ORIGINAL ARTICLE

Surgical Approaches to the Petrous Apex: Distances and Relations with Cranial Morphology

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ABSTRACT

Different pathologies may be located at the petrous apex. The primary surgical approaches used to remove such lesions are the pterional, subtemporal, presigmoid, and retrosigmoid. Each has advantages and disadvantages, and the distance to the petrous apex varies with the approach. Anatomical variations in cranial morphology may interfere with these distances. Dolichocephalic skulls have a longer anteroposterior axis than brachycephalic ones.

Three hundred computed tomographic scans and 65 dry human skulls were analyzed to determine if cranial morphology could indicate the shortest distance to the petrous apex. The distance between the external cortical table of the skull and the petrous apex in each surgical approach was measured. The lengths of the anteroposterior axis (L) and the widths of the lateral axis (W) were measured to determine the cranial index (W/L $\times$ 100).

This distance was longest in skulls with a high cranial index (brachycephalic) independent of the approach used. Statistical analysis showed that the distance to the previous apex was longest in the retrosigmoid approach and shortest in the pterional approach in all kinds of skulls. Brachycephalic skulls lose this ellipsoidal shape and the anterior laterolateral diameter is smaller than the posterior laterolateral diameter. Consequently, the distance from the cortical skull table to the petrous apex is shorter in brachycephalic skulls using all surgical approaches described in this article.

KEYWORDS: Petrous apex, surgical approaches, cranial morphology

The three cranial fossae of the skull base are situated at different levels: the anterior fossa is at a higher level than the posterior fossae.[1] The petrous portion of the temporal bone separates the middle fossa from the posterior fossa, and its apex is located deep and is related to important neurovascular structures.

The petrous apex is a pyramid-shaped bone with three surfaces: anterior, posterior, and inferior.[2] The anterior surface is limited by the foramen lacerum, sphenopetrous fissure, facial nerve hiatus, and arcuate eminence. The posterior surface is limited by the petro-occipitalis fissure (inferior petrosal sinus sulcus), the superior lip of the jugular foramen, and the posterior border of the internal auditory canal. The inferior surface of the petrous apex is limited by the foramen lacerum, petro-occipitalis fissure, medial lip of the carotid canal, and sphenopetrous fissure. These three surfaces point to the clivus region posteroanteriorly.[2] Gianoli and Amedee (1994)[3] also described the petrous apex as a pyramidal segment and divided this structure in two parts through the internal auditory canal. The anterior portion is related to the auditory tuba, the major superficial petrous nerve, the trigeminal nerve, the cavernous sinus, and the internal carotid artery. The posterior portion, formed by dense bone, is located between the internal auditory canal and semicircular canals.

Most of the multidisciplinary approaches to the skull base were developed in the 1980s. These combined strategies improve the results of the surgical removal of petrous bone and petrous apex lesions.

Petrous apex lesions may be approached surgically in different ways. The choice of approach is determined by the extent and nature of the pathology, by the patient's preoperative clinical condition, and by the surgeon's experience. The distance between the craniotomy and petrous apex also may be an important factor in choice of surgical access.

Skull morphology varies among individuals. Although the topic has been discussed at skull base surgery congresses, the influence of skull morphology on the choice of the surgical approaches has not been reported. This was the objective of the present study.

MATERIAL AND METHODS

Eighty-four dry human skulls and 1503 computed tomographic (CT) films were analyzed. Sixty-five dry human skulls were measured at the Departments of Anatomy of the Universidade Federal do Paraná, Pontifícia Universidade Católica do Paraná, and Universidade Tuiuti do Paraná with the written permission of each department's chairperson. A pachymeter and a millimetrically graduated ruler were used for measurements (Fig. 1). Nineteen dry skulls were excluded for not fulfilling the measurement criteria: integrity of the cranial bone, bilateral symmetry of cranial structures, and presence of reference structures (i.e., posterior clinoid process, petrous pyramid).

The CT scans were analyzed and measured at Centro de Diagnóstico por Imagem do Paraná (CEDIP), authorized by the directors of the center under discretion policy. CT scans were obtained with a General Electric (USA) Sytec 3000 scanner with transverse cuts parallel to the orbit meatal plane. Three hundred and one images were measured, and 1203 examinations were excluded for not fulfilling the following criteria: patient's age (18 and older), integrity of the cranial bone, orbitomeatal plane of the image (examinations not parallel to the orbitomeatal plane were excluded), or bilateral symmetry of the cranial reference structures (posterior clinoid process and petrous pyramid).

