

## Quantitation of Neurosurgical Landmarks on Human Skulls In Relation To Sphenoidal Ridge: A Combined Anatomical and Radiological Study

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### Original Research Article

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#### Article History

Received: 19.11.2017

Accepted: 24.11.2017

Published: 30.11.2017



**Abstract:** Sphenoid ridge, paraclinoid region and the surrounding structures are commonly involved in conditions such as meningiomas, carotid aneurysms and fistula. To provide accurate information the current study investigated the measurement of sphenoidal ridge in relation to surrounding structures in three independent parts. An anatomical study was on dry skull formalin fixed cranial cavity and computed tomographic scans of skulls. Hundred adult skulls of unknown sex, thirty adult formalin fixed human cadaveric heads and 100 anonymised CT images were examined for morphometry of sphenoid ridge. The length of the sphenoid ridge on right side was more as compared to left side on cadaveric and osteological specimen. Sphenoid ridge documented as lengthier on radiological examination as compared to osteological and cadaveric examination. The mean distance of crista alaris to foramen ovale on skulls, cadavers and CT images was found to be same on both sides. The anatomical orientation of sphenoid ridge, paraclinoid region and its distances from vital structures help in determining the safety and precision during surgeries in this area.

**Keywords:** Lesser wing of sphenoid, Sphenoid ridge, Skull base, Cranium.

### INTRODUCTION

Anatomy of intracranial bony landmarks provides excellent orientation to the surgeons during various kinds of surgical procedures.

The prerequisite of substantial knowledge of these landmarks is approved by many authors in neurosurgical literature for various simple and reliable approaches determining the strategic steps involved in operation [1]. The importance of the sphenoid bone in neurosurgical studies is mainly, owing to its central position at the skull base and its relation with significant neurovascular contents [2-4]. The sphenoid ridge is the posterior border of the lesser wing of sphenoid bone. Its medial end is anterior clinoid process; the lateral end known as crista alaris extends up to pterion [5]. The lesser wing extends across anterior half of the body of sphenoid and joins to form a jugum sphenoidale. This forms the elevated smooth planum sphenoidal[6]. Embryologically, the sphenofrontal suture between lesser wing and orbital process of frontal bone is a boundary between the chondrocranium and neurocranium[7]. The lesser wing and its posterior edge (Sphenoid ridge) have been referred as bony frontier between the frontal and temporal lobes [8]. Laterally, the lesser wing approximates the pterion at the sphenosquamosal

suture. That is Sylvian point. The sphenoid ridge and surrounding structures are commonly involved in conditions such as meningiomas, carotid aneurysms and fistulas. For treatment of these conditions, new procedures and techniques such as endoscopic surgery and surgery through keyhole approaches have been developed. In particular, during endoscopic navigation, relationship and measurement of the sphenoid ridge and surrounding structures is very useful. There has been an increasing interest in the so-called minimally invasive procedures or keyhole approaches to treating cerebral aneurysms in specific locations. A novel keyhole approach has been described that was conceived to achieve the angle of vision and advantages of the classic pterional approach. This surgical approach is based on the anatomic location of the sphenoid ridge and its relationship with the sylvian fissure, basal cisterns and surrounding structures. The initial incision is made over the hairline behind the external border of the eye on the side selected. A skin and muscular flap is reflected anteriorly, and a small 3 x 3-cm craniotomy is completed around the external landmarks of the

sphenoid ridge. The detailed anatomical knowledge of the sphenoid ridge and its morphometry in relation to surrounding landmarks will give more insight to neurosurgeons in implementing surgical strategy during surgical intervention in this region.

## MATERIAL AND METHODS

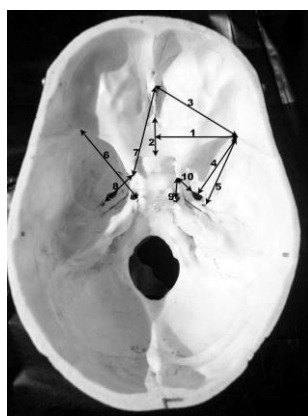
After taken the Institutional ethical clearance, the present study was conducted over a period of one year in three parts. For part one, hundred cranial cavities on dry human adult skulls of unknown sex and Indian origin were studied for sphenoidal ridge morphometry i.e. posterior edge of lesser wing of sphenoid. Only those bones were chosen for study which were intact and free from any pathological or congenital anomalies. In part two, following removal of brain, measurements were made between the sphenoidal ridge and surrounding intracranial structures in thirty adult formalin-fixed human cadavers. The morphometric analysis included the following measurements (Figures 1, 2, 3).

