.1639

Table 3B: Shows mean and standard deviation of transverse and vertical diameters of supratrochlear foramen

RIGHT SIDE

Transverse diameter	Vertical diameter
Mean = 6.35 mm	Mean = 4.16mm
S. D= 1.57	S. D=0.673
Variance =2.47	Variance =0.453
Standard error of mean=0.437	Standard error of mean=0.186

supratrochlear septum when illuminated by a source of light from behind (Figure 2). Perforations in the region of supratrochlear septum was observed in 7 bones. The data was tabulated and was statistically analyzed. It was compared with the data obtained in other studies carried out in India and abroad.

## Discussion

The function and formation of supratrochlear foramen is largely obscure. Normally foramina serve as conduits for vessels and nerves, while apertures are merely openings in bones with no structure passing through them [13]. No anatomical structure is known to pass through the STF and thus it does fit the definition of foramina.

There are numerous theories that have been proposed as to how these foramina are formed. STF may be an atavistic character [12]. Another hypothesis suggests that the STF's are mechanically induced and can be considered as part of the mechanical & anatomical relationship between humerus and ulna during normal flexion and extension at the elbow [13].

Some believe that STF is formed by resorption from anterior surface of septum [4]. A greater degree of joint hypermobility in females than in males can be

the reason behind the greater prevalence of septal aperture in females [14]. A small flexion angle is associated with high robusticity of the humerus [15]. It has often been noticed that populations which have a high frequency of septum perforation tend also to have a low robusticity of the bones [16].

Overall, studies have shown that septal apertures were more common among ancient human populations, especially in late Europeans. Its left side frequency can be explained on the basis of handedness. It is more common on the non-dominant left hand as the dominant right limb has more robust bones [17,18]



Fig. 2: Shows translucency of supratrochlear foramen

Table 4: Shows incidence of STF's in different populations in percentages

Populations of countries	Incidence in percentage
South Africans	32.5%
Egyptians	7.9%
Greeks	0.304%
Americans	6.9%
Japanese	18.1%
Chinese	17.5%
Netherlands	6.1%
Italians	9.4%
African negroes	21.7%

The prevalence of STF in the present study is 22.96%. The prevalence of the STF in the human population varies from 0.3% to almost 60% worldwide (Table 4). In the present study, the prevalence of the STF was higher on the left side.

In our study, majority of STF were oval (61.29%) followed by round apertures (32.25%). This is similar to the findings of Veerappan et al who found oval STF's in 42.85% & round apertures in 37.71% of humeri. Translucent septum was seen in 16.29% of cases which is much less than reported by Nayak et al who recorded it as 56.7%. Veerappan et al also

observed translucent supratrochlear foramen in 50% of subjects.

In the present study, the mean transverse diameter of the STF was 6.49mm and 6.35 mm, on left and right sides respectively while the vertical diameter was 4.88mm and 4.16 mm on left and right sides respectively (Table 3A & 3B).

This result was consistent with a study by Mathew et al. [22]. The results obtained in the present study are comparable with that of other authors like Nayak et al. [21], Krishnamurthy et al. [23], and Veerappan et al. [5]

Incidence in Indian populations showed 27.4% in Eastern Indians [9], 32% in Central Indians [24], 27.56% in North Indians [25], 28% in South Indians [6] and 34.4% in overall Indians [24].

The below table shows the comparative data in south (Table 5.1, Table 5.2, Table 5.3, Table 5.4 and Table 5.5) Indian population.

**Table 5.1:** Tamilnadu

Suba Ananthikumaraswamy et al [28]	31.3%
Veerappan et al[5]	19.1%

**Table 5.2:** Karnataka

Soubhagya R Nayak et al [21]	34.3 %
Suruchi Singhal et al [26]	28%
Raghavendra et al [27]	28%
Varalaxmi K L et al [29]	25.8%

**Table 5.3:** Telangana

B. Mahitha et al [26, 28]	18.7%
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**Table 5.4:** Kerala

Mathew A J et al[22]	24.5%
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**Table 5.5:** Andhrapradesh

P Sharmila Bhanu et al [7]	30.58%
Krishnamurthy A et al [23]	23%
Hima Bindu et al[9]	20%

## Conclusion

Thus, to conclude, observations in this study are comparable to other data obtained from Andhra Pradesh. This study showed a prevalence of STFs as 22.96% and more common on left side as reported by many other workers. Knowledge of supratrochlear foramen in the distal humerus is important as a diagnostic tool in orthopedics for intramedullary nailing of the humerus

Also presence of STF as a radiolucent area in radiographs and may be misinterpreted as an osteolytic or cystic lesion resulting in wrong diagnosis and complications.

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## Stature prediction from Anthropometric Feet Dimensions: A Study of Relationship

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### Abstract

Anthropologists and forensic medicine personnel estimate height of an individual as one of criteria to establish identity of an individual. It is also useful for physical assessment of status of nutrition in an individual by nutritionists and physicians. Stature prediction from incomplete and decomposing skeletal remains is one of most useful criteria in establishing the identity of an unknown individual. It is a useful tool in medico legal and forensic examination. *Study Design:* Descriptive cross-sectional study. *Place of Study:* Department of Anatomy, MGM medical college, Aurangabad, India. *Material:* 185 young and healthy college students aged between 18 to 24 years, without any disease or deformity were examined anthropometrically in respect to their height and foot dimensions. *Method:* Measurement of height and foot dimensions of right and left side was taken with a standard anthropometer and a Vernier caliper respectively. *Result:* The present study showed significant ( $p < 0.001$ ) positive correlation between the stature and feet dimensions with sexual dimorphism.

**Keywords:** Anthropometric Measurement; Skeletal Remains; Height; Stature; Foot Length; Foot Width; Stature.

### Introduction

Since many years artists, scientists, anatomists, anthropologists and medico legal experts [1] has been studying dimensional relationship between body segments and stature for different reasons of which the prime importance is to establish the identity of individual. Other uses include ergonomic designing of machines and fashion designing.

The identity of an individual has to be established in cases of mutilated, decomposed, & amputated body fragments in recent times which may occur due to natural disasters like earthquakes, tsunamis, cyclones, floods or man-made disasters like terror attacks, bomb blasts, mass accidents, wars, plane crashes etc.

The determination of stature is an important step in the identification of fragmented/dismembered remains [2].

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Hence, personal identification of the victims [3] by estimation of stature from extremities and their parts plays avital role in identifying the dead in forensic examinations. Stature and body parts show significant biological correlation [4].

Also, evaluation of various anthropological parameters with proportions has an important role in sports medicine, designing of instruments and education [5].

Height of an individual is also affected by diverse factors such as race, gender and nutrition. An individual's height is also under the control of genes and environment [6].

The body size such as height and weight can be assessed by growth, nutritional status, body surface area and pulmonary function of children [7,8].

Natural height or stature of a person is usually taken in upright position. The foot dimensions can be used as a basis for estimating age-related loss in stature [9,10,11].

Hence, we attempted to study the correlation between stature and various dimensions of foot with a mention to gender, in Medical students in age group of 18-24 years by using linear univariate and multiple regression formulae.

## Materials and Methods

### Method of Data collection

The study was started after all necessary permissions from authorities and written consent from subjects were taken. Stature and foot dimensions were recorded of 185 students consisting of 81 males and 104 females in the age group of 18-24 years studying in MGM Medical College, Aurangabad, India.

Selection of male and female adult subjects for measurements was taken as below:

### Inclusion Criteria

1. Healthy and normal adult subjects in the age group 18-24 years.
2. All students of MGM medical college in the age group of 18-24 year

### Exclusion Criteria

1. Subjects with musculoskeletal deformities like kyphosis, scoliosis, poliomyelitis, trauma etc., hormonal disorders like gigantism, dwarfism, etc. and genetic disorders like Turner's syndrome, etc. which will affect the normal measurements of stature and foot dimensions.

The following instruments were used to carry out this study:

1. Anthropometer (Stadiometer).
2. Vernier (Sliding) calipers (digital type).
3. Steel tape.

### Method of Measurements [12,13]:

1. *Stature*: Measurement was taken as vertical distance from vertex (the highest point on the top of head) to the floor in mid-sagittal plane with subject standing barefooted, on an even floor and



Fig. 1:

the head being oriented in the Frankfurt's plane. Stadiometer (Anthropometer) was used for the measurement of Stature.

2. *Foot length*: Measurement was taken as the straight distance from the most posterior projecting point on the heel to the tip of the most anterior projecting toe when the subject is standing erect. It was measured with the help of Digital Vernier calipers.
3. *Foot breadth*: It was measured as distance between the most prominent point on the medial aspect of head of first metatarsal and the most prominent point on the lateral aspect of head of fifth metatarsal.



Fig. 2:



Fig. 3:

The measurements were taken from foot of both sides of the body. Both, male and female readings for each parameter were obtained, separated and analyzed. Measurements were taken at a fixed time between 3:00 p.m. and 5.30 p.m. to minimize diurnal variation and were taken in a room with reasonable light. Measurements were done and recorded only by me, to eliminate inter observer error in methodology. All the measurements were recorded thrice and then their mean was calculated for accuracy.

The height, foot length and foot breadth of subjects was used to assess the relationship between the foot dimensions and stature. Analysis was done for all parameters by calculating mean, STD error of mean, STD deviation, Maximum, Minimum separately, Skewness and Kurtosis. Then correlation and coefficients between these anthropometric measurements were calculated. The regression

equations of stature as dependable variable were fitted with foot dimensions as independent variables. The effectiveness of these regression equations was tested. Stature (Height) was considered to be independent for every parameter and correlation was checked between the height and other parameters. Univariate and multivariate regression formulas were derived for each parameter later on. The data were subjected to statistical analysis using statistical package for social sciences (SPSS).

**Observation**

The following things were observed as shown in table 1 below:

Table 1 shows that values here are showing negatively skewed distribution in males and

positively skewed distribution in females with platykurtic distribution.

One way ANOVA shows F value as 170.143 with 0.00 significance suggesting statistically significant difference in male and female height as shown in Table 2.

Foot length is showing positively skewed distribution of values in both males and females. Kurtosis shows platykurtic distribution.

One way ANOVA shows F value as 20.010 with 0.00 significance suggesting statistically significant difference in male and female foot length.

Foot breadth is showing positively skewed distribution of values in both males and females. Platykurtic distribution is observed in kurtosis.

**Table 1:** Height (in centimetre's)

	Male	Female
Mean	171.116	157.578
Std. Error of Mean	0.843	0.637
Std.Deviation	7.684	6.348
Maximum	188	175
Minmum	147	141
Skewness	-0.283	0.228
Kartosis	0.660	-0.090

**Table 2:**

One-way ANOVA			Sum of Squares	DF	Mean Square	F	Sig.
Ht (cm)	Between Groups	(Combined)	8561.364	1	8561.364	170.143	0.000

**Table 3:** Foot Length (in centimeter's)

	Male		Female	
	Right	Left	Right	Left
Mean	25.46	25.455	23.307	23.333
Std. Error of Mean	0.132	0.132	0.125	0.479
Std.Deviation	1.186	1.191	1.430	1.367
Maximum	28.34	28.1	29.5	29.4
Minmum	22.7	22.67	20.2	20.1
Skewness	0.100	0.142	1.413	1.250
Kartosis	0.009	-0.073	4.853	3.793

**Table 4:**

One-way ANOVA			Sum of Squares	DF	Mean Square	F	Sig.
FL (cm)	Between Groups	(Combined)	144.210	1	144.210	20.010	0.000

**Table 5:**

	Male		Female	
	Right	Left	Right	Left
Mean	9.628	9.603	8.792	8.731
Std. Error of Mean	0.070	0.067	0.055	0.057
Std.Deviation	0.642	0.616	0.574	0.590
Maximum	11.24	10.95	10.2	10
Minmum	8.3	8.37	7.16	7.04
Skewness	0.214	0.111	0.013	0.069
Kartosis	-0.093	-0.458	-0.190	-0.281

Table 6:

One-way ANOVA		Sum of Squares	DF	Mean Square	F	Sig.
FB (cm)	Between Groups (Combined)	30.647	1	30.647	84.346	0.000

One way ANOVA shows F value as 84.346 with 0.00 significance suggesting statistically significant difference in male and female foot breadth.

Following regression formulae has been derived using SPSS of one variable and multivariables. They are as follows:

### Univariate Analysis

#### 1. Foot Length (Equ.Uni-1)

R Value = 0.399 F Value = 35.833

Height = 129.514 + [1.383 \* (Right foot length)]

#### 2. Foot Breadth (Equ.Uni-2)

R Value = 0.627 F Value = 122.196

Height = 86.036 + [8.453 \* (Right Foot breadth)]

### Multivariate Analysis

#### 1. Height versus Right Foot Length and Left Foot length. (Equi. Muti-1)

R Value = 0.432 ANOVA is significant

Height = 122.285 + [1.242 \* (Right Foot length)] + [0.433 \* (Left Foot length)]

#### 2. Height versus Right Foot breadth and Left Foot breadth. (Equi. Muti-2)

R Value = 0.645 ANOVA is significant

Height = 83.690 + [2.684 \* (Right Foot breadth)] + [6.056 \* (Left Foot breadth)].

#### 3. Height versus Right Foot breadth, Left Foot breadth, Right Foot Length and Left Foot length. (Equi. Muti-3)

R Value = 0.658 ANOVA is significant

Height = 78.428 + [2.218 \* (Right Foot breadth)] + [5.424 \* (Left Foot breadth)] + [0.430 \* (Right Foot Length)] + [1.93 \* (Left Foot length)].

### Discussion

Ancient Egyptians (Richer and Hale, 1971) [13] were one of the first people to use anthropological rules for stature prediction. Studies done by Pearson (1899) [14], Trotter and Glessler (1952) [15] have shown the prediction of stature from skeletal remains or mutilated limbs done mostly from long bones.

In India, Athwale et al (1963)[16], Patel et al (1964)[17], Joshi et al (1964, 65) [17,18], and Jasuja et al (1991, 1993, 1997)[19,20], studied stature estimation by significant dimensional relationship of length of foot, hand, hand with forearm, arm, upper extremity, length of head, height of head, Crown to rump and rump to heel ratio etc. They concluded that there exists significant correlation between body segments and height. There also exists a population variation in anthropometric dimensions. Stature is partly determined by length of bones in upper limb and lower limb. It may also be influenced by many other factors such as genetics, environment, gender, age and physical activity [21]. In addition, it is also true that, the rate or growth in males and females varies during the course of development till the ossification being complete and skeletal maturity attained by the age of 25 years.

All parameters show significant sexual dimorphism in this present study. There was a strong positive correlation between foot breadth and stature ( $p < 0.01$ ). Hence these can be successfully used for estimation of stature. Anatomists, archaeologists, anthropologists, design engineers and forensic scientists can now predict height of an individual more accurately by the regression equations derived from this study. The only condition is, these formulae are applicable to the Indian region population from which the data has been collected. It is due to the inherent population variation in these dimensions, which may be attributed to genetic, lifestyle differences and environmental factors like nutrition, climate etc.[22].

The feet provide a firm base to support the vertical height of a person. This implies that increase in the height is associated with an increase in foot dimensions [23]. From this study both in males and females, foot breadth is the best parameter for estimation of stature. The relatively low estimate of standard error of mean for the foot breadth in males ( $\pm 0.068$ ) and for foot breadth in females ( $\pm 0.056$ ) ensures better accuracy in stature estimation.

The evidence of a positive linearity between the anthropometric parameters and estimation of stature helps in formulation of regression equations which can be successfully utilized for stature estimation in Indian population. In the present study, males showed higher mean values in all parameters studied when compared with mean values of female parameters.

Stature estimation studies by Kaur [30] and OP Jasuja [25] has reported significant higher mean values for males amongst Indians but both their study groups were from North India. Danborn B [27] also reported higher value as the study was conducted on Nigerians which belongs to different race groups. Fusion of epiphysis of bones occurs earlier in females

than in male leads to differences of mean in stature between males and females. Males have about two more years of bone growth than females [21].

This present study was done in medical students of all India region of age group 18-22 years and the mean of stature came as 171.11 cm in males and 157.57 cm in females.

**Table 7:** Stature

Sr. No.	Name of the author	Sex	Min. Stature	Max. Stature	Mean	± SD	± SE
1.	Thakur <sup>[24]</sup> (1975)	-	-	-	167.4	6.4	-
2.	Jasuja <sup>[25]</sup> (2004)	Male	166.2	185.6	175.2	5.24	0.957
		Female	152	167.9	159.7	5.17	0.945
3.	Patel <sup>[26]</sup> (2007)	Male	-	-	170.96	5.13	-
		Female	-	-	156.14	5.15	-
4.	Danborn B <sup>[27]</sup> (2008)	Male	-	-	173.73	7.13	-
		Female	-	-	160	6.22	-
5.	Ilayperuma <sup>[28]</sup> (2009)	Male	-	-	170.14	5.22	-
		Female	-	-	157.55	5.75	-
6.	Rahul <sup>[29]</sup> (2013)	Male	157	192	169.97	5.71	-
		Female	139	167	154.2	7.15	-
7.	Kaur et al <sup>[30]</sup> (2013)	Male	-	-	175.98	6.76	-
		Female	-	-	160.91	5.75	-
8.	Srivastava <sup>[31]</sup> (2014)	Male	-	-	170.9	-	0.371
		Female	-	-	156.21	-	0.49
9.	Present Study (2014)	Male	147	188	171.11	7.68	0.84
		Female	141	175	157.57	6.34	0.63

**Table 8:** Foot Length

Sr. No.	Authors	Measurement's	Sex	Side	Min	Max	Mean	± SD	± SE
1	Patel <sup>[26]</sup> (2007)	Foot Length	Male	-	-	-	24.4	0.99	-
			Female	-	-	-	22.3	1.12	-
2	Danborn B <sup>[27]</sup> (2008)	Foot Length	Male	Right	-	-	28.4	1.73	-
				Left	-	-	26.4	1.6	-
			Female	Right	-	-	24.5	9.08	-
				Left	-	-	24.7	1.1	-
3	Srivastava <sup>[31]</sup> (2014)	Foot Length	Male	-	-	-	25.1	-	0.12
			Female	-	-	-	22.7	-	0.1
4	Present Study (2014)	Foot Length	Male	Right	22.7	28.3	25.5	1.18	0.13
				Left	22.7	28.1	25.5	1.19	0.13
			Female	Right	20.2	29.5	23.3	1.43	0.13
				Left	20.1	29.4	23.3	1.36	0.48

**Table 9:**Foot Breadth

Sr. No.	Authors	Measure-Ments	Sex	Side	Min	Max	Mean	± SD	± SE
1	Danborn B <sup>[27]</sup> (2008)	Foot Breadth	Male	Right	-	-	9.02	0.72	-
				Left	-	-	9.09	0.94	-
			Female	Right	-	-	8.23	0.63	-
				Left	-	-	8.11	1	-
2	Arti <sup>[32]</sup> (2013)	Foot Breadth	Male	Right	8.7	11.6	10.48	0.51	-
				Left	8.7	11.7	10.55	0.52	-
			Female	Right	8.2	11.1	9.33	0.53	-
				Left	8.3	11.2	9.39	0.53	-
3	Srivastava <sup>[31]</sup> (2014)	Foot Breadth	Male	-	-	-	9.36	-	0.06
			Female	-	-	-	8.36	-	0.05
4	Present Study (2014)	Foot Breadth	Male	Right	8.3	11.24	9.62	0.64	0.07
				Left	8.37	10.95	9.6	0.61	0.067
			Female	Right	7.16	10.2	8.79	0.57	0.055
				Left	7.04	10	8.73	0.59	0.057

Mean foot lengths reported by Danbornob [27] in Nigerian population are on the higher side than the Indian counterparts. This is seen by the mean foot length values reported in the Gujarat medical students in India by Patel [26], in the Bundelkhand region in India by Srivastava [31] and in the present study. The sexual dimorphism is evident by female values being lower than the males in all of the above studies including the present one.

Arti [32] reported high values of mean foot breadth which she studied in medical students at Nagpur India. These values are higher than the mean values reported by Danbornob B [27] which was studied in the Nigerian students which is quite unusual. Whereas in study by Srivastava [31] in the

Bundelkhand region India and also in the present study the mean values are nearer to each other. It is also closer to the mean values reported by Danbornob [27] suggesting that there is less difference in foot breadths in spite of the difference in race.

Now comparing mean value of stature according to different equations derived from our formulae we get:

In our study these formulas do give a good predictive value as illustrated by the chart above with the regression formulas as below. But also, these give a lesser (r) value. The best formulae which also gives good r value that can be used are:

$$1. \text{ Height} = 83.690 + [2.684 * (\text{Right Foot breadth})] + [6.056 * (\text{Left Foot breadth})]. \text{ (Equ. Muti-2)}$$

Table 10:

Actual Height (Cms)	Equi (Uni-1)	Equi (Uni-2)	Equi(Multi-1)	Equi (Multi2)	Equi(Multi-3)
164.34	163.242 R =0.399	163.702 R=0.627	163.130 R=0.432	163.924 R = 0.645	176.795 R=0.658

Table 11: Comparisons of studies of Foot Length (FL)

Sr. No.	Author	Year	Population	Sex	Correlation Coefficient(r)	Regression Equation
1.	Giles E <sup>33</sup>	1991	US Army	Male	0.68	S=82.21+3.45(FL)
2.	Giles E <sup>33</sup>	1991	US Army	Female	0.69	S=75.07+3.61(FL)
3.	SanliS. G <sup>22</sup>	2005	Turks	Male	0.72	S=37.23+2.58(FL)
4.	SanliS. G <sup>22</sup>	2005	Turks	Female	0.69	S=74.31+1.73(FL)
5.	Kewal Krishan <sup>34</sup>	2007	Rajput	Male	0.73	S= 68.09+4.05(FL)
6.	Kewal Krishan <sup>34</sup>	2007	Rajput	Female	0.74	S= 71.94+3.70(FL)
7.	Ilayperuma I <sup>35</sup>	2008	Galle SriLanka	Male	0.73	S= 79.04+3.59(FL)
8.	Ilayperuma I <sup>35</sup>	2008	Galle SriLanka	Female	0.72	S= 65.54+3.94(FL)
9.	Present Study	2014	Medical Students	-----	0.39	S=129.51+1.383(FL)

Table 12: Comparisons of studies of Foot Breadth (FB)

Sr. No.	Author	Year	Population	Sex	Correlation Coefficient(r)	Regression Equation
1.	Kewal Krishan <sup>34</sup>	2007	Rajput	Male	6.19	S=135.24+3.47(FB)
2.	Kewal Krishan <sup>34</sup>	2007	Rajput	Female	4.17	S=135.41+2.37(FB)
3.	Present Study	2014	Medical Students	-----	0.627	S= 86.03+8.45(FB)

$$2. \text{ Height} = 86.036 + [8.453 * (\text{Right Foot breadth})]. \text{ (Equ. Uni-2).}$$

In the data, the mean value of stature is 164.34, if stature is calculated according to Univariate regression equation of:

1. Giles E [33] it is 166.3926,
2. Sanli S. G [22] it is 100.184
3. Kewal Krishan [34] it is 166.9131
4. Ilayperuma I [35] it is 166.6387

$$5. \text{ Present Study it is } 163.2562$$

This shows that in the present study foot length has more closeness to the actual values.

So, the univariate regression equation; Stature = 129.514 + [1.383 \* (Right foot length)], derived from this study has better predictive value in the estimation of stature than the others.

Actual mean stature from our data pool is 164.34Cms.

In the Present study the calculated stature from regression formula is 163.15 and that from Kewal Krishan [34 ] is 166.91.

This shows that the univariate regression equation, Height = 86.036 + [8.453 \* (Right Foot breadth)], derived from this study has better predictive value in the estimation of stature than the other studies above.

In case of multivariate regression equation, the present study has derived and analyzed it. No studies were found who have attempted to derive or analyze the multivariate equation.

### Conclusion

It is found that there exists a significant sexual dimorphism in male and female population. It is well predicted in foot dimensions. Males have higher values than the females in dimensions of foot.

The multivariate regression formulas used to calculate the stature from the foot dimensions in both sexes gives a better prediction of stature than the univariate type. Foot breadth is more positively related in lower limb than foot length.

