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A multipurpose landmark for skull-base surgery: Henle's spine

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Abstract

Objective: To determine whether Henle's spine could be used as a reliable and multipurpose landmark for the other important structures of the skull base.

Materials and methods: Ninety-two specimens from 46 cadaveric adult dry skulls were studied. Two imaginary lines and a triangle were defined: a spinopterygoidal line extending from Henle's spine to the root of the medial pterygoid plate, a bispinal line extending from one Henle's spine to the contralateral one, and a parapetrosal triangle lying between the spinopterygoidal line, the bispinal line and the sagittal midline. The parapetrosal triangle encompasses nearly all the main structures of the skull base, including the petrosal internal carotid artery.

Results: Along the spinopterygoidal line the distance from Henle's spine to the spine of the sphenoid was found to be about 3 cm, to the foramen spinosum 3.5 cm, to the posterior and anterior margins of the foramen ovale 4 and 4.5 cm, to the root of the lateral pterygoid plate 5 cm, to the root of the medial pterygoid plate 5.5 cm, and to the vomer 6.5–7 cm. Along the bispinal line, the distance from Henle's spine to the stylomastoid foramen was found to be about 1.5 cm, to the lateral and medial margins of the jugular foramen 2.5 and 3.5 cm, to the external orifice of the hypoglossal canal 4 cm, and to the foramen magnum 5 cm.

Conclusion: Henle's spine with its superficial and central position can be used to localize important anatomical structures during skull-base surgery.

Key words: Skull Base; Temporal Bone, Otologic Surgical Procedures

Introduction

Since the beginning of the 20th century many approaches have been described for skull-base surgery, including anterior, anterolateral, lateral, and posterolateral. All these approaches require much experience, surgical dexterity, and good anatomic knowledge of the region. Moreover, because the skull base is a very complex region with many vital structures, and the main part of the skull base is obscured deep in the bone, landmarks for this region have special importance. Correct orientation for any skull-base approach begins with consideration of surface anatomic landmarks.[1,2]

Henle's spine, also referred to as the suprameatal spine, is well recognised as a guide to the lateral wall of the mastoid antrum.[3,4] Some authors have also reported Henle's spine as a guide to some structures in the temporal bone.[5,6] However, it has received almost no attention as a guide to other structures of the external surface of the skull base.

This anatomic study was performed to show that Henle's spine can be used as a multipurpose landmark to define nearly all the important structures of the cranial base. In order to demonstrate this, we determined two imaginary lines and a triangle, namely a spinopterygoidal line extending from Henle's spine to the root of the medial pterygoid plate, a bispinal line extending from one Henle's spine to the contralateral one, and a parapetrosal triangle lying between the spinopterygoidal line, the bispinal line and the sagittal midline (Figures 1 and 2).

Materials and methods

The material for this prospective study consisted of 92 specimens of 46 cadaveric dry skulls. All skulls were obtained from the collection of the Department of Anatomy of the Istanbul Medical Faculty of the Istanbul University, and the study was conducted at the same institution. The skulls belonged to male, adult Caucasians. There were no variations or pathological findings on the skulls. All measurements were made on the external surface of the skull base, i.e. basis cranii externa, by an

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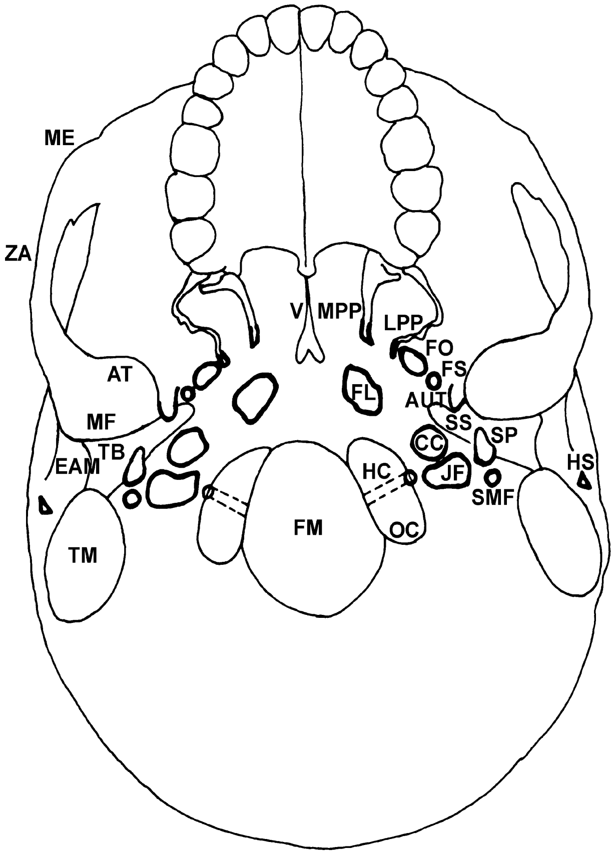