- Length of sphenoid ridge measured from midline to lateral tip of sphenoid ridge.
- The width of lesser wing in midline.
- Distance from crista alaris to tip of crista galli
- Distance from crista alaris to foramen ovale (mandibular nerve's exit site).
- Distance from crista alaris to foramen spinosum (middle meningeal artery entering the skull).
- Distance from crista alaris to tip of the posterior clinoid process (closely related to oculomotor nerve).

- Distance from anterior clinoid process to crista galli.
- Distance from anterior clinoid process to foramen spinosum (middle meningeal artery entering the skull).
- Distance from anterior clinoid process to tip of the posterior clinoid process (closely related to oculomotor nerve).
- Distance from anterior clinoid process to foramen ovale (mandibular nerve's exit site).

Anatomical measurements were taken using a vernier caliper (accurate to 0.1 mm), divider and scale. Appropriate statistical analysis was done of all the parameters on both right and left sided sphenoidal ridge.

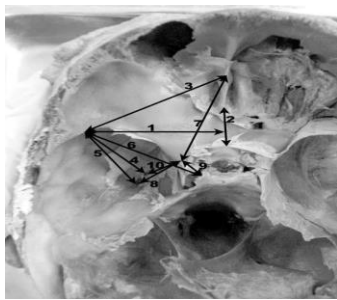
In part three, we evaluated the radiological anatomy of sphenoidal ridge. A high resolution CT scan data was collected from the hospital data pool, with slice thickness of 1mm, contiguous non overlapping slices, gantry setting, 0 degree, scan window diameter, 225 mm, pixel size more than 0.44. Identifying information of CT scans was removed. Fossae in cranial cavities of the CTs were studied to exclude any pathological, congenital or traumatic problems. Finally, 100 CTs were selected. Syngo fast View (software Registered trademark of Siemens AG, Berlin and Munchen) was used to generate three dimensional reconstructed CT scans. The distances of various landmarks from the sphenoidal ridge were measured. Appropriate statistical analysis was done of all the parameters on both right and left sided sphenoidal ridge.



**Fig-1: Showing various measurement on dry skull**

Fig-1: Measurements between the parts of lesser wing of sphenoid and surrounding neuroanatomical structures on human dry skull.1. Length of sphenoid ridge measured from midline to lateral tip of sphenoid ridge.2. The width of lesser wing in midline.3.Distance from crista alaris to tip of crista galli .4.Distance from crista alaris to foramen ovale.5. Distance from crista

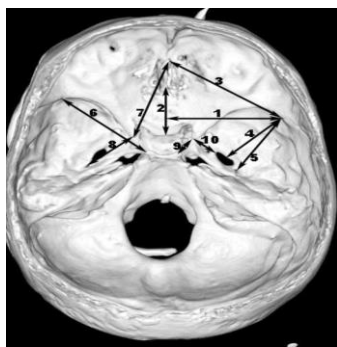
alaris to foramen spinosum .6. Distance from crista alaris to tip of the posterior clinoid process.7. Distance from anterior clinoid process to crista galli 8. Distance from anterior clinoid process to foramen spinosum.9. Distance from anterior clinoid process to tip of the posterior clinoid process.10. Distance from anterior clinoid process to foramen ovale.



**Fig-2: Showing various measurement on Wet skull**

Fig-2: Measurements between the parts of lesser wing of sphenoid and surrounding neuroanatomical structures on human wet skull.1. Length of sphenoid ridge measured from midline to lateral tip of sphenoid ridge.2. The width of lesser wing in midline.3.Distance from crista alaris to tip of crista galli .4.Distance from crista alaris to foramen ovale.5. Distance from crista alaris to foramen spinosum .6.

Distance from crista alaris to tip of the posterior clinoid process.7. Distance from anterior clinoid process to crista galli 8. Distance from anterior clinoid process to foramen spinosum.9. Distance from anterior clinoid process to tip of the posterior clinoid process.10. Distance from anterior clinoid process to foramen ovale.



