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Morphometric Evaluation Of Skull Base Foramina Among The Indian Population-A Ct Scan Comparative Study

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ABSTRACT

Introduction

Computerized tomographic imaging of the skull base region has become a vital tool for the explorative surgery. The middle cranial fossa is an important area of the skull base with vital neurovascular structures passing through the foramina. Direct and CT anatomical measurements of foramina were compared to assess the accuracy of the osseous structures.

Methods

An observational retrospective study on selected skull base foramina were carried out on dry skulls and on CT images among the Indian population.The parameters were compared with dry skulls without any developmental abnormalities.Morphometric measurements of the inter-foramina distance were assessed and tabulated.

Results

The measurements of dry skull base foramina were similar with CT scan distance. Except for foramen ovale and foramen spinosum distance, rest of the skull base foramina was statistically significant.Maximum of our study results were similar to measurements done among the European population.

Conclusion

Knowledge about the foramina of the dry skull provides understanding about the orientation in the CT images and aids in confirming the reproducibility of the position of the foramina and provides a confident approach for the neurosurgeons.

Keywords: *CT scan, skull foramina, foraman ovale, optic canal, carotid canal, internal acoustic meatus*

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I. INTRODUCTION

Base of the cranium are subdivided into anterior, middle and posterior cranial fossae.The anterior area is formed by roof of the orbit. The middle fossa is mainly occupied by the sphenoid bone, the apical area of petrous part of the temporal bone and basilar part of the occipital bone. The posterior part is formed by the occipital bone.The inferior of the skull base comprises of many foramina through which the neurovascular structures exit and enters the cranial cavity (1).

Along with anterior and posterior cranial fossae, the middle one is connected to the orbit by the optic canal and superior orbital fissure, to pterygopalatine fossa through the foramen rotundum and to the base of the skull by the foramen ovale, foramen spinosum, carotid canal, internal auditory meatus and hypoglossal canal (2).

The medial part of the greater wing of the sphenoid bone presents foramen ovale and spinosum, located on the basal aspect. The foramen ovale located medial to the foramen spinosum and anterolateral to the foramen lacerum in the infratemporal surface of greater wing of sphenoid bone. Carotid canal is located behind and posterolateral aspect of the foramen lacerum in the petrous part of the temporal bone (1).

The internal carotid artery enters the skull through the same foramen, ascends in the carotid canal, and then turns anteromedially to reach the posterior aspect of the foramen lacerum(1,2).

The hypoglossal canal, directed laterally and slightly forwards, traverses deep to each occipital condyle and transmits the hypoglossal nerve, the meningeal branch of the ascending pharyngeal artery and an emissary vein from the basilar plexus (1).

Detailed assessment of skull foramina provides a thorough information for the neuro vascular surgeons during treatment interventions.Advancements regarding radiological techniques like magnetic resonance imaging (MRI) and computed tomography scan (CT) made a revolutionary change in the diagnostic modalities (2).

These foramina along the base of the skull are clearly visible in radiological examinations and their morphologies were compared with dry skulls among the Indian population.

II. MATERIALS AND METHODS

STUDY DESIGN

The patients attending the Department of Radio Diagnosis & Imaging, in our institution, for head & neck diseases were the participants of this study. Computerized tomography (CT) scan was taken as a part of routine clinical evaluation for diagnostic purposes.

The data collection was done from the CT images of the referred patients. Informed consent was obtained from the participants who were willing to participate in the study.

The present study is an observational study (n=100) done among the south India population. They are categorized into randomly selected dry skulls (n=50), and CT scan images (n=50). All the participants below 18 years, inadequate visualization of CT images, erosions and osseous defects in the dry skull base and those not consenting to participate were excluded.

METHODOLOGY

CT scanner (Somatom Spirit (79627), SIEMENS AG,Germany) was used in the present study. The machine was a spiral CT scanner with multiple slices.Inter foramina distance measurements of skull foramina are assessed on dry skulls and CT scan images (3). Theyare optic canal(OC), foramen rotundum(FR), foramen ovale(FO),foramen spinosum(FS),carotid canal(CC), internal auditory meatus(IAM) and hypoglossal canal(HC). All measurements were performed using calibrated measurement window which guaranteed repeatability of the study results.