Fig. 1

External surface of the skull base. HS: Henle's spine, SS: spine of sphenoid, FS: foramen spinosum, FO: foramen ovale, LPP: lateral pterygoid plate, MPP: medial pterygoid plate, V: vomer, AUT: auditory tube, SMF: stylomastoid foramen, SP: styloid process, JF: jugular foramen, HC: hypoglossal canal, OC: occipital condyle, CC: carotid canal, FL: foramen lacerum, ME: malar eminence, ZA: zygomatic arch, AT: articular tubercle, MF: mandibular fossa, TB: tympanic bone, EAM: external acoustic meatus, TM: tip of mastoid, FM: foramen magnum.

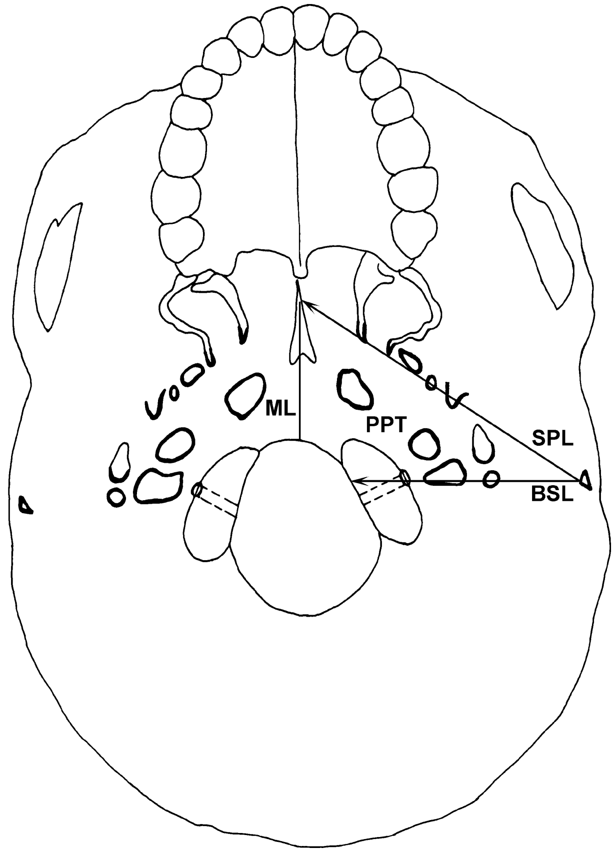

Fig. 2

The parapetrosal triangle. SPL: spinopterygoideal line, BSL: bispinal line, ML: midline, PPT: parapetrosal triangle.

experienced neuro-otologist (TU) and two experienced anatomists (AO, KS). Digital calipers (measuring range: 300 mm, Water and Coolant Resistant S235 Caliper, Sylvac, Switzerland) and a goniometer (Baseline 180° 8" Stainless Steel Goniometer, Fabrication Enterprises Inc, USA) were used which are accurate to 0.01 mm and 1°, respectively. The SPSS 7.5 statistical program (SPSS Inc., Chicago, USA) for Windows was used in the statistical analysis of all the measurements, and the mean, standard deviation, minimum and maximum values were calculated for each measurement.

