Offprint from
Advances and Technical Standards in Neurosurgery, Vol. 31
Edited by J.D. Pickard
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Surgical Anatomy of Calvarial Skin and Bones—With Particular Reference to Neurosurgical Approaches

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With 16 Figures

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Abstract

This chapter on surgical anatomy is addressed to young neurosurgeons and could be used as an introduction to basic neurosurgical technique. It aims to cover the basic anatomy relevant to making incisions in the scalp and creating bone flaps, an essential preliminary to any form of intracranial surgery. We will examine the anatomy of the scalp, its arterial and venous supply and its nervous system, as well as providing some technical points related to the cranial vault and the base of the skull. It will be explained how a well-grounded knowledge of the anatomical details makes it possible to execute correctly two of the most common approaches in neurosurgical practice, namely the pterional approach and an approach around the sinuso-jugular axis.

Keywords: Anatomy; operative technique; pterional craniotomy; scalp; skull base; vascularisation; venous sinuses.

Introduction

It has long been recognized that a key capacity for any operator who wishes to gain access to a lesion within the skull is the ability to install and center a bone flap as effectively and accurately as possible. Nothing is as detrimental as a poorly oriented head or a badly centered flap. The position of the incision into the scalp should therefore be first decided according to the location of the lesion to be accessed as well as on the basis of criteria pertaining to the creation of a suitable flap. Without losing sight of this key point, two other principles need to be borne in mind when making incisions: firstly the need to preserve the vasculature and nervous supply of the scalp; and secondly, aesthetic considerations and the possibility of hiding the scar. Our aim here is not to give technical details about surgical procedures but rather to point out certain key anatomical features which dictate basic neurosurgical technique.

Descriptive Anatomy of the Different Layers Covering the Cranium (Fig. 1)

A great deal of work has been carried out on the scalp [3, 8, 9, 12]. What follows is a description of the various layers as they appear on dissection.

The scalp is made up of the skin, sub-cutaneous tissue and the galeal aponeurosis.

The skin and subcutaneous tissue are extremely thick, representing one of the special features of the scalp. The vessels and nerves are found at the lower surface of the sub-cutaneous adipose tissue.

The innermost border of this sheet is delineated by the epicranium or galeal aponeurosis. The terms epicranium or superficial musculoaponeurotic fascia are used to designate what is routinely referred to as the galea. Strictly speaking, the galea corresponds to the aponeurotic compartment of the fascia which incorporates a series of paired muscles (the frontal, auricular and occipital muscles) as well as an aponeurotic sheet. This sheet

