Facial Injections and Blindness

A Review on Anatomy

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Abstract: With the sudden emergence of new medical aesthetic fillers, the number of fillers injected worldwide has exploded, but there are also worrying risks in the pursuit of beauty. At present, many cases of blindness caused by injection of aesthetic fillers have been reported. Most of the cases are caused by irreversible vascular embolism. This is a rare yet greatly feared complication of using facial cosmetic fillers. This article reviewed and analyzed the literature and summarized the changes in the anatomical structure of facial blood vessels related to blindness during facial injection.

Key Words: facial injection, blindness, facial blood vessels, anatomy

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The 21st century has gradually entered the era of minimally invasive treatment and minimally invasive plastic surgery, facial injection is one of the most important techniques of minimally invasive plastic surgery.[1] With the development of technology and the pursuit of beauty, people's acceptance of facial injections is also increasing. By injecting the filling material directly into the local or specific part, the effect of improving the physical and mental state is finally achieved. The number of facial soft tissue injections is increasing every year, but the subsequent complications are also gradually increasing. Povolotskiy et al[2] indicates that about 10% of facial injections have corresponding vascular complications. Skin ischemia, blindness, and cerebral embolism are uncommon but extremely devastating.[3,4] Goodman et al[5] conducted a survey of 52 plastic surgeons from 16 countries and found that 71% had injection experience 11 years and longer, and 62% reported 1 or more intravascular injections. This is enough to cause every plastic surgeon to attach great importance.

The causes of eye blinding complications during facial injection are as follows: (1) the filler accidentally enters the blood vessel; (2) excessive dosage of filler causes local tissue edema to compress blood vessels; (3) the syringe needle pierces the blood vessel wall and initiates the endogenous blood coagulation pathway; (4) local hemorrhage, hematoma, and adjacent tissues compress blood vessels.[6] The injured vessels are mainly the ophthalmic artery and its branches. The central retinal artery is the terminal branch of the ophthalmic artery and lacks collateral vascular anastomosis. Once embolization occurs, it will cause severe retina ischemia, and hypoxia will eventually lead to irreversible visual damage.[7] The factors that cause ophthalmic artery embolism: retrograde blood flow caused by high injection pressure and delivery of sufficient injection into the blood vessel.[8] With the widespread use of autologous fat, autologous fat has surpassed hyaluronic acid as the most dangerous facial soft tissue filler that causes blindness.[9] This is closely related to the volume of autologous fat, the greater the volume of autologous fat easier ophthalmic artery proximal occlusion, ischemia greater range, resulting in more severe visual impairment.[10]

For the injection site that is most likely to cause blindness during facial injection, the conclusions drawn by different studies are slightly inconsistent. Sito et al[11] have shown that the risk is from high to low, the areas most likely to cause blindness are the nose, glabella, nasolabial, but glabella, nose, nasolabial indicated by Alam et al.[12] No matter who ranks first, the nose, glabella, and nasolabial are high-risk areas for blindness caused by facial injections. Scheuer et al[13] summarized the 6 major risks of facial injection based on the occurrence of facial injection complications: brow and glabella, temporal, nose, nasolabial fold, lips/commissure, and infraorbital. In the process of facial injection, it is very important to accurately grasp the anatomical position of each area, the distribution and shape of the corresponding blood vessels. Based on this foundation, this article mainly focuses on the arteries related to blindness and summarizes the anatomical characteristics and variations of facial blood vessels reported in the past 10 years.