Both univariate and multivariate regression formulae are equally sensitive for prediction of stature in case of lower limb. The multivariate formula (equi. multi. 2) with correlation coefficient (r) of 0.645: Height = 83.690 + [2.684 \* (Right Foot breadth)] + [6.056 \* (Left Foot breadth)] is more sensitive in prediction than the others. In case of univariate type, the following gives a good predictive value of stature than the others. (equi.uni. 2) with correlation coefficient (r) of 0.645: Height = 86.036 + [8.453 \* (Right Foot breadth)].

The regression equations derived from present study give a better predictive value than the formulas that have been derived by other authors as evident from the correlation coefficient. These formulas can be used effectively to estimate the stature of the individual in case mutilated bodies and also can be used effectively in ergonomics such as furniture designing, machine designing and sports as well as forensic cases.

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## Study of Branching Pattern of Pelvic Artery

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### Abstract

Vascular variations have always been a subject of controversy as well as curiosity, because of their clinical significance. Pelvic arteries are the arteries supplying the lesser pelvis i.e. walls of pelvis and pelvic organs. The major neurovascular structures of pelvis lie extraperitoneally against the posterolateral walls. The nerves lie most external or superficial (adjacent to the walls), with the vascular structures internal or deep (medial) to them. Generally, the veins are external (lateral) to the arteries. So study of pelvic artery i.e. internal iliac artery was done. Cadavers of both the sexes were dissected. Pelvic artery or internal iliac artery showed variable branching pattern like, obturator artery taking origin from posterior division of internal iliac artery or arising from external iliac artery, inferior vesical artery arising from obturator artery, middle rectal artery originating from other branches of internal iliac artery, common stem was found for internal pudendal and inferior gluteal arteries, even variable pattern of branches of posterior division of internal iliac artery were observed. All the variations were photographed, tabulated and discussed.

**Keywords:** Internal Iliac Artery; Branches of Anterior Division; Branches of Posterior Division; Variations.

### Introduction

The pelvic walls and viscera are supplied by branches of the internal iliac artery. The major neurovascular structures of pelvis lie extraperitoneally against the posterolateral walls. The nerves lie most external or superficial (adjacent to the walls), with the vascular structures internal or deep (medial) to them. Generally, the veins are external (lateral) to the arteries [1].

The abdominal aorta bifurcates into the right and left common iliac arteries to the left side of the fourth lumbar vertebral body. These arteries diverge as they descend to divide at the level of the sacroiliac joint into external and internal iliac arteries. The external iliac artery is the principal artery of the lower limb and the internal iliac artery provides

the principal supply to the pelvic viscera and walls, the peritoneum and the gluteal region.

Each internal iliac artery, approximately 4 cm long, begins at the common iliac bifurcation. It descends posteriorly to the superior margin of greater sciatic foramen, where it divides into an anterior trunk, which continues in the same line towards the ischial spine, and a posterior trunk, which passes back to the greater sciatic foramen.

In the adult it is the smaller of the two branches of the common iliac artery, though it is larger in the foetus when it transmits blood to the placenta through the umbilical artery. At birth the umbilical arteries are tied, and rapidly degenerate into fibrous cords to the level of the last persistent branch, the superior vesical artery. The internal iliac artery, formerly known as hypo gastric artery is the main artery of the walls and contents of the pelvis. The arrangement of its visceral branches is very variable [2]

### *Branches of the Anterior Division of Internal Iliac Artery*

1. *Superior Vesical Artery:* it is the first large branch of anterior trunk. It lies just below the pelvic brim and supplies the distal end of ureter, the bladder, the proximal end of vas deference and the seminal

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vesicles. From the proximal patent part of the umbilical artery arises the superior vesical artery, which supplies the upper portion of the bladder.

2. *Inferior vesical artery*: It supplies the bladder, the prostate, the seminal vesicles and the vas deference. In females it is often replaced by vaginal artery.
3. *Obturator artery*: It runs anteroinferiorly from the anterior trunk along the lateral wall of pelvis, leave the pelvis via obturator canal and divides into anterior and posterior branches.
4. *Middle rectal artery*: the middle rectal artery is often multiple and may be small. It runs into the lateral fascial coverings of mesorectum. It occasionally arises as a common stem with inferior vesical artery.
5. *Internal pudendal artery*: It arises just below the obturator artery, descends laterally to the inferior rim of greater sciatic foramen, where it leaves the pelvis between the piriformis and ischiococcygeus to enter the gluteal region. It gives off several muscular branches in the pelvis and gluteal region which supplies adjacent muscles and nerves.
6. *Inferior gluteal artery*: It is the greater terminal branch of anterior division of internal iliac trunk and principally supplies the buttock and thigh.
7. *Uterine artery*: It is the additional branch in females. It is a large artery which arises below obturator artery on the lateral wall of the pelvis and runs inferomedially into the broad ligament of uterus.
8. *Vaginal artery*: In females vaginal artery may replace the inferior vesical artery. It may arise from the uterine artery close to its origin.

#### *Branches of the Posterior Division of the Internal Iliac Artery*

1. *Iliolumbar artery*: It is the first branch of the posterior trunk and ascends laterally to the sacroiliac joints. It divides into iliac and lumbar branches. The lumbar branch supplies the psoas major and quadratus lumborum. The iliac branch supplies the iliocostalis muscle and gives nutrient artery to the ilium.
2. *Lateral sacral arteries*: It is usually double, the large superior branch passes into first and second anterior sacral foramina, supplies the sacral vertebra and contents of sacral canal and comes out through dorsal sacral foramina. Inferior artery passes anterior to piriformis and form anastomosis with its fellow and median sacral artery.
3. *Superior gluteal artery*: It is the largest branch of internal iliac artery and forms continuation of its posterior division. It runs posteriorly between the lumbosacral trunk and the first sacral ramus, leaves the pelvis through greater sciatic foramen

above piriformis, dividing into superficial and deep branches [3].

Pelvic vessels play an important role in pelvic support. There is significant anatomic variation between individuals in branching pattern of Internal iliac vessels [4].

Nine major types of branching and 49 subtypes have been described. The structure and regions supplied by the branches of the artery, however, are quite constant [5].

### **Materials and Methods**

Thirty five pelvises (70 arteries) from 35 cadavers were procured from the department of Anatomy of Dr. D. Y. Patil Medical College, Pimpri, Pune, which comprised the material for the present study. These cadavers were embalmed with 10 per cent formalin and fixed.

They were labelled from 1-35, left and right side. After separating the pelvis from the cadaver, sagittal section of the pelvis was taken, by cutting the sacrum in the midline. Branches of internal iliac artery were dissected following dissection procedure as per Cunningham's manual [6].

The Steps of Dissection were as Follows:

- Dissected cadavers were cut at the level of twelfth thoracic vertebra.
- Sagittal section of this cut pelvis was taken in the midline.
- The specimen was labelled with number & side.
- External & internal iliac arteries were exposed by removing the fascia over it.
- Branches of internal iliac artery supplying the pelvic organs like urinary bladder, uterus, rectum, were traced and identified with all these organs in situ.
- Thus superior vesical artery, inferior vesical artery, middle rectal artery, uterine and vaginal arteries in females, was identified.
- The origin of all the branches was noted.
- The pelvic organs were removed and internal pudendal artery, inferior gluteal artery, and branches of posterior division were identified.
- Variations in origin of all the branches of internal iliac artery were noted according to the side of the specimen and the sex.
- Photographs of the variations were taken.

## Results

Different types of variations were observed in the branching pattern of internal iliac artery. They were as follows-

A-Variations in the branches of anterior division of internal iliac artery:

1. *Superior Vesical Artery*: No variation was found in the origin of superior vesical artery.
  2. *Inferior Vesical Artery*: right sided inferior vesical artery showed variant origin from obturator artery in one case (Figure 1).
  3. *Obturator Artery*-
    - Arising from the posterior division of internal iliac artery in 6 cases. One bilateral and five unilateral (Figure 2).
    - Was seen arising from the external iliac in 3 cases. Two bilateral and one unilateral (Figure 3).
    - From internal pudendal artery in 3 cases. One bilateral and two unilateral.
    - From inferior gluteal artery in 2 cases. Both unilateral.
  4. *Middle Rectal Artery*-
    - It was arising from the internal pudendal artery in 9 cases. Four bilateral and five unilateral.
    - Two cases unilaterally showed common stem for middle rectal, internal pudendal and inferior gluteal artery. Both unilateral.
    - Was arising from the inferior vesical artery in 1 case on the right side (Figure 4).
    - As a branch of obturator artery in 2 cases. Both on the left side.
  5. *Internal Pudendal Artery* showed only variation that it arose as a common stem with inferior gluteal artery in 12 cases. Four cases showed bilateral variation while eight were unilateral (Figure 5).
  6. *Inferior Gluteal Artery* Arose from the posterior division in 3 cases and from inferior gluteal artery in 3 cases. In all cases finding was unilateral.
- Absent inferior gluteal artery was found in one case (Figure 6).
7. *Uterine Artery*- common stem for uterine artery and internal pudendal artery was seen on left side in one case out of five (Figure 7).

B- Variations in the Branches of Posterior Division of Internal Iliac Artery :

1. *Iliolumbar Artery*-

- Was arising from the main trunk of internal iliac artery in 9 cases. All were unilateral.
  - Common iliac artery gave origin to iliolumbar artery in 1 case on left side (Figure 8).
  - Iliac branch from the posterior division and lumbar from the internal iliac was seen in 4 cases. All unilateral.
  - Iliac branch from the obturator artery and lumbar from the posterior division in 3 cases. All unilateral.
2. *Lateral Sacral Artery* -
    - One from the posterior division other from the inferior gluteal artery in 2 cases. Both unilateral.
    - One from the posterior division other from the internal iliac in 5 cases. All unilateral.
    - One from the anterior division other from posterior division in 2 cases. Both unilateral (Figure 8).
    - From the common iliac in 1 case. It was found on left side.

*Superior Gluteal Artery* didn't show any variations in its origin, it was always the continuation of posterior division.

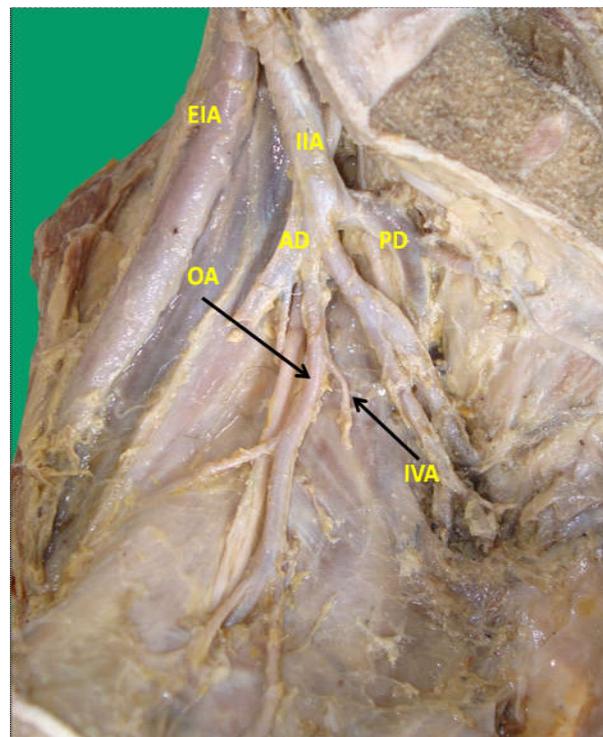
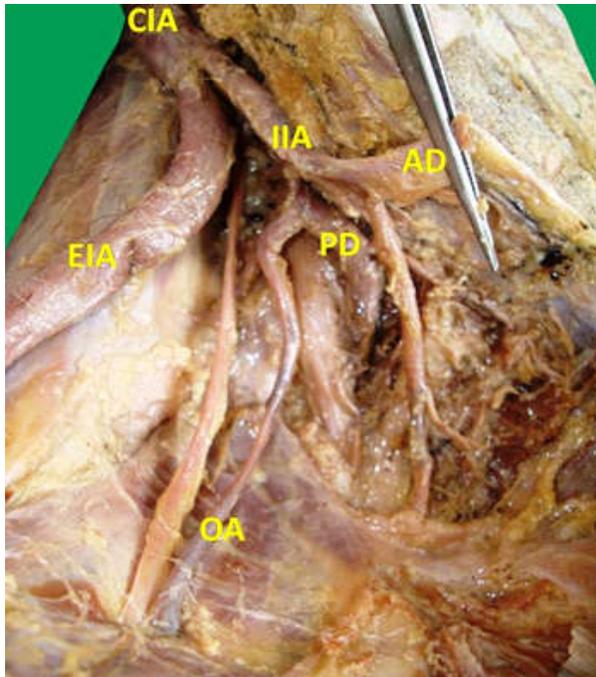
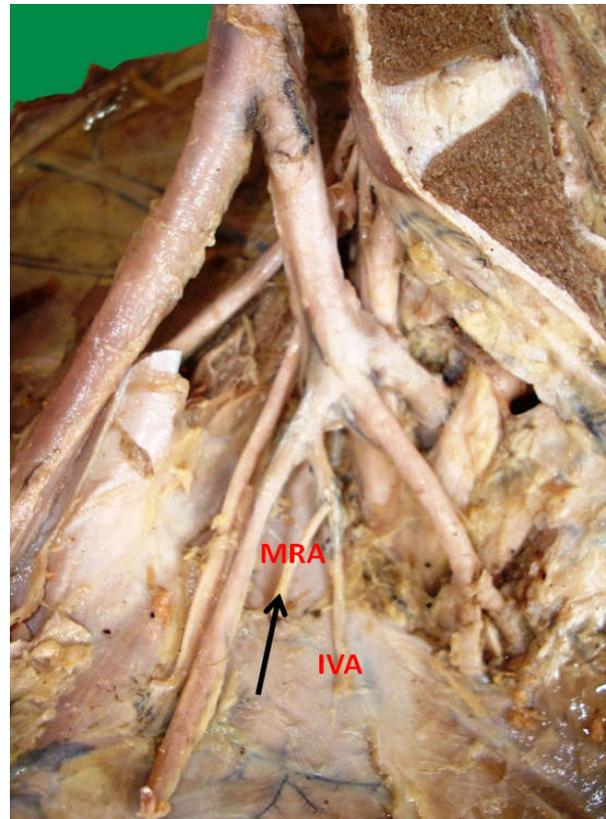


Fig. 1: *Inferior vesical artery* from obturator artery

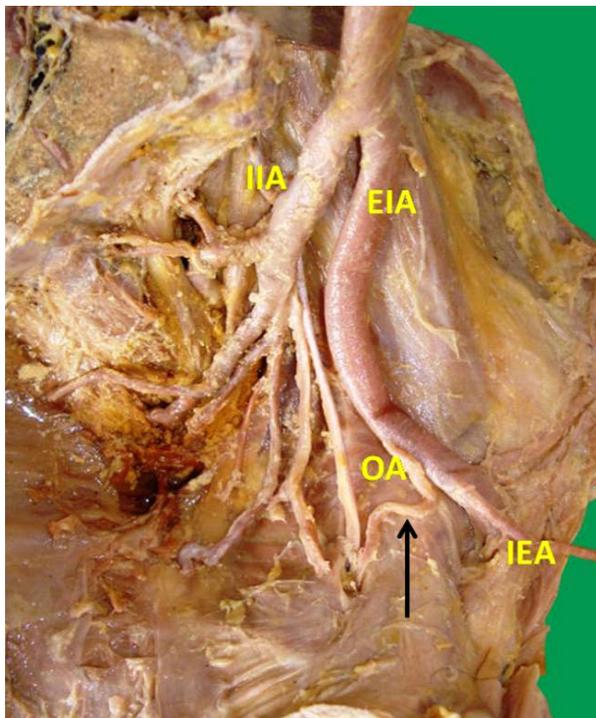
IIA- Internal Iliac artery  
 EIA- External Iliac artery  
 OA- Obturator artery  
 AD- Anterior division  
 PD- Posterior division.  
 IVA - Inferior vesical artery



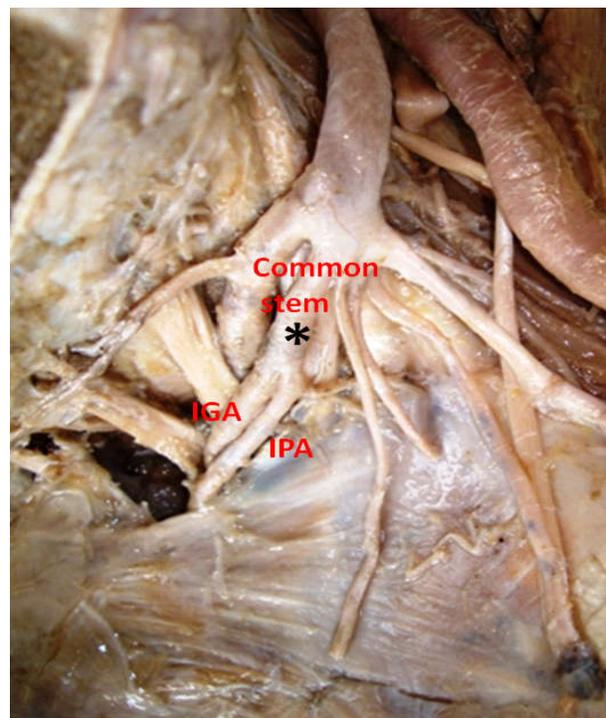
**Fig. 2:** Obturator artery arising from the posterior division of internal iliac artery  
 CIA- Common Iliac artery  
 IIA- Internal Iliac artery  
 EIA- External Iliac artery  
 OA- Obturator artery  
 AD- Anterior division  
 PD- Posterior division.



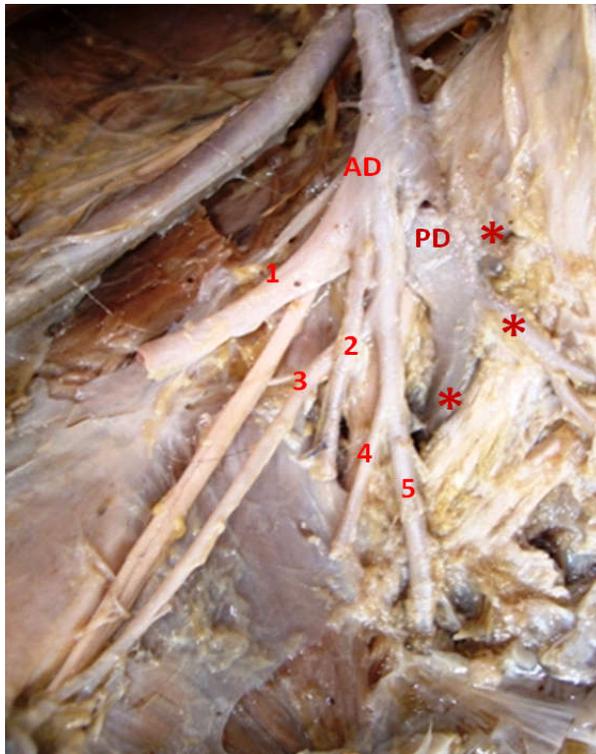
**Fig. 4:** Middle Rectal artery from the inferior vesical artery  
 MRA-middle rectal artery  
 IVA-inferior vesical artery



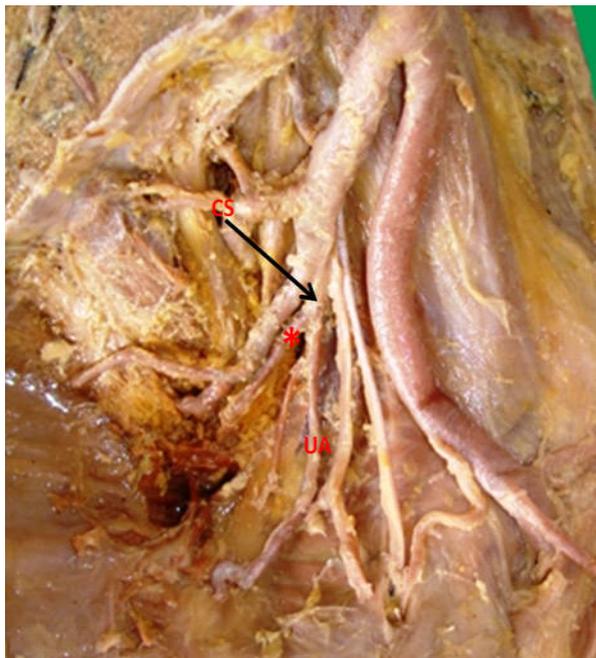
**Fig. 3:** Obturator artery arising from external iliac artery  
 IIA- Internal Iliac artery,  
 EIA- External Iliac artery  
 OA- Obturator artery,  
 IEA- Inferior Epigastric artery



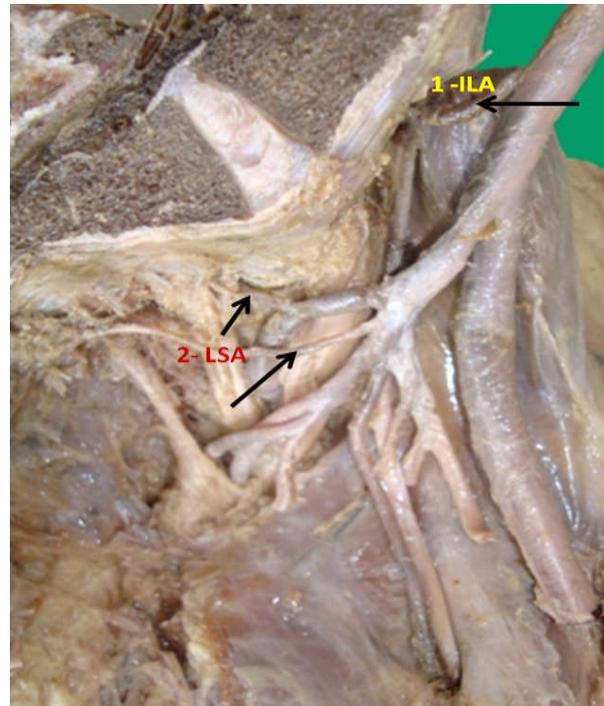
**Fig. 5:** Internal Pudendal artery had common stem with Inferior gluteal artery.  
 IGA- Inferior gluteal artery  
 IPA-Internal pudendal artery



**Fig. 6:** Absent Inferior Gluteal artery.  
AD-anterior division  
1- superior vesical artery  
2- inferior vesical artery  
3- obturator artery  
4- middle rectal artery  
5- internal pudendal artery  
PD-posterior division



**Fig. 7:** Uterine artery has common stem with Internal Pudendal artery  
UA-uterine artery  
\*- internal pudendal artery



**Fig. 8:** Iliolumbar artery from Common iliac artery and Lateral sacral artery from anterior division of internal iliac artery.  
ILA-Iliolumbar artery  
LSA -Lateral sacral artery

## Discussion

Thirty five pelvises (70 internal iliac arteries) were dissected for the study of branches of internal iliac artery. All the branches of the anterior and posterior divisions of internal iliac artery were studied. Pelvic arteries showed numerous variations in their origin.

The inferior vesicle artery arose in common with the middle rectal artery in 3% cases this finding correlates with the finding of Ronald Bergman [7].

Sometimes the inferior vesicle artery arise in common with superior vesicle artery which correlates with study of Parsons and Keith [8]. Benjamin Lipschutz [9] found the origin of Inferior vesicle artery from the vaginal artery in 2.5% of cases, and from the internal pudendal artery in 2% of cases,

In the present study obturator artery was arising from the posterior division of internal iliac artery in 10% of cases, this finding was correlating with the finding of Pushpa M.S. [10].

Levi [11] reported two roots for the obturator artery, one from the anterior division and the other from the posterior division.

Mangala M. Pai. Observed the origin of Obturator artery from the external iliac artery. Sometimes it was

arising separately from the external iliac and sometimes as a common stem with the inferior epigastric artery.

Anomalous origin of obturator artery from the posterior division may be beneficial to vascular surgeons ligating the internal iliac artery. The obturator artery is known to supply the head of the femur and in the event of the obturator artery arising from the posterior division of the internal iliac artery; it may be spared during any injury to the anterior division.

Obturator artery arising from the external iliac artery is called as aberrant obturator artery. General surgeons dealing with laparoscopic herniorrhaphy should be aware of the aberrant obturator artery that crosses the superior pubic ramus and is susceptible to injuries during surgery. It may cause serious complications during femoral ring procedures or laparoscopic interventions. It may compress the external iliac vein and can result in venous stagnation in the lower limb. Besides, it may be an additional source of bleeding in cases of hemorrhage secondary to pelvic fracture. The "corona mortis" is an anatomical variant, an anastomosis between the obturator and the external iliac or inferior epigastric arteries, located on superior pubic ramus. It is significant because hemorrhage may occur if the corona mortis is accidentally cut and achievement of subsequent hemostasis is difficult. Orthopedic surgeons planning an anterior approach to the acetabulum, such as the ilioinguinal or the intrapelvic approach, must be cautious when dissecting near the superior pubic ramus [12].