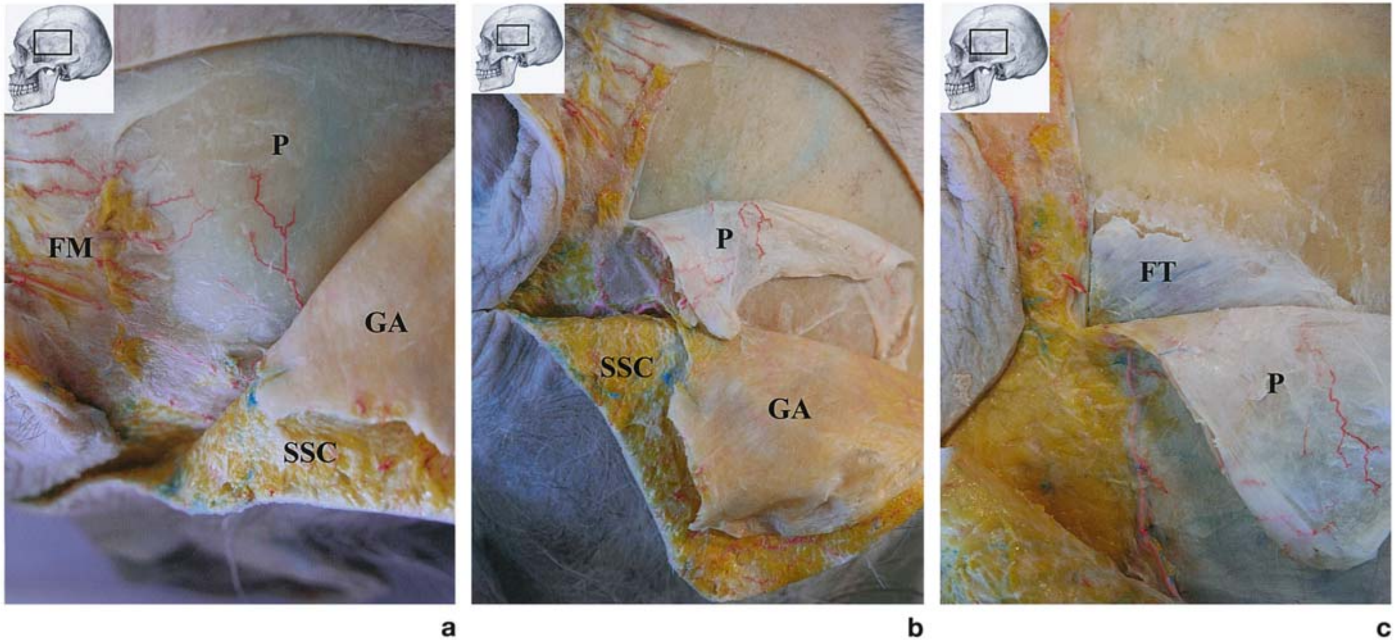


Fig. 1. Left lateral view of the scalp in a cadaver specimen following skin incision and colored latex injection. (a) The galeal aponeurosis (*GA*) has been incised at the level of the frontalis muscle (*FM*) and has been turned with the skin and subcutaneus tissue (*SST*). The pericranium (*P*) is identified. (b) The pericranium (*P*) has been turned. The 3 layers can be identified: skin and subcutaneus tissue (*SST*), the galeal aponeurosis (*GA*) and the pericranium (*P*). (c) Periosteum (*P*) resection with exposure of the fascia temporalis (*FT*)

extends from the frontal region back to the occiput, and from the vertex to the zygomatic arches. In front, it continues into the face. It is difficult to separate the galea from the sub-cutaneous fatty sheet because of the many arterial ramifications which originate in the vascular network of the galea and travel outwards. It is a dictum that when the galea moves, the skin and the fatty tissue moves with it [3, 12]. The lateral extension of the galea is sometimes called the temporoparietal fascia, and it is over this that the superficial temporal artery runs. This sheet is less dense. The frontal muscles arise in the galea and are inserted deep in the dermis. They are separated from one another by an extension of this fascia. The occipital muscles originate at the superior nuchal line and are inserted in the galea. The auricular muscles are very thin and are difficult to separate out by dissection.

The periosteum of the skull—also referred to as the pericranium—is a thin, fibrous sheet which is only loosely attached to the bone apart from along the sutures. It is easily lifted off the bone. It is conventionally said that the periosteum of the skull is continued at the temporal region by the aponeurosis of the temporal muscle (the temporalis fascia). This continues on down to attach at the zygomatic arch. The temporalis fascia is particularly strongly attached to the galeal aponeurosis. Thus, the temporalis muscle is situated between its fascia externally and bone internally. Blood and trophicity are supplied to this muscle by the deep temporal arteries which run across the muscle's internal surface.

Between the galea and the periosteum of the skull or the pericranium is found a tissue layer at which the scalp can be detached, namely the layer of subaponeurotic areolar connective tissue.

In the light of these anatomical considerations, it can be seen that the classic galeal flap described in the surgery of the anterior cranial base is, in reality, a periosteal flap.

In conclusion, in practical terms the surgeon needs to bear in mind that there are four successive layers between the skin and the periosteum of the skull:

- skin and subcutaneous tissue
- galeal aponeurosis (epicranium)
- subaponeurotic areolar connective tissue
- periosteum (pericranium)

Vasculature of the Scalp (Figs. 2–7)

The corrosion casting technique—the various possibilities of which are thoroughly described by Hill in 1981 [5]—reveals the richness of the vascular network at the cephalic extremity. It gives a picture of the intracranial and extracranial arterial and venous tree because it removes both soft tissues and the cranium.