GLABELLA/FOREHEAD

With aging, to solve "Bunny lines" and forehead wrinkles, injection of HA between the glabella and forehead has become the important solution to eliminate these 2 wrinkles. Glabella and forehead high injection rate and anatomical characteristics led to a high incidence of complications in the region.[14] The facial artery and superficial temporal artery from the external carotid artery, the ophthalmic artery, infraorbital artery, and zygomatic facial artery from the internal carotid artery are the main supply arteries of the face. The supraorbital artery, supratrochlear artery, dorsal nasal artery, medial canthal artery, and superior palpebral artery are the extraorbital branches of the ophthalmic artery. The supraorbital artery and the supratrochlear artery have abundant vascular branches and anastomosis between the brow and forehead.[15] During the puncture process, if the syringe accidentally punctures the supraorbital artery and the supratrochlear artery, plus enough bolus pressure will cause the drug embolus to flow back into the ophthalmic artery, and once the injection pressure disappears, the drug embolus will enter and embolize the ophthalmic artery and its branches.[16] Very few drug emboli can cause embolism of the ophthalmic artery. Coleman[17] measured the threshold volume of emboli required to fill the ophthalmic artery as 0.1 mL. Khan et al[18] measured the volume of the supratrochoidal artery as only 0.085 mL.

Cong et al[19] divided the distribution of the supratrochlear artery and supraorbital artery into 2 types: type I (deep branch of the supratrochlear artery—present pattern), type Ia, the superficial branch of the supratrochlear artery supplies the superficial inner side of the forehead, and the superficial branch of the supraorbital artery supplies the outer side, the deep branch of the supratrochlear artery, and the deep branch of the supraorbital artery were distributed deep to the frontalis; type Ib, the central artery, the paracentral artery, the superficial branch of the supratrochlear artery, and the superficial branch of the supraorbital artery supply the superficial frontal; the deep layer is the same as type Ia. Men are mainly in 1b, whereas women are mostly in 1a. Type II (deep branch of the supratrochlear artery-absent pattern), the supply of the superficial frontal layer is the same as type Ia; the deep frontal layer is only supplied by the deep branch of the supraorbital artery. At

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the same time, the measurement found that the average coordinate of the supraorbital artery passing through the frontal muscle is the horizontal distance from the vertical line passing the inner canthus is about 29.6 ± 4.1 mm, and the vertical distance from the supraorbital rim is about 20.7 ± 5.1 mm.

Ashton et al[20] proposed that there are choke blood vessels in the forehead, glabella, nose, and lips. The choke blood vessels are functional and can temporarily or permanently control the flow between the vascular. When the diameter of the choke vessel is small enough, it can block the flow of drug emboli between the vascular, but when it is transformed into a real vascular anastomosis with a larger diameter, its function disappears. Taylor et al[21] injected 20 mL of lead oxide into the vein in the center of the forehead, applying pressure on the nose, the lead oxide can be pushed to the 2 orbits, and finally into the cavernous sinus and dural vein. At the same time, they found orange lead oxide particles in the blue ophthalmic veins next to the ophthalmic artery by injecting lead oxide into the artery. In addition, they also found more than 1 arteriovenous shunt about 0.5 mm in diameter in the inner canthus and nasolabial fold. This seems to provide another way for drug emboli to enter the ophthalmic artery: intravenous injection flows to the artery through the arteriovenous shunt. Schelke et al[22] successfully injected hyaluronidase into the artery and not only restored normal blood flow in the artery but also observed changes in the accompanying venous blood flow through ultrasound. Arunakirinathan et al[23] reported that the injection of sclerosing agent into the forehead vein caused the ophthalmic artery embolism, which eventually caused irreversible vision loss.

NOSE

The nose is in the middle of face, so the nose shape plays a decisive role in the coordination of the face. In addition to prosthesis and cartilage, soft tissues, such as autologous fat and hyaluronic acid, are often used to improve the shape of the nose. Facial artery and ophthalmic artery vascularize the nose. The vasculature of the dorsum of the nose is very superficial. There are not only the vascular anastomoses between the dorsal nasal artery, the lateral nasal artery, and the angular artery but also the vascular anastomoses between the dorsal nasal artery and the supratrochlear artery.[24] Bae et al,[25] Thanasarnaksorn et al,[4] Ozturk et al[26] have reported that nasal injection causes varying degrees of vision loss. Usually, the dorsal nasal artery is located on both sides of the nose, Wu et al[7] found 3 thicker branches of the dorsal nasal artery in a few cadavers, which increased the chance of accidental puncture of the dorsal nasal artery. For patients who have undergone rhinoplasty in the past, they should be extra careful when performing soft tissue filling on the nose because the anatomical plane has been destroyed, and the natural anastomosis between different layers may no longer exist.[13] Through comparison, Huang et al[27] found that patients who had undergone surgical rhinoplasty surgery showed a significantly increased chance of adverse events due to anatomical changes. Accidental arterial puncture in the glabella, forehead, and nose mostly damage directly on the ophthalmic artery and its branches. This is different from the accidental puncture of the facial artery in that it is not controlled by the vascular anastomosis. The drug embolus directly enters the branch of the ophthalmic artery, and the occurrence of visual impairment is more direct and faster. Taylor et al[21] found that the venous reflux of the nose flows to the inner canthus and the nasion, and the arteriovenous anastomosis may be formed between the veins and arteries in the inner canthus.

