Original article:

Landmarks for Keyhole Neurosurgical Procedures through Pterion

Richa Gupta1, Manisha B Sinha2, Anjali Aggarwal1, Tulika Gupta1, Harjeet Kaur 1, Daisy Sahni1,
Rajeev Garg3

1 Department of Anatomy, PGIMER, Chandigarh, India
2 Department of Anatomy, AIIMS, Raipur, CG, India, Pin-492099
3 Consultant, Department of Neurosurgery, Fortis Hospital, Chandigarh, India

Corresponding Author: Dr Manisha B Sinha

Abstract

Background: Pterion is a very crucial landmark. Thus, the present study was conducted to study pterion from morphometric as well as surgical point of view and its relation with underlying brain structures.

Material and methods: The current study was conducted on 46 pterion in dry, adult human skulls and 20 in cadaveric skulls. Various types of pterion and their distance from other landmarks were determined. Parameters measured on dry skulls included distance from center of pterion to middle of zygomatic arch, fronto-zygomatic suture, temporo-zygomatic suture and external auditory meatus, respectively. In cadaveric skulls, relation of these parameters with underlying brain structures was observed.

Observations: Incidence of different types of pterions was found to be 60.83% sphenoparietal; 23.8% epipteric; 12.17% stellate and 3.2% frontotemporal. Distance from center of pterion to middle of zygomatic arch was significantly high in stellate variety of pterion. Distance from center of pterion to middle of frontozygomatic suture was seen corresponding with inferior border of frontal lobe.

Conclusions: This information can be useful for keyhole surgeries in and around pterion and can be useful for selection of appropriate site of craniotomy for approaching deeper structures of brain.

Keywords: Pterion, morphometry, neurosurgical approach, surgical anatomy

Introduction

According to Scholz et al (2010), in neurosurgeries, successful treatment of pathologies with minimally invasive approach is the main objective. Thus, it becomes mandatory to have the precise knowledge of suitable bony aperture and its location. Minimally invasive keyhole surgeries allow safe intraoperative approach alongwith adequate removal of intracranial lesions. Essential precondition for keyhole surgeries are accurate preoperative planning and placement of the craniotomy tailored to the individual case. Reisch et al (2013) also observed that it is essential to determine the appropriate site, size, optimal place of craniotomy as well as the trajectory of the surgical target for successful keyhole surgeries. However, according to Yasargil et al (2002), this result can be achieved only if surgeon acquires an in depth knowledge and understanding of the surgical anatomy in area of these tumours. Most commonly used external landmarks in most of the neurosurgical procedures is pterion as reported by Ersoy et al (2003). Therefore, according to previous studies by Nathal and Gomez-Amador (2005), Mori K et al (2007), its precise location in relation to other
surrounding visible landmarks like zygomatic arch, frontozygomatic suture, and external acoustic meatus can be very useful for keyhole surgeries in these areas. The current study reappraises the surface anatomy of pterion, incidence of its various types along with correlation of these types and surrounding landmarks with the underlying brain structures. So this study is aimed to determine the morphology of pterion, pattern of pterion type (symmetrical or asymmetrical) in skulls and morphometry of pterion to the surrounding structure henceforth it could help in keyhole neurosurgical procedures through pterion.

**Material and Methods**

To study type and location 46 sides of 23 dry and adult human skulls and 20 sides of 10 adult cadaveric skulls were obtained from Department of Anatomy, PGIMER, Chandigarh. Dry as well as cadaveric skulls without any evidence of deformity or trauma were included, while all skulls in which pterion could not be studied due to advanced synostosis or any other reason were excluded from the present study. We classified pterion into various types according to types of bones articulating directly with each other. Linear distances were measured bilaterally from the center of the pterion (CP) to surgically important identifiable bony landmarks using Mitutoyo digital caliper of precision 0.02mm. For curved distances, measurements were made with thread and then measured with Mitutoyo digital caliper. For location of CP, we drew circle with minimum diameter including all the four bone and its center was taken as CP. Various parameters observed on dry skulls were (Fig. 1):

1. Center of the pterion - Middle of Frontozygomatic suture (CP- MFZyg)
2. Center of the pterion - Middle of Zygomatic arch (CP- MZyg)
3. Center of the pterion - Middle of Temporozygomatic sutute (CP- MTZyg)
4. Center of the pterion - Anterior most point of external acoustic meatus (CP- EAM)

In cadaveric study after removing the calveria of skull, relation of CP to surrounding landmarks was correlated with underlying brain parts. This relationship between CP and other parameters with underlying brain parts was also observed among different types of pterions found in cadaveric skulls.