1. Distance between optic canal (OCM,OCL)- (medial,lateral)
2. Distance between foramen rotundum (FRDM,FRDL)- (medial,lateral)
3. Distance between foramen ovale (FOD)
4. Distance between carotid canal-extra cranial aperture(CCECA),
5. Carotid canal-horizontal position (CCHP) Right, Left(anterioposterior)
6. Distance between foramen spinosum (FSD)
7. Distance between internal auditory meatus(IAM)
8. Distance between hypoglossal canal(HC)

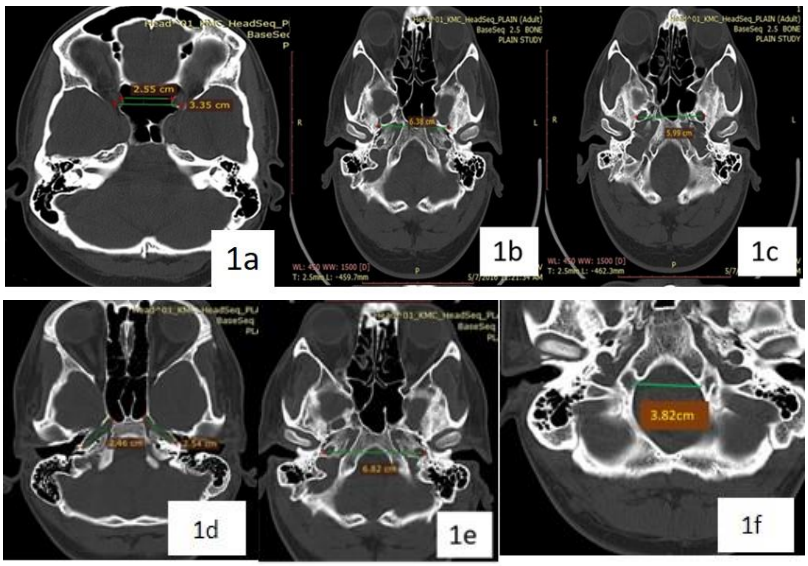

Figure 1(a-e). CT scan images showing

1.a)Distance between lateraland medial margin of optic canal.

1.b) distance between lateral border of foramen rotundum.

1.c) distance between lateral border of foramen ovale.

1.d)anterio posterior distance of carotid canal-horizontal position(right & left).

1.e) distance lateral border of carotid canal-extracranial aperture.
1.f) distance between hypoglossal canal

Figure 2:Morphometric measurements of skull base foramina in the dry skull using Vernier Calipers

STATISTICAL ANALYSIS

Data analysis was done using SPSS (version 21) package. Descriptive statistics was evaluated using mean, and standard deviation. Inferential statistics were applied with unpaired t' test for quantitative variables, to test the significance. The P-value less than 0.05 were considered statistically significant.

III. RESULTS

Morphometric measurements of skull base foramina identified using dry skull and CT scan the study groups were shown in Table 1.

Inter foramen measurements	Mean ± Standard Deviation (mm)		t-value	P-Value
	Dry skull	CT Scan		
OCM	19.05 ± 1.51	25.02 ± 3.07	8.73	0.00**
OCL	25.38 ± 3.31	33.31 ± 3.67	8.03	0.00**
FRD-M	39.20 ± 3.23	30.96 ± 4.02	7.99	0.000***
FRD-L	46.56 ± 2.86	36.24 ± 4.34	9.93	0.000***
FOD	55.44 ± 5.62	53.28 ± 3.26	1.66ns	0.104
FSD	61.48 ± 4.16	60.49 ± 3.33	0.93ns	0.359
CCECA	59.88 ± 3.54	65.12 ± 3.29	5.42	0.00**
CCHP-A	23.36 ± 3.29	25.75 ± 2.76	2.79	0.008**
CCHP-P	23.34 ± 3.23	25.52 ± 2.23	2.77	0.008**
IAM	53.06 ± 4.18	59.50 ± 4.54	5.22	0.000***
HC	41.56 ± 2.89	37.63 ± 2.97	4.74	0.000***

IV. DISCUSSION

Evaluation of skull base foramina is a significant part of diagnostic medicine, also pertinent to anatomists, radiologists, neurosurgeons, head & neck surgeons and vascular surgeons.Various measurements of the skull base have been conducted previously. However, most studies have been conducted on skulls using Vernier calipers. No complete study has assessed the position of skull base using CT scans in India. Parameters like distance between OC,FO, FR, FS,CC,IAM,HC was measured on dry human skulls and compared with CT scans, to provide precise information about skull base anatomical location.