The parameters measured were maximal length and width of the skulls and the distances from the entry point of the different surgical approaches (i.e., pterional, subtemporal, presigmoid, and retrosigmoid) to the petrous apex (see Fig. 2). The left side of the brain was measured in all images and skulls, and this was an aleatory choice. All measurements were performed from the external cortical table of the skull. The reference point for the location of the petrous apex was the posterior
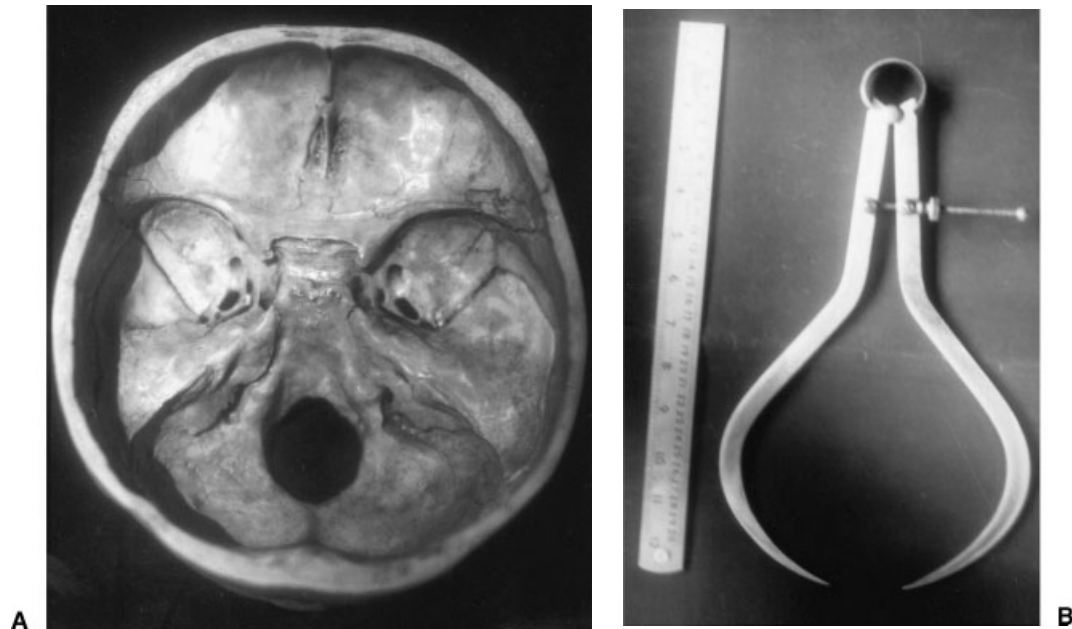
Figure 1   (A) Dry human skull base. (B) Pachymeter and millimetrically graduated ruler.

clinoid process, which delimits the sella turcica posteriorly due to its easy visualization on the CT scans.

Metrical scales of the CT examinations (centimeter) were used to convert the obtained data to actual distance.

Classification of cranial index (described by Morrison[3a] in 1973 and mentioned by Pereira and Alvin in 1979)[4] was simplified to provide a clear analysis of the obtained data as follows: (1) dolichocranium, for cranial indexes up to 74.9; (2) mesocranium, for cranial indexes ranging from 75 to 79.9; and (3) brachycranium, for cranial indexes more than 80.0 cm.

RESULTS

The smallest cranial index obtained was 66.42 (classified as dolichocranium) and the largest cranial index was 91.32 (classified as brachycranium). Both were based on CT measurements.

Of the cranial indexes, 47 were dolichocranium (34 results from CT scans and 13 from dry skulls), 173 were mesocranium (148 from CT scans

Figure 2   Illustration of a dry human skull (after craniotomy and removal of the calvaria).The arrows identify different approaches to the petrous apex. The arrow above the bottom arrow identifies the pterional approach; the bottom arrow, the subtemporal approach; the arrow below the top arrow, the presigmoidal approach; and the top arrow, the retrosigmoidal approach.
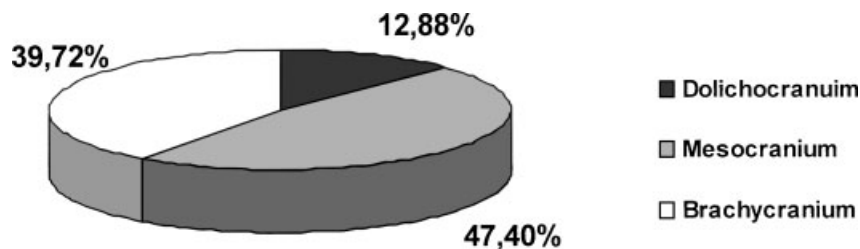
Figure 3   Classification of skulls according to cranial index.

and 25 from dry skulls), and 145 were brachycranium (118 from CT scans and 27 from dry skulls) (Fig. 3).