NASOLABIAL FOLD/LIPS

In most people, the nasolabial fold is observed lateral to the nose, as a distinct or ambiguous crease from the ala of the nose to the cheilion area of smiling.[28] The most important vasculature in the nasolabial fold is the facial artery. The facial artery travels to the inner canthus in the nasolabial fold and migrates to the angular artery. The angular artery is anastomosed with the dorsal nasal artery,[15] but the angular artery in the nasolabial fold and lateral nasal area is highly variable in both 2 dimensional (D) and 3D. Kim et al[29] divided the facial artery into 4 types, of which about 22.8% lacked the angular artery, this type of lateral nasal and nasolabial fold area is dominated by the retrograde of the ophthalmic artery terminal branch. Lee et al[30] found that the facial artery is about 26 mm from the commissure on the commissure-earlobe line, and about 12 mm from ala nasi on the tragus-ala nasi line. Yang et al[31] analyzed the positions of the nasolabial fold and facial artery in 35 cadavers, about 42.9% of the facial arteries are located inside the nasolabial fold, 23.2% are located outside the nasolabial fold, 19.6% cross the nasolabial fold, and 14.3% gradually approach the nasolabial folds from the outside to the inside.

Rayess et al[32] pointed out that among the 1748 adverse events analyzed, about 30% of the cases came from lip injection. Taylor et al[20] also found that the facial artery and the contralateral artery formed an extensive vascular anastomosis on the upper lip and apex nasi, and the branches of the ipsilateral ophthalmic artery and facial artery were anastomosed at nasal dorsum and nasolabial fold. Zhao et al[33] used 3D scanning of 21 fresh cadavers and found that 90% of the supratrochlear artery came from the trochlear branch of the ophthalmic artery in 42 half faces, 2.5% came from the supraorbital artery, and more importantly, there were 7.5% comes from angular artery. Zhu et al[34] also mentioned that the angular artery is the terminal branch of the facial artery in the nasolabial fold or infraorbital trunk that moves directly forward to forehead, and then communicates with the ophthalmic artery through the choke vessel with a smaller diameter. When the supratrochlear artery comes from the angular artery, accidental puncture of the angular artery at the nasolabial fold can be retrogradely entered into the ophthalmic artery through the branch of the supratrochlear artery and the supraorbital artery. Lazzeri et al[35] reported that there are several arteriovenous anastomosis channels near the nasal mucosa, which may also cause drug emboli to flow between the arteries and veins.

TEMPORAL

With aging, the connective tissue in the temporal area near the root of the zygomatic arch decreases, resulting in a depression on the side of the face and affecting appearance. The use of facial soft tissue fillers can improve the local depression and improve the appearance of aging. The most important vasculature in the temporal region is the superficial temporal artery (STA) and its branches. The STA is a terminal branch of the external carotid artery, and it ascends between the tragus and the posterior root of the zygomatic arch and divides into the anterior frontal branch and the posterior parietal branch. The average diameter of the STA is about 2.73 ± 0.51 mm.[36] In the study of Tansatit et al,[37] in the case of blindness after accidental puncture, the branches of the ophthalmic artery at the puncture site are connected with the branches of the STA, maxillary artery, and facial artery. The frontal branch of the STA forms an anastomosis with the branches of the supraorbital artery in the deep and superficial layers of the frontotemporal and is the most common way for the temporal retrograde embolization to the ophthalmic artery. Blindness caused by accidental puncture in the temporal area is sudden and immediate, which is related to the peak velocity of STA vasoconstriction reaching 42 cm/s and the emboli reaching the ophthalmic artery circulation in a fraction of a second.[38] Tansatit et al[37] injected dye into the STA of 12 cadavers and found that the dye entered the ipsilateral eyeball in 3 cases and the contralateral eyeball in 2 cases. Zhu et al[34] found that the frontal branch and the zygomatic orbital branch of the STA, the superior palpebral artery, and the facial artery formed an extensive anastomosis in the lateral orbit. Vascular anastomosis is formed between the branches of the zygomatic facial artery, the zygomatic orbital artery, and the facial artery.[39] Accidental puncture in the temple can not only cause visual impairment but also block the middle cerebral artery.[40]