DISTANCE BETWEEN OPTIC CANAL

In our study, OCM distance was 19.05mm ± 1.5, 25.02 mm ± 3.07 and OCL was 25.38mm ± 3.31, 33.31mm ± 3.67for both dry skull and CT measurements. OCM and OCL were significant at 1% level.In a study done by Berlis et al(3), for OCM,CT measurements were 20.95mm ± 2.99, for OCL-CT distance was 32.83mm ± 2.76 and skull were 33.13mm ± 2.77, which was similar to our study.The distance between optic canal and sagittal midline was measured in the study done by Cheng et al (4).Distance was 6.64mm ± 0.97 mm in the right side and 6.48 mm ± 0.90 on the left side.Knowledge about the anatomical position of optic canal and its positional relationship between them and sellar region is of pristine importance during the trans-sphenoidal pituitary surgeries (4). Careful identification of the OC location is very important for neurosurgeons to prevent iatrogenic injuries of optic nerve and ophthalmic artery within the OC.

DISTANCE BETWEEN FORAMEN ROTUNDUM

In our study, dry skull and CT measurements for FRD-M was 39.20 mm ± 3.23 and 30.96 mm ± 4.02 and the FRD-L was 46.56mm ± 2.86 and 36.24mm ± 4.34 respectively. Both the measurements were significant at 1% level. In a study done by Berlis et al(3), dry skull and CT measurement of FR was33.39mm ± 3.63 and 33.00mm ±3.5.Location of FR was proximal to pterygopalatine fossa,that makes the neural contents of FR vulnerable to transphenoid sinus surgeries.In a study performed by Edouard et al(5), the measurements were 1.71mm ± 0.21 and 1.81mm ± 0.22 respectively and was statistically significant (<0.001*).As maxillary division of trigeminal nerve passes through the foramen rotundum,surgeons has to be cautious during removal of nasopharyngeal and brain tumors (5).

DISTANCE BETWEEN FORAMEN OVALE

In our study, FOD measurements in dry skull and CT image was 55.44mm ± 5.62 and 53.28mm ± 3.26 and was non-significant. In a study done by Berlis et al (3), the skull measurements were 45.38mm ± 4.12 and CT distance was 44.47mm ± 4.17.

Locating the exact position of foramen ovale can be done by measuring the distance from the mid line to FO.In the study done by Patil et al (6),the mean distance was 25.83mm ±1.26 on right side and 25.08mm ±1.31 on left side.As mandibular division of trigeminal nerve passes through foramen ovale, it serves as a pertinent neurovascular landmark during interventional procedures like electroencephalographic analysis,trigeminal rhizotomy and biopsy from cavernous sinus neoplasms(6).

DISTANCE BETWEEN FORAMEN SPINOSUM

The FS is a landmark in middle cranial fossa surgery. However, there is a shortage of data regarding the normal anatomy and shortage in studies regarding its morphometric measurements. In our study, dry skull and CT image measurements of FSD were 61.48mm ± 4.16 and 60.49mm ± 3.33 and were non-significant. In a study by Berlis et al (3) on European population,the skull measurementsof FSD were 8.42mm ± 4.28 and CT distance was 58.29mm ± 4.28.In a study done by Sugano et al (7) on Brazilian population, right side measurement was 9.99 mm, 9.93 mm and left side was 9.53 mm,9.68 mm,respectively.As vascular dilatation induced diseases affect the middle meningeal vessels and nervous spinosum,while passing through this foramen.

DISTANCE BETWEEN CAROTID CANAL-EXTRA CRANIAL APERTURE

Location and distance measurements of the carotid canal are very important for surgery at the skull base. Exposure of the internal carotid artery at the different course of carotid canal is the most challenging task (8-10).In our study, the measurements in dry skull was 59.88mm ± 3.54 and in CT was 65.12mm ± 3.29,respectively and was significant at 1% level.