**Statistical analysis**

All measurements and frequencies of the data were tabulated and separated according to sides and types. Statistical Package (version 11.5) software (SPSS; Chicago, IL, USA) was used for the analysis. The mean, standard deviation (SD) and range for each of the measurements were assessed. The Chi-square test was used to observe the intertype differences. To determine right – left side differences, paired t test was conducted. Differences among groups were considered statistically significant at p values of less than 0.05.

**Results**

We observed four types of pterion on the basis of bones articulating directly with each other (Fig 2). These were sphenoparietal (Sp), epiperic (E), frontotemporal (F) and stellate (S). In Sp type, greater wing of sphenoid and parietal bone were in direct articulation with each other and formed horizontal limb of this H shaped suture. In F type, frontal bone and squamous part of temporal bone were directly articulating with each other. In S type, all four bones were in direct articulation with each other at a common point and in E type, none of the bones was in direct contact with each other due to the presence of sutural bones in between. Most common type was observed to be Sp type (60.83%), E type...
(23.8%), S type (12.17%) and F type (3.2%). On right side, the order of incidence was: Sp type (65.3%) > E type (21.7%) > S type (8.7%) > F (4.3%). On left side, the order was: Sp type (56.6%) > E type (26.0%) > S type (8.7%) > F type (8.7%). F type was not found in any of the skulls on the right sides. Incidence of Sp type was more on right side, while E and S types had same incidence on both sides of skull. We did not find statistically significant right – left side differences in the incidence of various types of pterion (p > 0.05). We observed six combinations among various types on both sides of the skull (Table 1). Comparatively higher incidence of symmetrical combinations (52.3%) was observed among Sp (43.6%) and E type (8.7%). Asymmetrical combinations (47.7%) were observed between Sp - E type (26%) and Sp - S type (8.7%). F type did not exhibit combination with any other type, except S type (8.7%).

We observed values of various parameters like CP-MZyg, CP – MFZyg, CP-EAC and CP – TZyg. On comparison of these values among different types of pterion, we did not observe any significant intertype differences, except CP-MZyg arch, which was found to be significantly high in S type of pterion (Table 2). We also studied relationship of MTZyg suture with CP. MTZyg suture was observed to be lying posterior to pterion in 76.14% cases, at level of pterion in 19.56% and anterior to pterion in 4.3% cases.

In cadaveric study, we found Sp (87%), E (11%) and E (2%) type of pterion. However, we did not find S variety of pterion in any of cadaveric skulls studied. An oblique line drawn from CP-MFZyg was seen corresponding with inferior border of frontal lobe. CP-MZyg arch corresponded with course of frontal branch of middle meningeal artery. EAC marked end of sylvian fissure. CP-EAC corresponded with posterior ramus of sylvian fissure. These relationships between CP and other parameters were found to be same among all the types of pterion we found in cadaveric skulls.

Discussion

Main aim of minimal invasive approach is to treat neurosurgical pathologies through minimum tissue dissections, thus allowing shorter recovery time and great sense of well being.

In most of the neurosurgeries, common external landmark considered is pterion. Pterion is amenable for gaining access to many regions of the brain like tumours in region of sylvian fissure, trauma to middle meningeal artery, middle cerebral artery aneurysms etc. Despite considerable knowledge of intracranial anatomy, little is known about various types of pterion, eloquent brain parts lying underneath and their relationship to overlying bones. For successful surgeries it is important for surgeons to be well aware with the normal and variational surgical anatomy of pterion and its relationship with surrounding landmarks as well as underlying brain parts.