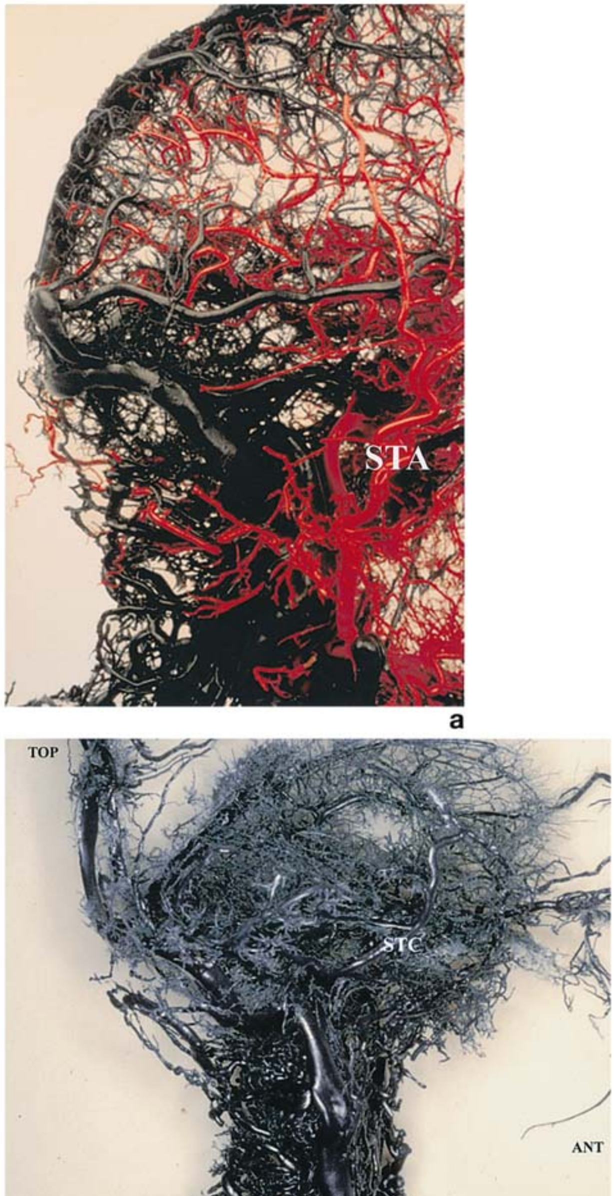


Fig. 2. (a and b) The arteries and veins to and from the head: Complete corrosion of the tissues leaves the cast of the intra and extracranial arterial and venous tree. Note the presence of a well identified superficial temporal artery (*STA*). The extracranial venous pattern is not systematized. See the superficial temporal collector (*STC*)

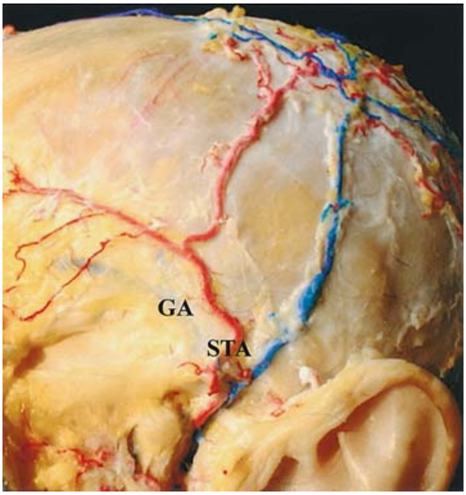


Fig. 3. Lateral view of a left superficial temporal artery (*STA*) (following colored latex injection) running over the galeal aponeurosis (*GA*)

Arteries

Superficial Temporal Artery (STA)

Extensive investigation has shown that the STA alone supplies not only the scalp but also the superior lateral half of the face, half of the parotid gland and part of the temporomandibular joint [6, 7, 10, 11]. Although in practice, interrupting its flow actually causes little damage to the scalp (mainly

Fig. 4. The skin incision for the frontopterional approach

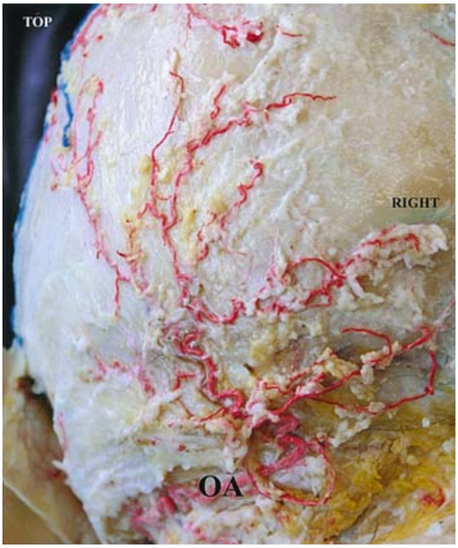


Fig. 5. Posterior view of the left occipital artery following colored latex injection

because of the existence of a vast network of anastomoses), it is nevertheless important when it comes to the creation of reconstructive flaps or extracranial anastomoses with the petrous carotid artery in the course of certain surgical procedures at the base of the skull.

Originating in the external carotid artery, the STA arises at the neck of the condyle and then rises vertically in front of the tragus. At the zygoma, it has an external diameter of the order of 2.2 mm [7]. It passes at an aver-

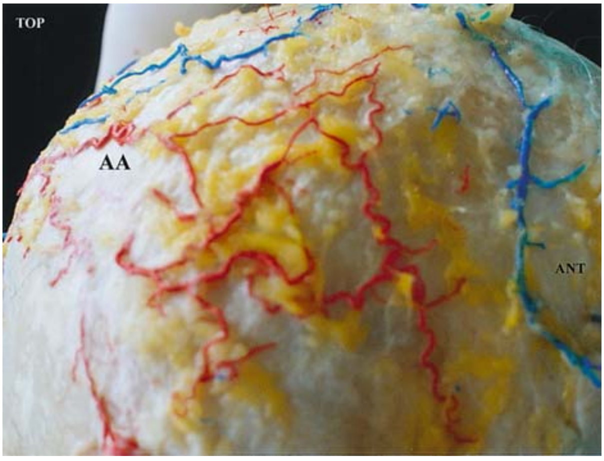


Fig. 6. Anastomosis (*AA*) between arteries of the scalp at the level of the vertex

Fig. 7. Venous right sided injection of the scalp. Note the poor filling of the frontal area with a single pretragal collector

age of 0.94 $\pm$ 0.38 cm from the anterior edge of the tragus [11]. It runs along the internal surface of the sub-cutaneous tissue. Its average length between the zygoma and its branches is 31.7 mm [7]. In nearly 92% of the cases, the STA presents a bifurcation with branches to supply the frontal and parietal regions [7]. At this branch point, its diameter is no greater than 1.9 mm [7]. The frontal branch runs obliquely upwards and forwards. It forms numerous branches which form anastomoses. The parietal branch continues vertically up towards the vertex in a two-centimeter-wide band centered on the external auditory meatus and parallel to the frontal plane (landmark skin band) [6].