Taking Henle's spine as the origin of the measurements, we determined two imaginary lines: the spinopterygoidal line and the bispinal line. The spinopterygoidal line begins from the tip of Henle's spine and extends through the medial margin of the foramen ovale to the posterior margin of the root of the medial pterygoid plate (Figure 2). The distances between the tip of Henle's spine and the following anatomical structures lying on the spinopterygoidal line were measured (Figure 3): (1) the posterior margin of the spine of the sphenoid, (2) the posterior margin of the foramen spinosum, (3) the posterior margin of the foramen ovale, (4) the anterior margin of the foramen ovale, (5) the posterior margin of the root of the lateral pterygoid plate, (6) the posterior margin of the root of the medial pterygoid plate, (7) the point at which the spinopterygoidal line crosses the vomer, and in addition (8) the external orifice of the bony auditory tube which is several millimeters medial to the spinopterygoidal line. The other imaginary line, the bispinal line, begins at the tip of Henle's spine and extends to the tip of the contralateral Henle's spine (Figure 2). The distances between the tip of Henle's spine and the following anatomical structures lying on the bispinal line were measured (Figure 3): (9) the lateral margin of the stylomastoid foramen, (10) the posterolateral margin of the styloid process which is several millimeters anterior to the bispinal line, (11) the posterolateral margin of the jugular foramen, (12) the posteromedial margin of the jugular foramen, (13) the external orifice of the hypoglossal canal, (14) the lateral margin of the occipital condyle on the bispinal line, (15) the medial margin of the occipital condyle on the bispinal line, and (16) the point at which the bispinal line crosses the midline. In addition, the angle between the spinopterygoidal line and the bispinal line was measured as no. 17 (Figures 2 and 3), and the area, which took the form of a triangle between the spinopterygoidal line, the bispinal line and the midline of the skull, was defined as the parapetrosal triangle.

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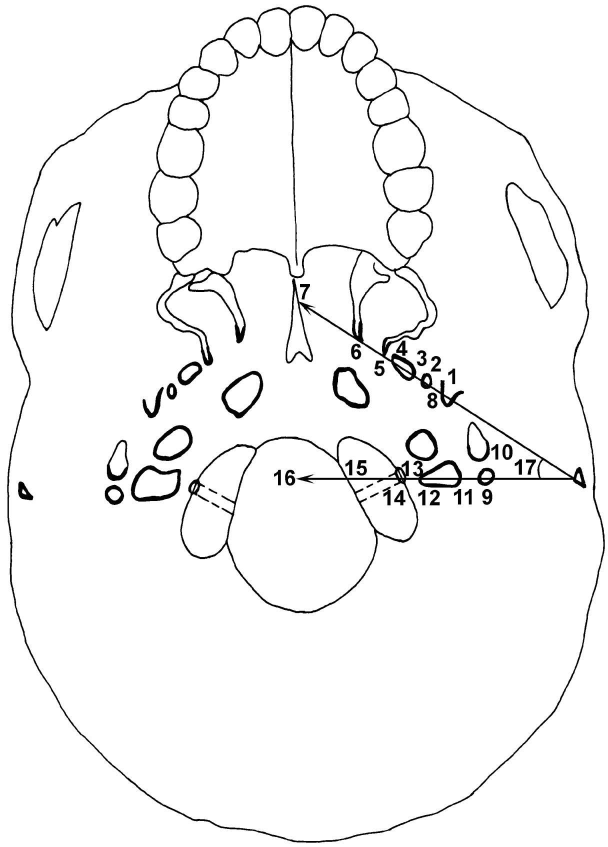

FIG. 3
Measurements 1–17.