For the branching of the STA, different scholars use different measurement methods to obtain different results. Mwachaka et al[41] measured the distance between the STA and the zygomatic arch as 50.8 ± 20.9 mm; Kim et al[42] measured the distance between the STA and the zygomatic arch as 21.7 ± 15.8 mm. Jean-Philippe et al[43] measured that on the eye-tragus-line, the distance between the tragus and STA was 15.55 ± 4.5 mm; the average length of the frontal branch of STA was 58.11 ± 16.9 mm, and the average length of the posterior parietal branch was 54.01 ± 16.34 mm. About 60% to 82.6% of STA's division is located above the zygomatic arch.[42,44] It is fairly difficult to consider each and every branch when having STA inoculated because of anatomical variation. The middle temporal vein is located in the deep temporal fascia near the lateral rim of the orbit. It extends between the 2 layers of the deep temporal fascia and merges into the superficial temporal fascia venous plexus about 1 cm from the tragus and 2.5 cm above the tragus. Several reports have pointed out that accidental puncture in the middle temporal vein leads to nonthrombotic pulmonary embolism, and other serious complications, which deserves attention as much as blindness.[45]

INFRAORBITAL

In the past, it was generally believed that the lower eyelid area was mainly vascularized by the infraorbital artery and facial artery. Based on the recognition of the facial artery, it is generally believed that there is less superficial vasculature in the infraorbital area.[46] The infraorbital artery is the terminal branch of the maxillary artery that appears in the face through the infraorbital foramen. This artery can be distributed to the lower eyelid, the lateral nasal and the upper lip, the branches of these arteries are usually anastomosed with the facial artery. When the angular artery migrates to the inner canthus, it branches to the lateral nasal and connects to the infraorbital artery.[24] After dissecting 72 cadavers, Kim et al[47] found that the eyelid branch of the infraorbital artery was most commonly located at 1 o'clock in the infraorbital foramen, the nasal branch was most located at 5 o'clock, and the lip branch was most commonly located at 6 o'clock. About 60% of the nasal branches are anastomosed with the facial artery. Experts such as Carruthers et al[48] suggest that injections in the infraorbital area should be injected behind the muscle or on the periosteum. However, Hufschmidt et al[49] reported that the branches of the infraorbital artery after exiting the infraorbital foramen mainly walk on the surface of the periosteum, and the nasal branch is always in the periosteum and is anastomosed with the angular artery, dorsal nasal artery, or directly with the supratrochlear artery, the zygomatic facial artery begins to become shallow about 17 mm inside the zygomatic arch. Based on the above research results, Hufschmidt further distinguished 2 dangerous subzones for infraorbital injection: the lateral third of the zygomatic bone is vulnerable to damage to the zygomatic facial artery, which can easily cause local skin ischemia, and the periosteum layer injection in the tear groove area can easily cause ophthalmic artery embolism. Yang et al[31] conducted an autopsy on 35 fresh cadavers and found that 18 of 70 half-faces had the circumflex branch of the facial artery in the infraorbital area, 39.2 ± 5.8 mm from the outside of the midsagittal line of the face, 35.2 ± 8.2 mm below the line of the lateral medial canthus, and then moved to the inner canthus to become the angular artery. In the absence of angular artery, the inner canthus is mainly vascularized by the nasal branches of the infraorbital artery.[50,51] These branches can be directly anastomosed with the ophthalmic artery branches, providing another way for retrograde embolization.

