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Review Article

Supraorbital artery: Anatomical variations and neurosurgical applications

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ABSTRACT

Background: The supraorbital artery (SOA) originates from the ophthalmic artery in a superomedial aspect of the orbit, exiting through the supraorbital groove to emerge onto the forehead. The SOA has important neurosurgical considerations regarding different approaches and bypasses. The SOA is poorly described in the standard anatomical textbooks. Therefore, we present this article to describe the anatomical variations of the SOA and their implications on the neurosurgical field.

Methods: We conducted a literature review in PubMed and Google Scholar databases to review the existing literature describing the SOA anatomy and its neurosurgical applications.

Results: While reading the available articles and original works regarding SOA, we identified 22 studies that discuss the SOA. We noticed the anatomical variations of the SOA in terms of origin, course, diameter, branches, depth, and distance in relation to the midline and vertical glabellar line. We also discussed certain applications of SOA and its importance in neurosurgical approaches, bypass, photoplethysmography, aneurysms, and reconstruction of cranial fossa defects.

Conclusion: The variable anatomy of the SOA has a paramount impact on performing different neurosurgical approaches. Therefore, cadaveric studies of the SOA are important to explore potential methods for the preservation of the artery in different neurosurgical applications.

Keywords: Anatomical variation, Neuroanatomy, Supraorbital artery

INTRODUCTION

The supraorbital artery (SOA) originates from the ophthalmic artery in a superomedial aspect of the orbit, exiting through the supraorbital groove to emerge onto the forehead. It ends with two terminal branches: superficial and deep. SOA supplies the skin of the forehead and the periosteum of the frontal bone, along with the superior rectus and levator palpebrae superioris muscles. Its terminal branches are anastomose with their contralateral counterparts, as well as the ipsilateral supratrochlear and superficial temporal arteries.[8]

The SOA has important neurosurgical considerations regarding different approaches and bypasses. This importance lies in its involvement in lesions such as aneurysms,[2,6,7,12,13,16,18] and its incorporation in reconstruction flaps for skull base and skin defects.[5,10,14,19]

The SOA is poorly described in the standard anatomical textbooks. The literature describing the SOA mostly fails to provide a precise, cumulative, or integrated description of the artery. An accurate definition of the SOA branches needs more attention to highlight the variance between SOA's deep and superficial branches.[15]

For the purpose of drawing a complete picture of the anatomical disparities, we, hereby, describe the anatomical variations of the SOA and their implications on neurosurgical applications.

MATERIALS AND METHODS

A bibliographic search in Google Scholar and PubMed medical databases for studies on SOA and its clinical relevance was performed. The following search terms were used: "Supraorbital artery vascular anatomy" and "supraorbital artery neurosurgical applications." Inclusion criteria were as follows, (i) English language and (ii) suitable methodology of the targeted data, while exclusion criteria were as follows, (i) non-English papers and (ii) questionable results. Results were categorized and selected appropriately. The data extraction includes surgical anatomy and neurosurgical applications of the SOA.

RESULTS

While reviewing the available articles and original works regarding SOA, considering the inclusion and exclusion criteria, we identified 22 articles that discuss the anatomical variations and neurosurgical applications of SOA. Certain parameters are used to describe the surgical anatomy of SOA, including origin, course, diameter, branches, depth, and distance in relation to the midline and vertical glabellar line. We also discussed certain applications of SOA and its importance in neurosurgical approaches, bypass, photoplethysmography, aneurysms, and reconstruction of cranial fossa defects.

DISCUSSION

SOA anatomy

SOA is one of the arteries that have considerable variations in anatomy. Certain parameters are implicated to discuss these variations, including origin, course, branches, diameter, depth, distance from midline, and its relationship with the vertical glabellar line.