Jastschinski found the origin of middle rectal artery from the internal pudendal in 40% cases, from the inferior gluteal in 26.7% and from the internal iliac in 16.8% cases. It can also occur as a common stem with the inferior gluteal, the uterine or from the posterior division [13]. In the present study middle rectal artery was arising from the common stem for internal pudendal and inferior gluteal in two cases. It was arising from the inferior gluteal in 2.1% of cases and from the obturator in 4.8% of cases. Middle rectal artery was arising as a the common stem with internal pudendal which was similar with the finding of Ronald A. Bergman [7]. It was also arising in common with inferior vesical in 4.3% of cases.

In the present study there was a common stem for the internal pudendal, inferior gluteal and obturator arteries which was similar to the finding of Benjamin Lipschutz [9]. Internal pudendal was arising in common with inferior gluteal which was similar with finding of Ronald A. Bergman [7]. Such type of variation of internal pudendal artery leads to erectile dysfunction.

Benjamin Lipschutz found the origin of the inferior gluteal in common with the superior gluteal in 24 % cases. Inferior gluteal can arise from the internal iliac, it can be the continuation of the lateral sacral or it can be doubled [9]. In the present study a rare variation of absence of inferior gluteal artery was found which was similar to that of Sreenivasulu Reddy [14]. Inferior gluteal artery was absent in 7.5% of cases and superior gluteal artery was supplying its region. In such cases if the superior gluteal artery is compressed, the blood supply to the gluteus maximus muscle will be diminished since the inferior gluteal artery is absent.

Also present study showed inferior gluteal as a separate branch of the anterior division which was similar to the finding of Cruveilhier and Sappey [15].

Inferior gluteal was from the posterior division of the internal iliac artery which was similar to finding of Ronald A. Bergman [7]. Inferior gluteal was arising in common with internal pudendal which was coinciding with finding of Benjamin Lipschutz [9].

M. Bajka [16] reported that the uterine artery was a branch of the inferior gluteal artery. It was also found to arise as a common stem with inferior vesicle in 16.9% cases and there was a common stem for the uterine and middle rectal arteries in 1% cases.

In the present study uterine artery arose as a common stem with internal pudendal artery which was similar with finding of Ronald A. Bergman [7].

Pelage reported 1, 3 or 4 stems to the uterine artery. Variations of the uterine artery should be known to gynecologists dealing with different surgical procedures. Bleeding from a uterine or cervical perforation during instrumentation of the uterus in the area of the uterine artery and vein can lead to severe blood loss. Direct rupture of an arterial branch can manifest as rapid catastrophic bleeding during the trauma or operation, necessitating immediate embolization.

Uterine curettage or surgical trauma can cause uterine vascular abnormalities, including pseudo aneurysms, acquired arteriovenous malformations, arteriovenous fistulas, and rupture of vessels. Recognition of these abnormalities as the cause of hemorrhage is important [17].

Study of Ronald A. Bergman Iliolumbar artery showed the origin of superior gluteal artery in 3.8% cases and branch of anterior division in 3% cases. Also it was reported that one stem of iliolumbar was arising from lateral sacral and other from the posterior division and one stem from posterior division and other from the inferior gluteal [7]. Parsons and Keith reported it as the as a branch of middle rectal artery [8].

In the present study origin of Iliolumbar from the Common Iliac artery was seen in 7% cases and also from the internal iliac which was coinciding with the finding of Rusu Mc et al [18]. Iliolumbar artery arising from the Internal Iliac artery was also seen which was similar to that of Ronald A. Bergman [7]. In some cases it was showing one twig from posterior division and the other from the Internal Iliac artery. Common stem for the iliolumbar and obturator artery was reported which was coinciding with that of Parsons and Keith [8]. A common trunk for two lateral sacral arteries was seen in 51% cases and presence of three lateral sacral arteries [9]. Also only one lateral sacral artery was reported in 1% cases [7].

The present study showed one lateral sacral artery arising from the anterior division and other from the posterior division in 1.6% cases. In 1.7% cases it was arising from the Common Iliac. The lateral sacral artery arising as a single branch from the superior gluteal artery and the other from the inferior gluteal which was similar to the finding of Parsons and Keith [8]. Lateral sacral from the internal iliac was reported in 8.8% of cases. The present study also showed double origin from the posterior division in 40% cases.

Cruveilhier and Theile found the superior gluteal artery arising as a common trunk with inferior gluteal in 24% and sometimes obturator is the branch of superior gluteal. In the present study it was the continuation of the posterior division in all the cases.

Regarding branching pattern of Internal Iliac artery the present study shows origin of inferior vesicle in common with middle rectal in 4.3%. Surgeons operating the rectum in rectal carcinoma must know this variation to avoid damage to the middle rectal artery.

In 2.5% of cases inferior vesicle artery was arising from the obturator artery. During ligation of the branches of internal artery this variation is important.

In the present study superior gluteal artery was the continuation of the posterior division in all the cases. No variation in its origin was found.

The ramification of superficial branch of superior gluteal artery is used to construct skin flaps hence construction of any graft or flap requires very accurate knowledge about the vascular supply.

Accidental haemorrhage is common during erroneous interpretation of anomalous blood vessels. Alarming, haemorrhage has been considered the leading cause of obstetrical mortality in all the developing countries of the world. Thus, a thorough knowledge of the normal and the abnormal anatomy of the branches of the internal iliac artery is essential for obstetric surgeons.

### ***Developmental Aspect of Branches of Internal Iliac Arteries***

*Superior Gluteal Artery:* The umbilical arteries initially paired ventral branches of the dorsal aorta, course to the placenta in close association with the allantois. During the fourth week, each artery acquires a secondary connection with the dorsal branch of the aorta, the common iliac artery, and loses its earliest origin. After birth the proximal portions of the umbilical arteries persist as the internal iliac and superior vesical arteries, and the distal parts are obliterated to form the medial umbilical ligaments.

*Inferior Gluteal Artery:* The axial artery (sciatic artery) is the major arterial supply to the lower limb bud at an early embryological stage. It primarily originates from the dorsal root of the umbilical artery. In the adult, remnants of the sciatic artery persist as the proximal portion of the inferior gluteal artery, the popliteal and fibular arteries.

*Obturator Artery:* Embryologically, Obturator artery has been reported to arise late in the development. abnormal regression of primitive vascular channels and abnormal selection of vascular channels leads into numerous variations in the final arterial pattern [19].

### **Conclusion**

After studying the branching pattern of internal iliac artery it was observed that there are numerous variations in the branching pattern of internal iliac artery, mainly branches of anterior as well as posterior division showed different types of variations in their origin. All these variations are important for orthopaedic surgeons during repair of pelvic fractures, gynaecologists during hysterectomy and general surgeons during repair of femoral hernia.

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## Study of Sexual Dimorphism in Sacrum Based On Corporobasal Index and Alar Index

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### Abstract

Skeleton is an excellent material in living and non-living population for forensic investigation. Sacrum is an ideal bone for determination of sex because it not only reflects general difference between two sexes but shows special adaptation in females for child bearing. It is believed that reliability in identifying female bone is more using alar index and transverse diameter of S1. In our study 100 sacra of both sexes were compared for of Body of First Sacral Vertebra (S1), alar index and corporobasal index. The results show Index of Body of First Sacral Vertebra (S1) in male is 62.53 and in females it is 54.74 Corporobasal Index in male is 57.89 and in females it is 52.80. One way ANOVA shows 0.001 significance suggesting statistically highly significant difference in male and female for both Corporobasal index and Index of Body of First Sacral Vertebra (S1). Alar Index in male is 66.68 and in females it is 71.21. One way ANOVA shows f value as 2.715 which is non-significant. The results show that Index of Body of First Sacral Vertebra (S1) and Corporobasal Index are more reliable parameters than Alar index for determination of sex of Sacrum.

**Keywords:** Sacrum; Sexual Dimorphism; Parameters; Index of Body of First Sacral Vertebra (S1); Corporobasal Index.

### Introduction

The sacrum is a large, triangular bone of pelvis. It is present on the postero-superior wall of the pelvic cavity, wedged between the two innominate bones. It is formed by fusion of five vertebrae [1]. Sexual dimorphic characters can be studied both morphologically and metrically in the determination of personal individuality from adult human skeletal remains.

Determination of sex is an integral first step in the development of the biological profile in human osteology. Sex determination is necessary to estimate age, ancestry and stature. The developmental age changes are different in male and female bones

including sacrum [2]. The pelvic girdle is the most accurate area to determine sex and methods using the pelvic girdle tend to make successful predictions in 90 to 95 percent of individuals [3].

The sacrum has always attracted the attention of medicolegal experts for establishing the sex due to its contribution to the pelvic girdle and associated sex differences, which are augmented due to reproductive functions, mainly influenced by sex hormones [4]. Accurate estimation of sex from an unidentified human skeleton can be difficult when incomplete remains are encountered. This research provides a novel technique for determining sex from the human sacrum using a discriminate function analysis of geometric morphometric data.

### Material and Method

The present study was carried out at Department of Anatomy, Government medical college Aurangabad and MGM medical College, Aurangabad. Approval was obtained from Institutional Ethical committee.

Written permission was taken for collection of 100 sacra of both the sexes from HOD Department of Anatomy, Govt. Medical College and MGM medical

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College, Aurangabad. Non ossified and fragmented sacra were excluded from the study.

The sliding Vernier caliper with scale graduated from 0 to 150 mm of Mitutoyo absolute digimatic company, made in Japan was used to measure minimum Sacral width, maximum Sacral width, transverse diameter of body of S1. Length of alae of sacrum was measured by standard metallic scale.

1. *Maximum sacral width*: The straight distance between two points at the lateral most part of alae of sacrum.
2. *Minimum sacral width*: Minimum transverse distance measured midpoint of fourth and fifth sacral vertebra, near the apex.  
Width of sacrum was calculated by taking average of maximal and minimal sacral width.
3. Transverse diameter of the body of the first sacral vertebra was measured by taking one point on each side of the lateral most point on the superior surface of the body of first sacral vertebra.
4. Antero-posterior diameter of body of the first sacral vertebra: It is the maximum possible diameter of body of first sacral vertebra taking one point on the antero-superior border and other on the postero-superior border and was measured by Vernier caliper.
5. Length of alae It was measured on both sides by taking one point on lateral most point of superior surface of body of first sacral vertebra and another point on lateral most point of ala. The mean length of two sides is taken as length of ala of that vertebra.

6. *Indexing*: The Index of body of 1st Sacral vertebra, Alar index and Corporo-basal index were calculated by formulas [3] given below-

1. Index of body of 1st Sacral vertebra =

$$\frac{\text{AP Diameter of body of S1} \times 100}{\text{Transverse dia. of body of S1}}$$

2. Corpora-basal index =

$$= \frac{\text{Transverse diameter} \times 100}{\text{Width of Sacrum}}$$

3. Alar index =

$$\frac{\text{Length of ala} \times 100}{\text{Transverse diameter of body of S1}}$$

The parameters and indices were analysed statistically by using SPSS 19 software and compared for multivariate analysis.

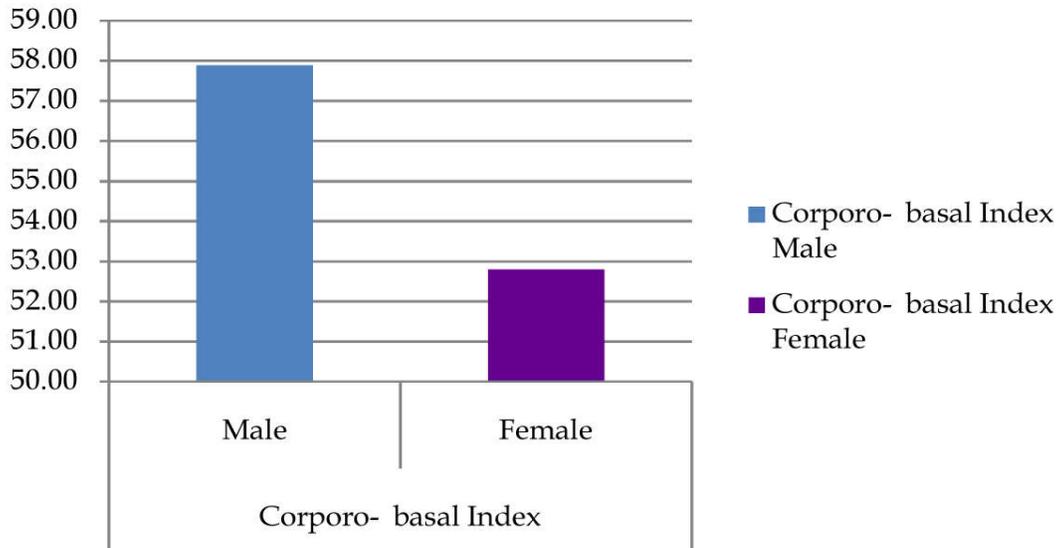
## Result

The mean, standard deviation and test of significance were calculated from the data by using SPSS version 19 for the identification of sex using the parameters mentioned above.

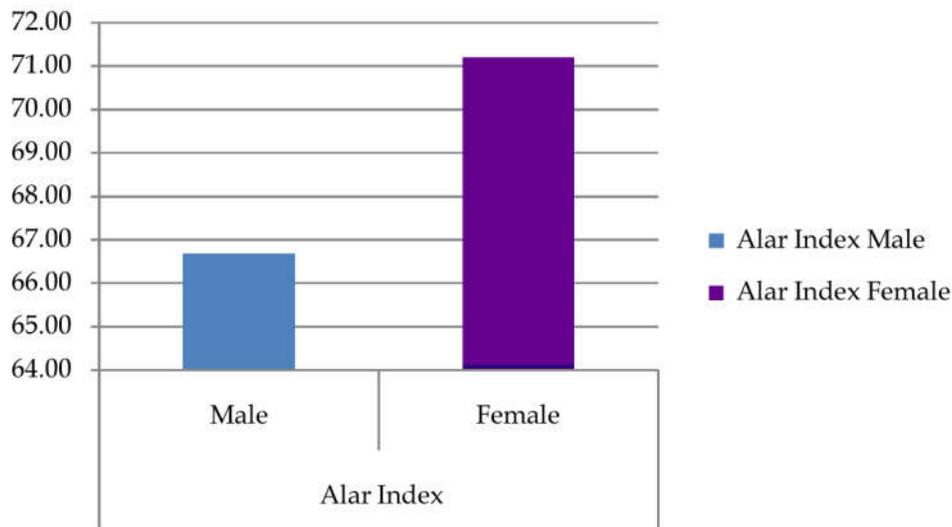
It is observed that mean of sacral maximum width in male is 106.46 and in females it is 98.00 this shows that sacral max width is more in males as compared to female. Sacral minimum width in male is 61.49 and in females it is 57.94 this shows that sacral minimum width is more in males as compared to female though not significant statistically.

Parameter	Sex	Mean ± SD	ANOVA(f)	p value
Sacral Maximum width (mm)	Male	106.46 ± 6.08	22.918	0.000***
	Female	98.00 ± 10.72		
Sacral minimum width (mm)	Male	61.49 ± 8.49	3.446	0.66 (NS)
	Female	57.94 ± 9.98		
Transverse Diameter of Body of First Sacral Vertebra (mm)	Male	48.57 ± 5.61	29.362	0.000***
	Female	41.20 ± 7.53		
Antero-Posterior Diameter of Body of First Sacral Vertebra (S1) (mm)	Male	30.13 ± 3.27	49.824	0.000***
	Female	22.69 ± 7.07		
Length of alae (mm)	Male	32.09 ± 5.01	4.782	0.0035***
	Female	28.9 ± 8.09		
Index of Body of First Sacral Vertebra (S1) (mm)	Male	62.53 ± 10.40	11.776	0.001***
	Female	54.74 ± 14.32		
Corporo-basal Index (mm)	Male	57.89 ± 5.90	15.079	0.000***
	Female	52.80 ± 7.10		
Alar Index (mm)	Male	66.68 ± 10.84	2.715	0.103 (NS)
	Female	71.21 ± 21.20		

\*\*\* - statistically highly significant  
NS- not significant



Graph 1: Corporo- basal Index



Graph 2: Alar Index

It is observed that mean of Transverse Diameter of Body of First Sacral Vertebra in male is 48.57 and in females it is 41.20 this shows that Transverse Diameter of Body of First Sacral Vertebra is significantly more in males as compared to female.

It is observed that mean Antero-Posterior Diameter of Body of First Sacral Vertebra (S1) in male is 30.13 and in females it is 22.69 the difference being statistically significant .

The mean of Length of alae in male is 32.09 and in females it is 28.90. Length of alae shows more significant difference in males as compared to female.

## Discussion

The determination of sex is considered as one of the important steps in the identification of disintegrated remains. It becomes more challenging job for anatomist, when only a single bone like sacrum from entire skeleton is available for giving his opinion. In present study most of the parameters show significant sexual dimorphism.

Index of body of 1<sup>st</sup> sacral vertebra is significantly higher in males as compared to females in our study. When compared with other studies mean Index of body of first sacral vertebra in male is higher than the

studies by S.S. Dapate [5], Kothapalli et. al [6]. and Mazumdar et. al [7], and it is lower than study done by Shailja Math [8]. The result in present study was almost equal with studies by Rajuet. al. and with Bagde. Mean Index of body of first sacral vertebra in female was found to be lower than the studies by Raju et. al. [9], Bagde, S.S [10] Dapate [5], Shailja Math [8], kothapalli [6] and Mazumdar et. al. [7].

In present study mean Corpora-basal index was found to be significantly higher in male as compared to female sacra. Similar results were found in studies done by in Mishra et. al [11], Kanika et. al. [12], Mazumdar et. al. [7], Kothapalli [6] and Shreekrishna HK [13].

Alar index do not show significant variation in male and female sacra in our study. It was the only index which was more in female as compared to male sacra. Study by Kothapalli [6] show results comparable with our study. Study by Mishra et. al. [11] show significant variation in Alar index between male and female sacra.

Sacral parameters like Index of body of first sacral vertebra and Corporo-basal Index in our study are more significant parameters than alar index for sexual dimorphism in sacra.

### Conclusion

The present study has very significant role to determine appropriate indices of sexual dimorphism for sacral bone. The study concludes that no single index can identify sex of sacrum accurately so we suggest use of multiple indices for sex determination of sacral bone over any single index.

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## A study of Comparison of Quadriceps Angle (Q-angle) in Indian and East African Adults

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### Abstract

Q-angle is indicator of force produced by quadriceps and is a clinical tool to measure the knee function and alignment. It is well established that normal reference value of Q-angle varies in different racial groups like Caucasians, Americans, Asians and Africans owing to different anatomical and biomechanical features of knee joint complex. However, there is dearth of literature comparing values of Q-angle between Indian and East African population. *Objective:* (1) establish a baseline reference value of Q-angle among asymptomatic adults belonging to eastern Africa; and (2) To compare these values with their Indian counterparts. *Materials and Methods:* The study was done in Anatomy department on 100 students of Sharda University, Greater Noida. Bilateral Q-angle was measured with subjects standing in an erect, weight-bearing position. The subjects were divided into two groups (n=50 each group) Group-I (Indian) and Group-II (East African). Group-II subjects belonged to Kenya (n=23) and Tanzania (n=27). Bilateral asymmetry and gender variation was determined using appropriate statistical method. *Result and Conclusion:* In Group-I and in Group-II, the mean Q-angles values of 100 limbs were  $13.78^{\circ} \pm 2.41$  and  $17.06^{\circ} \pm 3.73$  the values were significantly higher in latter group ( $p < 0.001$ ). Both the groups showed significant bilateral asymmetry ( $p < 0.05$ ) and gender variation with Q-angle values being greater for women than in men ( $p < 0.001$ ).

**Keywords:** Q-Angle; Bilateral Symmetry; Patellofemoral Alignment.

### Introduction

Anatomical variability has been noted among various racial groups, particularly the African and Caucasians who have shown distinctive differences in their skull and pelvic anatomy.

A Caucasoid cranium is longer in height with round saggital contour and they have narrow nose while Negroid cranium has lower height with flat saggital contour and a broad nose [1].

White American women have a wide transverse diameter of pelvic inlet as well as of outlet, and thin pelvic diaphragm musculature as compared to Afro-American women [2,3].

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Earlier studies have also documented difference in values of Q-angle in the above mentioned races [4-7]. Q-angle is a useful parameter to evaluate effect of the quadriceps mechanism on the patellofemoral joint and also gives information concerning the alignment of the lower limb [8-11]. It is formed by the crossing of two imaginary lines, the first line extends from the anterior superior iliac spine (ASIS) to the centre of the patella (CP) and the second line is drawn from the tibial tuberosity (TT) to the CP. The American Orthopaedic Association considers the Q-angle value of  $10^{\circ}$  to be normal and  $15-20^{\circ}$  to be abnormal [13] but, in one of the study values between  $8-10^{\circ}$  for men and up to  $15^{\circ}$  for women were considered normal and values higher than these indicated patellofemoral joint pathology [14]. The inability to reach a definitive value for the Q-angle can be ascribed to methodological differences in measurement and bilateral symmetry or asymmetry. The angle is clinically relevant because of the pull it exerts on the patella. Higher Q-angle value increases the lateral pull of the quadriceps muscle on the patella, hence makes the individual prone to its recurrent lateral subluxation or chondromalacia patellae [4]. A lot of studies have been carried out to establish different values for Q-angles in men and women among the

Caucasians, Americans, and Africans, however there is dearth of literature comparing values between Indian and East African population. Hence this study was undertaken to (1) establish a baseline reference value of Q-angle among asymptomatic adults belonging to eastern Africa; and (2) To compare these values with their Indian counterparts.

## Materials and Methods

To carry out this study, we selected 100 subjects using convenience sampling method from various schools of Sharda University. The subjects were asymptomatic adults (students) of age group 18-25yrs, with the mean age of the subjects was 19 years. They had no history of lower limb, spinal or neurological injury and any appreciable leg length discrepancy. The subjects were divided into two groups (n=50 each group) Group-I (Indian) and Group-II (East African). Group-II subjects belonged to Kenya (n=23) and Tanzania (n=27). All subjects were informed about the purpose of the study and signed consent was obtained. Ethical clearance for the study was obtained from the Institutional Ethical Review committee. We recorded the age and gender of each subject and gave instructions regarding positioning for measurement.

Q-angle was measured bilaterally in each subject in standing position the feet are placed together touching medially (with feet parallel), on the floor. ASIS, The centre point of the patella (CP) and tibial tubercle was palpated and then marked with a water soluble marker. The pivot of the Universal goniometer was placed on the midpoint of patella and a string was stretched between the ASIS and midpoint of patella to ensure accurate alignment of stationary arm of goniometer. The movable arm was aligned along

the line joining the tibial tubercle to midpoint of patella. The angle thus formed between the two arms of goniometer was measured and recorded as Q-angle.

## Statistical Analysis

The mean and standard deviation were determined for age, and Q-angle in the two groups. Gender difference in above mentioned parameters and also bilateral differences in Q-angle were tabulated. The independent t-test was used to compare the Q-angle values in the male and female groups. The paired t-test was used to test for bilateral asymmetry.

All statistical analysis was performed using SPSS version 21.0 for windows.

## Results

In Group- I and in Group- II, the mean Q-angles values of 100 limbs were  $13.78^{\circ} \pm 2.41$  and  $17.06^{\circ} \pm 3.73$ . East African subjects had significantly higher value ( $p < 0.0001$ ) than the Indian subjects the descriptive analysis of Q-angle for Group-I and Group-II subjects are shown in Table 1 and Table 2.

The study established that in both the groups Q-angle values for males was between  $10^{\circ}$ - $15^{\circ}$  and none of our male subjects in either group had values of  $\geq 20^{\circ}$ . The Q-angle in adult Indian females was between  $14^{\circ}$ - $22^{\circ}$  and for African females it was  $16^{\circ}$ - $24^{\circ}$ . 11.5% of the female subjects in Group- I and 58% percent in Group-II had Q angles  $> 20^{\circ}$ . The mean Q-angles values in both the groups showed significant bilateral asymmetry ( $p < 0.05$ ) and gender variation (Table 1 & 2) with Q-angle values being greater for women than in men ( $p < 0.0001$ ).