The shortest distance for the pterional approach was 2.94 cm (CT scan, cranial index 81.12, Fig. 4) and the longest distance was 7.10 cm (dry skull with a cranial index of 81.18, Fig. 5). The shortest distance for the subtemporal approach was 3.14 cm (CT scan, cranial index 81.12, Fig. 6), and the longest distance obtained was 6.40 cm (dry skull, cranial index 90.17, Fig. 7). The shortest distance for the presigmoid approach was 3.72 cm (CT scan, cranial index 81.12, Fig. 8), and the longest distance obtained was 7.60 cm (dry skull, cranial index 85.14, Fig. 9). Finally, the shortest distance for the retrosigmoid approach was 4.24 cm (CT scan, cranial index 81.12, Fig. 10), and the longest distance obtained was 9.16 cm (dry skull, cranial index 82.63, Fig. 11).

Tables 1 and 2 present the maximal, medial, and minimal distances, mean, and standard deviation of the different approaches based on the CT examinations and skulls, respectively. Table 3 presents the maximal and minimal distances of the different approaches in CT related to the cranial morphology. (See Figs. 12 and 13.)

DISCUSSION

Petrous apex lesions are defined differently by otologists and neurosurgeons. Traditionally, otologists consider petrous apex lesions as those involving bone erosion or the petrous bone itself (e.g., congenital cholesteatomas, facial nerve neurinomas, and cholesterol granulomas). Neurosurgeons include other lesions related to the petrous apex;
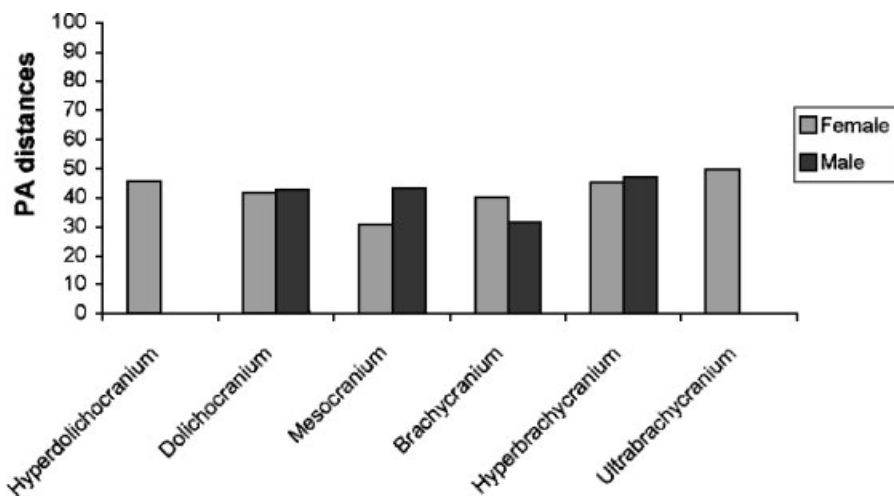

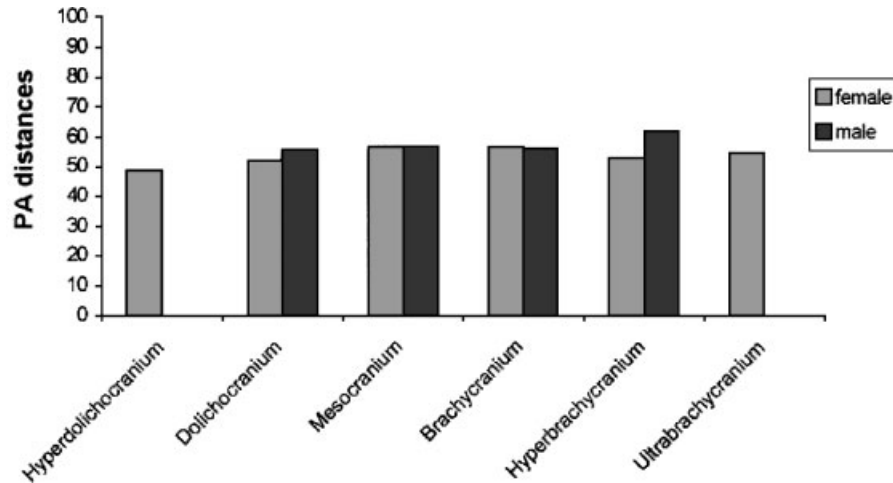**Figure 4**   Minimal distance of the pterional approach as a function of gender.

Figure 5 Maximal distance of the pterional approach as a function of gender.

they do not necessarily involve bone erosion (e.g., petroclival meningiomas, trigeminal neurinomas).[2] Naguib, Aristegui, Saleh et al[5] suggested a division of the petrous apex into two portions with different characteristics: an anterior triangular area, where the trigeminal ganglion is located, and a posterior quadrangular area, close to the internal acoustic meatus.

According to Grasek,[6] petrous apex lesions are primary if they originated in this region or secondary if they started in another region and extended to the petrous apex.