This architecture is important when it comes to frontopterional incisions at the hair line which can be made just in front of the tragus behind the STA [14]. Some surgeons make the incision in front of the STA [1].

Occipital Artery (OA)

The OA originates on the posterior side of the external carotid artery near the posterior belly of the digastric muscle. It runs along the digastric muscle as far as the mastoid region where it passes under the longissimus and splenius capitis muscles to form two terminal branches. The lateral branch carries on vertically upwards in the sub-cutaneous layer. The medial branch continues horizontally as far as the external occipital protuberance before turning through a right angle to carry on vertically across the trapezius muscle, ending in the sub-cutaneous tissue.

A paramedian skin flap hinged at the bottom to expose the posterior fossa can become necrotic if the stalk is too narrow.

Posterior Auricular Artery

This also originates at the posterior side of the external carotid artery from where it travels along the sternohyoid muscle to divide into two different branches at the mastoid aponeurosis. These branches supply the retroauricular regions and the pinna.

Arterial Anastomoses

Here, we will not discuss anastomoses between the territories of the internal carotid (via branches of the ophthalmic artery) and the external carotid: although familiarity with these is essential when it comes to embolization techniques, it is not relevant to installing skin flaps.

There are many anastomoses between the various territories of the external carotid artery, with the number apparently increasing as one gets closer to the vertex where circles of anastomotic density can be described. These anastomoses may be homo or contra-lateral.

For practical purposes, it is important to remember that:

– All the arteries of the scalp run into the sub-cutaneous tissue;
– All the arteries of the scalp flow upwards (so skin flaps must always be created with an inferior stalk);
– Anastomoses between the three main arterial territories of the scalp form from one side and with the opposite side, thereby justifying all the flaps envisaged by plastic surgeons.

Veins

The venous network has traditionally been seen as the poor cousin in the scalp's vascular system, and its extreme variability has probably put many off attempting to describe it. The idea that veins follow the path of arteries is particularly subject to doubt in this location, and this is probably the reason for the resounding failure of certain forms of flap. Although most drainage occurs via a superficial temporal collector, corrosion casts have revealed the great richness of the venous network. On the basis of the dissections that we have prepared, it appears that there are few venous collectors in the frontotemporal region which might explain why there is such extensive edema of the face sometimes following fronto-pteriono-temporal detachment of the scalp. This hypothesis was proposed by Lebeau in 1986 [6].

Innervation of the Scalp (Figs. 8 and 9)

Frontotemporal Branch of the Facial Nerve

The frontotemporal region is innervated by the superior or frontotemporal branch of the facial nerve. This branch leaves the parotid gland and

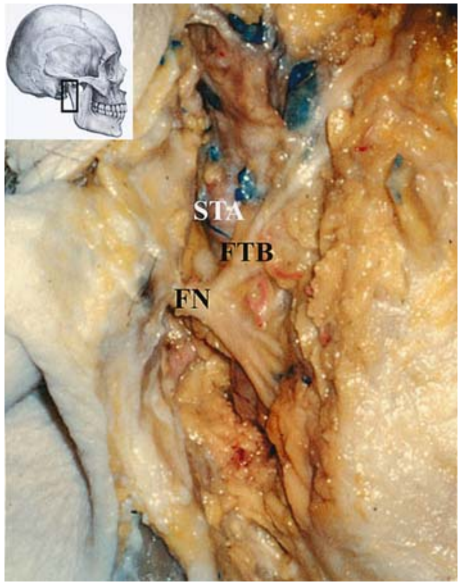


Fig. 8. Dissection of a right facial nerve (*FN*) in a cadaver specimen. Note the relationships between the frontotemporal branch of the facial nerve (*FTB*) and the trunk of the superficial temporal artery (*STA*)

climbs up across the lateral zygomatic arch at the internal surface of the sub-cutaneous tissue to the galeal aponeurosis or temporoparietal fascia which is particularly strongly attached to the temporalis fascia at this point. The zygomatic arch is crossed about one centimeter in front of the trunk of the STA [14].

This anatomical architecture has an important consequence: whatever method is used to lift the scalp following a pterional approach, the skin incision should not extend down as far as the zygoma and detachment of the galea should not be excessively anterior. It should stop no further than two fingerbreadths from the orbital arch and should carry the temporal fascia with it to avoid damaging the superior branch of the facial nerve. This has spurred the development of various techniques designed to overcome this problem [13, 14].