Based on the similarity between rabbits and human facial arteries, Zheng et al[16] performed facial artery injections in 20 live rabbits, and finally found that only 1 rabbit had blue dye in the ophthalmic artery system, and the remaining 19 live rabbits were all negative. However, all 20 dead rabbits showed the appearance of dye on the fundus. Although this shows that there is a huge difference in hemodynamics between cadavers and living bodies, the process of injecting soft tissue fillers into the face should not be taken lightly. Pavicic et al[52] reported that under the condition of autopsy, although the needle size and injection angle are different, the injection still cannot reach the subperiosteal. This indicates that the injection can spread uncontrollably into more superficial layers, further increasing the risk of adverse aesthetics and vascular events.

CONCLUSIONS

With such a large population base for facial injections, even a 0.001% complication rate requires the attention of every plastic surgeon. There is no "safe area" in the process of facial soft tissue filling, understanding the shape of the ophthalmic artery and its branches and its relationship with other major facial arteries can effectively reduce the possibility of ophthalmic artery embolism during facial injection. At the same time, the choke blood vessels between the arteries and veins should also be paid attention to. This article only summarizes part of the local vasculature distribution that causes visual impairment during the facial injection process, and further improvements are needed in the later stage.

REFERENCES

1. Decates TS, Kruijt Spanjer EC, Saini R, et al. Unilateral facial edema after filler injection of the lower eyelid. *Dermatol Ther*. 2020;33:e13539.
2. Povolotskiy R, Oleck NC, Hatzis CM, et al. Adverse events associated with aesthetic dermal fillers: 10-year retrospective study of FDA data. *Am J Cosmet Surg*. 2018;35:143–151.
3. Chatrath V, Banerjee PS, Goodman GJ, et al. Soft-tissue filler-associated blindness: a systematic review of case reports and case series. *Plast Reconstr Surg Glob Open*. 2019;7:e2173.
4. Thanasarnaksorn W, Cotofana S, Rudolph C, et al. Severe vision loss caused by cosmetic filler augmentation: case series with review of cause and therapy. *J Cosmet Dermatol*. 2018;17:712–718.
5. Goodman GJ, Roberts S, Callan P. Experience and management of intravascular injection with facial fillers: results of a multinational survey of experienced injectors. *Aesthet Plast Surg*. 2016;40:549–555.
6. Cho KH, Dalla Pozza E, Toth G, et al. Pathophysiology study of filler-induced blindness. *Aesthet Surg J*. 2019;39:96–106.
7. Wu S, Pan L, Wu H, et al. Anatomic study of ophthalmic artery embolism following cosmetic injection. *J Craniofac Surg*. 2017;28:1578–1581.
8. Lazzeri D, Agostini T, Figus M, et al. Blindness following cosmetic injections of the face. *Plast Reconstr Surg*. 2012;129:995–1012.
9. Prado G, Rodríguez-Feliz J. Ocular pain and impending blindness during facial cosmetic injections: is your office prepared? *Aesthet Plast Surg*. 2017;41:199–203.
10. Kim YK, Jung C, Woo SJ, et al. Cerebral angiographic findings of cosmetic facial filler-related ophthalmic and retinal artery occlusion. *J Korean Med Sci*. 2015;30:1847–1855.
11. Sito G, Manzoni V, Sommariva R. Vascular complications after facial filler injection: a literature review and meta-analysis. *J Clin Aesthet Dermatol*. 2019;12:E65–E72.
12. Alam M, Kakar R, Dover JS, et al. Rates of vascular occlusion associated with using needles vs cannulas for filler injection. *JAMA Dermatol*. 2020. doi:10.1001/jamadermatol.
13. Scheuer JF 3rd, Sieber DA, Pezeshk RA, et al. Anatomy of the facial danger zones: maximizing safety during soft-tissue filler injections. *Plast Reconstr Surg*. 2017;139:50e–58e.
14. Sorensen EP, Council ML. Update in soft-tissue filler-associated blindness. *Dermatol Surg*. 2020;46:671–677.
15. Carruthers JDA, Fagien S, Rohrich RJ, et al. Blindness caused by cosmetic filler injection: a review of cause and therapy. *Plast Reconstr Surg*. 2014;134:1197–1201.
16. Zheng H, Qiu L, Liu Z, et al. Exploring the possibility of a retrograde embolism pathway from the facial artery to the ophthalmic artery system in vivo. *Aesthet Plast Surg*. 2017;41:1222–1227.
17. Coleman SR. Avoidance of arterial occlusion from injection of soft tissue fillers. *Aesthet Surg J*. 2002;22:555–557.
18. Khan TT, Colon-Acevedo B, Mettu P, et al. An anatomical analysis of the supratrochlear artery: considerations in facial filler injections and preventing vision loss. *Aesthet Surg J*. 2017;37:203–208.