Different surgical approaches to this region have been described, and each has its advantages and disadvantages. The choice of surgical approach depends on the pathology, the clinical satus of
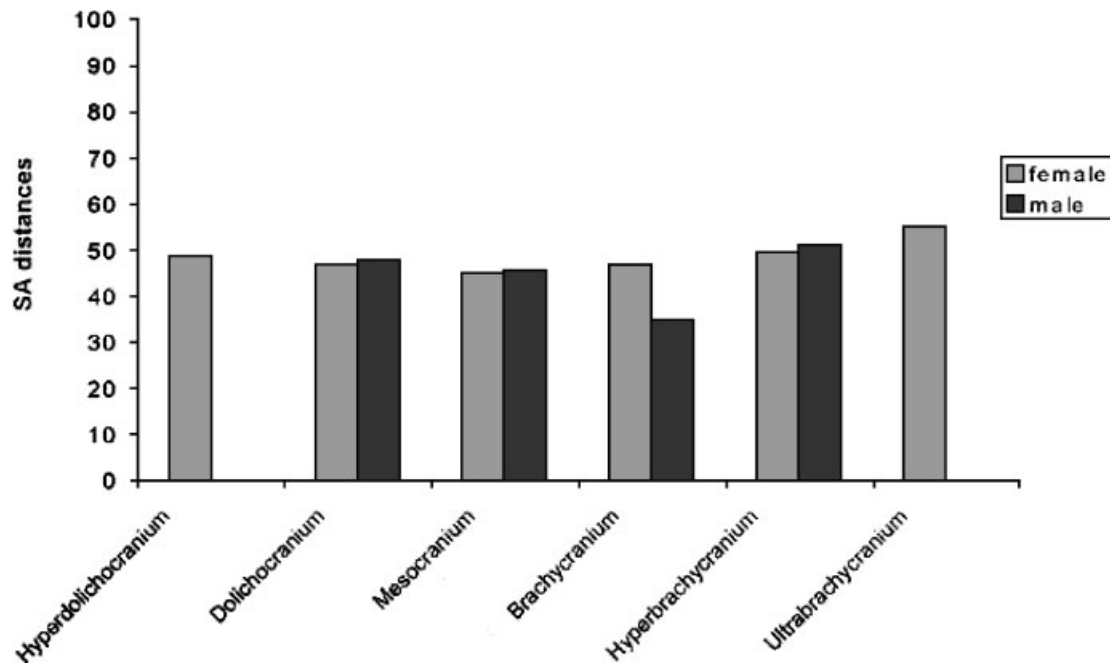

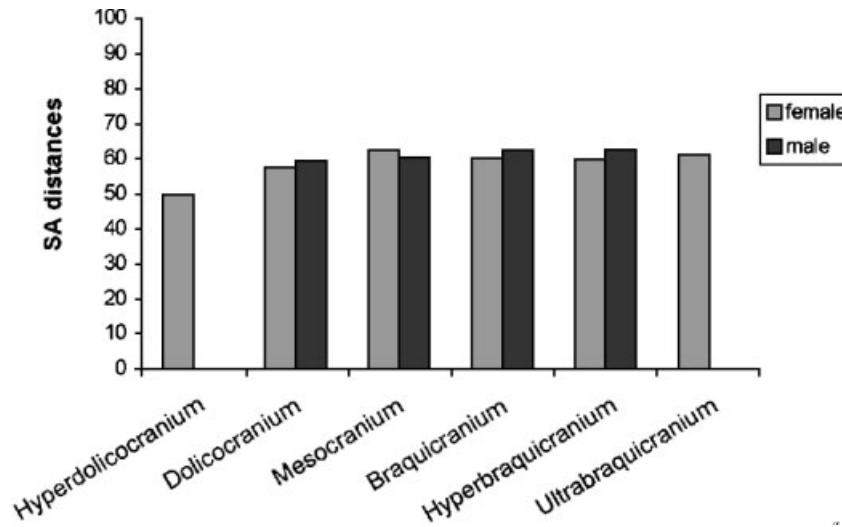**Figure 6** Minimal distance of the subtemporal approach as a function of gender.

Figure 7 Maximal distance of the subtemporal approach as a function of gender.

the patient (hearing grade, facial palsy, infection), the extent of the tumor, and the experience of the surgeon.[6] Skull morphology is also involved in the choice of an approach because the distance between the external cortical table of the skull and the petrous apex varies with skull types.

The pterional approach is performed through a frontotemporal craniotomy. According to Fournier et al,[7] the pterional approach described by Yasargil et al[8] offers limited exposure of the petrous apex. Additional exposure may be possible but extensive brain retraction is needed.