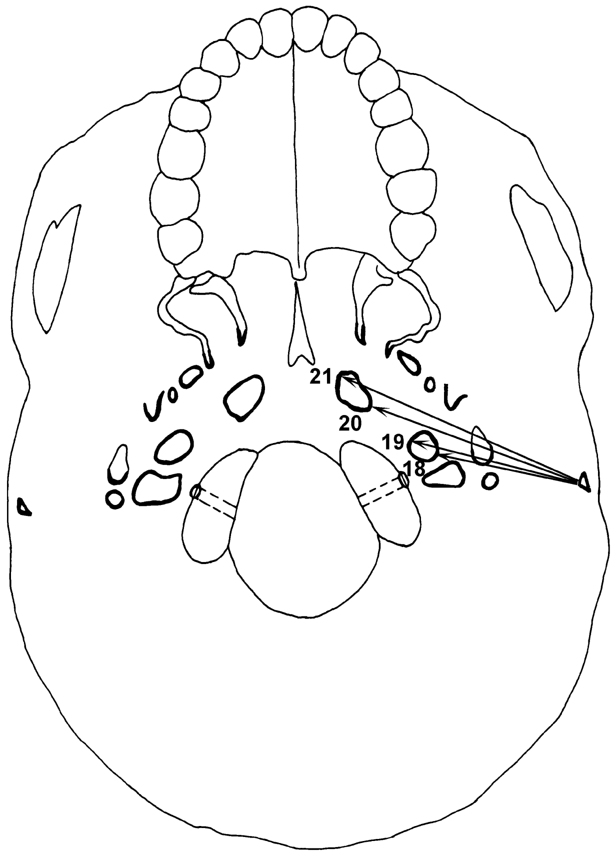

FIG. 4
Measurements 18–21.

Thereafter, the shortest distances between the tip of Henle's spine and the following structures lying in the parapetrosal triangle were determined (Figure 4): (18) the lateral margin of the external orifice of the carotid canal, (19) the medial margin of the external orifice of the carotid canal, (20) the posterolateral margin of the external surface of the foramen lacerum, and (21) the anteromedial margin of the external surface of the foramen lacerum. Furthermore, in order to define the size of the specimens, two morphometric measurements were performed: (22) the width of the skull (the distance between the two parietal tubers), and (23) the length of the skull (the distance between the glabella and the external occipital protuberance).

Results

The resulting measurements are all shown in Table I (refer also to Figures 1–4).

The mean distances of important anatomical structures from Henle's spine on the spinopterygoidal line were as follows: (1) to the spine of the sphenoid, 31.03 mm; (2) to the foramen spinosum, 33.62 mm; (3) to the posterior margin of the foramen ovale, 37.93 mm; (4) to the anterior margin of the foramen ovale, 44.71 mm; (5) to the root of the lateral pterygoid plate, 46.96; (6) to the root of the medial pterygoid plate, 52.73 mm; (7) to the point at which the spinopterygoidal line crosses the vomer, 68.08 mm; and

TABLE I

MEASUREMENTS OF SKULL-BASE STRUCTURES

No.	*n*	Mean	SD	Minimum	Maximum
1	92	31.03	2.00	26.2	38.3
2	92	33.62	1.89	30.1	37.8
3	92	37.93	1.85	33.4	42.3
4	92	44.71	2.81	38.4	52.3
5	92	46.96	2.96	39.7	54.5
6	92	52.73	2.39	47.7	58.6
7	92	68.08	2.29	59.9	74.7
8	92	34.02	1.97	29.8	38.9
9	92	16.52	1.47	12.4	19.6
10	92	16.58	1.41	13.8	19.9
11	92	23.40	2.37	19.3	30.2
12	92	34.35	2.01	29.1	38.5
13	92	37.96	2.22	32.9	42.9
14	92	39.94	3.29	32.9	48.3
15	92	50.05	3.48	41.1	58.2
16	92	59.81	2.79	54.2	69.7
17	92	37.57	2.81	30.0	42.0
18	92	28.70	3.74	23.1	29.1
19	92	34.50	2.08	28.3	38.9
20	92	47.09	2.16	38.9	51.9
21	92	52.63	2.37	46.6	59.1
22	46	139.45	6.60	125.0	150.0
23	46	175.77	8.80	158.0	197.0

Nos 1–8: distances (mm) on the spinopterygoidal line, Nos 9–16: distances (mm) on the bispinal line, No. 17: angle (degree) between the two lines, Nos 18–21: shortest distances (mm) from Henle's spine, Nos 22–23: morphometric measurements (mm) of the skull.