SOA origin

The SOA stems from the ophthalmic artery, lying medially to the optic nerve. At the orbital rim, the ophthalmic artery bifurcates into superior and inferior orbitoglabellar arteries in 65% of cases, according to Tansatit *et al*. At this junction, the SOA emerges from the superior orbitoglabellar artery (37.5%) either after passing underneath the corrugator supercilii muscle near the supraorbital foramen\notch or emerges separately from the ophthalmic artery through the supraorbital notch (25%) or foramen (10%) along the side of the supraorbital nerve.[21]

SOA course

The SOA courses 1–3 mm medially to the vertical mid-pupillary line. It travels lateral to the supratrochlear vasculature, close to the frontal bone. The SOA then either passes medially, where it pierces the corrugator supercilii muscle, or laterally where it has no connection with the muscle.[4]

SOA branches

There are two possible configurations for the SOA. In the first, the SOA bifurcates forming superficial and deep branches once it exits the supraorbital foramen. In the second, its deep branch extends superficially and superolaterally from the supraorbital notch, piercing the frontalis muscle and forming the superficial branch [Figure 1].[3] In 70% of cases, the division of the SOA into its superficial and deep branches happens at the level of the orbital rim or below, while in 20% of cases, deep SOA pericranial branches are separated from the superficial branch about 8.6 mm directly above the orbital rim.[22]

Phumyoo *et al*. evaluated the SOA[17] stating that the superficial branch is present in 50% of cadavers. The superficial branch mostly (57.9%) arises at the superior orbital fissure (SOF) and in 42.1% of cadavers from the superior orbitoglabellar artery.

On the other hand, the deep branch is recognized in 100% of cases. In 60.5% of cadavers, it stems from the superior orbitoglabellar artery, and in cadavers 39.5% at the supraorbital notch. Typically, the SOA artery has a singular deep branch; nevertheless, Phumyoo *et al*. detected the presence of a double deep branch on the same side, as medial and lateral segments, in 34.2% of cadavers.[17]

Kleintjes identified the terminal branches of the SOA, in order of frequency; deep branches include the vertical (100%), oblique, and lateral rim (91% each), and medial (44%) branches. Superficial branches include; superficial vertical (9%) and brow (5%) branches [Figure 2].[15]

Terminal branches of SOA deviate laterally at two-thirds of the eyebrow to anastomose with the superficial temporal artery frontal branch, confirming the existence

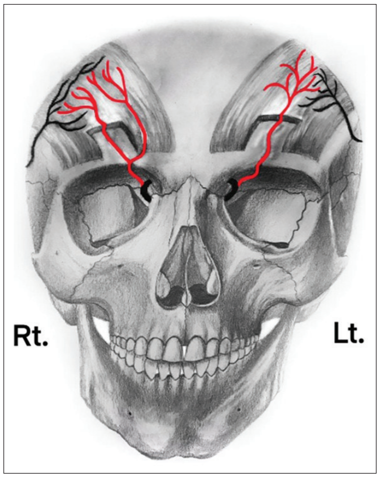

Figure 1: Anatomical variation of superficial and deep branches of SOA. On the right (Rt) hemi-forehead, SOA divides into superficial and a deep branches after it exits the supraorbital foramen. On the left (Lt) hemiforehead, deep branch of SOA extends superficially and superolaterally from the supraorbital notch; then, it pierces the frontalis muscle forming the superficial branch. SOA: Supraorbital artery.

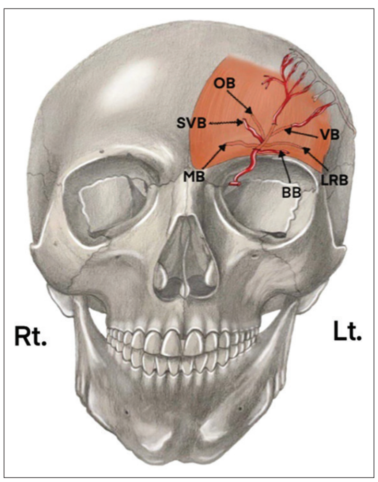

Figure 2: The left (Lt) hemi-forehead view demonstrates the terminal branches of the supraorbital artery. This includes the superficial branches on the left hemi-forehead: brow branch (BB) and superficial vertical branch (SVB), as well as the deeper branches: medial branch (MB), oblique branch (OB), vertical branch (VB), and lateral rim branch (LRB).

of anastomosis between the two carotid systems.[17] The SOA also anastomoses with the angular artery close to its anastomoses with the superficial temporal artery.[20]