**Fig-3: Showing various measurement of skull on computed tomography scan**

Fig-3: Measurements between the parts of lesser wing of sphenoid and surrounding neuroanatomical structures on human dry skull.1. Length of sphenoid ridge measured from midline to lateral tip of sphenoid ridge.2. The width of lesser wing in midline.3.Distance from crista alaris to tip of crista galli .4.Distance from crista alaris to foramen ovale.5. Distance from crista alaris to foramen spinosum .6. Distance from crista alaris to tip of the posterior clinoid process.7. Distance from anterior clinoid process to crista galli 8. Distance from anterior clinoid process to foramen spinosum.9. Distance from anterior clinoid process to tip of the posterior clinoid process.10. Distance from anterior clinoid process to foramen ovale.

Mean length of sphenoidal ridge was found to be as 4.3cm and 4.2 cm on both right and left side respectively (Table 1). It was observed that in 75% of cases, the length of sphenoidal ridge was 4.1 cm on both sides. The mean distance of crista alaris to foramen ovale was found to be same on both the sides, that is 4.3 cm (Table 1). Table 1 details the various measurements taken from crista alaris and anterior clinoid process to surrounding landmarks in the interior of skulls.Wet Skull study

Mean length of sphenoidal ridge was found to be as 4.3cm and 4.2 cm on both right and left side respectively. 71% of cases had sphenoidal length as 4.3 cm on both sides. The mean distance of crista alaris to foramen ovale recorded to be as 4.5 cm on both sides (Table 2). Table 2 details the measurements of parameters taken from crista alaris and anterior clinoid process to surrounding landmarks in the cranial cavity.

**RESULTS**

The data from the measurements of our series 1-10 of material and methods are given in table 1 (dry skulls), table 2 (wet skulls) and table 3 (CT scans).  
Dry Skull Study

CT scan study in the current study, mean sphenoidal ridge length was found to be 4.9 and 4.8 cm on right and left side respectively (Table 3). The mean

distance of crista alaris to foramen ovale was observed as 4.6 cm on both the sides. Table 3 details the measurements of various parameters taken from crista

alis and anterior clinoid process to surrounding landmarks in cranial cavity.

**Table-1: Morphometric Data from measurements of the parameters on dry skull**

Parameters	Right Side		Left Side	
	Range	Mean±SD (cm)	Range	Mean±SD (cm)
1.	3.5-4.4	4.3±1.8	3.6-4.3	4.2±1.3
2.	1.5-2.3	1.4±1.4	1.2-3.0	1.7±1.9
3.	4.3-5.0	4.7±1.9	4.1-4.9	4.5±2.0
4.	3.9-5.1	4.3±1.6	3.9-5.0	4.3±2.2
5.	4.0±5.2	4.9±2.0	3.9-5.0	4.8±1.6
6.	3.0-5.9	4.9±1.3	3.0-5.8	4.8±1.5
7.	2.9-5.3	4.1±1.5	3.1-5.2	4.2±1.4
8.	2.6-4.1	3.2±1.2	2.8-4.0	3.1±1.7
9.	0.7-2.8	1.1±1.7	1.1-2.2	1.3±1.6
10.	2.0-3.3	2.7±2.1	2.3-3.5	2.7±1.2

\*measurements of our series mentioned in material and methods section

**Table-2: Morphometric Data from measurements of the parameters on wet skull**

Parameters	Right Side		Left Side	
	Range	Mean±SD (cm)	Range	Mean±SD (cm)
1.	4.7-5.2	4.3±2.2	4.6-5.0	4.2±2.2
2.	1.3-1.8	1.4±1.6	1.3-2.1	1.8±2.3
3.	4.9-5.5	5.0±1.8	4.9-5.4	5.1±2.1
4.	4.4-5.2	4.5±1.4	4.1-5.1	4.5±1.1
5.	4.5-5.5	5.2±1.6	4.3-5.1	4.8±1.4
6.	4.6-5.6	5.1±1.8	4.5-5.5	4.8±1.6
7.	4.3-5.5	4.6±1.2	4.1-5.1	4.4±1.7
8.	2.8-3.8	3.4±1.1	2.5-3.5	3.2±1.9
9.	0.8-2.2	1.4±1.4	.9-2.0	1.3±1.9
10.	2.2-3.2	2.6±1.5	2.1-3.3	2.7±1.4