19. Cong LY, Phothong W, Lee SH, et al. Topographic Analysis of the supratrochlear artery and the supraorbital artery: implication for improving the safety of forehead augmentation. *Plast Reconstr Surg*. 2017;139:620e–627e.
20. Ashton MW, Taylor GI, Corlett RJ. The role of anastomotic vessels in controlling tissue viability and defining tissue necrosis with special reference to complications following injection of hyaluronic acid fillers. *Plast Reconstr Surg*. 2018;141: 818e–830e.
21. Taylor GI, Shoukath S, Gascoigne A, et al. The functional anatomy of the ophthalmic angiosome and its implications in blindness as a complication of cosmetic facial filler procedures. *Plast Reconstr Surg*. 2020;146:745.
22. Schelke LW, Cassuto D, Velthuis P, et al. Nomenclature proposal for the sonographic description and reporting of soft tissue fillers. *J Cosmet Dermatol*. 2020;19:282–288.
23. Arunakirinathan M, Walker RJE, Hassan N, et al. Blind-sided by cosmetic vein sclerotherapy: a case of ophthalmic arterial occlusion. *Retin Cases Brief Rep*. 2019;13:185–188.
24. Cotofana S, Lachman N. Arteries of the face and their relevance for minimally invasive facial procedures: an anatomical review. *Plast Reconstr Surg*. 2019;143: 416–426.
25. Bae IH, Kim MS, Choi H, et al. Ischemic oculomotor nerve palsy due to hyaluronic acid filler injection. *J Cosmet Dermatol*. 2018;17:1016–1018.
26. Ozturk CN, Li Y, Tung R, et al. Complications following injection of soft-tissue fillers. *Aesthet Surg J*. 2013;33:862–877.
27. Huang P, Liu A, Ren H, et al. Color Doppler flow imaging of retrobulbar ocular blood flow changes in retinal artery occlusions caused by cosmetic facial filler injections. *Ophthalmic Plast Reconstr Surg*. 2019;35:227–231.
28. Taylor GI, Corlett RJ, Ashton MW. The functional angiosome: clinical implications of the anatomical concept. *Plast Reconstr Surg*. 2017;140:721–733.
29. Kim YS, Choi DY, Gil YC, et al. The anatomical origin and course of the angular artery regarding its clinical implications. *Dermatol Surg*. 2014;40:1070–1076.
30. Lee HJ, Won SY, O J, et al. The facial artery: a comprehensive anatomical review. *Clin Anat*. 2018;31:99–108.
31. Yang HM, Lee JG, Hu KS, et al. New anatomical insights on the course and branching patterns of the facial artery: clinical implications of injectable treatments to the nasolabial fold and nasojugal groove. *Plast Reconstr Surg*. 2014; 133:1077–1082.
32. Rayess HM, Svider PF, Hanba C, et al. A cross-sectional analysis of adverse events and litigation for injectable fillers. *JAMA Facial Plast Surg*. 2018;20:207–214.
33. Zhao WR, Wang HB, Luo CE, et al. Three-dimensional computed tomographic study on the periorbital branches of the ophthalmic artery: arterial variations and clinical relevance. *Aesthet Surg J*. 2019;39:1109–1117.
34. Zhu GZ, Zhao WR, Luo CE, et al. High-throughput screening of full-face clinically relevant arterial variations using three-dimensional postmortem computed tomography. *Plast Reconstr Surg*. 2018;142:653e–664e.
35. Lazzeri D, Spinelli G, Zhang YX, et al. Panophthalmoplegia and vision loss after cosmetic nasal dorsum injection. *J Clin Neurosci*. 2014;21:890.