The incidence of SOA superficial branches is inconsistent, making it a poor candidate for consideration when planning skin flaps. On the other hand, the consistent existence of the SOA deep branches with their supplied areas marks them as important parameters for planning SOA-based flaps, taking into consideration varying and small contributions from the supratrochlear artery.[1]

Superficial branch

The branch progressively travels in a superficial plane around 20–40 mm beyond the supraorbital rim, and pierces the frontalis muscle to become superficial to this muscle until it reaches the region of mid-frontal depression.[8]

This branch first penetrates the corrugator supercilii muscle, followed by the frontalis muscles right underneath the midfrontal depression, 7.8 mm transversely from the medial canthus, and 11.5 mm vertically from the orbital rim [Figure 1].[17]

Deep branch

The deep branch emerges from the SOA at the supraorbital rim, and passes about 16–42 mm beyond this point, traveling beneath the frontalis muscle, and on the pericranium contained by the subgaleal fascia.[8] It runs either in the intramuscular plane or supraperiosteal plane while traveling the midfrontal depression to the frontal prominence territory.[17]

It, then, travels superolaterally, piercing the frontalis muscle and emerging on the other side of the muscle as the superficial branch.[3] Its horizontal distance is around 29.6 mm from the vertical line of the medial canthus of this penetrating point, and the vertical distance is around 20.7 mm from the supraorbital rim.[17] It should be noted that not all deep branches penetrate the frontalis muscle; some branches change their course to run in either the intramuscular or the supraperiosteal layer.

The medial, lateral rim and oblique branches are invariably deep to the periosteum. The vertical branch tends to branch into multiple tributaries shortly after its source, which is typically deep (periosteal). The oblique branch passes on the periosteum, then at the vertical line of the lateral orbital rim, where it enters the frontalis muscle anteriorly to anastomose with either the superficial temporal artery (STA) frontal branch or transverse frontal artery. Anastomosis typically takes place at the junction of the inferior and middle transverse thirds. However, it may occur at a higher transverse level, which gives the oblique branch an elongated course in the lateral forehead.[15]

SOA diameter

The average diameter of the SOA is 0.6 mm at the supraorbital rim for both deep and superficial branches, ranging from

0.5 to 1.4 mm at the horizontal mid-eyebrow level, which is somewhat larger compared to other levels.[11,20]

SOA depth

The mean distance between the SOA and the skin surface is around 3.54 mm, ranging from 2.2 to 6.0 mm.[11,20]

Distance of SOA from the midline

The mean distance of the SOA from the midline is 24.08 ± 5.5 mm with a range of 8.8–31.8 mm in males, while it is around 23.44 mm ranging from 14.0 to 32.2 mm in females.[11]

Relationship between SOA and vertical glabellar line

The mean distance between the midline and the vertical glabellar line at rest is around 5.55 mm for males and approximately 6.59 mm for females. The mean distance between the SOA and the ipsilateral vertical glabellar line is approximately 22.38 mm, ranging between 6.8 and 31.1 mm in males, and 20.73 mm, ranging from 6.2 to 28.8 mm in females.[11]

Neurosurgical applications of SOA

The SOA has important neurosurgical considerations; multiple approaches to the anterior cranial fossa, sellar and parasellar spaces, and orbit involve the artery.[2,6,18] The superficial temporal artery-SOA bypass can help ameliorate visual disturbances in the setting of vascular occlusive disease to the ophthalmic artery.[16] The artery is also relevant to SOA photoplethysmography,[12] and as a feeding artery in the cirsoid aneurysm.[7]

Related neurosurgical approaches

Eyebrow approach (transciliary or superciliary approach)

This approach is a modification to the standard pterional approach that is mostly related to the SOA and its anatomical variations. It delivers satisfactory visualization of the anterior fossa, the sellar, parasellar, and suprasellar territories. This approach can be used effectively to manage different lesions, such as aneurysms of the anterior circulation, and even skull base tumors, including pituitary adenomas, meningiomas, as well as craniopharyngiomas. During this approach, the SOA is the medial most boundaries to this approach. It is believed that deep lateral branches of the SOA can be affected during the transciliary approach.[2]