**Table 1:** Mean Q- angle values in Group- I subjects

Parameter	Male (n=22)	Female (n=28)	p- value
Right knee	12.45 $\pm$ 1.22	17.64 $\pm$ 1.87	<0.0001*
Left knee	11.77 $\pm$ 0.92	16.46 $\pm$ 1.71	<0.0001*

\* Indicates significant gender difference (using Independent t-test )

**Table 2:** Mean Q- angle values in Group -II subjects

Parameter	Male (n=26)	Female (n=24)	p- value
Right knee	14.30 $\pm$ 0.88	21.16 $\pm$ 1.57	<0.0001*
Left knee	13.26 $\pm$ 1.18	20.04 $\pm$ 1.87	<0.0001*

\* Indicates significant gender difference (using Independent t-test )

## Discussion

In the present study we identified the baseline values of Q-angle for Indian and East African adult. The Q-angle values in Group- I subjects are consistent with earlier studies done on white Americans [4,15-17]. However the values were higher than previous studies done on Indians [5,6]. The reason is the earlier authors have taken the measurements in supine position and our subjects were standing erect with Quadriceps relaxed.

Q -angle values in Group-II females were higher than those reported by Jaiyesimi and Jegede [18] who in their study on Nigerian population reported the average Q-angle in the female subject ( $n = 200$ )  $17.06^{\circ} \pm 3.64$  and  $14.84^{\circ} \pm 3.47$  for the right and left limb. Another study on Nigerian population of Urhobo ethnicity establishes the average Q-angle for the right and left lower limb in the female group ( $n=100$ ) had their RQA and LQA as  $16.93^{\circ} \pm 1.35$  and  $16.30^{\circ} \pm 1.20$  respectively [19]. However the values were lower than Omololu et al. [7] who in his study on Nigerian population females ( $n=123$ ) reported RQA and LQA as  $22.8^{\circ} \pm 4.7$  and  $22.7^{\circ} \pm 4.6$ . The possible explanation for this difference in Q-angle values compared to previous studies is our subjects belong to east Africa whereas above mentioned authors did study on Nigerian population .

### *Bilateral Asymmetry*

In the present study RQA was higher than the LQA in both the groups this is consistent with the result of previous authors [16,18,20], but differs with other authors who have reported higher LQA than RQA [21-23]. One of the explanations put forth for bilateral asymmetry is difference in the quadriceps strength. It was found that the Q angle is inversely related to the peak torque angle during active knee extension [17]. The other reasons postulated are relative alteration in the positions of the CP or TT. Higher Q-angle values were associated with lateral placement of the TT with respect to the CP [20]. However in the present study we have only measured the Q-angle and its alteration with positions of the CP or TT will be done in subsequent studies.

### *Gender*

In Group-I as well as in Group-II, females had significantly higher Q-angle as compared to males , this is consistent with previous studies [4,6,15,19,23] There are many reasons being documented for higher Q-angles in females, theoretically the combination of

wider hip and shorter femurs could increase the valgus of the lower limbs and thus increase the Q-angle [24]. Grelsamer et al. (2005) concluded that the slight difference in Q angles between men and women can be explained by the fact that men have longer femur and tend to be taller [25] gender difference in Q angle also depends on strength of muscle contraction [17]. The Q angle in females showed a significant positive correlation with the relative lateral placement of the TT [5,6] A more laterally placed TT in females could be due to an increase in the valgus angle or tibial torsion [26].

A higher Q-angle alters lower limb biomechanics and this has been associated with greater incidence of patellofemoral disorders hence females are more prone to patellofemoral pain syndrome, anterior knee pain and recurrent lateral subluxation of the patella.

## Conclusion

The present study has documented Q-angle values for two different races. The east African subjects had significantly higher values compared to Indian subjects. More similar studies with larger sample size need to be undertaken and should also be correlated radiologically to authenticate the result.

## Acknowledgement

The authors would like to thank all the subjects who consented to participate in this study.

The manuscript has not been presented or sent for publication elsewhere

### *Conflict of Interest*

Nil

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## Morphometric Study of First Sacral Vertebra in Dry Human Sacra

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### Abstract

**Introduction:** Sacrum is a well known site for internal fixation of spine. In internal fixation, iliosacral screws applied on sacrum corpus passes through S1 vertebra pedicle. There lies epidural space, nerve root and dural sac medial to the pedicle. So, it is important to know detailed anatomy of S1 vertebra to avoid neurovascular injuries. The present study was done to provide morphometric data about dimensions of first sacral vertebra to facilitate spinal instrumentation procedures by spine surgeons. **Aim:** To study the morphometric characteristics of first sacral vertebra in dry human sacra. **Methods:** This study was conducted on 109 dry human sacra, obtained from the bone library, Department of Anatomy of a tertiary care teaching institutes. **Results:** Vertebral body height of first sacral vertebra at midline ranged from 19-37 mm with mean of 30.0 mm. Vertebral body maximum transverse width and vertebral body mid-diameter of first sacral vertebra were ranged from 5-61 mm (mean of 44.6 mm) and from 23-37 mm (mean of 30.3 mm) respectively. Mean posterior pedicle height of S1 vertebra on left and right side were 25.2 mm and 25 mm respectively. Mean pedicle width of S1 vertebra on left and right side were 11.3 mm and 11.5 mm respectively. Mean pedicle depth of S1 vertebra on left and right side were 31mm and 29.1mm respectively. **Conclusion:** Data regarding first sacral vertebra will be useful for pedicle screw fixation and also for formation of screws.

**Keywords:** Morphometry; Pedicles; Screw Fixation.

### Introduction

The sacrum is a large, triangular fusion of five vertebrae and forms the posterosuperior wall of the pelvic cavity, wedged between the two hip (innominate) bones [1]. The sacrum bone is the fulcrum of support for the human torso and as such is well-designed to take great physical stress [2].

Lumbosacral fusion and instrumentation are common procedures for several spinal disorders including spondylolisthesis, lumbar scoliosis and for metastatic, infectious, degenerative and traumatic diseases affecting the sacrum [3]. Posterior decompressive procedures, fusion and internal

fixation procedures need detailed information regarding the anatomy of the first sacral vertebra. So, the aim of present study was to provide morphometric data about dimensions of first sacral vertebra to facilitate spinal instrumentation procedures by spine surgeons.

### Material and Methods

This study was conducted on 109 dry human sacra, obtained from Department of Anatomy of a tertiary care teaching institute. The sacra were of undetermined age and gender. Bones with lumbarisation of first sacral vertebra and sacralization of fifth lumbar vertebra were excluded from the study.

The measurements were taken by using digital Vernier calliper (0-200 mm with precision of 0.01mm), divider, ruler and thread.

### S1 Vertebral Body Height (VBH)

It is distance (mm) between superior and inferior limit of S1 body at midline, measured with divider and rule (Figure 1).

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### S1 Vertebral Body Mid-Diameter (VBD)

It is distance (mm) from anterior to posterior limit of S1 vertebral body at midline, measured with divider and ruler (Figure 2).

### S1 Vertebral Body Maximum Transverse Width (VBW)

It is measured with divider and ruler (Figure 3).

### Posterior Pedicle Height of S1 Vertebra (PPH)

It is distance (mm) between superior limit of S1 (at junction of pedicle and S1 vertebral body on dorsal aspect) and superior aspect of 1st sacral foramina. It is measured with divider and ruler (Figure 4).

### Pedicle Width of S1 Vertebra (PW)

It is perpendicular distance (mm) between line joining anterolateral edge of S1 vertebral body to lateral edge of superior facet of S1 (Point from which perpendicular line drawn is medial edge of pedicle) (Figure 5).

### Pedicle Depth of S1 Vertebra (PD)

It is distance (mm) between anterior limit (anterolateral edge of S1 vertebral body) and posterior limit (lateral edge of superior facet of S1) of pedicle at narrowest point. It is measured with divider and ruler (Figure 6).

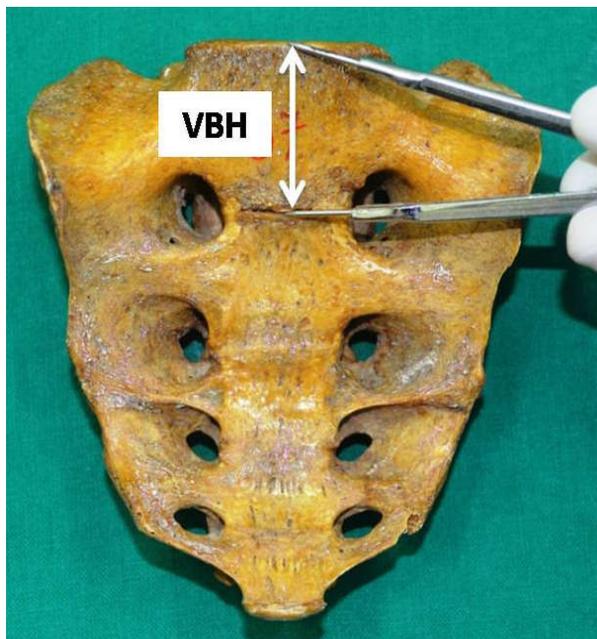


Fig. 1: Measurement of S1 vertebral body height (VBH)

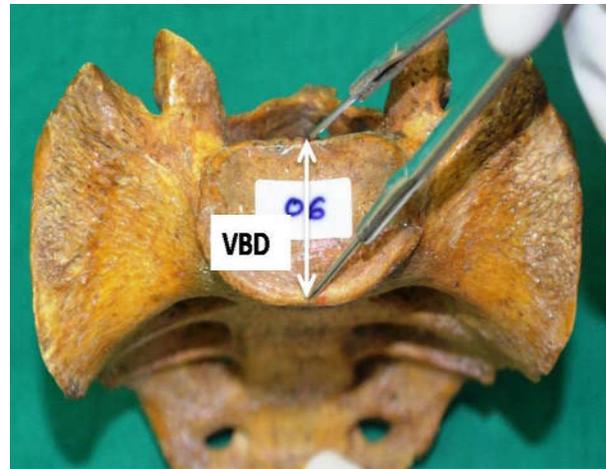


Fig. 2: Measurement of vertebral body mid-diameter (VBD) of first sacral vertebra

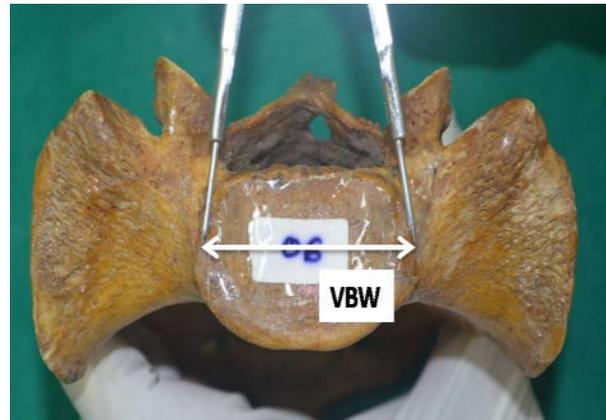


Fig. 3: Measurement of vertebral body width (VBW) of first sacral vertebra

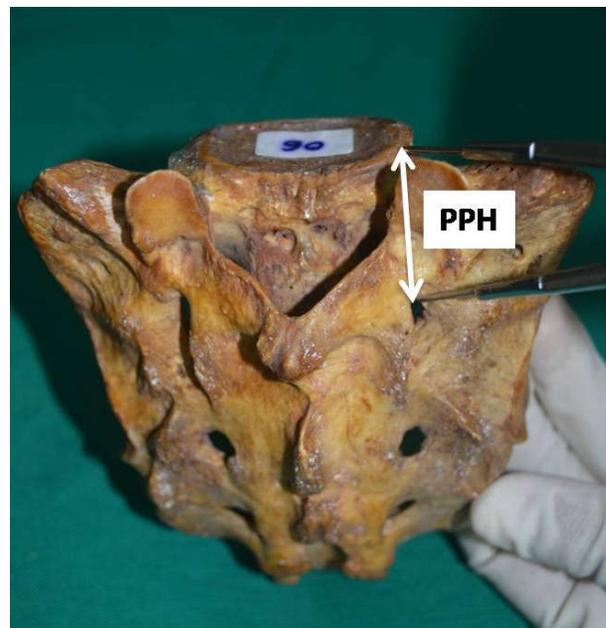


Fig. 4: Measurement of posterior pedicle height (PPH) of first sacral vertebra

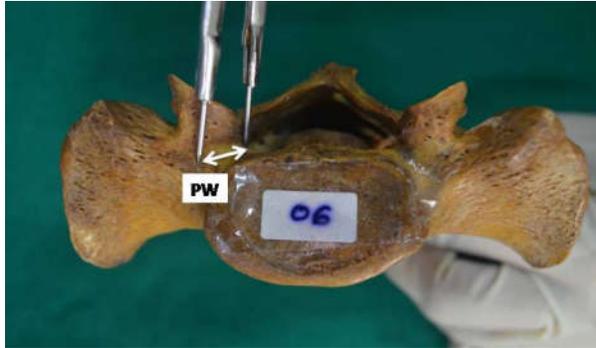


Fig. 5: Measurement of pedicle width (PW) of first sacral vertebra

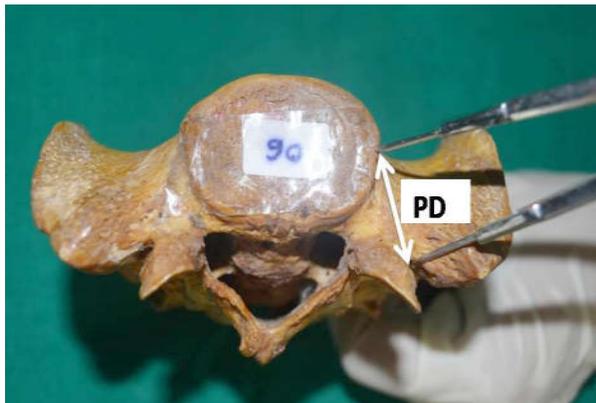


Fig. 6: Measurement of pedicle depth (PD) of first sacral vertebra

**Results**

Various parameters related to first sacral vertebra were measured in 109 dry human sacra of undetermined age and gender in the present study. All these measurements and observations are mentioned in Table 1 and 2.

**Discussion**

Lumbosacral screw fixation is used in treatment of lumbar burst fracture, vertebra metastases, lumbar scoliosis, spondylolisthesis and some other instability. Harrington and Dickenson suggested that most secure first sacral screw placement passes through the first sacral pedicle to the sacral promontory [4]. Anatomical structures along anterior surface of sacrum like lumbosacral trunk, internal iliac vessels are at high risk during sacral screw penetration [5]. Therefore, morphometric data of pedicle of first sacral vertebra is important for safe approach of screw placement.

The Tables 3-8 show comparison of means of various parameters of first sacral vertebra from previous studies; with that of the present study.

The mean vertebral body height in the present study is almost similar to that of previous studies mentioned in Table 3.

**Table 1:**

Parameters	Mean ± SD (in mm)	Range (in mm)
S1 Vertebral body height	30 ± 3.07	19-37
S1 vertebral body mid-diameter	30.3 ± 2.41	23-37
S1 vertebral body width	44.6 ± 5.91	5-61

**Table 2:**

Parameters	Mean ± SD (in mm)		Range (in mm)	
	Left	Right	Left	Right
Posterior pedicle height	25.2 ± 2.61	25.0 ± 2.43	20-32	19-31
Pedicle depth	31.0 ± 3.48	29.1 ± 3.00	20-44	22-39
Pedicle width	11.3 ± 1.38	11.5 ± 1.48	5-15	8-15

**Table 3:** Comparison of S1 vertebral body height (VBH) between superior and inferior limit of S1 body at midline with previous studies

Study	Year	Country	Material for study	Height (mm)
Candan A et al [3]	2009	Turkey	Dry bones	30.22 ± 2.35
Morales - Avalos R et al [7]	2012	Mexico	Dry bones	31.11 ± 2.80
Sinha M B et al [6]	2013	India	Dry bones	28.06 ± 2.30
Present study		India	Dry bones	30.0 ± 3.07

(mm - millimeter, VBH -Vertebral body height)

**Table 4:** Comparison of S1 vertebral body maximum transverse width (VBW) with previous studies

Study	Year	Country	Material for study	Width (mm)
Sachdeva K et al [10]	2011	India	Dry bones	M - 47.6 ± 7.1 F - 45.5 ± 4.8
Morales - Avalos R et al [7]	2012	Mexico	Dry bones	48.72 ± 4.64
Sinha M B et al [6]	2013	India	Dry bones	46.02 ± 4.64
Present study		India	Dry bones	44.6 ± 5.91

(mm - millimeter, VBW -Vertebral body width)

**Table 5:** Comparison of S1 vertebral body mid-diameter (VBD) with previous studies

Study	Year	Country	Material for study	Diameter (mm)
Basaloglu H et al [11]	2005	Turkey	Dry bones	31.0 ± 3.00
Candan A et al [8]	2009	Turkey	Dry bones	31.42 ± 2.83
Morales - Avalos R et al [7]	2012	Mexico	Dry bones	31.93 ± 2.91
Sinha M B et al [6]	2013	India	Dry bones	29.47 ± 2.48
Present study		India	Dry bones	30.3 ± 2.41

(mm - millimeter, VBD -Vertebral body mid-diameter)

**Table 6:** Comparison of posterior pedicle height of S1 vertebra (PPH) between superior limit of S1 & superior aspect of 1st sacral foramina with previous studies

Study	Year	Country	Material for study	Height (mm)
Candan A et al [3]	2009	Turkey	Dry bones	Left : 21.23 ± 2.18 Right : 20.74 ± 2.50
Morales - Avalos R et al [7]	2012	Mexico	Dry bones	Left : 24.42 ± 3.70 Right : 24.86 ± 3.89
Sinha M B et al [6]	2013	India	Dry bones	Left : 19.52 ± 3.14 Right : 19.33 ± 2.72
Present study		India	Dry bones	Left : 25.2 ± 2.61 Right : 25.00 ± 2.43

(mm - millimeter, PPH-Posterior pedicle height )

**Table 7:** Comparison of pedicle width of S1 vertebra (PW) between anterolateral edges of S1 vertebral body to lateral edge of superior facet of S1 vertebra with previous studies

Study	Year	Country	Material for study	Width (mm)
Sinha M B et al [6]	2013	India	Dry bones	Left : 11.50 ± 2.64 Right : 12.25 ± 2.36
Present study		India	Dry bones	Left : 11.3 ± 1.38 Right : 11.5 ± 1.48

**Table 8:** Comparison of pedicle depth of S1 vertebra (PD) between anterior & posterior limits of pedicle at narrowest point with previous studies

Study	Year	Country	Material for study	Depth (mm)
Sinha M B et al [6]	2013	India	Dry bones	Left : 28.55 ± 2.54 Right : 28.31 ± 2.66
Present study		India	Dry bones	Left : 31.00 ± 3.48 Right : 29.1 ± 3.00

Vertebral body maximum transverse width is used for calculation of index of body of first sacral vertebra (vertebral body mid-diameter / vertebral body width × 100) and corpo-basal index (S1 vertebral body width / sacral breadth × 100). Both these indices are useful in sex differentiation of sacrum [8,9]. The mean

vertebral body maximum transverse widths in the previous studies were higher than that in the present study.

The mean vertebral body mid-diameter in the present study is in accordance with that in previous studies.

Posterior pedicle height indicates safe vertical distance for screw placement without damage to adjacent structures [3]. The mean posterior pedicle height measured in present study resembles with that in studies by Morales Avalos et al [7] but it is higher than that in other studies by Sinha M B et al [6] and Candan A et al [3].

More pedicle width makes the sacrum stronger and it helps in fixation of screws [11]. It also indicates distance between sacral canal and path of screw placement. It helps to avoid injury to sacral canal structures. When compared with previous studies, mean pedicle width of S1 vertebra in the present study resembles that of left side and slightly higher on right side than that in the study by Sinha M B et al [6].

Sacral screws can be placed from posterior aspect either anteromedially or anterolaterally. Screws placed obliquely in a lateral direction can cause injury to iliac vessels, L5 nerve root and S1 nerve root. Safe screw implantation in the sacrum could be insured if it is placed above the level of first sacral foramen and directed forward and medially [12]. In the present study, pedicular depth is also measured in medial direction between lateral edges of superior articular facets of first sacral vertebra to the anterolateral edges of S1 vertebral body. Pedicular depth is important to know maximum safe length of screw. If length of screw is less than this distance, it may not produce harm to related structures [6].

In present study, pedicle depth of first sacral vertebra is higher on left side and resembles on right side on comparing with the study by Sinha M B et al [6].

## Conclusion

Various studies have been carried out in India and abroad by anatomists, anesthetists and radiologists about the parameters of sacrum. Most of these studies are focused on sacral hiatus. There is less number of studies done on Indian population for measurements of parameters of pedicles of first sacral vertebra. Hence, it is hoped that the present study will be useful for clinicians; especially spine surgeons as it gives comprehensive data about different parameters of first sacral vertebra in Indian population. This data will be useful for pedicle screw fixation and for formation of screws. This study will also help to avoid the neurovascular injuries during spinal procedures.

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# Magnetic Resonance Angiographic Study of Anatomic Variations of the Circle of Willis in Marathwada Population

Vaishali Inamdar<sup>1</sup>, Rachita Malwatkar<sup>2</sup>

## Abstract

**Background and Objectives:** The circle of Willis, an anastomotic polygon at the base of the brain, forms an important collateral network to maintain cerebral blood perfusion. The aim of this study was to investigate different anatomic variations of the circle of Willis and their prevalence. **Methods:** This cross-sectional study was conducted on 500 healthy participants including 200 men and 300 women. The mean age of the patients was 50 years. Three-dimensional time-of-flight magnetic resonance angiography (3D-TOF MRA) technique was used. Vascular variations in the anterior and posterior parts of the circle were evaluated. **Results:** The findings show that the complete circle of Willis was visible in a small number of patients. The circle of Willis had a complete vascular structure in 22% of the patients. The anterior part of the circle of Willis had a complete structure in 73% of the cases, while the posterior part had a complete structure in 18% of the cases. **Conclusion:** We observed wide variations in the circle of Willis configuration in our study. Similar to other studies, most variations are related to the posterior part of the circle of Willis. Absence of bilateral posterior communicating artery variation is more common than other types of variations in this population.

**Keywords:** Anatomic Variation; Cerebral Arteries; Circle of Willis; Magnetic Resonance Angiography.

## Introduction

The process of the formation of blood vessels in the human body is very complex, and the shapes of vessels in the embryonic phase are very different from those in adulthood. Numerous variations may occur during the transformation of embryonic vessels to adult vessels. Vascular variations are different and are not pathological in many cases. They may involve different origins, paths or artery diameter and size [1,2]. Due to its critical importance, blood supply to the brain is designed in such a way that vascular variations or vascular damage inflict minimum harm to this vital tissue [3].

The presence of an arterial circle in the brain was first suggested by Thomas Willis in 1966 [4]. This

circle is formed jointly by internal carotid arteries (ICA) and basilar artery (BA). Anterior cerebral artery (ACA) separates from the internal carotid artery and, together with the anterior communicating artery (ACo), forms the anterior section. The posterior section is formed by the posterior cerebral artery (PCA) and posterior communicating artery (PCoA). This arterial polygon has a great potential in establishing side nutritional routes in case of occlusion in the ICAs.

Studies have shown that the classic circle of Willis is observed in 18–25% of the cases. Previous studies have reported different variations in this arterial circle [5-7]. Most of these studies have been conducted on human cadavers. For example, Eftekhari et al. examined variations of the circle of Willis in 102 male cadavers [8]. Other studies have been carried out on the variations of the circle of Willis and reported agenesis, hypoplasia of the anterior communicating artery, posterior communicating artery, and posterior cerebral artery. Vascular variations have been examined using various methods including autopsy [9], angiography and magnetic resonance angiography imaging. Magnetic resonance angiography is a noninvasive sensitive method used to assess variations in vivo. This method, which is widely used to study brain vessels, does not require

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contrast injection. Three-dimensional images are prepared using time of flight (3D-TOF) method to examine the circle of Willis [10,11].

The use of high Tesla MRI machines yields high-quality images with better details, allowing for the study of smaller vessels [12-14].

### Materials and Methods

The cross-sectional study was conducted on the circle of Willis in 500 healthy patients. Patients who referred to the Radiology department as part of their health check-up were included in this study. Clearance from Institutional Ethical committee was obtained for this study.