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in addition (8) to the external orifice of the bony auditory tube, 34.02 mm. The mean distances of structures from Henle's spine on the bispinal line were as follows: (9) to the stylomastoid foramen, 16.52 mm; (10) to the posterolateral margin of the styloid process, 16.58 mm; (11) to the posterolateral margin of the jugular foramen, 23.40 mm; (12) to the posteromedial margin of the jugular foramen, 34.35 mm; (13) to the external orifice of the hypoglossal canal, 37.96 mm; (14) to the lateral margin of the occipital condyle, 39.94 mm; (15) to the medial margin of the occipital condyle, 50.05 mm; and (16) to the point at which the bispinal line crosses the midline, 59.81 mm. The mean angle between the spinopterygoidal line and the bispinal line (17) was found to be 37.57°.

The mean shortest distances from Henle's spine to the structures that are lying in the parapetrosal triangle were found to be as follows: (18) to the lateral margin of the external orifice of the carotid canal, 28.70 mm; (19) to the medial margin of the external orifice of the carotid canal, 34.50 mm; (20) to the posterolateral margin of the external surface of the foramen lacerum, 47.09 mm; and (21) to the anteromedial margin of the external surface of the foramen lacerum, 52.63 mm. The morphometric measurements of the skull revealed: (22) the mean width of the skull, 139.45 mm; and (23) the mean length of the skull, 175.77 mm.

Discussion

On the basis of anatomic knowledge, experience, surgical dexterity and different landmarks, many original surgical skull-base approaches have been described.[7–19] In order to improve the accuracy of these procedures, many skull-base surgeons and anatomists have performed different measurements on the cranium and defined various landmarks.[1–4,6,20–31] In this study, Henle's spine was considered as the main anatomical landmark to approach different bony structures that are encountered during skull-base surgery. Taking it as the origin, we defined two lines, the spinopterygoidal line and the bispinal line, by which many distances can be derived. In view of the authors' experience, these lines have been employed as reference guides during various skull-base procedures and have been found useful.

The angle between the spinopterygoidal line and the bispinal line was measured as approximately 40°. Along the spinopterygoidal line, the distances from Henle's spine to (i) the spine of the sphenoid, (ii) the foramen spinosum, (iii) the posterior and (iv) anterior margins of the foramen ovale, (v) the root of the lateral pterygoid plate, and (vi) the root of the medial pterygoid plate measured about 3, 3.5, 4, 4.5, 5, and 5.5 cm, respectively. The vomer lay approximately 6.5–7 cm away from Henle's spine. On the other hand, distances on the bispinal line from Henle's spine to (i) the stylomastoid foramen, (ii) the lateral and (iii) medial margins of the jugular foramen, (iv) the external orifice of the hypoglossal canal and the lateral margin of the occipital condyle, and (v) the margin of the foramen magnum were found to be about 1.5, 2.5, 3.5, 4, and 5 cm, respectively.

Although the relationship between the foramina and the spines is well recognised, especially along the petrotympanic fissure,[9,12,21] which corresponds approximately to the spinopterygoidal line, further descriptions or studies are lacking as to how they can be used as multipurpose landmarks, and how every bony structure can be the landmark for the other one. A review of the literature revealed no identical but some comparable measurements in the same area. In their study, Tedeschi and Rhoton[3] performed similar measurements, but between the zygoma root and mastoid apex as origin and the other structures. Their study revealed that the distance from the zygoma root to the foramen spinosum was 27.5 mm, and to the foramen ovale 30.5 mm. In our study, the distances to the same structures, but from Henle's spine, which is more posteriorly located than the zygoma root, were 33.62 and 37.93 mm, respectively. Tedeschi and Rhoton,[3] using the mastoid apex as origin, employed also other measurements, and reported that the distance to the stylomastoid foramen was 10.5 mm, to the lateral margin of the jugular foramen 18.5 mm, and to the external orifice of the hypoglossal canal 30 mm. In our study the distances to the same structures but from Henle's spine, which is more laterally and superiorly located than the tip of the mastoid, were 16.52, 23.40, and 37.96 mm, respectively. Day *et al.*[1] looked for different morphometric relationships between Henle's spine and other structures; they determined the distance between Henle's spine and the mastoid apex as 28.1 mm, and the distance between Henle's spine and asterion as 41.4 mm, but they didn't use Henle's spine as the main landmark for more important structures of the skull base. Goldenberg[20] took the malar eminence, zygoma root and mastoid tip as reference points and found that the distance of the spine of the sphenoid was 28.5 mm from the zygoma root. In our study the distance between Henle's spine and the spine of the sphenoid was 31.03 mm.