Superomedial transorbital approach

The superomedial transorbital approach can be employed with an extracranial-intracranial bypass to revascularize the intraorbital ophthalmic artery in cases of vascular occlusive disease of the artery. After the supraorbital foramen is identified, a “V-shaped” osteotomy is made to permit the release of the supraorbital nerve and SOA inferiorly, which are then displaced inferiorly in the direction of the periorbita.[18]

Transpalpebral approach

The SOA is an important landmark for the transpalpebral approach, along with the supraorbital nerve, supraorbital foramen, the frontal sinus, and the upper eyelid fold. This approach provides a surgical corridor to the anterior cranial fossa, parasellar region, orbital space, and frontal sinus. SOA is at risk of damage during this approach. As such, accurate localization of the supraorbital notch can decrease the risk of damaging the SOA, which, further, reduces its associated complications.[6]

Superficial temporal artery-SOA bypass

In cases of ocular ischemia associated with occlusive vascular diseases, it is believed that revascularization to the ophthalmic artery indirectly, through superficial temporal artery-SOA bypass, ameliorates visual activity in such circumstances. A study found that the use of superficial temporal artery-SOA bypass resulted in marked improvement of visual acuity in the affected eye and, surprisingly, in the contralateral eye as well. This may be attributed to enhanced blood flow in the ethmoidal collaterals.[9]

SOA photoplethysmography

An easy and rapid method that can be used safely to assess carotid artery occlusive disease, SOA plethysmographic curves can additionally be used to monitor bypass patency.[12]

Cirsoid aneurysms

Cirsoid aneurysms are uncommon arteriovenous fistulas of the scalp, and their cause is frequently inherited. The SOA can be one of the feeding arteries in scalp cirsoid aneurysms. These aneurysms are managed surgically; large vessels are separately ligated and divided, before raising the scalp flap, followed by careful dissection of the scalp from the cirsoid aneurysm, followed by ligating the feeding and draining vessels, including the SOA, and resecting the lesion together with underlying the pericranium. These steps are essential to obviate massive hemorrhage.[7]

Reconstruction flaps

Flaps used in the reconstruction of the skull base include; frontal and pericranial flaps,[5,19] in which the SOA is incorporated into the periosteal part.