#### Inclusion Criteria

Patients in both genders who referred to our hospital for health check-up.

#### Exclusion Criteria

Patients who have claustrophobia. Patients who have head and neck surgeries.

The patients' age ranged from 25 to 75 years. The mean age was 50 years. In total, 200 were male and 300 were female. The 3D time of flight MRA technique using 8 channels coils designed for heading MRI machine was first performed for all patients. The TR and TE parameters were 25 and 5.2 milliseconds, respectively, and the flip angle was 20°. Field of view of 230 x 150mm and slice thickness of 0.5 mm were used. Raw images were processed using the maximum intensity projection (MIP) algorithm to obtain the angiography images. Vessels with a diameter less than 0.8 mm were considered as hypoplastic.

Anatomic variations in the anterior and posterior of circle of Willis were categorized based on findings recorded in studies by Lippert and Pabst [15] Categorization is shown in Figures 1 and 2.

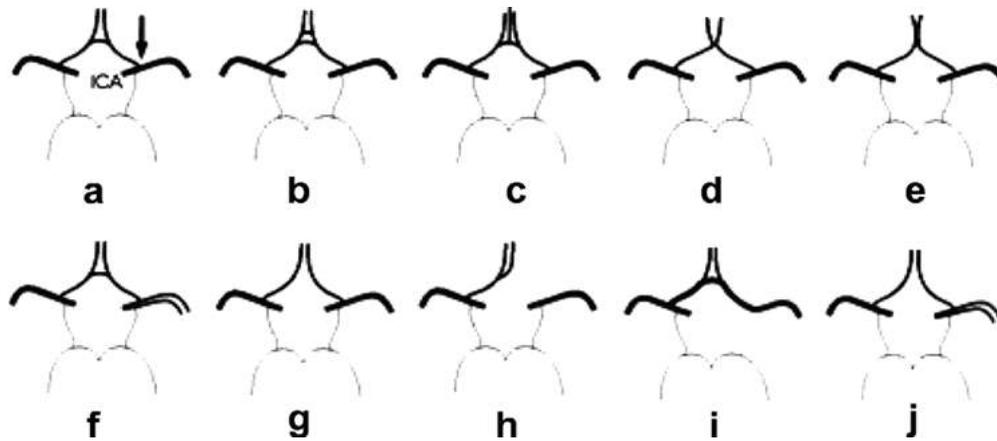


Fig. 1: Anatomic variations of the anterior part of the circle of Willis.

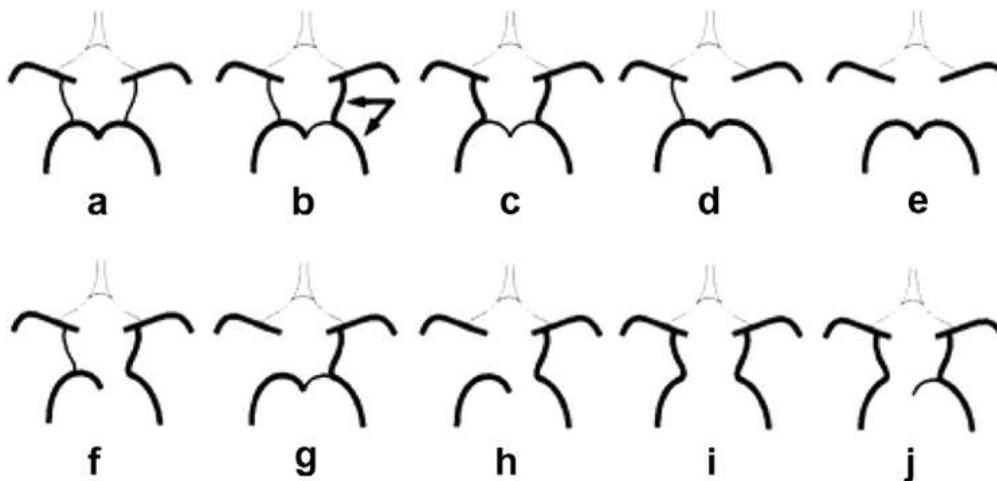
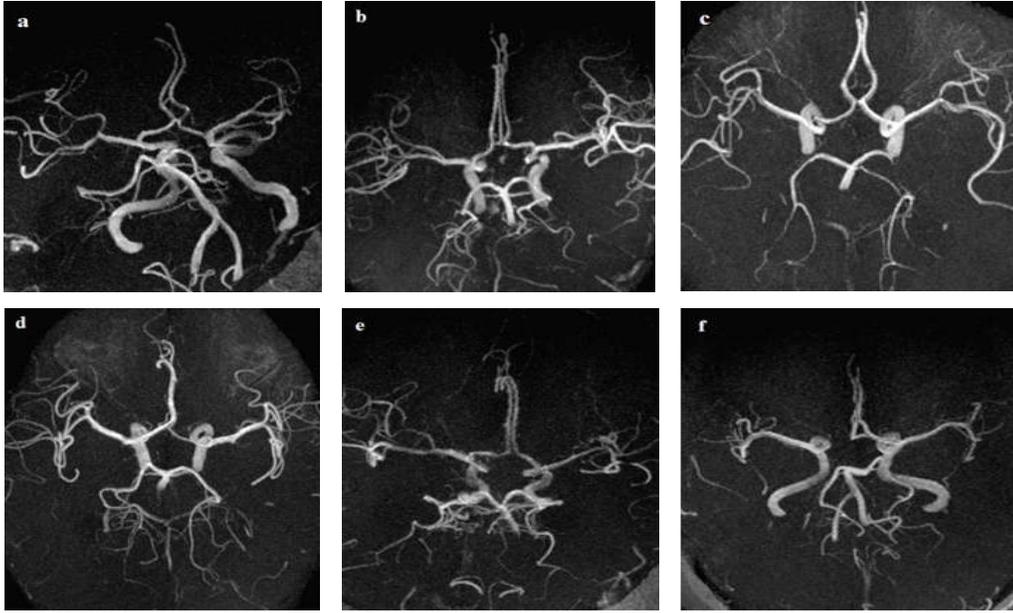
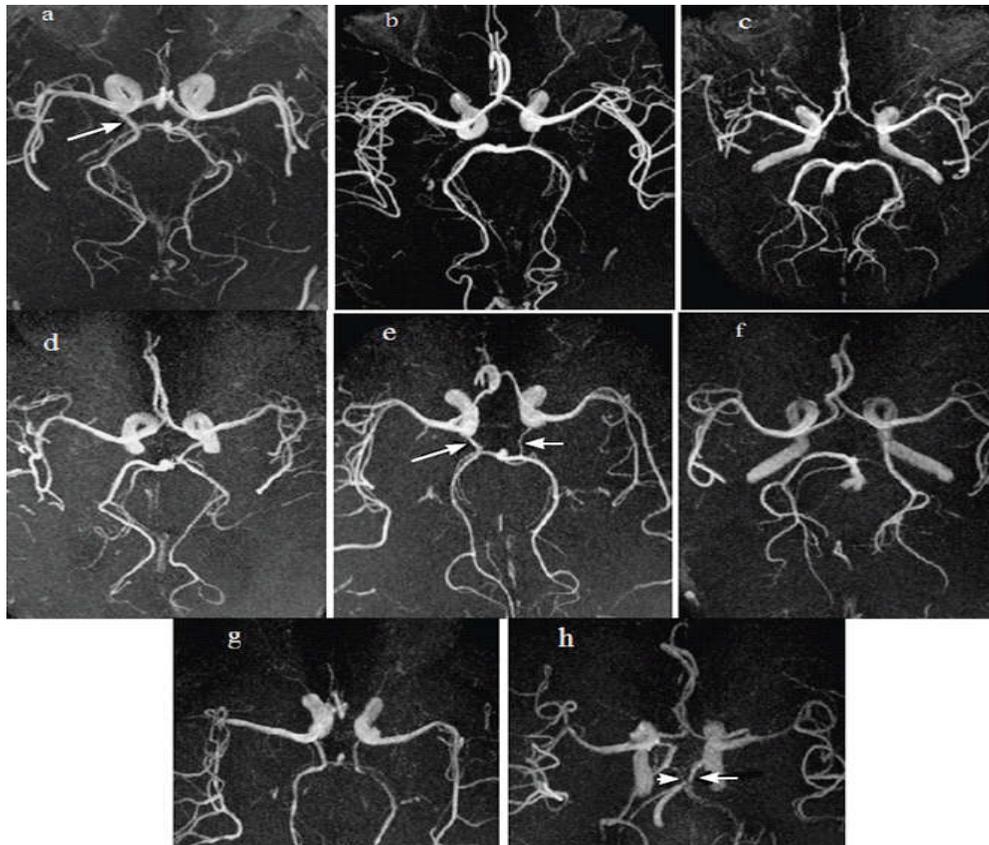


Fig. 2: Anatomic variations of the posterior part of the circle of Willis



**Fig. 3:** MRA images of circle of Willis vessels showing anatomical variations in the anterior part, (a) Anatomic variation type 1b, (b) Anatomic variations type 1c, (c) Anatomic variations type 1d. (d) Anatomic variations type 1e. (e) Anatomic variations type 1g. (f) Anatomic variations type 1h.



**Fig. 4:** Axial images of the circle of Willis vessels showing anatomical variations in the posterior part, (a) anatomic variation type 2b. PCA originates from ICA (long arrow), (b) anatomic variation type 2d, (c) anatomic variation type 2e, (d) anatomic variation type 2g, (e) anatomic variation type 2f, PCA originates from ICA (long arrow). The precommunicating part of PCA can be observed in the other side (arrow head), (f) anatomic variation type 2h, (g) anatomic variation type 2i, both PCA arteries originate from ICA. The precommunicating part of PCA is absent on both sides. (h) Anatomic variation type 2j. PCAs on both sides originate from ICA. PCA is not connected to basilar artery on one side (long arrow). The precommunicating part of PCA can be observed on the other side (arrow head).

**Results**

Anatomic variations of the anterior and posterior parts on the circle of Willis were examined separately. Variations in the anterior and posterior parts of the circle of Willis are shown in Figures 3 and 4, respectively. The results showed that the anterior part

of the circle of Willis had a complete structure in 73% of the cases. The vascular structure of the posterior part was complete in 18% of the cases (Table 1). Circle of Willis had a complete structure in 22% of the cases.

According to the results of this study, no significant differences were found between men and women in the prevalence of variants (Table 2).

**Table 1:** Prevalence of variants of the anterior and posterior part of the circle of Willis

Type of variants of anterior part	a	b	c	d	e	f	g	h	i	j	Complete configuration of anterior part (%)
Prevalence	365	5	10	30	5	0	65	20	0	0	73
Type of variants of posterior part	a	b	c	d	e	f	g	h	i	j	Complete configuration of posterior part (%)
Prevalence	90	15	0	90	220	40	10	25	5	5	18

**Table 2:** Prevalence of entirely complete and incomplete configuration of the entire circle of Willis according to sex

Group	Prevalence of entirely complete configuration	Prevalence of entirely incomplete configuration	Entirely complete configuration (%)
Male(n=200)	40	160	20
Female(n=300)	70	230	23.33
Total(n=500)	110	390	22

**Discussion**

Study of embryonic development of the circle of Willis shows that hemodynamic changes during fetal life may play an important role in determining the final form of the circle of Willis. A study conducted on the formation of the circle of Willis in fetus showed that, in a 29-day-old embryo, the posterior communicating artery originated from ICA. In the early stages of growth, the vertebrobasilar system is supplied by the carotid through the trigeminal artery.

Following the formation of the posterior cerebral artery, the circle closes and perfusion is established from the vertebrobasilar system to the carotid system. That study suggested that hemodynamic changes at this stage can cause different variations [16].

Van Overbeek et al. concluded that rapid growth of the occipital circle of Willis, especially in the posterior part [17].

In addition, some researchers believe that hemodynamic changes are not limited to the embryonic period and can even affect the formation of the circle in the first decade of life.

Many other factors may also be involved in the formation of different variations. In some cases, variations are pathological and, therefore, important.

Extensive research conducted on the effect of variations of the circle of Willis has proven the association between these variations and incidence of some neurovascular problems. For example, in a clinical study, Chuang et al. (2008) found that the absence or hypoplasia of PCoA can increase the risk of stroke in cases of ICA occlusion [18].

Similar to many previous studies, the present study confirms the wide range of variations in the circle of Willis. The prevalence of variations is different in previous studies, which is probably due to the type of study population and method of study. The findings of the present study are consistent with those reported by Chen et al [11].

In our study, full circle of Willis was observed in 22% of the cases, which was 21.3% in that study. Complete structure of the circle of Willis in the anterior and posterior parts was observed in 73% and 18% of the cases, respectively, which were 78.3% and 25.44% in the aforementioned study.

In conclusion, MRA findings showed that most variations are related to the posterior part of the circle of Willis. The interesting point in our finding is the high prevalence of absence of bilateral posterior communicating artery in our population. Since the absence or hypoplasia of PCoA can increase the risk of stroke in cases of ICA occlusion, prevalence of this type of variation can be important.

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## A Qualitative Study of Palmar Dermatoglyphics in Congenital Heart Diseases

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### Abstract

**Introduction:** The word "Dermatoglyphics" indicates the study of epidermal configuration on palms, soles and finger tips. In early foetal life the differentiation of epidermal ridges takes place. These patterns do not change in an individual throughout life and no two patterns are alike. The dermatoglyphic patterns were studied in cardiovascular disorders, but there are very few dermatoglyphic studies in congenital heart diseases (CHD). **Materials & Methods:** The cross sectional study with comparison group was designed. Hundred patients of congenital heart diseases (CHD) i.e. CHD group and hundred patients without CHD i.e. control group were examined during study period. Dermatoglyphic prints were obtained by using standard protocol method and finger tip patterns i.e. Arches, whorls, radial loops and ulnar loops were studied. **Results:** Among the qualitative parameters, finger print patterns were studied and analysed. The percent frequency of arches, whorls and radial loops showed statistically insignificant difference in CHD group and control group. While percent frequency of ulnar loops showed statistically significant difference in CHD group and control group. **Conclusion:** Ulnar loops are most frequently found in dermatoglyphic pattern of finger tips in CHD group as compared to control group

**Keywords:** Arches; CHD; Dermatoglyphics; Radial Loop; Ulnar Loop; Whorls.

### Introduction

The term dermatoglyphics was coined by Herold Cummins in 1926, an anatomist of Tulane university of Greece. The word "Dermatoglyphics" indicates the study of epidermal configuration on palms, soles and finger tips. It has long been recognized as a scientific and valuable method for medicolegal, anthropological and genetic studies.

It reveals the congenital links between our fingers and our intrinsic qualities and talents. In early foetal life the differentiation of epidermal ridges takes place. These patterns do not change in an individual throughout life and no two patterns are alike. In recent years, many countries like U.S and Japan have applied

dermatoglyphics to diagnose Down's syndrome, congenital disorders, genetic abnormalities etc.

There are very few studies of dermatoglyphic patterns in congenital heart diseases (CHD).

#### Aims & Objectives

- To evaluate the significance of dermatoglyphics in congenital heart diseases(CHD)
- To study and compare the dermatoglyphic pattern in normal and CHD patients
- To compare and correlate the findings of present study with previous studies

### Materials & Methods

The present study was carried out in one hundred patients of CHD and one hundred control individuals. Out of one hundred patients of CHD, sixty two were males and thirty eight were females. The control cases were fifty six males and forty four females.

The palmar prints of patients with CHD and control group were collected. The age group of CHD patients was ranging from 6-24 years and that of control group was from 18-25 years.

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The dermatoglyphic prints were taken using following method:

- Subjects were asked to wash their hands with soap and dry, to remove dust from palms
- Kores duplicating ink was applied on palms and palmar prints were taken on a white drawing paper
- For smearing the ink special ball was used, which was prepared from cotton gauze and linen
- Paper was kept on clean hard surface and the inked hand was placed on the paper
- At first, palmar aspect of patients wrist placed firmly on paper then all the fingers were firmly pressed on paper one by one
- Each finger tip was rolled for getting complete prints



Fig. 1: Materials used for taking dermatoglyphic prints

- The prints were studied with the help of hand lens and following qualitative parameters were studied

#### Finger tip patterns

1. Arches
  2. Whorls
  3. Radial loops
  4. Ulnar loops
- For statistical analysis, percent frequency, mean, standard deviation and Z test (Standard error of difference between two proportions of qualitative parameters) were used
  - The results were tabulated and analysed for statistical significance

#### Finger tip patterns



Arch

Whorl

Radial loop

Ulnar loop

**Results**

38 were females. The incidence of CHD was more in males (62%) than in females (38%)

Out of 100 patients with CHD, 62 were males and

**Table 1:** Percent frequency of arches in right and left hands combined

Cases	CHD group Arches	Percentage	Cases	Control group Arches	Percentage	Z = 1.82 P > 0.05 Insignificant
100 (1000 digits)	35	3.5	100 (1000 digits)	48	4.8	

Refer graph 1

**Table 2:** Percent frequency of whorls in right and left hands combined

Cases	CHD group Whorls	Percentage	Cases	Control group Whorls	Percentage	Z = 1.88 P > 0.05 Insignificant
100 (1000 digits)	201	20.1	100 (1000 digits)	232	23.2	

Refer graph 2

**Table 3:** Percent frequency of radial loops in right and left hands combined

Cases	CHD group Radial loops	Percentage	Cases	Control group Radial loops	Percentage	Z = 1.28 P > 0.05 Insignificant
100 (1000 digits)	99	9.9	100 (1000 digits)	121	12.1	

Refer graph 3

**Table 4:** Percent frequency of ulnar loops in right and left hands combined

Cases	CHD group Ulnar loops	Percentage	Cases	Control group Ulnar loops	Percentage	Z = 3.33 P < 0.05 Significant
100 (1000 digits)	665	66.5	100 (1000 digits)	593	59.3	

Refer graph 4

**Discussion**

Qualitative analysis of finger tip patterns

**Table 5:** Comparison of percent frequency of arches in right and left hands combined

Authors (Year of study)	CHD group (Percentage)	Control group (Percentage)
Cascos AS <sup>1</sup> (1964)	5.30	1.51
Rathod <sup>2</sup> (1993)	7.09	6.23
Present study	3.50	4.80

Cascos AS [1] found that there is significant increase in the frequency of arches in CHD group while Rathod [2] found insignificant increase.

In the present study, the incidence of arches was decreased in CHD group as compared to control group but was not statistically significant.

**Table 6:** Comparison of percent frequency of whorls in right and left hands combined

Authors (Year of study)	CHD group (Percentage)	Control group (Percentage)
Cascos AS <sup>1</sup> (1964)	46.16	42.31
Rathod <sup>2</sup> (1993)	53.11	54.94
Present study	20.10	23.20

In the present study, the incidence of whorls was lower in CHD group as compared to control group but was statistically insignificant.

The findings of previous workers indicate insignificant difference in the frequency of whorls, which correlates with present study.

**Table 7:** Comparison of percent frequency of radial loops in right and left hands combined

Authors (Year of study)	CHD group (Percentage)	Control group (Percentage)
Cascos AS <sup>1</sup> (1964)	5.63	5.39
Rathod <sup>2</sup> (1993)	4.30	7.87
Present study (2014)	9.90	12.10

In the present study, incidence of radial loops in CHD group is lower than the control group which was statistically insignificant.

significant difference in the frequency of radial loops do correlate with present study.

Thus the findings of Rathod [2], indicating no

While Cascos AS found almost equal number of radial loops in both the groups.

**Table 8:** Comparison of percent frequency of ulnar loops in right and left hands combined

Authors (Year of study)	CHD group (Percentage)	Control group (Percentage)
Cascos AS <sup>1</sup> (1964)	38.47	30.31
Rathod <sup>2</sup> (1993)	35.48	19.89
Present study (2014)	66.50	59.30

The present study shows the incidence of ulnar loops in CHD group was higher than that of control group and it is statistically significant.

group as compared to control group

The study by Cascos AS [1] and Rathod [2] also found statistically significant increase in the incidence of ulnar loops in CHD group. Hence, present study correlates with the previous studies.

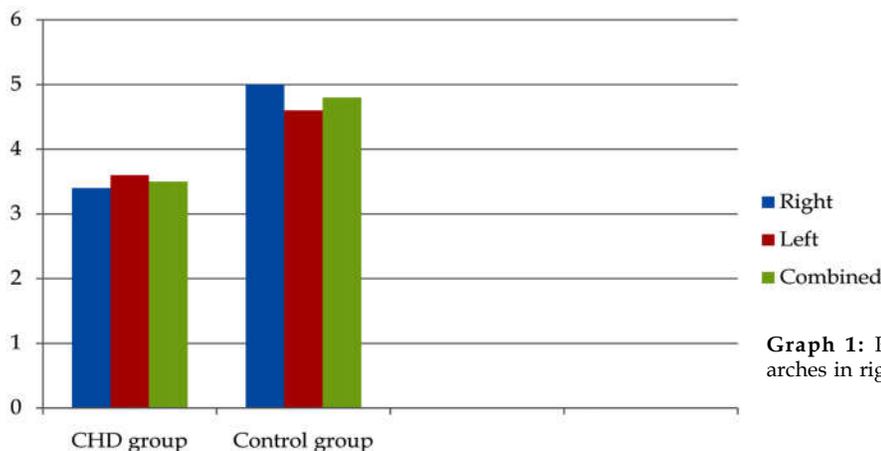
- Ulnar loops show statistically significant difference between CHD group and control group

## Conclusions

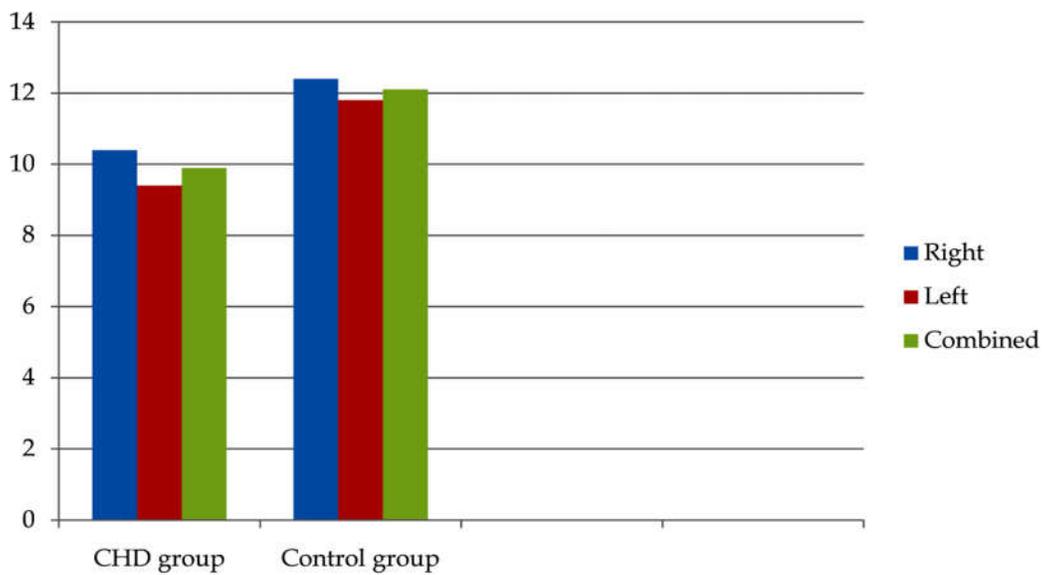
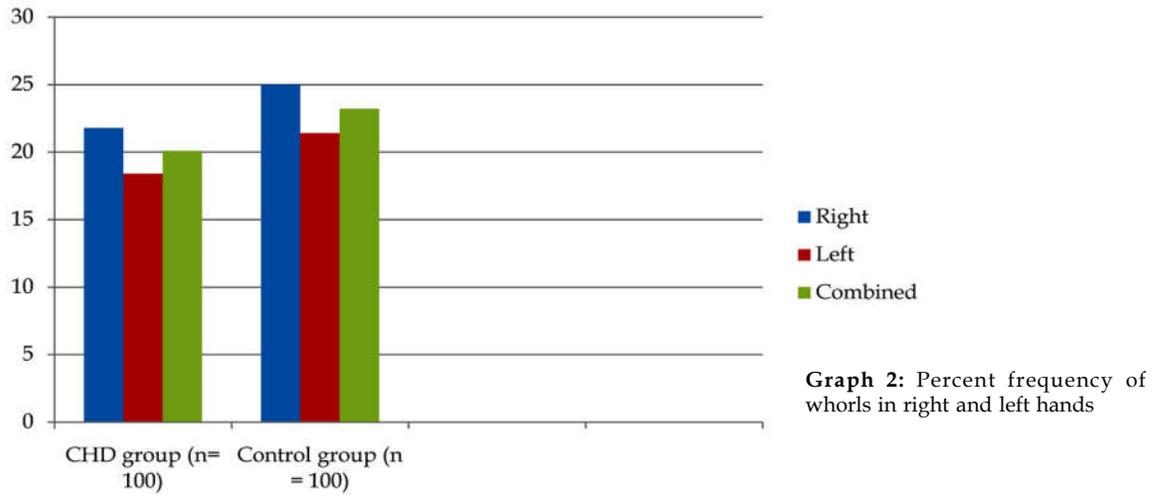
### Recommendations