Gene responsible for articulation of cranial bone in pterion is MSX2 (Hussain SS, 2011), thus this is responsible for pterion type and symmetry. In current study incidence order of pterion was Sp type > E type > S type > F type. While in Turkish population Sp type; 88% > E type; 10% > S type; 2% > F type; 0% (Oguz et al, 2004) and in Nigerian population Sp type; 86% > F type; 8.5% > S type; 5.6% > E type; 0% (Adajuwon et al 2013) were the order of incidence of pterion. Owing to ethnic and racial variation this was order of incidence.

Standard parameters being considered to determine location of pterion are MZyg and MFZyg suture. We observed distance among various types of pterion and these two parameters. In current study CP-MZyg
distance was ranged from 39.7mm to 43.3mm in different types of pterion and CP-MFZyg distance was from 31.9mm – 37.2mm (Table 2). On comparison of these values with previous studies, no significant difference was observed from that of other studies (Table 3). We did not observe any statistically significant intertype differences (p > 0.05) for CP-MFZyg whereas CP – MZyg distance was significantly high in S type of pterion as compared to other types (p < 0.05). We categorized pterion according to CP- MZyg distance into high type, if distance was equal to or more than 40 mm and low type, if distance was less than 40 mm. Forty millimeter is standard distance of CP-MZyg arch considered by most of studies like Zhou et al (2003) therefore we chose 40 mm as criteria for high or low pterion. In case of S type, CP-MZyg arch distance was more than 40 mm so in all the cases with S variety of pterion was of high type. In 49.9% cases, the pterion was of high type (28.2% on right side and 21.7% on left side). Surgically, this is a very crucial finding because in high type of pterion, there are chances that there may be change in location of brain parts lying underneath in relation to various external landmarks.

Similarly, we chose 35 mm as criteria for forward or backward pterion because CP-MFZyg suture distance is normally considered to be 35mm (Williams et al 1998, Zhou et al, 2003). Maximum frequency of high and backward pteria was observed in S type, followed by E type.

CP- EAC distance was ranged from 56mm to 61mm (mean 57.2 ± 4.06 mm) in different types of pterion and CP-MTZyg distance was from 41mm – 45mm (mean 43.1 ± 4.56 mm) (Table 2, Table 3). We further studied relation of these parameters with underlying brain parts in cadaveric skulls, to see if there was any difference in relations with underlying brain structures amongst different types of pterion. We found that an oblique line drawn from CP to MFZyg suture, corresponded to inferior border of frontal lobe. No intertype differences were observed in location of inferior border of frontal lobe and CP-MFZyg suture. However, this relationship could not be observed for S type as it was not found in any of cadaveric skulls studied. Similarly, we observed that CP-MZyg arch corresponded with the frontal branch of middle meningeal artery. This relation was also same in all the types of pterion we found in cadaveric skulls. Knowledge of relation of CP-MFZyg and CP-MZyg arch with underlying structures can prove very useful during keyhole surgeries in region of inferior frontal lobe, removal of extradural haematoma or tumours like meningiomas which are supplied by middle meningeal artery (Lama and Mottolese, 2000, Zhou et al, 2003).

Another parameter studied was CP-EAC. It was observed that EAC corresponded with end of sylvian fissure. CP-EAC corresponded with posterior ramus of lateral sulcus. This was observed in all the types of pterion that we found in cadaveric skulls. Thus, this parameter can be useful during surgeries in region of sylvian fissure, as well as superior temporal gyrus and inferior frontal gyrus. Middle cerebral artery and sylvian veins lie along this fissure. Knowledge of CP-EAC distance can be useful during keyhole surgeries for approaching various pathologies in region of sylvian fissure and can help to prevent iatrogenic injuries like damage to branches of middle cerebral artery or sylvian veins.

In dry skulls, we observed that CP-MZyg arch distance was significantly higher in S type of pterion. Similarly, authors like Ersoy et al (2003) observed that in E type of pterion, there is presence of extra
sutural bone among rest of four bones forming pterion, which can lead to misinterpretation of CP, thus leading to various complications like penetration of orbit during surgeries in region of pterion. This study can be useful for neurosurgeries in and around pterion and can provide useful data so as to minimize the rate of complications while approaching deeper structures in keyhole surgeries of brain.