The subtemporal approach is performed with or without removal of the zygomatic arch. Retraction of the temporal lobe is necessary, limiting the use of this approach. Fournier et al[7] recommended an extradural approach to achieve a better exposure with less retraction. Eisenberg et al[9] prefer the subtemporal approach because it is direct, extradural, and doesn't require major retraction of the temporal lobe.
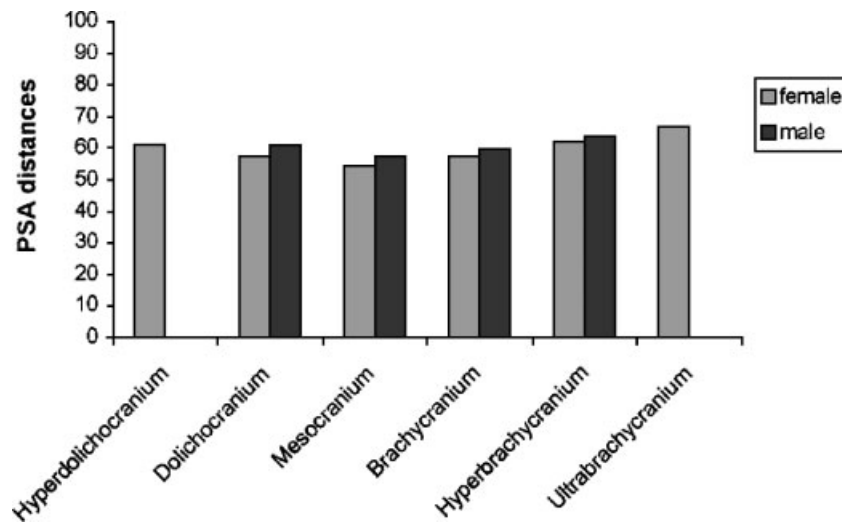

Figure 8 Minimal distance of the presigmoid approach as a function of gender.
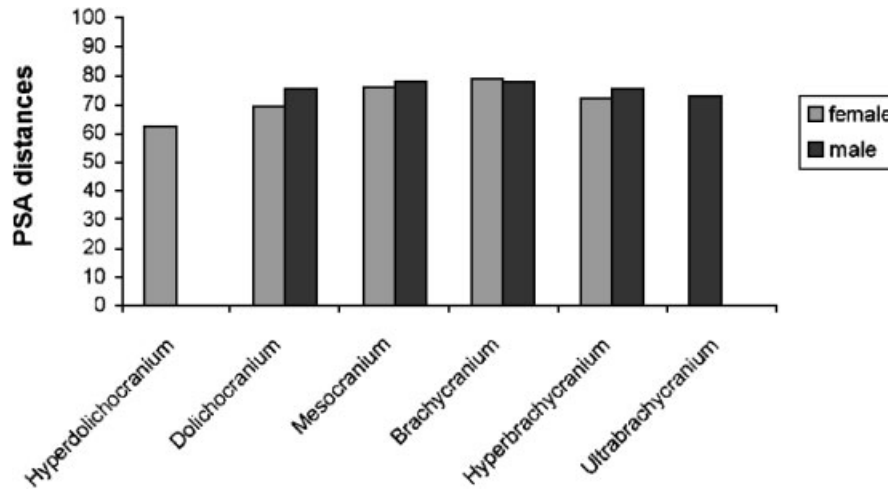
Figure 9 Maximal distance of the presigmoid approach as a function of gender.

The combined presigmoid approach exposes the sigmoid and the transverse sinuses. The dura mater is opened anteriorly to the sigmoid sinus. The translabyrinthine route does not preserve hearing. Brodke et al[10] performed the presigmoidal extradural approach in 11 patients with petrous apex cholesterol granulomas. Grasek (1975)[6] used the presigmoidal extradural approach in 16 patients with petrous apex pathologies (14–infralabyrinthine, 2–translabyrinthine). Harsh and Sekhar[11] described the surgical anatomy of a combined intradural presigmoid–subtemporal approach to the petrous apex, with ligature and section of the superior petrous sinus.

The vein of Labbé is considered the most crucial vein in the petrosal and other lateral skull base approaches. It connects the lateral sinus to the middle cerebral superficial vein on the posterolateral surface in the hemisphere. Sakata et al[12] usually divide the superior petrosal sinus anterior to its junction with the lateral sinus and then cut the tentorium. This maneuver widens the exposure with no risk to the vein of Labbé or lateral sinus.
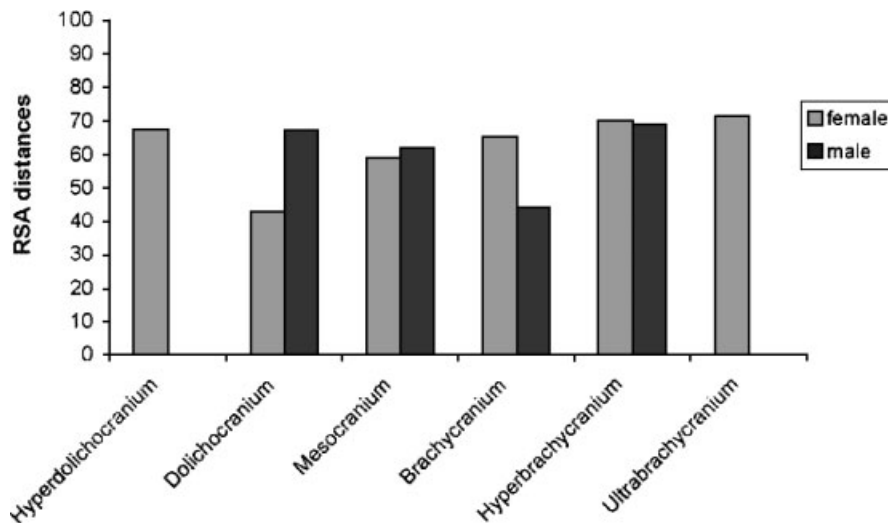