In the study done by Berliset al(3), skull measures were 50.58mm ± 4.77 and CT distance was 49.88mm ± 4.91. In a study done by Tewari et al (11), the mean distance of the carotid canal from the midline of skull base was 2.97 cm.

Aoun et al (12) conducted a study of 150 intact skulls, and the distance from the midline to the carotid canal was 2.878 and 2.819 cm in male skulls and 2.64 and 2.599 cm in female skulls, on both sides, respectively.CC-EA morphology is vital avoid iatrogenic damage to the ICA passing through the carotid canal during pathological situations(13,14).

DISTANCE BETWEEN CAROTID CANAL-HORIZONTAL PORTION

In our study, the anterior CCHP-A measurements in dry skull was 23.36mm ± 3.29 and in CT was 25.75mm ± 2.76.The posterior CCHP-P measurements in dry skull was 23.34mm ± 3.23 and in CT was 25.52mm ± 2.23 and both were significant at 1% level. In the study done by Berlis et al(3), skull measures were 27.90mm ± 2.52 and CT distance was 26.97mm ± 2.53.

In a study done by H Takegoshi, et al (15), measurements ranged from16.1 to 34.5 mm in length with an average of 26.7 mm. Length CCHP did not differ significantly between the left and right side. The petrous part of ICA injury is the most complicated situation during the skull base surgery. Numerous lesions affects the skull base, including the HP of the intrapetrous portion of ICA.

Surgical access to the HP segment may be challenging due to the deeper location and the approximation of the neurovascular structures(16-18).In a study done by Naidoo N et al (19), distance between the medial margins of external CC was 50.03 mm, the lateral margins of external CC was 62.73 mm.

Segmental divisions of ICA are surgically important for bypass procedures, around the cervico-petrous and petro-supraclinoid part of ICA to enucleate the nasopharyngeal tumors invading ICA(20).

DISTANCE BETWEEN INTERNAL AUDITORY MEATUS

In our study, dry skull and CT image measurements of IAMD-posterior margins were 53.06mm ± 4.18 and 59.50mm ± 4.54and was significant 1% level. In a study by Berlis et al (3),on European population, the skull measures of IAMD were57.57mm ± 4.82 and CT distance was 57.47mm ± 4.73.

DISTANCE BETWEEN HYPOGLOSSAL CANAL

Hypoglossal canal (HC) is important for anatomists, anthropologists, forensic experts, and clinicians, HC is located above the occipital condyle at the juncture of anterior one-third and posterior two-third.In our study, dry skull and CT image measurements of HC-anterior margins were 41.56mm ± 2.89 and 37.63mm ± 2.97 and was significant 1% level.

In a study by Berlis et al (3),on European population, the skull measurements of HC were 24.38mm ± 2.42 and CT distance was 24.63mm ± 2.43.In a study done by Kizilkanat et al (21), CT distance of HC were 25.45mm± 2.32.Location of HC is crucial during posterior and lateral approaches to the craniovertebral junction(22).During lateral condylar approach of occipital drilling surgeries,hypoglossal canal location has to considered, as the hypoglossal nerve supplying the muscles of the tongue passes through(23).

Morphometric analysis from the current study mostly falls well within the range of the study results by Berlis A et al (3), pertaining to European population. The measurements may vary, due to racial differences and we conducted our study on Indian population.

Our study results serve as a great information for the reference of surgeries at the base of the skull. They also showed an excellent significance for majority of the parameters, for the cranial opening is approximately at a right angle to the scan.

This knowledge also improves the identification and preservation of the neurovascular structures during approach to the middle cranial fossa region. The study results will form an anatomical reference to researchers, clinicians and surgeons during diagnosis and intervention.

V. CONCLUSION

Detailed knowledge about the anatomy of the skull base and the relations of surgical landmarks is important before beginning any kind of transsphenoidal surgery. Morphometric and morphological evaluation of skull base foramen will provide deep knowledge and act as a guiding map for the forensic pathologists, neurovascular surgeons and otolaryngologist

CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose. The authors have no competing interests to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

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AUTHORS CONTRIBUTIONS

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