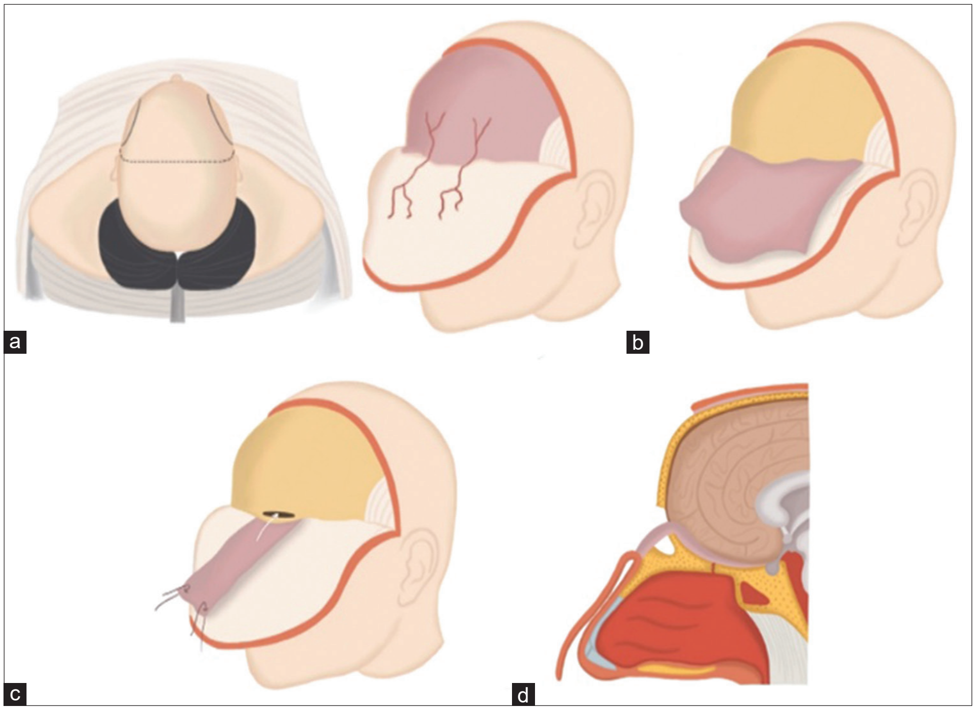

Figure 3: (a) Illustration of a skull base reconstruction procedure employing a pericranial flap derived from the supraorbital artery. This procedure involves making a bicoronal skin incision and carefully peeling forward the skin and galea-frontalis layers. (b) This step in the process involves carefully separating the pericranium from the galea-frontalis layer. The pericranium, harvested as a flap, is a vital component for the subsequent stages of the skull base reconstruction. This flap provides the necessary coverage and support for the newly reconstructed area. (c) The image depicts a frontal craniotomy procedure, a crucial step in the skull base reconstruction process. This involves craniotomy of the frontal bone to access the underlying structures for repair and reconstruction. (d) This image illustrates the crucial step of introducing the pericranial flap into the frontal cranial cavity. The flap is skillfully maneuvered to reconstruct the defect in the anterior cranial fossa, thereby restoring the anatomical integrity of the skull base.

Frontal flap

In performing supraorbital craniotomies, the frontal flap is considered a rapid and safe material to reconstruct defects in the frontal sinus, anterior cranial fossa, and orbit.[9] The SOA can be easily preserved during this flap as the supraorbital foramen is frequently not completed anteriorly, and the SOA can be freely dissected with the pericranium. However, in cases where the foramen is complete, the SOA is freely dissected by breaking the adjoining anterior bone using a small osteotome, followed by an anterior reflection of the SOA with the pericranium.[5]

Pericranial flaps

These have been an invaluable resource for anterior cranial fossa reconstruction before the development of the nasoseptal flap. The flap can be designed according to its blood supply into anteriorly and laterally based on pericranial flaps. The anteriorly based pericranial flap is supplied primarily from the deep supraorbital and supratrochlear arteries.[19] To preserve the arterial supply, the pericranial flap is separated from the galea-frontalis muscle. This separation should not extend more than 10 mm above the orbital rim [Figure 3].[22]

Temporofrontal fascial flap

Such a flap can penetrate the temporal muscle for the purpose of reconstructing the anterior and temporal skull base and dura. The arterial anatomical distribution of the temporofrontal fascia flap is the connective arteries between the supraorbital and middle temporal arteries near the temporal line. The SOA is included in the periosteal part of the temporofrontal fascia flap.[14]

Reconstruction of skin defects

Flaps based on the SOA used in the reconstruction of skin defects include the island flaps.[10] Those are rotational sensorial flaps based on the SOA. It is considered a good substitute for repairing small and medium full-thickness periorbital defects, such as those resulting from tumor resection, trauma, or burns.[10] It is helpful to identify the SOA preoperatively and intraoperatively using a Doppler flow meter to determine the pivot point and flap design. Taking all of the above-mentioned reconstructive and skin flaps into account, we understand that the SOA is not the main artery incorporated in the majority of flaps. However, it maintains an essential role in the maintenance of flap viability when the superficial temporal artery, on which most of the flaps are based, is not delivering adequate blood supply.

In a nutshell, appreciating the anatomy and variations of SOA is of great help in different surgical applications, enriching the surgeon's armamentarium during surgery as an additive source of blood supply when other collaterals are insufficient in performing reconstruction flaps for skull base or skin defects, and the importance of its preservation during transcranial approaches to avoid creating a hematoma.

CONCLUSION

The variable anatomy of the SOA has a paramount impact on performing different neurosurgical approaches and bypasses. In addition, it constitutes an important secondary source of blood supply for skull base reconstruction and skin flaps when the primary sources are compromised. Therefore, cadaveric studies of the SOA as it pertains to new and updated approaches are essential to explore potential methods for the preservation of the artery in different neurosurgical applications.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The author(s) confirms that there was no use of artificial intelligence (AI)-assisted Technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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