Figure 10 Minimal distance of the retrosigmoid approach as a function of gender.
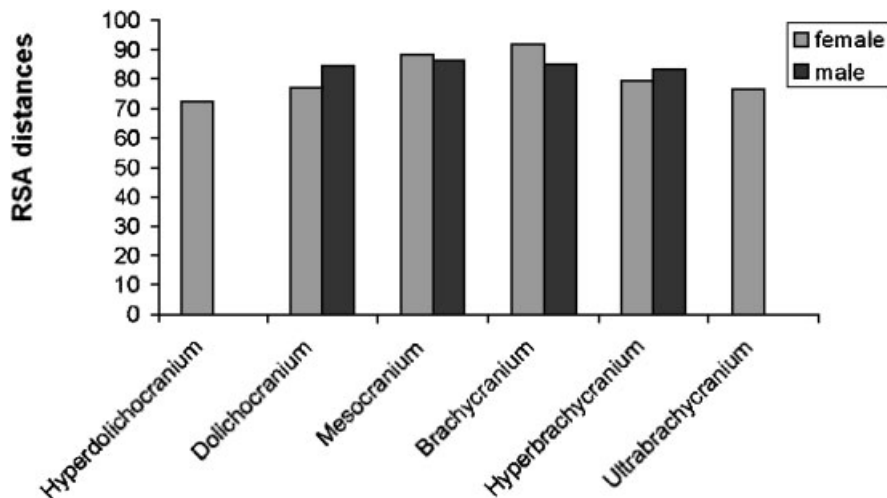
Figure 11 Maximal distance of the retrosigmoid approach as a function of gender.

The addition of a partial labyrinthectomy and petrous apicectomy (PLPA) to the petrosal presigmoid approach has been used for small, centrally located tumors that have not displaced brain stem structures. The PLPA petrosal approach is also indicated for patients with giant tumors that encase the vertebrobasilar vessels. This approach provides wider exposure with less temporal lobe retraction. Furthermore, the PLPA approach reduces the risk of injuring the vein of Labbé.[13]

The retrosigmoid approach is performed through a suboccipital craniotomy. Cerebellum retraction allows identification of the petrous apex in the cerebellopontine angle. Removal of the petrous apex allows resection of lesions that extend to the middle fossa.[14,15] Grasek[6] used the retrosigmoid approach in three patients with petrous apex pathol-

ogies. According to Fournier et al,[7] cerebellar retraction is a limiting factor for this approach.

The distance between the external cortical table of the skull, where the craniotomy is performed, and the petrous apex is very important when choosing the surgical approach. The shorter this distance is, the safer will be the operation to be performed.

Pereira and Alvin[4] introduced the cranial index, or length–width index, aiming to determine the skull shape in the horizontal or transverse planes. Morrison[3a] described the cranial index as the maximal width of the skull times 100 and divided by maximal skull length. Indices up to 64.9 are considered ultradolichocranium; between 65 and 69.9, hyperdolichocranium; between 70 and 74.9, dolichocranium; between 75 and 79.9,

Table 1 Maximal, Medial, and Minimal Distances, Mean, and Standard Deviation of Different Computed Tomographic Approaches

Approach	n	Medial	Mean	Minimal	Maximal	SD
Age	300	47.26	45.00	18.00	92.00	18.91
Pterional	300	48.87	48.95	30.66	62.10	3.69
Subtemporal	300	52.95	52.70	34.83	62.68	3.73
Presigmoid	300	66.43	66.36	54.29	78.82	4.70
Retrosigmoid	300	74.12	73.73	42.38	91.62	5.21
Cranial index	300	79.30	78.97	66.42	91.32	4.03

Table 2 Maximal, Medial, and Minimal Distances, Mean, and Standard Deviation of the Different Approaches in Skull Examinations

Approach	n	Medial	Mean	Minimal	Maximal	SD
Pterional	65	54.99	54.00	44.00	71.00	5.40
Subtemporal	65	52.19	53.00	42.50	64.00	4.54
Presigmoid	65	67.49	68.00	56.00	76.00	4.43
Retrosigmoid	65	74.30	75.00	58.00	84.00	4.87
Cranial index	65	79.09	78.45	70.39	90.17	4.68