\*measurements of our series mentioned in material and methods section

**Table-3: Morphometric Data from measurements of the parameters on CT scan**

Parameters	Right Side		Left Side	
	Range	Mean±SD (cm)	Range	Mean±SD (cm)
1.	4.8-5.1	4.9±2.3	4.7-5.0	4.8±2.2
2.	1.2-1.8	1.3±2.1	1.2-2.0	1.9±1.9
3.	4.8-5.5	4.9±1.9	4.9-5.5	5.0±1.6
4.	4.4-5.1	4.6±1.6	4.0-5.0	4.6±1.5
5.	4.5-5.4	5.1±1.4	4.2-5.0	4.9±1.8
6.	4.6-5.5	5.0±1.7	4.5-5.4	4.9±1.3
7.	4.3-5.3	4.5±2.0	4.1-5.0	4.4±1.6
8.	2.7-3.8	3.4±1.8	2.5-3.4	3.1±1.9
9.	0.8-2.1	1.3±1.6	0.9-1.9	1.2±1.5
10.	2.2-3.1	2.7±1.4	2.1-3.0	2.5±1.6

\*measurements of our series mentioned in material and methods section

**DISCUSSION**

The sphenoid bone is situated at the base of the skull in front of the temporal and basilar part of the occipital. It somewhat resembles a bat with its wings extended, and is divided into a median portion or body, two great and two lesser wings extending outward from the sides of the body, and two pterygoid processes

which project from it below. The sphenoid ridge is the posterior border of the lesser wing of sphenoid bone. Its medial end is the anterior clinoid process and lateral point is known as crista alaris.

The sphenoid bone is cartilaginous in origin and develops from presphenoidal and postsphenoidal

part during fourth week of gestation. Presphenoidal and postsphenoidal part fuses about the eighth foetal week [9]. The sphenoid bone has nineteen separate endochondral and intermembranous centers [10]. The major cartilageous precursor of the sphenoid bone are the alisphenoid, presphenoid, postsphenoid and orbitosphenoid [11]. The sphenosquamosal suture between the lateral tip of lesser wing (crista alaris and crista sylvii) and squamous temporal bone near the pterion ossifies in early childhood [12]. The sphenoid ridge shows various anomalies, one of the anomaly reported is pneumatization of the sphenoid ridge and fusion of lesser wing of sphenoid with greater wing of sphenoid bone, as they form superior orbital fissure [5]

The meningiomas of sphenoid ridge along with the parasagittal meningiomas [13]. Neurofibromatosis type I has sphenoid dysplasia, it may be due to neural crest disturbances associated with neurofibromatosis causes the sphenoid body dysgenesis [14].

The sphenoid ridge and the surrounding structures are commonly involved in conditions such as meningiomas, carotid aneurysms and fistulae. For treatment of these conditions, new procedures and techniques such as endoscopic surgery and surgery through keyhole approach have been developed. Removal of the inner part of the lesser wing forming the part of orbital roof and diploic part of the sphenoid bone has been reported to be appropriate for certain approaches. However, a careless approach may result in penetrating into the orbit and cavernous sinus [15]. The removal of the outer side of the lesser wing through the superior orbital fissure was reported to increase the exposure [16]. The lesser wing can also be used as guide from lateral to medial, to approach the cavernous sinus [17]. The current study aims at measuring the sphenoidal ridge and the distances from it to vital structures in the cranial cavity.

Most of the available study provides data from western population that cannot be relied upon for any kind of intervention in Indian population. In this study, focus was mainly on surgically crucial parameters which could be useful for successful instrumentation. The average linear length of the right and left of lesser wings of dry skull were 4.3cm and 4.2cm respectively in our study. The values obtained from the wet skulls were 4.3cm and 4.2cm respectively. There was no significant difference between the measurements made on dry and wet skulls ( $p > 0.05$ ). This conforms to earlier study done on Sri Lankans [18]. The readings for all parameters showed a narrow range in our study. It therefore, appears that the chosen parameters do not show wide variation among Indians.

Our current study found the most structures in which distances were measured were on average 1.8-6.0

cm away from any part of sphenoid ridge. Similar findings were reported in one of the earlier studies [5]. Most of the distances measured on CT scan images were observed to be of higher values than measurements on dry and wet skulls. This difference may be due to shrinkage or demineralization [19].