Yasargil developed the interfascial temporalis flap [14]. Dissection between the galea and the temporalis fascia is carried out from behind towards the front to stop two fingerbreadths (i.e. 3–4 cm) from the orbital arch. The temporalis fascia together with the muscle are incised vertically from the superior temporal line as far as the zygomatic arch. The temporalis fascia is then pulled forwards together with the muscle. Since there is

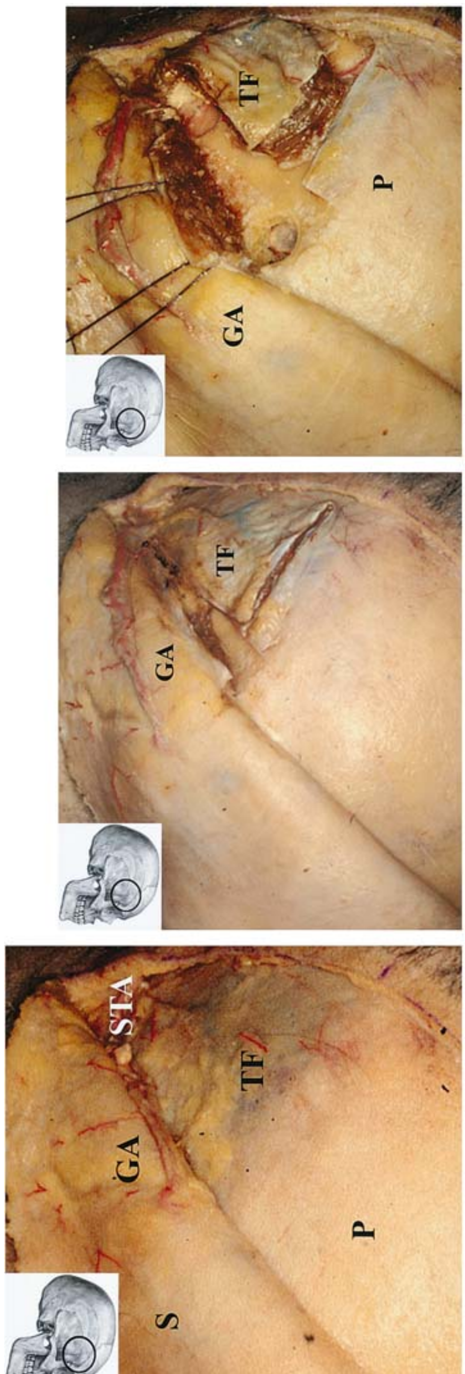


Fig. 9. The right pterional approach in a cadaver specimen. (a) The scalp (*S*) has been turned preserving the superficial temporal artery (*STA*), with exposure of the temporal fascia (*TF*) and periosteum of the skull (*P*). The dissection between the galeal aponeurosis (*GA*) and the temporal fascia has been stopped when reaching 4 centimeters from the orbital rim. (b and c) The temporal fascia (*TF*) is incised vertically from the temporal crest to the zygomatic arch and reflected forward in an "en bloc" fascion to preserve the frontotemporal branches of the facial nerve which are kept along with the superficial planes

no dissection between the galea and the temporalis fascia, there cannot be any damage to the nerve.

Spetzler suggests not separating the galea from the temporalis fascia at all with detachment of both cutaneous and muscle tissues achieved in a single step [13].

The Posterior Branch of the Second Cervical Nerve

This large nerve emerges from the trapezius muscle two centimeters below and lateral to the external occipital protuberance. In the sub-cutaneous tissue, it then branches out along a vertical and paramedian path. It provides the nervous supply to the posterior part of the scalp. Obviously, transverse incision in this region is precluded.

Identification of Surface Landmarks of the Skull

The Base of the Skull (Figs. 10 to 13)

Rather than describing the classic features of the base of the skull, we have chosen to focus on the orientation of the head in space and the consequences of its position during the operation. How the base of the skull is positioned for a pterional approach or one via the posterior fossa is extremely important and is going to determine the outcome of the procedure.

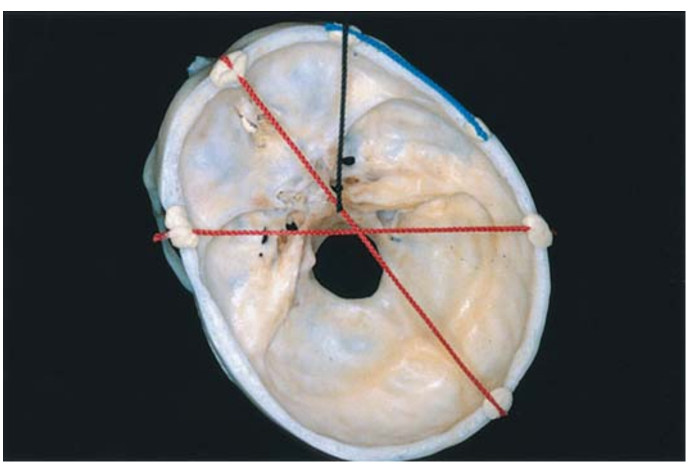


Fig. 10. Anatomical modifications after the patient's head has been rotated to the opposite side