Acknowledgements: Authors wish to thank Mr Vijaykant Bakshi and Mr Pradeep (artist) from department of anatomy PGIMER, Chandigarh India for their contribution in art work.

Conflict of Interest: Authors have no conflict of interest

References:
1. Adejuwon SA, Olopade F E, Bolaji M. 2013. Study of location and morphology of the pterion in adult Nigerian skulls. ISRN Anatomy http://dx.doi.org/10.5402/2013/403937

Fig. 1 Four types of pterion: Sphenoparietal; Frontotemporal; Epipteric; Stellate
F, frontal bone; P, Parietal bone; S, Sphenoidal bone; T, Temporal bone

Fig. 2 Measurements of distances from center of pterion, CP to:
MFZyg, Middle of frontozygomatic suture; MZyg, Middle of Zygomatic arch; MTZyg, Middle of Temporozygomatic suture; EAC, External auditory canal
Table 1)

<table>
<thead>
<tr>
<th>SN</th>
<th>Pattern of Pterion</th>
<th>Incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td>1</td>
<td>Sp</td>
<td>Sp</td>
</tr>
<tr>
<td>2</td>
<td>Sp</td>
<td>E</td>
</tr>
<tr>
<td>3</td>
<td>E</td>
<td>Sp</td>
</tr>
<tr>
<td>4</td>
<td>Sp</td>
<td>S</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>6</td>
<td>S</td>
<td>F</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>E</td>
</tr>
</tbody>
</table>

Symmetrical pattern 52.3
Asymmetrical pattern 47.7

[ Sp, sphenoparietal; E, epipteric; S, stellate; F, frontotemporal ]

Table 2:

<table>
<thead>
<tr>
<th>Type</th>
<th>CP-MZyg mean±SD (mm)</th>
<th>CP-MFZyg mean±SD (mm)</th>
<th>CP-EAC mean±SD (mm)</th>
<th>CP-MTZyg mean±SD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sp</td>
<td>39.7 ± 4.47</td>
<td>34.2 ± 1.88</td>
<td>56.5 ± 2.8</td>
<td>42.4 ± 1.0</td>
</tr>
<tr>
<td>E</td>
<td>40.3 ± 6.7</td>
<td>37.2 ± 4.72</td>
<td>56.9 ± 6.7</td>
<td>44.7 ± 3.01</td>
</tr>
<tr>
<td>S</td>
<td>43.3 ± 0.43</td>
<td>34.3 ± 1.68</td>
<td>60.8 ± 1.62</td>
<td>44.7 ± 1.54</td>
</tr>
<tr>
<td>F</td>
<td>40.9 ± 5.64</td>
<td>31.9 ± 3.4</td>
<td>58.9 ± 0.27</td>
<td>41.6 ± 5.67</td>
</tr>
</tbody>
</table>
Table 3:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CP-MZyg</td>
<td>40.2 ± 4.3</td>
<td>38.56±3.3</td>
<td>38.9±0.4</td>
<td>38.5±4.4</td>
<td>38.88+3.49 R 38.24+3.47 L</td>
<td>39.1 ± 0.58 R 38.77 ± 0.63L</td>
<td>40.5 ± 3.9 R 38.3±2.5 L</td>
</tr>
<tr>
<td>CP-MFZyg</td>
<td>34.8± 4.8</td>
<td>30.35±3.6</td>
<td>33.5±0.4</td>
<td>31.1±4.9</td>
<td>30.34+4.30 R 30.35+3.40 L</td>
<td>31.52 ± 0.67R 30.82 ± 0.80L</td>
<td>33.0±4.0 R 34.4±3.9 L</td>
</tr>
<tr>
<td>CP-EAC</td>
<td>57.2 ± 4.06</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CP-MTZyg</td>
<td>43.1 ± 4.56</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

[CP, center of pterion; MFZyg, middle of frontozygomatic suture; MZyg, middle of zygomatic suture; MTZyg, middle of temporozygomatic suture; EAC, external acoustic canal, R, right; L, left]