Table 3 Maximal and Minimal Distances of the Different Approaches

| Approach	Dolichocranium		Mesocranium		Brachycranium	
	Max	Min	Max	Min	Max	Min
PA	55.35	41.75	56.60	30.66	56.73	31.94
SA	59.33	46.87	62.57	45.14	62.42	34.83
PSA	75.45	57.14	77.95	54.29	78.82	57.20
RSA	84.70	42.38	88.12	59.00	91.62	44.20
CI	74.68	70.64	79.95	75.00	84.96	80.00

mesocranium; between 80.0 and 84.9, brachycranium; between 85.0 and 89.9 hyperbrachycranium, and more than 90.0, ultrabrachycranium. The objective of our study was to demonstrate the relationship between the cranial indices described by Mollison and the distance of the four main surgical approaches to the petrous apex.

In the material studied, the cranial index was a mean of 79.3 with a standard deviation of 16.24. These extremes of hyperdolicocranium and hyperbrachycranium were present only in women (three cases each). However, no correlation between sex and cranial index was observed (Pearson index 0.029).

Among the several indices, 47 skulls were dolichocranium, 173 were mesocranium, and 145 were brachycranium. Schlegel and Satravalha[16] examined the skull shape in 110 Javanese children from 6 to 16 years old, using the index described by Morrison.[3a] In this study, 2.1% of the boys and none of the girls had a mesocranium (i.e., indices lower than 81); 36.2% of the boys and 28.6% of the girls had a brachycranium (indices between 81 and 85.5). Indices higher than 85.5 (hyperbrachycranium) were present in 61.7% of the boys and 71.4% of the girls. These results differed from ours, reflecting ethnic and age characteristics.

The measurements obtained from the dry skull and CT scans were equivalent, except for those with the pterional approach, which was shortest on the CT scans. In dry skulls the shortest distance was associated with the subtemporal approach. The more brachycephalic a skull was, the longer were the distances for the approaches, except for the retrosigmoid approach, which was associated with relatively constant distances. This approach, however,
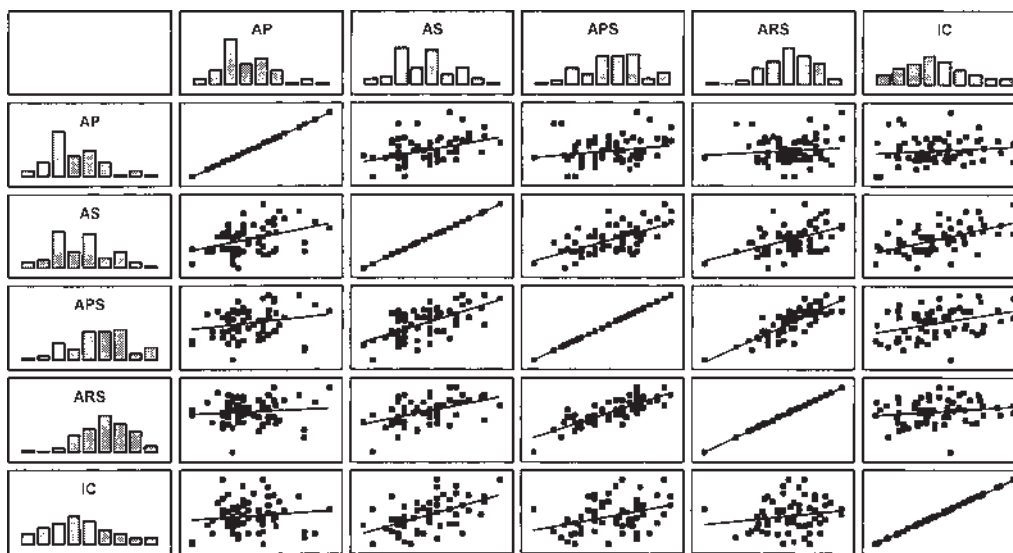
Figure 12 Relations between cranial indices and length of the approach in dry skulls.
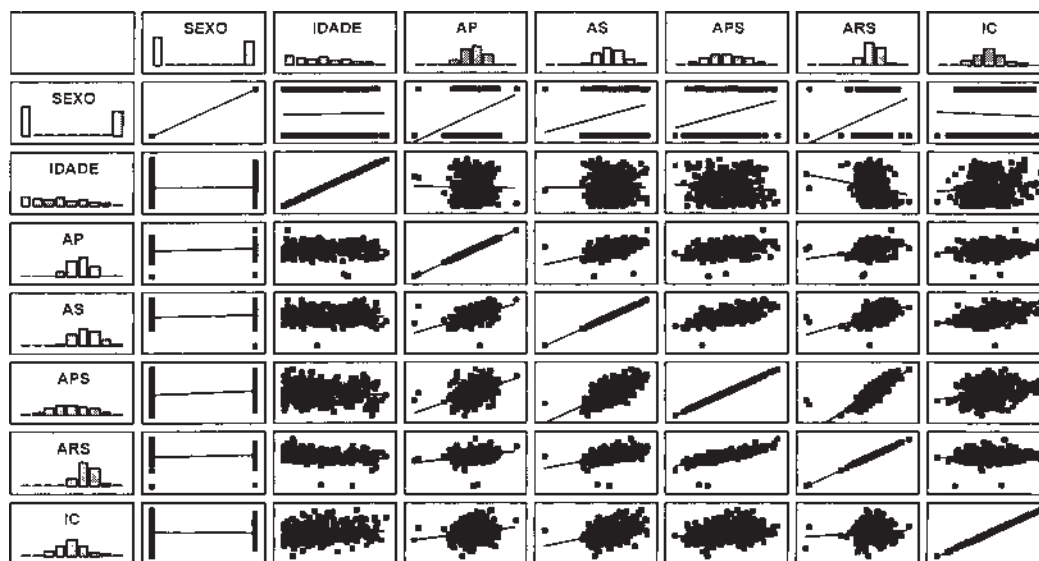
Figure 13 Relations between cranial indices and length of the approach on computed tomographic examinations.