36. Pinar YA, Govsa F. Anatomy of the superficial temporal artery and its branches: its importance for surgery. *Surg Radiol Anat*. 2006;28:248–253.
37. Tansatit T, Moon HJ, Apinuntrum P, et al. Verification of embolic channel causing blindness following filler injection. *Aesthet Plast Surg*. 2015;39:154–161.
38. Tucunduva MJ, Tucunduva-Neto R, Saieg M, et al. Vascular mapping of the face: B-mode and Doppler ultrasonography study. *Med Oral Patol Oral Cir Bucal*. 2016;21:e135–e141.
39. Funt DK. Avoiding malar edema during midface/cheek augmentation with dermal fillers. *J Clin Aesthet Dermatol*. 2011;4:32–36.
40. Wang X, Wu M, Zhou X, et al. Autologous fat used for facial filling can lead to massive cerebral infarction through middle cerebral artery or facial intracranial branches. *J Craniofac Surg*. 2018;29:1341–1343.
41. Mwachaka P, Sinkeet S, Ogeng'o J. Superficial temporal artery among Kenyans: pattern of branching and its relation to pericranial structures. *Folia Morphol (Warsz)*. 2010;69:51–53.
42. Kim BS, Jung YJ, Chang CH, et al. The anatomy of the superficial temporal artery in adult Koreans using 3-dimensional computed tomographic angiogram: clinical research. *J Cerebrovasc Endovasc Neurosurg*. 2013;15:145–151.
43. Jean-Philippe H, Benoît B, Françoise K, et al. Anatomy and external landmarks of the superficial temporal artery using 3-dimensional computed tomography. *Surg Radiol Anat*. 2021;43:283–290.
44. Stock AL, Collins HP, Davidson TM. Anatomy of the superficial temporal artery. *Head Neck Surg*. 1980;2:466–469. https://doi.org/10.1002/hed.2890020604;.
45. Kapoor KM, Bertossi D, Li CQ, et al. A systematic literature review of the middle temporal vein anatomy: 'venous danger zone' in temporal fossa for filler injections. *Aesthet Plast Surg*. 2020;44:1803–1810. doi:10.1007/s00266-020-01791-2.
46. Hu KS, Kwak HH, Song WC, et al. Branching patterns of the infraorbital nerve and topography within the infraorbital space. *J Craniofac Surg*. 2006;17: 1111–1115.
47. Kim HS, Lee KL, Gil YC, et al. Topographic anatomy of the infraorbital artery and its clinical implications for nasolabial fold augmentation. *Plast Reconstr Surg*. 2018;142:273e–280e.
48. Carruthers J, Rzany B, Sattler G, et al. Anatomic guidelines for augmentation of the cheek and infraorbital hollow. *Dermatol Surg*. 2012;38(7 Pt 2):1223–1233.
49. Hufschmidt K, Bronsard N, Foissac R, et al. The infraorbital artery: clinical relevance in esthetic medicine and identification of danger zones of the midface. *J Plast Reconstr Aesthet Surg*. 2019;72:131–136.
50. Jitaree B, Phumyoo T, Uruwan S, et al. The feasibility determination of risky severe complications of arterial vasculature regarding the filler injection sites at the tear trough. *Plast Reconstr Surg*. 2018;142:1153–1163.
51. Pilsl U, Anderhuber F, Neugebauer S. The facial artery—the main blood vessel for the anterior face? *Dermatol Surg*. 2016;42:203–208.
52. Pavicic T, Yankova M, Schenck TL, et al. Subperiosteal injections during facial soft tissue filler injections—is it possible? *J Cosmet Dermatol*. 2020;19:590–595.