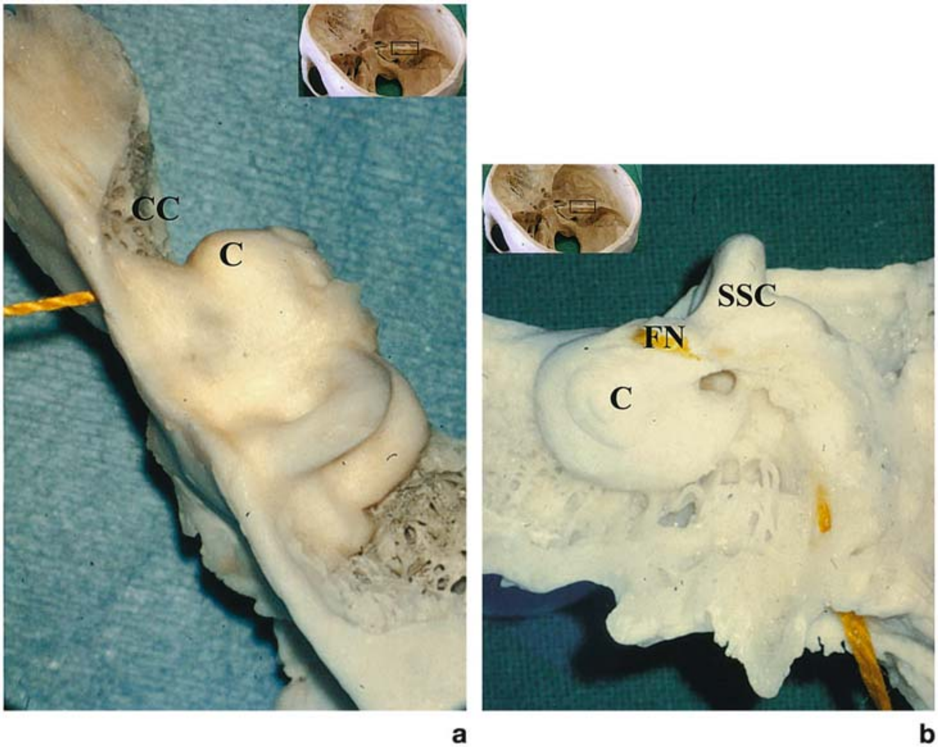


Fig. 11. Superior (a) and lateral (b) views of a drilled left dry bony labyrinth after resection of the middle ear. Note the carotid canal (*CC*) which is partially covered by the cochlea (*C*). Note the relationships between the facial nerve (*FN*) and the semicircular canals (*SSC*)

The performance of the surgeon's approach begins with proper positionning of the patient's head and proper location of the bone flap.

Important Points to Remember

The greater the inclination of the cranial axis away from the vertical, the more vertical will be the direction of the sphenoidal crest and the more horizontal will be that of the petrosal crest. It applies for the sitting position also: if the head is rotated, the petrosal crest is in a more sagital position. The positions of these bony landmarks are fixed and they can constitute a useful aid to establish spatial relationships during a procedure, as long as the "dynamic" characteristics of the anatomical situation are understood. The advent of surgical neuronavigation tools has not in any way dispensed with the need for a profound understanding of anatomy, and laboratory-based teaching of the spatial relationships is crucial.