was associated with the greatest distances in the most skulls. The pterional approach was associated with the shortest distances in skulls of all shapes. This finding may be explained by the asymmetric pattern of the width of the anterior and posterior fossae. In fact, it is believed that as the skull becomes brachycephalic, the ellipsoidal shape is lost and the anterior laterolateral diameter becomes shorter than the corresponding posterior distance. This fact may also explain the minimal variations in the distance to the petrous apex in the retrosigmoid approach. The correlations between the presigmoid and retrosigmoid approaches were positive and high ($p = 0.77$) as were the correlations between the retrosigmoid and subtemporal approaches ($p = 0.70$). These results confirm that the more brachycephalic the skull becomes, the shorter the anterior laterolateral diameter will be. This study shows that the shape of skull is an important factor in the choice of surgical approach.

CONCLUSION

Skull morphology was studied to determine the shortest and longest distances between the external skull surface and the petrous apex as reflected by the four main surgical approaches to this region.

Cranial indices may be used in the indication of the treatment of pathologies of the petrous apex. Skulls with higher cranial indices (brachycephalic) were associated with longer distances for all approaches. In brachycranium, dolichocranium, and mesocranium skulls the retrosigmoid approach was associated with the greatest distance and the pterional approach with the shortest distance to the petrous apex. As the skull becomes brachycephalic, its ellipsoidal shape is lost and the anterior laterolateral diameter becomes shorter than the posterior correspondent.

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Commentary

When choosing the surgical approach to skull base tumors and other abnormalities in the petrous bone region, the surgeon must consider the size, location, and extent (e.g., to or across midline) of a lesion and its likely relationship to critical neurovascular structures that must be preserved. The configuration of the skull base anatomy is also an important consideration. The surgeon would like to be as "close" to the lesion as possible as long as critical neurovascular structures do not impede reasonable access. The authors clearly describe the marked variability in skull configuration and how such variation could affect reasonable surgical access. This information provides a useful and valuable reminder that this variable should be included when choosing a surgical approach. As an example, I still prefer the presigmoid retrolaby-rinthine approach to many petrous apex tumors, especially those that reach or cross the midline, extend into the middle fossa, or both. This approach is tiring for the surgeon, as the authors point out, but the locations of cranial nerves III, IV, V, and VII along the skull base vessels and their critical perforators may limit adequate access to a lesion that extends significantly into the posterior fossa.

Donald P. Becker, M.D.[1]

Commentary

The authors analyzed 300 computed tomographic scans and 65 dry human skulls to investigate whether cranial morphology determines the shortest distance to the petrous apex. The cranial index was defined as width divided by length multiplied by 100 and was used to determine the best approach.

In patients with brachiocephalic skulls and high cranial indices, the distance to the petrous apex was long and depended on the approach. Regardless of the cranial index to the petrous apex, the distance was longest with the retrosigmoid approach. The pterional approach represented the shortest approach. In all approaches, the distance to the petrous apex was shortest in dolichocephalic skulls.

It is unclear, however, where the pterional and subtemporal approaches begin and end. For

example, a pterional approach can be extended laterally, with or without removal of the zygoma, to approach a lesion through a combined approach. The limits would be influenced by the size and extent of a tumor and by its location above and below the tentorium.

Overall, these measurements provide useful data for skull base surgeons contemplating various skull base approaches to remove lesions of the petrous apex.

Randall W. Porter, M.D.[1]