## CONCLUSION

Detailed knowledge of sphenoid ridge is essential for both preoperative and postoperative strategy and it can lower the risk of unwanted complication during neurosurgical approaches. Moreover it will give surgeon sense of depth during exposure of a different pathological entity (tumors and aneurysm). In the present study, an attempt is made to determine distances of surgically important landmarks from sphenoid ridge for Indian population which could serve as a future reference.

## ACKNOWLEDGMENT

We are indebted to the donors who donated their bodies for research and teaching purposes.

## Conflicts of Interest

The authors has none to declare

## REFERENCES

1. Kahilogullari G, Uz A, Eroglu U, Apaydin N, Yesilirmak Z, Baskaya MK, Egemen N. Does the sphenoid angle effect the operation strategy? Anatomical and radiological investigation. Turkish neurosurgery. 2012;22(5):618-23. Govsa F, Kayalioglu G, Erturk M, Ozgur T. The superior orbital fissure and its contents. Surgical and Radiologic Anatomy. 1999 May 1;21(3):181-5.
2. Sharma PK, Malhotra VK, Tewari SP. Variations in the shape of the superior orbital fissure. Anatomischer Anzeiger. 1988;165(1):55-6.
3. Shi X, Han H, Zhao J, Zhou C. Microsurgical anatomy of the superior orbital fissure. Clinical Anatomy. 2007 May 1;20(4):362-6.
4. Tubbs RS, Salter EG, Oakes WJ. Quantitation of and measurements utilizing the sphenoid ridge. Clinical Anatomy. 2007 Mar 1;20(2):131-4.
5. Kuta AJ, Laine FJ. Imaging the sphenoid bone and basiocciput: anatomic considerations. In Seminars in Ultrasound, CT and MRI 1993 Jun 1 (Vol. 14, No. 3, pp. 146-159). WB Saunders.
6. Capiter G, Cristol R, Montoya P, Prudhomme M, Godlewski G. Prenatal organization and morphogenesis of the sphenofrontal suture in human skull. Cell Tissue Organ 2003;175: 98-104.
7. Nathal E, Gomez Amador JL. Anatomic and surgical basis of the sphenoid ridge keyhole approach for cerebral aneurysms. Neurosurgery 2005; 56: 178-185.
8. Standring Susan. Gray's Anatomy, 40<sup>th</sup> edn. Spain: Churrchill Livingstone Elsevier; 2008: 530.

9. Kier EL, Rothman SLG. Radiologically significant anatomical variations of the developing sphenoid in humans In: Bosma JF (ed) Development of basicranium . Bethesda:US: Department of health education and welfare. 1976:107-140
10. Fawcett P. Notes on the development of human sphenoid. J Anat Physiol 1910;44: 207-222.
11. Hoyte Dan . The cranial base in normal and abnormal skull growth. Neurosurg Clin North Amer 1991; (2): 515-537.
12. Brotchi J, Bonnal JP. Meningiomas. 1<sup>st</sup> ed. Lateral and middle sphenoid wing meningiomas, New York: Raven Press.1991; 413-425.
13. Jacquemin C, Mullaney P, Bosely TM. Abnormal development of the lesser wing of sphenoid with microphthalmos and microcephaly. Neuroradiology. 2001; 43: 178-182.
14. Dolenc VV. Transcranial epidural approach to pituitary tumors extending beyond the sella. Neurosurgery. 1997 Sep 1;41(3):542-52.
15. Meyer FB. Atlas of neurosurgery-Pterional approach. Churchill Livingstone, Newyork,1999; 1-48.
16. Coscarella E, Başkaya MK, Morcos JJ. An alternative extradural exposure to the anterior clinoid process: the superior orbital fissure as a surgical corridor. Neurosurgery. 2003 Jul 1;53(1):162-7.
17. Nugaliyadde A, Wajirani JM, Sabanayagam MI. A Morphometric study of the Sphenoid Ridge and Surrounding Structure. 2006.
18. Kanodia Gautam, Parihar Vijay, Yadav R Yad, Bhatele R Pushap, Sharma Dhananjay. Morphometric analysis of posterior fossa and foramen magnum. J Neurosci Rural Pract.2012; 3(3):261-268.