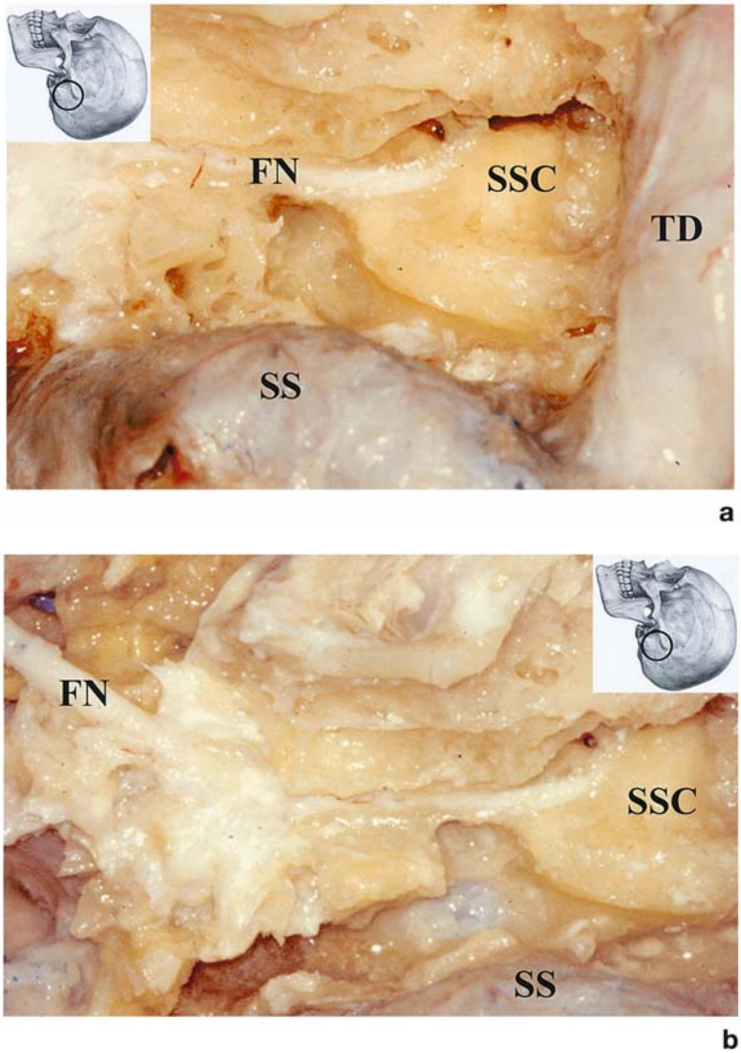


Fig. 12. (a and b) Drilling of a left bony labyrinth in a cadaver specimen to show the relationships between the facial nerve (*FN*) and the bony structures. Note the location of the sigmoid sinus (*SS*) and the temporal dura (*TD*)

Important Relationships at the Skull Base: The Bony Labyrinth, the Facial Nerve and the Petrous Segment of the Carotid Artery

A comprehensive review of the anatomy of all the bones of the base of the skull is beyond the scope of this chapter [4] but an awareness of certain anatomical relationships is essential if the principle of the trans-petrous approaches is to be grasped.

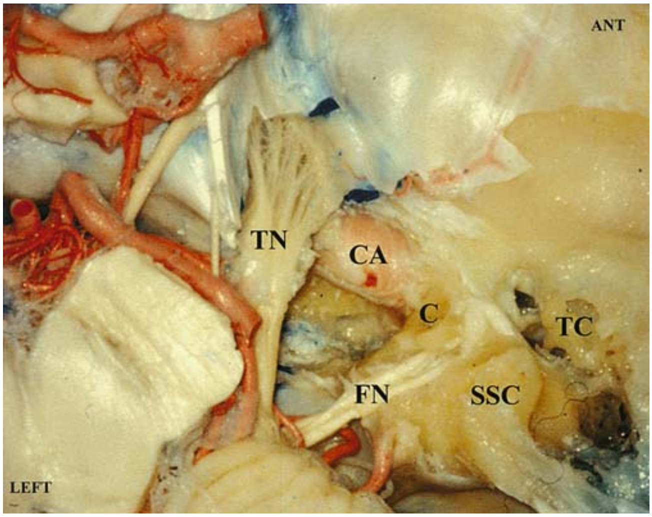


Fig. 13. Superior view of a drilled right middle cranial fossa in a cadaver specimen to show the relationships between the trigeminal nerve (*TN*), the carotid artery (*CA*), the facial nerve (*FN*), the cochlea (*C*), the semicircular canals (*SSC*) and the tympanic cavity (*TC*)

A dry specimen of a left sided drilled bony labyrinth can be used to show the ventral segment (cochlea) and the dorsal segment (vestibule and semicircular canals). Its length is about 2 cm located in the long axis of the petrous pyramid. The relationships between the lateral tract of the lateral semicircular canal and the second portion of the facial nerve, and between the ampullae of the superior and lateral semicircular canals and the genu of the facial nerve are to be emphasized. These landmarks are routinely used as a guideline when drilling the bone to avoid damage to the facial nerve during posterolateral approaches.

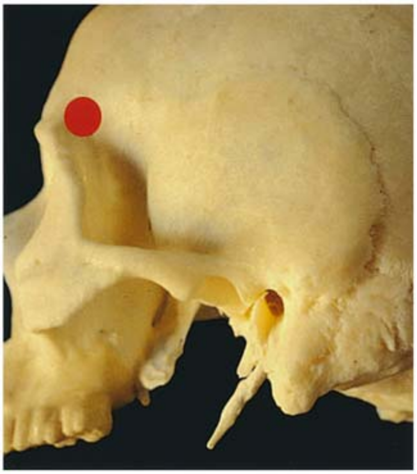
The cochlea lies near the cortical substance of the petrous apex. The carotid canal is usually partially covered by the cochlea so it is impossible to displace the carotid artery downwards from above without entering the cochlea. The petrous segment of the carotid artery may be or may not be covered by bone at the level of the middle cranial fossa. If not, it is separated from the trigeminal enlargement by a dural layer. If the floor of the middle cranial fossa is drilled, the facial nerve within the internal auditory meatus, the geniculate ganglion, and the middle ear will be exposed. Drilling the petrous apex medial to the carotid artery gives access to the posterior fossa along the inferior petrosal sinus.

The Key Surface Structures (Figs. 14 to 16)

The "keyhole" concept makes appropriate placement of the first burr hole of importance. Two of these are particularly important, the one in the pterional region and that around the sinuso-jugular axis.