- Finger tip patterns like arches, whorls and radial loops show statistically insignificant difference in CHD group and control group
- Ulnar loops are most frequently found in dermatoglyphic pattern of finger tips in CHD

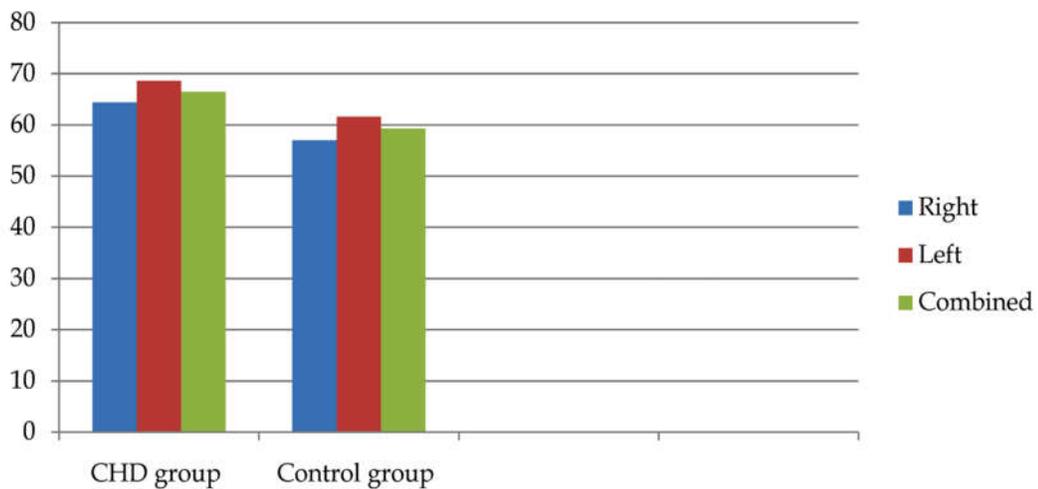
- The dermatoglyphic study is a useful investigation. It is inexpensive and can be recorded quickly. It hardly requires any elaborate equipments and analysis is a matter of training only.
- It can serve to strengthen a diagnostic impression and useful screening device to select individuals for further extensive investigations.
- A large scale study should be undertaken to draw more useful and definitive conclusions regarding the value of dermatoglyphics



**Graph 1:** Percent frequency of arches in right and left hands



**Graph 3:** Percent frequency of radial loops in right and left hands



**Graph 4:** Percent frequency of ulnar loops in right and left hands

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## Impaction of Foreign Body in Upper Digestive Tract: Unravelling the Anatomical Perspective

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### Abstract

**Context:** A foreign body is any object in a region it is not meant to be, where it can cause harm by its mere presence and may require medical intervention if not spontaneously expelled from the body. Foreign bodies in the upper GI tract are usually swallowed, purposefully or accidentally which are more likely to be impacted at cricopharynx or esophagus. Present study identifies the pediatric population to be especially at a high risk of foreign body ingestion and our aim is to highlight the anatomical aspects contributing to this.

**Aims:** To identify the commonest site of impaction of foreign body in upper digestive tract and then study the causative anatomical factors leading to this.

**Methods and Material:** A Retrospective study conducted in the department of Otorhinolaryngology including previous records from 2014 onwards in tertiary care hospital of central India. A total of 160 patients of digestive tract foreign body were taken and categorized according to age, sex, site of impaction and type of foreign body.

**Results:** The foremost site of foreign body impaction is at Upper esophageal sphincter followed by upper 1/3<sup>rd</sup> of esophagus and commonest age group is 1-4 years.

**Conclusions:** Swallowing is not as coordinated and successful as in planned intake of bolus of food. This clearly affects the opening of UES leading to impaction of the foreign body at this commonest site followed by upper 1/3<sup>rd</sup> of esophagus and piriform fossa thereafter.

**Keywords:** Upper Esophageal Sphincter (UES); Cricopharynx; Foreign Body (FB); Piriform Fossa; Impaction; Pharyngeal Constrictors.

### Introduction

Foreign body in ear, nose and upper aero-digestive tract are common occurrences forming a large share of the emergencies dealt by the otorhinolaryngologists in a tertiary care hospital. Virtually any object small enough to pass through the pharynx may be swallowed. Items commonly ingested by children include coins, small toys, pencils, pens and their tops, batteries, safety pins, needles, hairpins (which are mainly radio-opaque), beads, pebbles and popcorn-kernels. Food-related items, such as fish, meat and chicken bones, are more often ingested by older

children and adults and tend to be radiolucent. In adults, dentures or parts from dentures can be swallowed accidentally. Psychiatric disorder, alcohol intoxication, developmental delay and secondary gain seeking behaviour favour true foreign body ingestion (i.e non-food objects) in adults [1].

The majority of ingested foreign bodies will pass spontaneously but those that are retained need to be diagnosed and managed accordingly. We aim to first identify the common sites for impaction or retention of foreign body after accidental ingestion in upper digestive tract and secondly to find the anatomical reasons for the same. In one study showing the distribution of aeroesophageal FB, 90% of patients had a retained FB, while it passes in the other 10% [2]. Approximately 80% to 90% of ingested FBs are passed spontaneously without complications [3-5]. Radiographic evaluation including soft tissue lateral neck radiograph and wide chest radiograph of neck and chest suggests the level of impaction and gives clues regarding shape, size and nature of the foreign body. Coin and battery cell are usually oriented

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coronally in the esophagus mostly at the level of cricopharynx [6]. (UES- upper esophageal sphincter)

The pharynx is a musculo-membranous tube extending from the base of the skull to the level of the sixth cervical vertebra where it is continuous with the oesophagus. The interior of the pharynx is divided into three parts- nasopharynx (epipharynx), oropharynx (mesopharynx) and laryngopharynx (hypopharynx). The pharynx acts as a common channel for both deglutition and respiration, because the food and air passages cross each other in this region.

#### *Dimensions of adult pharynx:*

Length – 12 to 14 cm

Width – Maximum of about 3.5 cm in the nasopharynx

Minimum of about 1.5 cm at the Pharyngo-oesophageal junction (UES)

Structure of the pharynx : The wall of the pharynx presents from outside inwards the following coats: areolar (buccopharyngeal fascia), muscular, submucous (pharyngeal aponeurosis) and mucous.

Muscular coat : It consists of striated muscles which are arranged in outer circular and inner longitudinal layers. The circular layer comprises superior, middle and inferior constrictor muscles; the longitudinal layer consists of three paired muscles: stylopharyngeus, palatopharyngeus and salpingopharyngeus [7].

## Materials and Methods

This is a retrospective study where data from January 2014 onwards till July 2017 was obtained from records of ENT department in tertiary care hospital in central India. We included 160 patients with history of accidental ingestion and impaction of foreign body in upper digestive tract specifically as per records in inpatient, outpatient and emergency care units referred to ENT department. These patients were categorized according to age, sex, site of impaction and type of foreign body which was then related to the anatomical factors contributing to such occurrences.

As per records, most of the foreign bodies were detected by plain X-ray chest AP and soft tissue neck lateral view along with X-ray barium swallow for radiolucent vegetative foreign bodies, plastic objects and mutton piece without bone. All foreign bodies were removed by rigid endoscopy under general anaesthesia and postoperative period was uneventful as per records.

## Results

Out of 160 patients studied, 109 were males and 51 were females. The age group of the patients varied from 1 to 60 years. Around 60% of patients were in the age group 1-4 years owing to higher cases of accidental ingestion of foreign body (Chart 1).

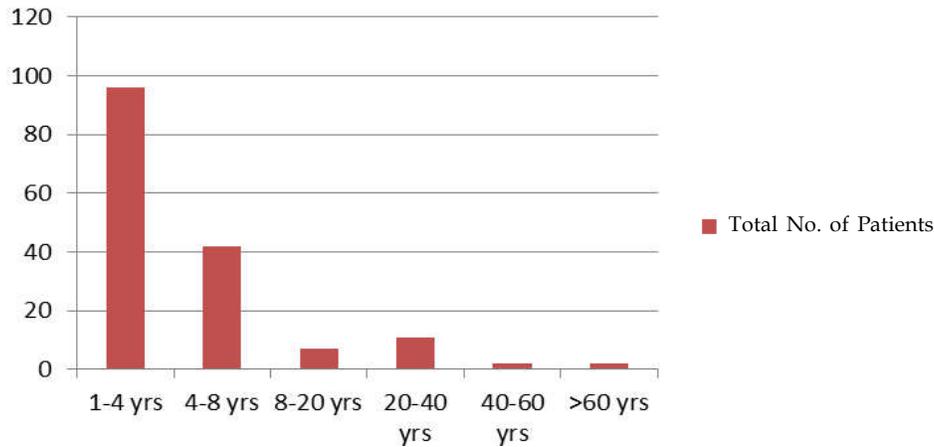
**Table 1:**

Site	Cases	Percentage
Piriform fossa	2	1.25%
Post cricoid	1	0.625%
Cricopharynx (UES)	138	86.25%
Upper 1/3rd esophagus	18	11.25%
Middle 1/3rd esophagus	1	0.625%
Lower 1/3rd esophagus	0	0.00

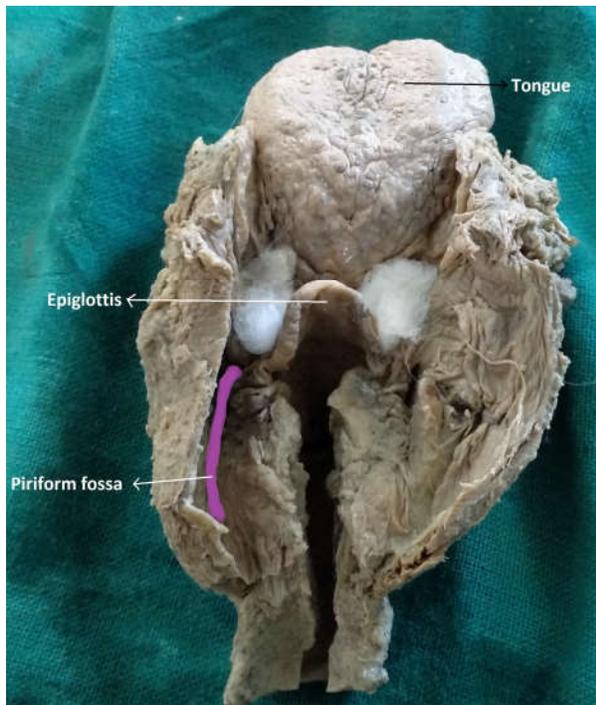
**Table 2:**

Type of foreign Body	Cases	Percentage
Age 0-20 years		
<b>Metallic object</b>	127	79.37
<b>Non-metallic Object</b>	18	11.25
Age 20-40 years		
<b>Metallic object</b>	02	1.25
<b>Non-metallic Object</b>	09	5.63
Age 40-60 years		
<b>Meat bone</b>	3	1.875
Age >60 years		
<b>Denture</b>	1	0.625

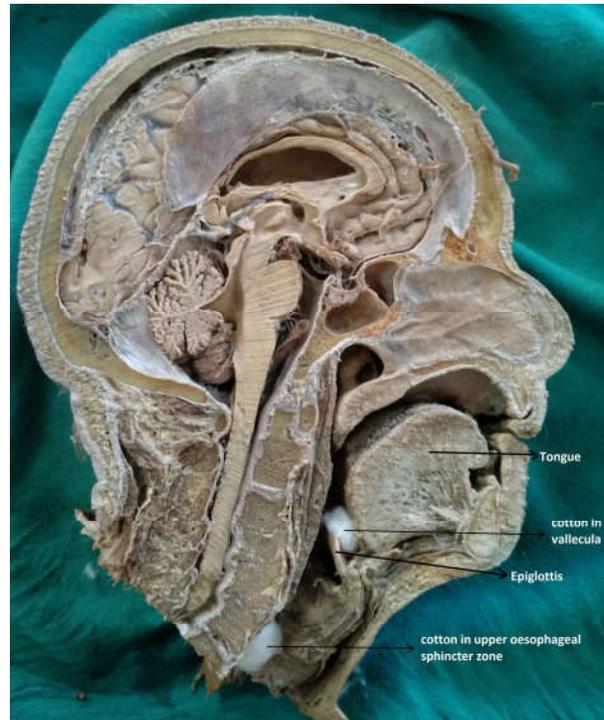
**Total No. of Patients**



**Chart 1:**



**Fig. 1:** Image of specimen of tongue, pharynx and larynx showing cotton placed in vallecula and extent of piriform fossa marked on the left side



**Fig. 2:** Image of sagittal section head and neck showing cotton placed in vallecula and upper esophageal sphincter zone

According to the data obtained; most common site of impaction was Cricopharynx (UES-upper oesophageal sphincter) in 86.25% cases followed by upper 1/3<sup>rd</sup> of oesophagus in 11.25% cases and piriform fossa in 1.25% cases. Solitary cases of impaction in post-cricoid region and middle 1/3<sup>rd</sup> of oesophagus were also reported. (Table 1).

In the age group 1-20 years, metallic foreign bodies were found more frequently (79.37% cases) including coins, batteries, safety pins, needles and hair pins

while non-metallic foreign bodies including plastic toys, pencils and vegetative seeds were found in 11.25% cases.

With advancing age, non-metallic foreign bodies were more commonly found in 5.63% of cases as compared to metallic foreign bodies in only 1.25% cases in the age group of 20-40 years. In the age group of 40-60 years, meat bones were found in 1.875% cases and a solitary case of denture impaction was reported in the age group >60 years. (Table 2).

## Discussion

Sphincters are found in the respiratory, genitourinary and especially alimentary tracts considering the complex changes of physical and chemical form which take place in ingested materials during their delayed passage from mouth to anus. It is this delay which is one of the essential functions of the alimentary sphincters [8]. Upper esophageal sphincter (UES) has also been referred to as the inferior pharyngeal sphincter because it is located at the lower end of pharynx and guards the entrance into the esophagus. It is the narrowest part of the alimentary tract (except for the vermiform appendix) and is constricted at the beginning (15 cm from the incisor teeth), It has two major functions: (1) to prevent air from entering into the esophagus during breathing and (2) to prevent reflux of esophageal contents into the pharynx to guard airway aspiration [9].

Anatomically, there are three well recognized sphincter mechanisms to be considered in the pharyngeal region of the gastro-intestinal tract. First, the palatopharyngeal sphincter which prevents the bolus from passing upwards into the nasopharynx while swallowing. Second, the larynx which prevents the inhalation of swallowed liquids and solids. And third the crico-pharyngeus which acts as an upper esophageal sphincter which relaxes to allow the bolus to pass into the esophagus. In our study it is this site where we found maximum number of cases (86.25%) presenting with foreign body impaction. This is also in accordance with the findings in the study conducted by Park SM, Chung MS, Choi JY, et al [10].

Considering from an anatomical point of view; we know that the constrictor muscles take limited origin from the front (bones, ligaments or cartilages) and possess expanded insertion behind in a median fibrous raphe extending from the pharyngeal tubercle at the basi-occiput to the pharyngo-oesophageal junction. Close to the insertion, the constrictors overlap one another from below upwards like the placing of three flower pots one within the other [7].

The superior constrictor constricts the upper part of the pharynx while the middle constrictor constricts the middle part of the pharynx during swallowing. The inferior constrictor is the thickest of the three constrictor muscles, and is usually described in two parts, thyropharyngeus and cricopharyngeus. Thyropharyngeus arises from the oblique line of the thyroid lamina, a strip of the lamina behind this, and by a small slip from the inferior cornu. Some additional fibres arise from a tendinous cord that loops over cricothyroid. Cricopharyngeus arises from the side

of the cricoid cartilage between the attachment of cricothyroid and the articular facet for the inferior thyroid cornu. It consists of a superficial upper oblique portion, the pars oblique, and a lower, deeper, transverse portion, the pars fundiformis. The upper part attaches to the median raphe while the lower part forms a circular band that lacks a median raphe. The area demarcated by the pars oblique and pars fundiformis of cricopharyngeus is termed Killian's dehiscence (or Killian's triangle). A second triangular area, Laimer's triangle, can be identified beneath cricopharyngeus between the longitudinal fibres of the oesophagus as they pass laterally on either side to attach to the cricoid cartilage: only the circular muscle of the oesophagus forms the wall here. Both triangles are postulated to be sites of weakness in the wall of the pharynx and oesophagus, and are therefore areas where diverticula could potentially form. Both cricopharyngeus and thyropharyngeus spread posteromedially to join the contralateral muscle. Thyropharyngeus is inserted into the median pharyngeal raphe and its ascending fibres surround the middle constrictor muscle where the lumen of the pharynx is widest however, descending from this point, the lumen decreases in size and is at its narrowest at the level of the circular fibres of the cricopharyngeus muscle [11]. This anatomical difference is functionally highlighted during the act of swallowing where in the middle constrictor muscle and the thyropharyngeal part of the inferior constrictor act as propulsive muscles for the bolus, while cricopharyngeus acts as the sphincteric part of the muscle that relaxes to allow the passage of the bolus into the oesophagus.

Thyropharyngeus constricts the lower part of the pharynx. Cricopharyngeus is the main component of the upper oesophageal sphincter, or pharyngoesophageal high-pressure zone, the other parts being thyropharyngeus and the proximal cervical oesophagus. (The extent to which the lower fibres of thyropharyngeus and the upper fibres of the oesophageal musculature are involved in closing the upper end of the oesophagus appears to depend on the physiological state, whereas cricopharyngeus always participates in closure). The upper oesophageal sphincter is defined manometrically as a region of elevated intraluminal pressure, 2-4 cm long, located at the junction of the hypopharynx and cervical oesophagus. Normal UES pressure is approximately 100mm Hg in the antero-posterior direction and approximately 50mm Hg laterally. UES pressure is distributed predominantly in the anterior-posterior directions; lateral pressures are about 33% of the anterior-posterior ones [9].

Cricopharyngeus contains about 40% of endomysial connective tissue, much of which is elastic, but it lacks muscle spindles. It contains both slow-twitch type I and fast-twitch type II fibres, a structural arrangement that underpins the various functions of the upper oesophageal sphincter, i.e. maintaining constant basal tone, yet being able to relax and contract rapidly during swallowing, belching and vomiting. The tonic activity of cricopharyngeus between swallows prevents influx of air during inspiration and tracheobronchial aspiration and pharyngeal reflux of oesophageal contents during oesophageal peristalsis [12].

Swallow-induced relaxation of the UES lasts for 0.32–0.5 seconds and is directly related to the bolus volume [13]. Two distinct events are responsible for the swallow-induced relaxation of UES: (1) cessation of tonic discharges of the motor neurons of nucleus ambiguus and (2) anterior and superior lift of the hyoid, cricoids, and UES by the contraction of suprahyoid muscles. Cessation of motor neuron discharges causes UES relaxation which is seen as the cessation of EMG activity in the cricopharyngeus and thyropharyngeus muscles. A residual UES pressure of 10–15 mm Hg [14], following cessation of the EMG activity in these muscles, is because of the viscoelastic properties of muscle and surrounding structures. The residual UES pressure is ablated by a forceful superior (2.5 cm) and anterior (0.75 cm) stretch exerted on the UES by contraction of suprahyoid muscles (geniohyoid and mylohyoid), which results in the UES opening. Extent of UES opening is related to bolus volume and bolus pressure. UES during a swallow is described as a grabber because it ascends to grab the bolus and then descends with it.

It is well known that the esophagus has four areas of physiological narrowing. Apart from the earlier mentioned upper esophageal sphincter; the others include: eminence of the aortic arch (22.5 cm from the incisor teeth), the left main bronchus (27.5 cm from the incisors), and the lower esophageal sphincter (40 cm from the incisors) [11]. The esophageal stage of swallowing is achieved by sequential contractions of the circular and longitudinal esophageal muscles which are controlled by medullary swallowing centers via vagus nerve. The anatomical constrictions accompanied by functional disturbances in sequential contractions may be responsible for the upper 1/3<sup>rd</sup> oesophagus being the 2<sup>nd</sup> commonest site of foreign body impaction in our study.

Also lateral to epiglottis are the pharyngo-epiglottic or lateral glosso-epiglottic folds which are regarded as forming the upper boundary of the hypopharynx and beneath the level of these folds the hypopharynx

expands antero-laterally between the inner surface of the thyroid cartilage and the postero-lateral surfaces of the arytenoid and cricoid cartilages. These bilateral expansions are the piriform sinuses, recesses or fossae. Closure of laryngeal inlet during deglutition takes place by the apposition of the aryepiglottic folds due to the contraction of aryepiglotticus muscles. These aryepiglottic folds forming the medial boundary of the piriform fossa are kept upright by the backward pull of posterior crico-arytenoids on the arytenoid cartilages and the cuneiform cartilages acting as a passive prop [7]. It is probably reasonable to assume that the sequence of events that close the glottis may alter according to the type of swallow and consistency of the bolus. The sequential contraction by the constrictors of pharynx including propulsive force by the base of tongue may facilitate clearance ('stripping') of the pharyngeal walls and piriform sinuses. If this is so, residues that remain in the vallecula must reflect inadequate tongue force generation at the end of the oral phase of swallowing. Foreign bodies not infrequently lodge here and this is the 3<sup>rd</sup> commonest site of foreign body impaction in our study. In accidental ingestion swallowing is not as coordinated and successful as in planned intake of bolus of food. This clearly affects the opening of UES leading to impaction of the foreign body at this commonest site followed by upper 1/3<sup>rd</sup> of esophagus and piriform fossa thereafter. The entire process of swallowing is closely coordinated through the medullary swallowing centres [15].

In the adult, the tip of the epiglottis is significantly lower than the inferior edge of the soft palate while in the neonate, the larynx is high in the neck and the epiglottis may extend above the soft palate so that the laryngeal airway is in direct continuity with the posterior nares in neonates. The pediatric population shows a higher propensity of placing every object in their mouth due to their inquisitive nature besides contributory factors like playing, boredom, imitation, crying, laughing and immature swallowing coordination. Mental retardation, insanity, attention deficit disorder along with availability of objects and absence of watchful caregivers further enhance instances of foreign body ingestion in children [16].

The presenting symptoms were sudden onset dysphagia to solids, pain in throat, vomiting, epigastric pain, cough, dyspnea, stridor and mild distress as per case history records in our study. Impaction of a foreign body in the esophagus causes edema of the mucosa, and the esophageal wall becomes weakened. Retention leads to perforation, which is only a matter of time. Therefore, all foreign bodies retained in the esophagus should be removed

as soon as diagnosed [17,18]. The upper esophageal sphincter (UES) is located at the level of C5-C6 [19] as reflected in the sagittal section (Figure 2). The cricopharyngeus, attached to the posterior laminae of the cricoid cartilage is considered responsible for the sling effect that results in a high pressure zone at the esophageal opening.

### Conclusion

Commonest site of impaction of foreign body in upper digestive tract in humans is the upper oesophageal sphincter zone followed by upper 1/3<sup>rd</sup> of esophagus and piriform fossa thereafter. The opening of the UES due to its active relaxation from the usually tonic cricopharyngeus is a vital step in preparing to convert the pharynx into a majorly swallowing pathway before the beginning of the pharyngeal stage in anticipation of the arrival of a food bolus. So during accidental ingestion of a foreign body, the medullary control in preparing the pharynx for swallowing is not as coordinated and successful as in planned intake of bolus of food.

### Acknowledgement

Nil

### Conflict of Interest

None

### Key Messages

Anatomical dimensions and constitutions of the upper esophageal sphincter zone along with medullary control of swallowing are the major determining factors for impaction of accidental ingestion of foreign body in upper digestive tract in humans.