The petroclival region defines a very important junctional area formed by the sphenoid, temporal and occipital bones,[3] but its boundaries do not help the surgeon orientate during skull-base surgery. However, in the case of the parapetrosal triangle, whose boundaries also include the petroclival region, the surgeon is provided with valuable guidance for nearly all the important structures of the skull base. These can be listed as the petrosal internal carotid artery, the jugular bulb, the cranial nerves IX, X, XI, XII (only the external orifice of XII), VII, VIII, inner ear (except the posterior part of the labyrinth), III, IV, V1, V2, V3 (except the anterior part after the wall of the cavernous sinus), II (except the anterior part after the anterior clinoid process), the greater petrosal nerve and lesser petrosal nerve, and the intracranial entrance point of the middle meningeal artery.

This study was performed on the external surface of the skull base (basis cranii externa), but all these measurements, lines, and the triangle can also be applied to the internal surface of the skull base (basis cranii interna). Important bony anatomical structures, tegmen tympani, eminentia arcuata, and the meatal plane, all lie within the parapetrosal triangle on the internal surface of the skull base.

- **This study examines the possibility of using Henle's spine as a reliable landmark for skull-base surgery**
- **The authors examined 92 temporal bones assessing the relationship of Henle's spine to the foramen ovale and the medial pterygoid plate**
- **These skull-base structures appear to have a constant relationship to Henle's spine, which can hence be used as a landmark in skull-base surgical approaches**

Henle's spine, the spinopterygoidal line, the bispinal line, and the parapetrosal triangle seem to be very useful guides especially during infratemporal fossa approaches. However, they may also be helpful for orientation during middle cranial fossa, anterior or posterior approaches. If the cortex of the mastoid is not exposed, the beginning point of the helical crus at concha auriculare marks the position of Henle's spine; thus, in this situation the helical crus will be the landmark. If the cranial base is approached from the top through the middle cranial fossa, the posterior root of the zygomatic arc may be used to define the position of Henle's spine, which is approximately 1.5 cm posterior and 0.5 cm inferior to the posterior root.

Use of Henle's spine as the first landmark is not always necessary. If one anatomical structure is localized on the spinopterygoidal line or the bispinal line, the position of other structures can be estimated from the two lines and the parapetrosal triangle. For example, identifying the foramen ovale during any part of the surgery may allow the surgeon to localize Henle's spine on the spinopterygoidal line at an angle of 40° from the coronal plane, approximately 4 cm posterolaterally, and the vomer on the same line 2.5 cm anteromedially; therefore the carotid canal will be in the parapetrosal triangle medial to this imaginary line, and the surgeon will be aware of the location of the internal carotid artery.

Conclusions

Henle's spine with its superficial and central position can be used as the main landmark during skull-base surgery. Important anatomical structures, such as the spine of the sphenoid, foramen spinosum, foramen ovale, the root of the lateral and medial pterygoid plate, and the vomer, lie on the spinopterygoidal line in ascending order of distance from Henle's spine as follows: 3 cm, 3.5 cm, 4–4.5 cm, 5 cm, 5.5 cm, and 6.5–7 cm at an angle of 40° to the coronal plane. Other important anatomical structures on the coronal plane of the bispinal line include the stylomastoid foramen, the jugular foramen, the occipital condyle with external orifice of the hypoglossal canal and the foramen magnum; these lie in ascending order of distance from Henle's spine as follows: 1.5 cm, 2.5–3.5 cm, 4 cm, and 5 cm. The parapetrosal triangle between the spinopterygoidal line, the bispinal line and the midline encompasses the whole or part of all the main structures of the skull base, including the petrosal internal carotid artery, the jugular bulb, nearly all the cranial nerves (II–XII), the trigeminal ganglion, the cochlea, the greater and lesser petrosal nerves, and the intracranial entrance of the middle meningeal artery. Knowledge of the constant relationship of the skull-base structures to Henle's spine would be useful for safe surgery with better outcomes in skull-base approaches.

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