The Pterional Approach

The hole should be made behind the lateral crest of the external orbital rim of the frontal bone. This will afford access to the inferior surface of the frontal lobe just above the roof of the orbit.



a

b

Fig. 14. (a and b) The pterional keyhole burr hole is show for the pterional approach

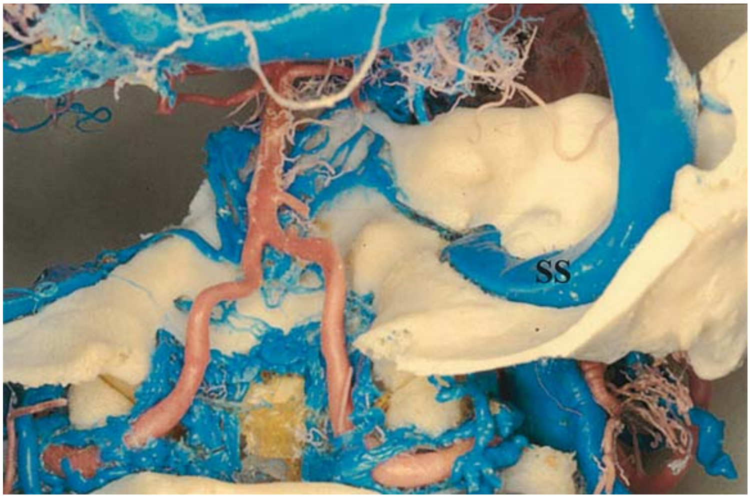
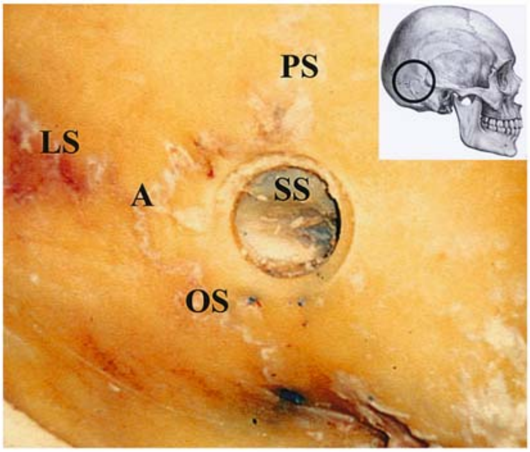


Fig. 15. Corrosion cast showing the relationships between the sigmoid sinus (*SS*) and the bony structures at the skull base

Venous Sinus Relationships to Surface Landmarks of the Skull

The sinuso-jugular axis is one of the keys to access to the base of the skull. It is dangerous (being surrounded by many other structures) but accessible (superficial, posterior, continuous). All corrosion casts show that the transverse sinus, the transverse-sigmoid junction and the sigmoid sinus are deeply located within a large bony groove which makes the first burr hole quite difficult and risky if placed just on the venous structure.

Placement of the burr holes for craniotomy must be compatible with the position of the transverse and sigmoid sinuses. Posterior surface landmarks have been proposed in the literature [2]. The asterion, the mastoid groove and the superior nuchal line were found to be the most valuable landmarks. Because the asterion could not be identified in almost 60% of the cadaver specimens, various methods have been proposed. We believe that the first burr hole can be placed in the angle between the asterion, the parietomastoid and the occipitomastoid sutures. The second burr hole can be placed in the angle between the asterion, the lambdoid and the occipitomastoid sutures. Doing so on both sides of the occipitomastoid suture, you stay below the venous structures. Making the holes on either side of the occipitomastoid suture ensures avoidance of the venous structures above. For combined exposure with via a supratentorial approach, third and fourth burr holes can be placed on both sides of the squamosal suture.



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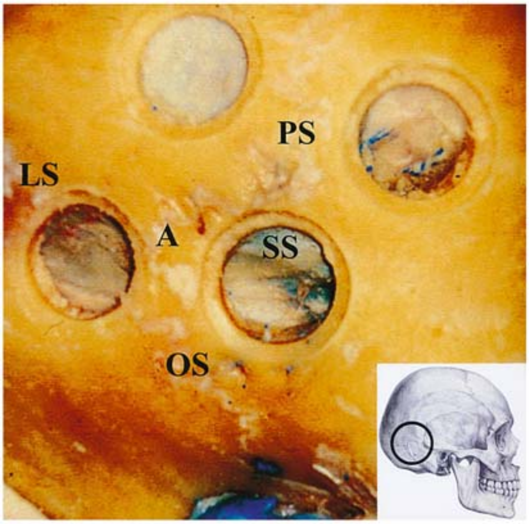

b

Fig. 16. (a and b) The keyhole burr holes are shown along the right sinuso-jugular axis; (*A* asterion; *LS* lambdoid suture; *OS* occipitomastoid suture; *PS* parietomastoid suture)

Conclusion

Although today's young neurosurgeons have at their disposal sophisticated surgical neuronavigation tools, they nevertheless still need the basic anatomical knowledge which is indispensable to understanding and executing a classic cranial approach. Teaching how to make the exposure to create a perfect, centered bone flap needs to be kept as a priority in the surgical training of even the youngest surgeons. The basic anatomy described in this chapter is by no means exhaustive but it is intended to serve as a working basis and to stimulate thought about the major role that the Anatomy Laboratory should play in any neurosurgery training program.

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