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## Measurement of Bowing of Radius in Dry Bone

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### Abstract

Radial architecture is unique with curvature or bowing, and is of importance in normal range of rotation of the forearm. Radial bow is two dimensional but is apparent in coronal plane. Any alteration in bowing will affect proximal and distal radio ulnar articulations and hence forearm rotations. Mild changes in bowing are difficult to recognize when compare to axial and translational changes. Changes in curvature can occur following fractures, traumatic bowing and green stick fracture in children. Maintenance of bow is of utmost importance in surgical management of fractures involving radius. In 1992 Schemitsch and Richards described a method to measure radial bowing on radiographs. A radiograph of anterior-posterior view of forearm in full supination was taken and radial bow was measured using three parameters. In the present study we tried to apply similar measurement on dry bone radius of Indian population. There are studies on measurement and quantification of radial bowing using radiographs of forearm, but no studies available on dry bones. The mean value of site of maximum bow was 46.668% (SD±3.219%) of length of entire bow. The mean value of magnitude of bow was 5.0472% (SD±0.6393%) of length of entire bow. The length of entire bow of the radius and the site of maximum bowing and magnitude of bow are strongly correlated. The magnitude of bow is within 7% of entire length of bow. This is the first study of bowing of radius on dry bones.

**Keywords:** Radial Bow; Site of Maximum Bow; Dry Bone Radius; Schemitsch EH; Richards RR.

### Introduction

Supination and pronation movements of forearm takes place between radius and ulna. This rotational movement takes place around the axis passing through head of the radius and head of the ulna. Distal end of radius moves around the head of the ulna, while proximally head of the radius rotates within the annular ligament [1]. Radial architecture is unique with curvature and is of importance in normal range of rotation of forearm. Radial curvature is three dimensional but is apparent in coronal plane. There are two curves in coronal plane, a small proximal curve with medial convexity and large curve with lateral convexity in mid portion. This large curve is referred to as radial bow [2]. Any alteration in this

bowing can affect proximal and distal radio ulnar articulations and hence the normal forearm rotations [3,4]. Mild changes in bowing are difficult to recognize when compared to axial and translational changes. Changes in curvature of radius can occur following fractures, traumatic bowing (also known as bow fractures or plastic deformation) and green stick fractures in children [2,3]. Radial bowing is of functionally important morphological feature. Normal range of supination 61°-66° and pronation is 71°-77° [1].

In 1992 Schemitsch and Richards developed a method to measure radial bowing using radiographs. For the assessment of radial bow an antero-posterior view of fore arm in neutral rotation was taken and three parameters were measured from the radial radiograph. They used the measurements to determine the relationship between restoration of function (movements) of forearm to restoration of normal amount and location of anatomical bowing of the radius after plate fixation of fractures of both bones of forearm [4]. Morphology of radius with respect to bowing is very important for its function. In the clinical practice this is assessed based on movement and radiologically. There are few

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radiological studies on radial bowing in relation to fracture treatment and functional outcome.

In the present study we tried to apply similar measurement on dry radius bones. Knowledge of dry bone measurement of bowing of radius is significant since maintenance of normal amount of bow is of utmost importance in surgical management of fractures involving radius to restore normal function. This is the first study on dry bone radius available on magnitude and site of bowing.

Radius has curvatures in coronal and sagittal planes. In 2012 a study by Shavantha L. Rupasinghe, has shown that there is a significant sagittal bow of the proximal shaft of the radius. The author described that plating this with contoured plates in the sagittal plane improves rotation when compared with straight plates [5].

But most of the studies including this study, the radial bow is measured in coronal plane. The kinematics of the forearm is complex and their study requires sophisticated techniques [6].

## Materials and Methods

For this study, we used 105 dry radii which were available in our department and from our students. Deformed, mal united bones were excluded from the study. Digital vernier caliper and a metal scale are used for the measurements. We adopted Schemitsch and Richards's method on dry bone in our study. The bones are numbered and three points marked (Figure 1a), as

1. Distal point- which is on the proximal articular margin of distal radio-ulnar joint facet. (Figure 1b),
2. Medial highest point over the radial tuberosity.
3. Point of maximum bowing over medial margin of radius.

Then radius is placed on a horizontal platform/surface with the dorsal aspect facing upwards (pronated position). Metal scale is placed as a line

between distal point (point 1) to radial tuberosity (point 2).

*Following measurements are taken*

- Length of entire bow (y) - is the distance between point 1 and point 2.
- Maximum radial bow (b) - is the perpendicular distance from point 3 to scale.
- Distance to site of maximum bow (x) from radial tuberosity - is the distance between point 2 and point 3.

To compare bones of different length the values are expressed as percentage of length of entire bow. The distance to site of maximum bow(x) is expressed as % of length of entire bow(y) =  $(x/y) * 100$ . This is termed as site of maximum radial bow. The maximum radial bow (b) is also expressed as % of length of entire bow(y) =  $(b/y) * 100$ . This is termed as magnitude of bow. The measurements were statistically analysed using 'Minitab@ 17.1.0, © 2013 Minitab Inc. The data were checked for its distribution analysis using Anderson's Darling test. All the data were presented as Mean and standard deviation (SD) or median with Interquartile ranges (IQR). A Pearson's correlation tests were attempted to find out the association between the numerical variables of radius. A probability, P of <0.05 was considered as statistically significant.

## Results

The comprehensive lists of statistical averages of radius bone are detailed in Table 1.

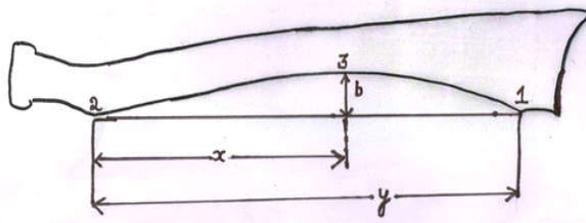
The mean value of length of entire bow of the radius (y) is 195.15 mm (SD ±13.01mm). The mean value of site of maximum bow was 46.668% (SD ±3.219%) of length of entire bow. The mean value of magnitude of bow was 5.0472 % (SD ±0.6393%) of length of entire bow. The data was analysed using Anderson Darling test. The results showed the data as non normal distribution (Figure 4).

**Table 1:** The anatomical details of the radial bone. The data are in mm of statistical averages or in percentages (N=105, SD= Standard deviation, IQR= Interquartile range)

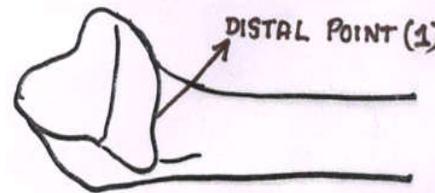
Variable	Mean	SD	Minimum	Maximum	Median	IQR
Length of entire bow Y ( mm )	195.15	13.01	160	228	197	19
Distance to site of maximum bow x (mm )	91.105	8.984	70	109	90	13
Maximum radial bow b ( mm)	9.844	1.372	7.2	13.34	9.56	1.78
Site of max bow (%)	46.668	3.219	40	53.846	46.429	4.35
Magnitude of bow (%)	5.047	0.639	3.990	6.67	4.9514	0.952

**Table 2:** Values of radial bow from the different age groups and by different methods

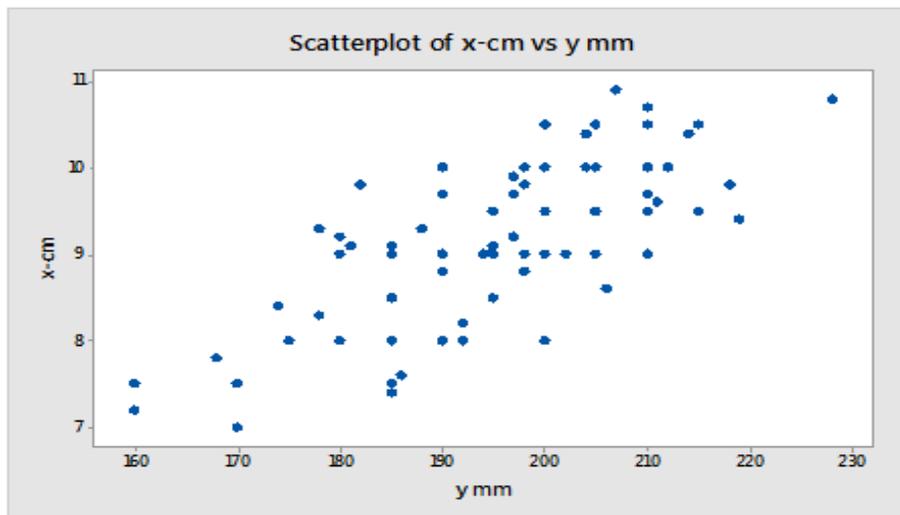
Study	M.Firl&L.Wunsch (radiographic study)	Schemitsch&Richards (radiographic study)	Present Study (dry bone study)
Number	100	55	105
Site of Max. Bow (Mean, SD%)	60.39 (3.74)	59.9 (0.7)	46.67(3.219)
Max. Bow (Mean, SD, %)	7.21 (1.03)		5.047(0.639)
Age Group	paediatric	adult	adult



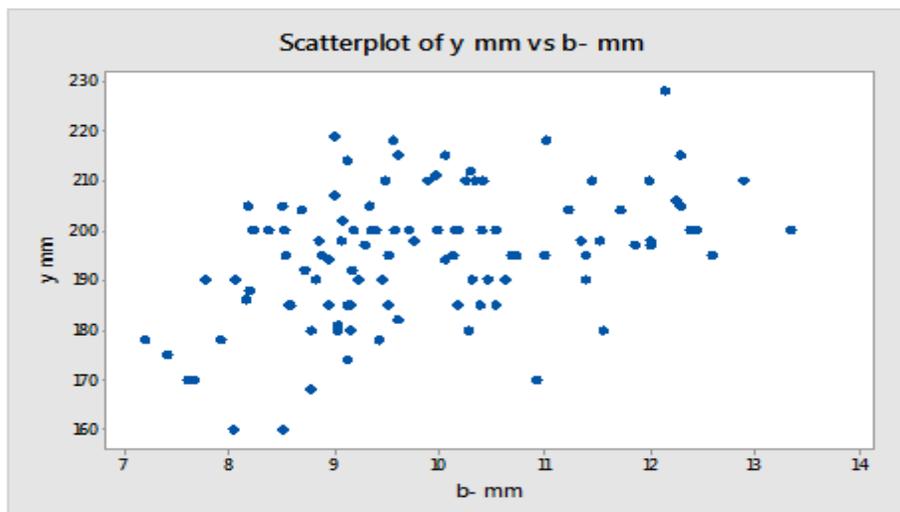
**Fig. 1a:** Points of markings and measurements of radial bow



**Fig. 1b:** Distal end of radius showing distal radioulnar articular facet



**Fig. 2:** Scatter plot showing the correlation between the length of the entire bow(y) to the distance to site of maximum bowing (x)



**Fig. 3:** Scatter plot showing the correlation between the lengths of the entire bow(y) to magnitude of bow (b).

A correlation was attempted between the length of entire bow(y) of radius and bowing dimensions. A 'Pearson correlation' test revealed the strong relation of dimensions to each other. Therefore, we observed as the length of entire bow(y) increases, the maximum radial bow (b) also increases. (Correlation: y-mm versus b-mm, Pearson correlation = 0.411, P-value = 0.000, Figure 3). Similarly, we also correlated the length of the entire bow(y) to the distance to site of maximum bowing (x). Here, too a similar correlation was found between the two variables (Correlation: y mm, x-cm, Pearson correlation,  $r = 0.721$ , P-value = 0.000, Figure 2).

### Discussion

Radius is one of the two bones of the forearm, placed laterally to ulna. It has expanded proximal and distal ends. The shaft is convex laterally and concave anteriorly in its distal part. It is triangular in section with sharp interosseous border [1]. Anterior surface, between anterior and interosseous borders, is concave transversely and shows a distal forward curvature. It moves around ulna during supination, pronation around an axis running between head of the radius and head of the ulna. Distally radius articulates with carpal bones to form wrist joint [1]. In the forearm radius articulates with ulna at distal radio-ulnar joint, proximal radio ulnar joint and through interosseous membrane. Weight/force transmit through radius from wrist to elbow. Supination, pronation movement takes place between the two bones. This is possible because of architecture of radius, which has three dimensional curvatures along its long axis. Kinematics of this movement is complex. Any alteration of the bowing will affect its articulation with ulna and in turn the rotatory movements between them. In the anatomical position (in anterior posterior view) that is in coronal plane radial bow is more obvious. There are radiological studies on quantification of radial bow and its affect on forearm rotations.

In 1992, Schemitsch and Richards were the first authors to describe the normal values of radial bow in adults using the measurements from antero posterior radiograph of both forearms. They developed a technique to measure the amount of bow of radius and to determine the relationship between restoration of functions (movements) and restoration of anatomical bowing of the radius after plate fixation of fractures of both bones of forearm. They compared the bowing of normal forearm with the surgically corrected opposite forearm and observed

that better results were found after plating if the degree of bowing approached normal. They suggested that location of maximum radial bow was of greater functional importance than the depth of the bow (magnitude of bow). Shape of the radius changes by both site of maximum bow and depth of bow [4].

In 2004, Firl and L.Wunsch modified the method used by Schemitsch and Richards and described values of radial bowing in the Antero posterior radiographs in children. From their study they found that radial length (length of entire bow) and the maximum radial bow increases with age. But the site of maximum bowing does not change. The median site of maximum radial bow was 60.39% (SD±3.74%). The maximum bowing did not exceed 10% of entire bow length. Their study result was similar to that of Schemitsch and Richards. Measurement of radial bowing in children can be used for diagnostic and therapeutic purpose [3].

Our study was done on dry bones of Indian population to determine the normal values of radial bow. We found that the mean length of entire bow is 195mm (SD±13.01mm). The mean of magnitude of bow is 5.0472% of length entire bow. The site of maximum bow is 46.668% of length of entire bow. Site of maximum bow was within 54% of length of entire bow. Maximum bow is less than 7% of bow length. Our study gives similar inference as that of radiological studies (Table 2). But radiological measurement of bowing cannot be compared with dry bone measurement. There will be difference in the rotational position of radius in complete supination in living human being as compared to dry bone on horizontal plane.

Knowledge of dry bone measurements would be of importance for clinicians during surgical correction and plating of radial fractures since the functional outcome would depend on the near normal restoration of radial bow. Our observation during the study is that the site of maximum bow is at or close to the site of insertion of pronator teres. This shows that pronator pull act at the apex of the bow for maximum efficiency.

### Conclusion

Site of maximum bow of radius is in constant relation to length of entire bow. Maximum bow is within 7% of length of entire bow of radius. More dry bone of studies of different population is required to standardize the results.

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## Study of Various Sacral Indices for Sexual Dimorphism in Sacrum

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### Abstract

Determination of sex is an integral first step in the development of the biological profile in human osteology. The general anatomical regions used for sex determination are the pelvic girdle, skull and long bones, although other bones have also been utilized [1]. The developmental age changes are different in male and female bones including sacrum [2]. The pelvic girdle is the most accurate area to determine sex and methods using the pelvic girdle tend to make successful predictions in 90 to 95 percent of individuals [3]. In our study 100 sacra of both sexes were compared for Body of First Sacral Vertebra (S1), sacral index, curvature index and auricular index. The results show Index of Body of First Sacral Vertebra (S1) in male is 62.53 and in females it is 54.74. Sacral Index in male is 97.45 and in females it is 101.49. One way ANOVA shows 0.001 significance suggesting statistically highly significant difference in male and female for both sacral index and Index of Body of First Sacral Vertebra (S1). Curvature Index in male is 100.57 and in females it is 99.33. One way ANOVA shows f value as 3.650 which was statistically significant. Auricular index in male is 51.34 and in female it is 50.11. One way ANOVA shows f value as 1.037 which was not significant statistically. The results show that Index of Body of First Sacral Vertebra (S1), Sacral index and curvature Index are more reliable parameters than auricular index for sexual dimorphism assessment.

**Keywords:** Sacrum; Sexual Dimorphism; Parameters; Sacral Index; Index of Body of First Sacral Vertebra (S1); Curvature Index; Auricular Index.

### Introduction

The sacrum is a large, triangular bone of pelvis. It is present on the postero-superior wall of the pelvic cavity, wedged between the two innominate bones. It is formed by fusion of five vertebrae [4].

Sexual dimorphic characters can be studied both morphologically and metrically in the determination of personal individuality from adult human skeletal remains. The sacrum has always attracted the

attention of medicolegal experts for establishing the sex due to its contribution to the pelvic girdle and associated sex differences, which are augmented due to reproductive functions, mainly influenced by sex hormones [5].

The female sacra are shorter and wider and make the pelvic cavity broad. By measuring the length and width of sacrum, sacral index can be calculated and on the basis of this index, the sacrum can be divided into three groups (vide Wilder's manual of Anthropometry).

The three groups were Dolichohieric: sacral index < 100 (up to 99.99), Sub-plathyhieric: sacral index 100-106, Plathyhieric: sacral index > 106. It is observed that a very little work is done on sacrum [6], hence; the present work is an attempt to establish role of various parameters and indices like sacral index, index of body of first sacral vertebra, curvature index and auricular index which will be of great help in sex determination in anthropometric & medico legal study, of a defined area over a period of time.

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## Material and Method

The present study was carried out at Department of Anatomy, Government medical college Aurangabad and MGM medical College, Aurangabad. Approval was obtained from Institutional Ethical committee.

Written permission was taken for collection of 100 sacra of both the sexes from HOD Department of Anatomy, Govt. Medical College and MGM medical College, Aurangabad. Non ossified and fragmented sacra were excluded from the study.

The sliding Vernier caliper with scale graduated from 0 to 150 mm of Mitutoyo absolute digimatic company, made in Japan was used to measure minimum Sacral width, maximum Sacral width, transverse diameter of body, Antero-Posterior Diameter of Body of First Sacral Vertebra, Straight Length, Length of Auricular Surface. Mid Ventral Curved Length was measured by standard measuring tape.

1. Maximum sacral width: The straight distance between two points at the lateral most part of alae of sacrum.
2. Minimum sacral width: Minimum transverse distance measured midpoint of fourth and fifth sacral vertebra, near the apex.  
Width of sacrum was calculated by taking average of maximal and minimal sacral width.
3. Transverse diameter of the body of the first sacral vertebra was measured by taking one point on each side of the lateral most point on the superior surface of the body of first sacral vertebra.
4. Antero-Posterior Diameter of Body of First Sacral Vertebra was measured by taking one point on the antero-superior border and other on the postero -superior border and was measured by Vernier caliper.
5. Straight Length: It was measured along the midline of sacrum with the Vernier calliper from

the middle of the antero-superior margin of sacral promontory to middle of antero inferior margin of last sacral vertebra.

6. Mid Ventral Curved Length: It was measured It was measured by using the flexible Ribbon tape along the ventral concave median length in centimeters from midpoint of sacral promontory to the midpoint of apex of sacrum.
7. Length of Auricular Surface: It was measured on lateral aspect of sacrum. One point is on the uppermost part of auricular surface and second on its lower most part .The mean length of two sides is taken as maximum length of auricular surface.
8. Indexing: Sacral Index, Index of Body of First Sacral Vertebra (S1), Curvature Index, Auricular Index were calculated by formulas [3] given below-

1. Sacral Index=

$$\frac{\text{Width} \times 100}{\text{StraightLength}}$$

2. Index of body of 1st Sacral vertebra =

$$\frac{\text{AP Diameter of body of S1} \times 100}{\text{Transverse dia. of body of S1}}$$

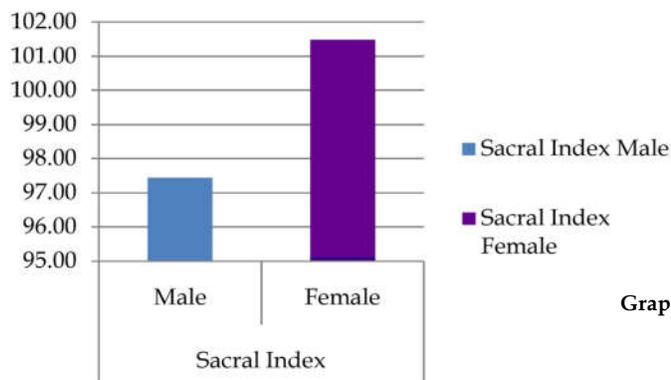
3. Curvature Index=

$$\frac{\text{StraightLength} \times 100}{\text{Mid Ventral Curved length}}$$

4. Auricular Index=

$$\frac{\text{Length of auricular surface} \times 100}{\text{Width of Sacrum}}$$

The parameters and indices were analysed statistically by using SPSS 19 software and compared for multivariate analysis.



Graph 1: Sacral Index

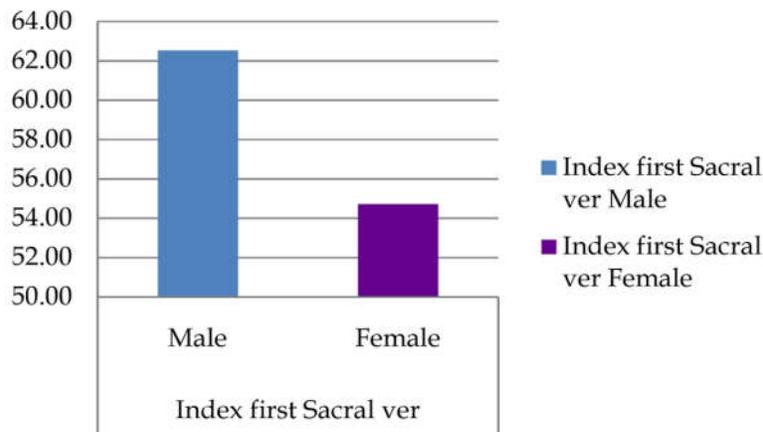
**Table 1:**

Parameter	Sex	Mean $\pm$ SD	ANOVA(f)	p value
Sacral Maximum width (mm)	Male	106.46 $\pm$ 6.08	22.918	0.000***
	Female	98.00 $\pm$ 10.72		
Sacral minimum width (mm)	Male	61.49 $\pm$ 8.49	3.446	0.66 (NS)
	Female	57.94 $\pm$ 9.98		
Transverse Diameter of Body of First Sacral Vertebra (mm)	Male	48.57 $\pm$ 5.61	29.362	0.000***
	Female	41.20 $\pm$ 7.53		
Antero-Posterior Diameter of Body of First Sacral Vertebra (S1) (mm)	Male	30.13 $\pm$ 3.27	49.824	0.000***
	Female	22.69 $\pm$ 7.07		
Straight Length (mm)	Male	108.30 $\pm$ 8.86	39.547	0.000***
	Female	95.19 $\pm$ 13.24		
Mid Ventral Curved Length (mm)	Male	109.61 $\pm$ 10.16	27.722	0.000***
	Female	97.12 $\pm$ 9.34		
Length of Auricular Surface (mm)	Male	54.50 $\pm$ 5.07	35.570	0.000***
	Female	49.07 $\pm$ 4.58		
Sacral Index	Male	97.45 $\pm$ 7.09	11.168	0.001***
	Female	101.49 $\pm$ 11.59		
Index of Body of First Sacral Vertebra (S1) (mm)	Male	62.53 $\pm$ 10.40	11.776	0.001***
	Female	54.74 $\pm$ 14.32		
Curvature Index (mm)	Male	100.57 $\pm$ 8.39	3.650	0.049**
	Female	99.33 $\pm$ 10.91		
Auricular Index (mm)	Male	51.34 $\pm$ 4.92	1.037	0.311 (NS)
	Female	50.11 $\pm$ 7.33		

\*\*\* - statistically highly significant

\*\* - statistically significant

NS - not significant

**Graph 2:** Index of Body of First Sacral Vertebra (S1)

## Result

The mean, standard deviation and test of significance were calculated from the data by using SPSS version 19 for the identification of sex using the parameters mentioned above.

It is observed that mean of sacral maximum width in male is 106.46 and in females it is 98.00 this shows that sacral max width is more in males as compared to female. Sacral minimum width in male is 61.49 and in females it is 57.94 this shows that sacral

minimum width is more in males as compared to female though not significant statistically.

It is observed that mean of Transverse Diameter of Body of First Sacral Vertebra in male is 48.57 and in females it is 41.20 this shows that Transverse Diameter of Body of First Sacral Vertebra is significantly more in males as compared to female. The mean AP diameter of First sacral vertebra in male is 30.13 and female is 22.69mm with the difference being statistically highly significant. The mean ventral straight maximum length (straight length) in male is 108.30mm and in female is 95.19mm. The difference

between both sexes is statistically significant. Mean Mid-ventral curved length was 109.61 in male and 97.12mm in female with the difference being statistically highly significant. Mean length of auricular surface in male was 54.50 and 49.07 in female sacra. The difference was found to be highly significant.

## Discussion

Determination of sex is an integral first step in the development of the biological profile in human osteology. In present study most of the parameters show significant sexual dimorphism.

The parameters like sacral maximum width, sacral minimum width, ventral straight length, mid ventral curved length, transverse and AP diameter of body of first sacral vertebra, maximum length of auricular surface show significant variation in male and female sacra. Indices like Sacral index, Index of body of first sacral vertebra and curvature index showed statistically significant variation in male and female sacra and can be successfully utilized for sexing of the sacrum.

In the present study the mean sacral index in male sacra, is higher than that of Gray's Anatomy [4], Charnalia [7], Flander [8], Kothapalli [9] and lower than that Bagde [10], Vinod Kumar et. al [11], Jana et. al [12], Singh et al [13], S.S. Dapate [14] and Shailja Math [15]. Present study is comparable with Raju et al [16] and Kanika et al [17].

The mean sacral index in female sacra in present study is higher than that observed in Grays anatomy [4], Charnalia [7], Flander [8], Raju et. al [16], Bagade [10], Shailja Math [15], Kanika et. al [17], Kothapalli [9].

Present study is comparable with studies by Singh et. al [13], Jana et. al [12], vinod kumar et. al [11], Flander [8], S.S. Dapate [14] and Mazumdar et. al [18].

Index of body of 1<sup>st</sup> sacral vertebra is significantly higher in males as compared to females in our study. When compared with other studies mean Index of body of first sacral vertebra in male is higher than the studies by S.S. Dapate [14], Kothapalli et. al [9] and Mazumdar et. al [18], and it is lower than study done by Shailja Math [15].

The result in present study was almost equal with studies by Raju et. al [16] and with Bagde [10]. Mean Index of body of first sacral vertebra in female was found to be lower than the studies by Raju et. al [16], Bagde [10], S.S Dapate [14], Shailja Math [15], kothapalli [9] and Mazumdar et. al [18].

In present study mean curvature index in male and female was found to be higher than studies by Kanika et. al [17], Mazumdar et. al [18], Kothapalli et. al [9] and Shreekrishna HK [19]. In present study mean Auricular index is found to be lower than that the study done by Kothapalli [9] in case of both male and female.

Sacral parameters like sacral index, Index of body of first sacral vertebra, curvature index in our study are more significant parameters than auricular index for sexual dimorphism in sacra.

## Conclusion

The present study has very significant role to determine appropriate indices of sexual dimorphism for sacral bone. The study concludes that no single index can identify sex of sacrum accurately so we suggest use of multiple indices for sex determination of sacral bone over any single index.

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## Schizencephaly: A Neuronal Progression Disorder

Junagade Bhavana S.<sup>1</sup>, Sabnis Anjali S.<sup>2</sup>

### Abstract

Schizencephaly is a congenital cleft in cerebral mantle extending from pial surface to the lateral ventricle. It is lined by heterotopic grey matter. It is rare, with a prevalence of 1.48/1,00,000 births. In this case study, adult female brain specimen showed unilateral open lipped cleft - schizencephaly, in the left hemispheric perisylvian region communicating with the left lateral ventricular cavity. Cleft was lined by heterotopic grey matter. Schizencephaly is considered as the neuronal progression or migration disorder. It is also thought to be a brain segmentation disorder. This disruptive birth defect may have ischaemic - vascular injury at its root or it could be a presence of infection like Cytomegalo virus. Mutations in Homeobox gene EMX2 have been also implicated in this congenital anomaly. Our study indirectly confirms that unilateral cases of Schizencephaly may lead long life remaining undiagnosed till death.

**Keywords:** Unilateral Cerebral Cleft; Perisylvian; Open Lipped Cleft; Heterotopia.

### Introduction

Schizencephaly is a rare congenital disorder in which there is a cleft in cerebral mantle from pial surface to lateral ventricles. Such clefts are lined by heterotopic grey matter. It is of two types - closed lip and open lip, depending upon relation of the cleft with the lateral ventricle.

Any abnormality in the process of cortical neuronal migration results in various congenital anomalies like agyria, polymicrogyria, schizencephaly, lissencephaly. [1]

### Case Report

We came across this brain from adult female cadaver, around 45 years old, while working on museum specimens.

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The specimen showed presence of type II - unilateral left side open lip schizencephaly.

Cleft involved frontal and parietal lobes (precentral and postcentral gyurs), above posterior ramus of lateral sulcus (Perisylvian), in the territory of middle cerebral artery.

The surface opening was large, circular with average diameter of 55.28 mm. [Figure 1- line A]

The communication with the lateral ventricle was smaller, circular with average diameter of 14.76 mm. [Figure 1 - line B and Figure 2]

The cleft was 27.5 mm deep occupying full thickness of hemisphere from surface to ventricle.

The cleft was medium size being slightly more than 1/3<sup>rd</sup> of the length (frontal to occipital pole) of the left hemisphere (150 mm).

The cleft was lined by heterotopic cortical grey matter extending up to ventricle.

There was complete absence of septum pellucidum. Normalcy of optic nerve could not be commented upon. Corpus callosum was present. Flattening of pyramid of medulla oblongata was observed on the left side.

Samples from lip and subependymal region of the cleft were stained with 'Luxol fast blue and Cresyl violet' stain. Heterotopic cortical grey matter was found in subependymal region.

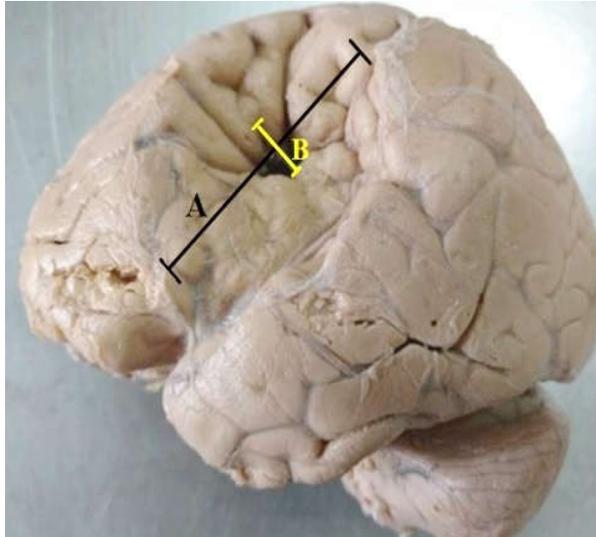


Fig. 1: External view of the left open lip cleft, Line A-surface opening, Line B-ventricular opening

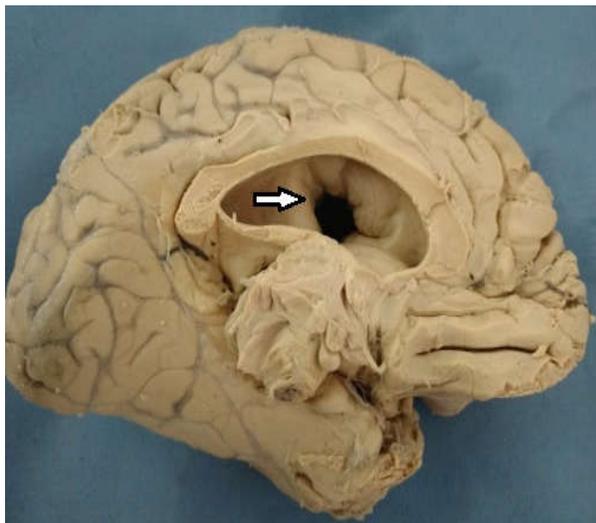


Fig. 2: Ventricular view of the left open lip cleft, White arrow-pointing to the ventricular opening

## Discussion

Schizencephaly is a rare congenital brain anomaly, with a prevalence of 1.48/1,00,000 births [2].

It presents as a cleft in the cerebral mantle extending from the pial surface to the lateral ventricles. The cleft is lined by heterotopic grey matter [3].

*It is of 2 types -*

**Type I** is closed lipped with edges of cleft appearing to be fused at pial-ependymal seam.

**Type II** is open lipped with widely separated cleft communicating with the lateral ventricle and lined by heterotopic grey matter.

In 70% of the cases it involves frontal and parietal lobes around central sulcus [4].

Causative developmental mechanism of schizencephaly is poorly understood and heterogenous.

Normally the cerebral cortex develops from the roof and lateral walls of the telencephalon. Neural development is said to be a longitudinal assemblage along a spatial grid at a specific time.[3]

The whole process of the human cortical development can be divided into five stages like, neuronal precursor proliferation at the ventricular zone, neuroblast departure from the ventricular zone, neuroblast migration, migration arrest, and neuronal organization.[5]

The cell migration starts in eighth week and continues for two months, mostly getting over in sixteenth week. After this, there is cell migration in smaller waves stretching up to 25 weeks [6].

To establish boundaries of various areas of forebrain, OTX 1, EMX1 and 2 are expressed in overlapping pattern in the future forebrain region of neural plate [7].

One of the causes of cleft formation can be failure of regional specification of clones of cells in germinal matrix of future cerebral cortex. It could also be vascular disruptive birth defect occurring early in gestation at critical time of neuronal development, but before end of neuronal migration [3].

Cortical mantle development flaws of cell migration in the first trimester or an encephaloclastic process due to ischaemic injury in middle cerebral artery distribution, in the third trimester (31 to 35 weeks) have also been suggested as a cause for cleft formation [8].

Causative agents could be teratogens like warfarin, alcohol or cocaine [3].

Cleft formation has also been associated with infections from Cytomegalo virus and Herpes virus.

Familial cases of schizencephaly suggest genetic factor. Commonly implicated factor is a germline mutation in homeobox gene EMX2 [8]. This gene is required in patterning of forebrain and cortical arealization.

As per Wayne et al [9] classification of cortical malformations, based on the primarily disturbed developmental process, schizencephaly comes in fourth group, as destructive lesion. They say it could be resulting from vascular disruptive lesion happening before 25 weeks of gestation. It can happen due to attempted abortion, amniocentesis, vehicular

accident. Mostly the territory of middle cerebral artery is involved.

Trudy Pang et al [5] consider schizencephaly as part of large spectrum of disorders under heading of Malformations of Cortical Development (MCD). They say that, but for the advent of MRI, many of these cases were previously directly seen at the autopsy. They categorize schizencephaly as a disorder due to abnormal neuronal organization. Neuronal organization is the last stage in the process of cortical development and involves synaptogenesis, neuronal maturation, synapse pruning and apoptosis. In this spectrum schizencephaly is considered to be an extreme form of polymicrogyria.

Utku Senol et al [10] has reported a rare case of dizygotic twins. One of the twins showed bilateral closed lip schizencephaly while the other had focal cortical dysplasia. There was involvement of the same parietal lobe in both the cases. They have discussed, that not only the focal cortical dysplasias (FCDs) are most commonly associated with schizencephaly, but also they seem to be resulting from the same pathologic process. Either FCD or schizencephaly develops depending on whether the anomalous process involves only superficial layer of brain or full thickness of hemispheric cortex. Both their 'study twins' also had absent septum pellucidum, which they have reported to be associated with schizencephaly in 80 to 90% of the cases.

M Avellanet et al [6] also agree that schizencephaly is associated with absent septum pellucidum in 80% cases, out of which 40% also have optic dysplasia.

But Bhatnagar S. et al [2] say that schizencephaly is associated with septo-optic dysplasia (SOD) in 25% cases. They also claim maternal age as important factor in schizencephaly with young mothers being at higher risk.

Depending on clinical manifestations, age at detection may range anywhere between 8 months to 30 years. 17% cases of schizencephaly have mild deficits or no problem [1].

Persons with unilateral clefts may lead a long good quality life. The case studied by M Avellanet et al [6] was unusual, with bilateral schizencephaly having a seizure free life in her 40s. The bilateral clefts otherwise usually present severe impairment. They present a range of neurological disabilities in accordance with their cortical involvement.

Post mortem detection of cleft in our 40 year old female brain, indirectly confirms the possibility of long life in unilateral cases of schizencephaly.

## Conclusion

Even though schizencephaly is rare, its unilateral cases may go undiagnosed till adulthood, with possible detection only after death.

### *Conflict of Interest*

NIL

### *Source(s) of Support*

NIL

### *Presentation at a Meeting*

NIL

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## Persistent Left Superior Vena Cava and its Clinical Correlation: A Cadaveric Case Report

Nishat Ahmed Sheikh<sup>1</sup>, Sachendra Kumar Mittal<sup>2</sup>, Prabhjot Kaur Chhabra<sup>3</sup>

### Abstract

Presented is a case of Persistent left superior vena cava draining into the right atrium through coronary sinus and finally opens into Right Atrium. Abnormalities of the vascular system are more commonly seen due to its importance in circulation. Persistent left superior vena cava is rare but important congenital vascular anomaly. It results when the left superior cardinal vein caudal to the innominate vein fails to regress. The venous anomaly of a persistent left superior vena cava (PLSVC) affects 0.3%–0.5% of the general population. Normally the superior vena cava is a single vascular structure formed by the union of right and left brachio-cephalic veins which are in turn formed by the union of corresponding internal jugular and subclavian veins of corresponding side, draining the head and neck as well as the superior extremity. During routine dissection in the Department of Anatomy, Jaipur National University Institute for Medical Sciences And Research Centre (JNU IMSRC) Jaipur. We found persistent left superior vena cava in a 64-year-old male cadaver. Both the vena cavae were formed as continuations of brachiocephalic veins of the corresponding side. The persistent left superior vena cava opened into the enlarged coronary sinus that drained into the right atrium between the opening of inferior vena cava and right atrio-ventricular orifice it has important clinical implications in certain clinical interventions. It may complicate placement of cardiac catheters or pacemaker leads.

**Keywords:** Persistent Left Superior Vena Cava; Coronary Sinus; Superior Vena Cava; Right Atrium.

### Introduction

Persistent left superior vena cava (PLSVC) is a rare venous abnormality. It is, however, the most common congenital anomaly of thoracic venous system with a frequency of less than 0.5% of the general population and up to 10% of patients with congenital heart disease [1-3]. Normal anatomy describes the formation of a single superior vena cava by the union of right and left brachio-cephalic veins which are in turn is formed by the union of corresponding internal jugular and sub-clavian veins, draining the head and neck as well as the superior extremity [4]. Double superior vena cava (SVC) with the persistent left

superior vena cava (PLSVC) is a rare venous malformation. Patients with PLSVC may have other associated cardiac malformations such as atrial septal defect, ventricular septal defect or endo-cardial cushion defect [5,6]. Presence of PLSVC may also interfere and cause problems during various invasive procedures such as pacemaker implantation, central venous catheterization, retrograde delivery of cardioplegia and retrograde left ventricular pacing [7,8].

### Case Report

During routine dissection in the department of Anatomy, JNU IMSRC, Jaipur, we found double superior vena cava with persistent left superior vena cava (PLSVC) in a 64-year-old male cadaver there is no joining between left brachio-cephalic vein and right brachio-cephalic to forming a single superior vena cava, Both the vena cavae were formed as continuations of brachio-cephalic veins of the corresponding sides (Figure 3). The PLSVC had the larger length compared to the superior vena cava (Figure 1). When we traced, it opened into the enlarged

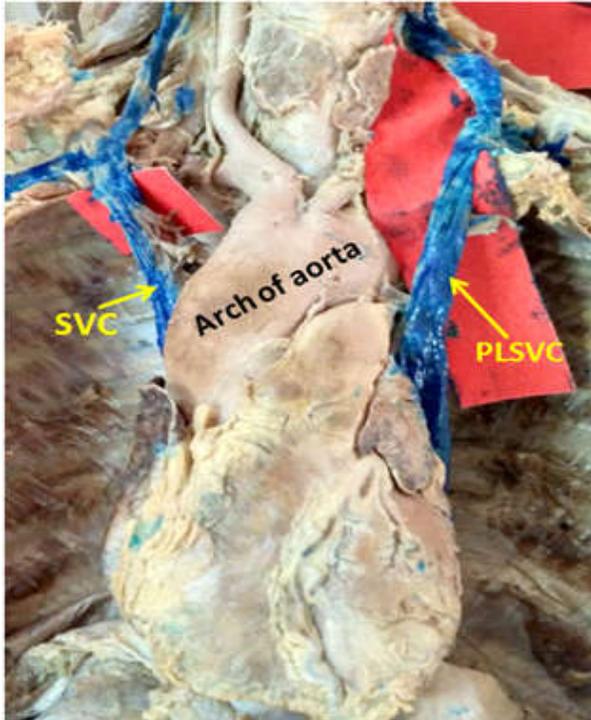
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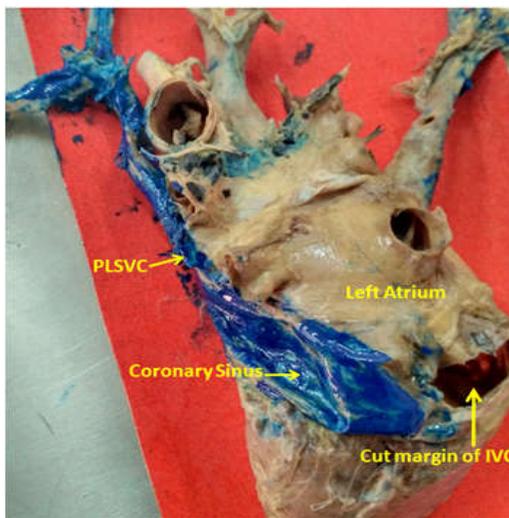
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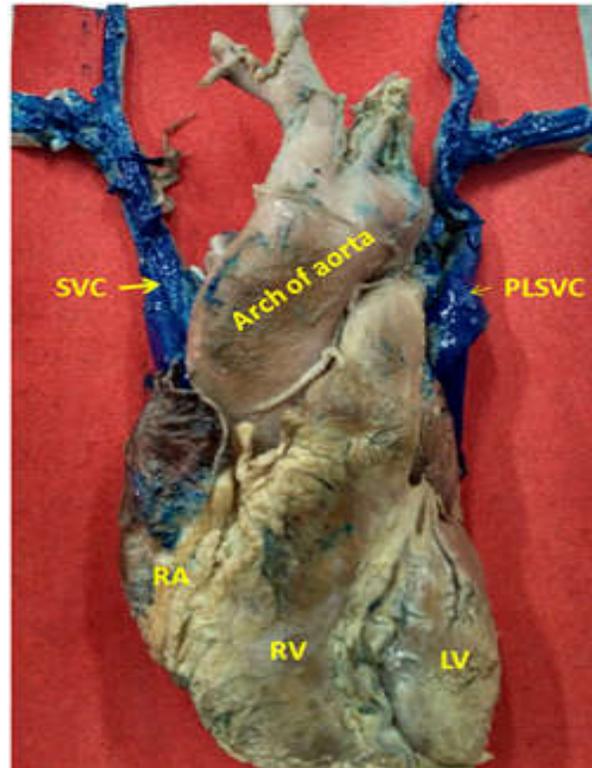
coronary sinus that further drained into the right atrium between the opening of inferior vena cava and right atrio-ventricular orifice (Figure 2). There was no communication between the two vena cavae (Figure 1). The hemiazygos and accessory hemiazygos veins drained normally into the azygos vein which in turn drained into the right superior vena cava. No other associated variations were observed.



**Fig. 1:** Showing persistent left superior vena cava (PLSVC). Both the vena cavae (SVC & PLSVC) were formed as continuations of brachio-cephalic veins of the corresponding side. There is no communication between the two veins.



**Fig. 2:** Showing the persistent left superior vena cava (PLSVC) opening into the enlarged coronary sinus that drains into the right atrium between the opening of inferior vena cava and right Atrio-ventricular orifice.



**Fig. 3:** Showing persistent left superior vena cava (PLSVC) and superior vena cava (SVC) on Both side. There is no communication between the two veins. SVC- Superior vena cava PLSVC- persistent left superior vena cava RA- Right Atrium, RV -Right ventricle, LV- left ventricle

## Discussion

During the fifth week of intrauterine life, in the human fetus, three pairs of major veins can be distinguished: the vitelline veins, carrying blood from the yolk sac to the sinus venosus; the umbilical veins, originating in the chorionic villi and carrying oxygenated blood to the embryo; and the cardinal veins, draining the body of the embryo proper. The cardinal veins form the main venous drainage system of the embryo. This system consists of the anterior cardinal veins, which drain the cephalic part of the embryo, and the posterior cardinal veins, draining the remaining part of the body of the embryo. The anterior and posterior veins join to form common cardinal veins and enter the right and left horns of the sinus venosus. Formation of the vena cava system is characterized by the appearance of anastomoses between the left and right sides in such a manner that the blood from the left side is directed to the right side. The anastomosis between the anterior cardinal veins develops into the left brachiocephalic vein. Most of the blood from the left side of the head and the left

upper extremity is thus directed to the right. The terminal portion of the left anterior cardinal vein entering into the left brachiocephalic vein is retained as the left superior intercostal vein. The superior vena cava is thus formed by the right common cardinal vein and the proximal portion of the right anterior cardinal vein. On the other hand, the left common cardinal vein and the distal part of the left horn become atretic and forms the ligament of Marshall or ligament of the left superior vena cava. If this normal regression of the left cardinal vein fails to occur, it results in a PLSVC [9].

The PLSVC is normal in some mammals but it is rare in man. Congenital abnormalities of the superior vena cava generally fall into one of two categories: anomalies of position or anomalies of drainage. Anomalies of position, especially a PLSVC are far more frequent than those of drainage. A PLSVC in itself causes no haemodynamic disturbance [10].

PLSVC is an uncommon and yet the most commonly reported thoracic venous abnormality. The frequency of a PLSVC is 0.3-0.5% among healthy individuals and as many as 10% of patients with congenital heart diseases [1-3]. There are two types of PLSVC described in the literature. In 92% of cases, PLSVC connects to the right atrium via coronary sinus with no hemodynamically significant consequence and in 8% of cases, PLSVC connects directly or through the pulmonary veins to the left atrium causing a right to left shunt [11].

The most common thoracic venous abnormality is the LPSVC draining into the coronary sinus in the presence of both left and right superior vena cavae. This anomaly is usually asymptomatic and does not require treatment unless accompanied by other cardiac anomalies [12].

This PLSVC drains into the right atrium *via* the coronary sinus in 92% of cases. But in the remainder of cases, it connects to the left atrium in such variants with absent or unroofed coronary sinus or normal coronary sinus and so creates a right-to-left shunt. Although the anomalies of systemic venous connection to the right atrium require no treatment when they occur alone, the PLSVC assumes particular significance when it communicates with the left atrium. Such patients usually present with cyanosis, polycythaemia or clubbing, although some have no clinical findings [13].

In the present case, a double SVC with a PLSVC was observed and there was no communication between the two superior vena cavae unlike as reported previously. PLSVC may also give rise to rhythm disturbances such as sinus node dysfunction

and atrioventricular block. These rhythm problems may be related to the stretching of the conduction tissue caused by the enlargement of the coronary sinus [3]. It may also be associated with other malformations such as situs inversus or tetralogy of Fallot [9].

During cardiac surgery, the presence of PLSVC would be a relative contraindication to the administration of retrograde cardioplegia. It may be possible to clamp the PLSVC to avoid the cardioplegia solution from perfusing retrograde up the PLSVC and its tributaries. However, there is a possibility that there may be some steal of cardioplegia solution through an accessory vein. Further, the coronary sinus catheter balloon may not be able to occlude the dilated coronary sinus. This may result in the failure of flow of cardioplegia solution to the myocardium. Thus, the cardioplegia solution administered would largely be distributed to the left internal jugular and left subclavian veins, rather than the myocardium [14].

## Conclusion

Persistent left superior vena cava PLSVC is a rare congenital anomaly and is separately available in the medical literatures. Therefore for the clinicians should be alerted about the possible existence of these venous anomalies, other cardiac abnormalities associated with it and their clinical consequences so as to prevent possible complications in routine clinical practice and during cardiopulmonary bypass surgeries. The present case report adds to the existing knowledge of these congenital abnormalities and stresses on the use of different diagnostic techniques for its accurate diagnosis thereby avoiding further complications while planning different interventions.

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*Conflict of Interest:* No conflict.

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