An Anatomical Analysis of the Supratrochlear Artery: Considerations in Facial Filler Injections and Preventing Vision Loss

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Abstract

Background: Embolia cutis medicamentosa (ECM) is a rare phenomenon attributed to intra-arterial drug injection. Glabellar filler injections can result in potentially devastating visual loss from inadvertent retrograde arteriolar embolization due to the extensive vasculature within the upper face. The minimum amount of filler necessary to potentiate this complication has not yet been reported.

Objectives: We aim to determine the volume of filler necessary to occupy the supratrochlear artery from the glabella to the bifurcation of the ophthalmic and central retinal arteries. We specifically examine the volume of the supratrochlear artery from the glabella to orbital apex.

Methods: The study was approved by Duke University Institutional Review Board and involved surgical dissection of six fresh tissue cadaver heads (12 hemifaces). The arterial system in each cadaver head was injected with latex for visualization. The supratrochlear arteries were isolated anteriorly from the glabella to the orbital apex posteriorly. Intra-orbital vessel radius and length were measured. The vessel volume was calculated by water displacement of the intra-arterial latex.

Results: The vessel volumes ranged from 0.04 to 0.12 mL. The average vessel volume was calculated as 0.085 mL, the average length as 51.75 mm, and the average radius as 0.72 mm.

Conclusions: Vascular occlusion from filler injections can lead to devastating visual consequences due to inadvertent retrograde intra-arterial embolization. Our findings indicate that the average entire volume of the supratrochlear artery from the glabella to the orbital apex is 0.085 mL. Injectors should be aware that a bolus of this critical volume may lead to a significant adverse outcome.

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Embolia cutis medicamentosa (ECM), also known as Nicolau syndrome, is a phenomenon in which iatrogenic embolization of an artery with an injected substance causes a local cutaneous reaction resulting in significant pain and ischemic pallor, eventually leading to skin necrosis and atrophic changes. The literature has described devastating permanent visual loss from injections in the head and neck region for various benign lesions (ie, chalazion, capillary hemangioma) and, more recently, from aesthetic filler injections in the glabellar region. The probable mechanism theorizes that the injected substance causes retrograde flow along the involved artery toward the orbital apex, followed by anterograde flow through the ophthalmic artery and the central retinal artery to subsequently cause a vascular occlusion in the retina and thus blindness. Other possible sites of occlusion include the short and long posterior ciliary arteries that supply the optic nerve and can cause a posterior ischemic optic neuropathy, or even the internal carotid artery, which may result in cerebral infarction.

The most likely violated facial arteries include supratrochlear, supraorbital, dorsal nasal, and angular, relative to the proximity of injections in the glabella, nasal dorsum, midface, and nasolabial folds. The substance must be injected against the systemic arterial pressure to rapidly fill the entire vessel retrograde past the bifurcation before it flows anterograde into the central retinal artery. Coleman estimates the threshold amount of filler necessary to reach the ophthalmic artery is 0.1 mL. Our study sought to anatomically determine the volume of

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filler necessary to occupy the supratrochlear artery from the glabella to the bifurcation of the central retinal artery and ophthalmic artery and cause an anterograde occlusion of the central retinal artery.

**METHODS**

The study was carried out in the anatomy laboratory at Duke University School of Medicine in Durham, North Carolina. Study approved by Duke University Institutional Review Board. Eight fresh tissue cadaver heads (16 hemifaces) were dissected in a single session during October 2015 by one surgeon (TTK) to ensure consistent surgical technique. The arterial system in each cadaver head was injected with latex (Ward’s Science latex injection medium, red solution, Rochester, NY) to allow for better visualization of the vasculature. The vessel walls were carefully dissected away from the latex cast occupying the vascular lumen. An assumption was made that the intravascular volume filled with latex in the cadaver heads was similar to the intravascular volume of blood in a living patient. Two cadaver heads did not demonstrate good vessel symmetry between the hemifaces and did not show proper uptake of the latex to reliably identify the arterial system. As such, they were discarded, in the attempt to control for consistent quality of vasculature and dissection. Five of the heads were male and one was female. One of the male heads was of African American descent, and all the rest were Caucasian. To preserve anonymity of the cadaveric donors, age and other health identifiers were not made available to the authors.

All data obtained were analyzed. The data were expressed in standard International System of Units (SI units): millimeters (mm) for length and radius and milliliters (mL) for volume. The standard deviation (SD), mean, median, and mode for each data set were calculated.

### Surgical Technique

Under loupe magnification (× 2.5), a vertical midline incision was made at the level of the procerus. The subcutaneous dissection was then carried out laterally along the supra- medial orbit wall, with anterior exposure of the supratrochlear artery at the supraorbital notch. The vessel was explored posteriorly through the orbit to the optic canal and carefully dissected away from the surrounding orbital fat and adnexal tissue. The vessel walls were then dissected off the intravascular latex. The following measurements were then recorded for the intravascular latex occupying the vessel lumens: length and radius.

### Volume Displacement

A 1 cc syringe was filled with 0.8 mL saline. Each vessel was then successively submerged in the filled syringe. The new height of the fluid meniscus was recorded and subtracted from the pre-existing meniscus to provide the calculated volume of the supratrochlear artery (Figure 1).

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<th>Eye laterality</th>
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**Figure 1.** (A-L) External photographs of individual supratrochlear arteries submerged in saline depicting the method of volume displacement used to calculate vessel volume.
RESULTS

A total of 12 supratrochlear arteries were harvested from the six cadaver heads (Figure 2). The vessel volumes ranged from 0.04 to 0.12 mL (Table 1, Figure 1). The average vessel volume was calculated as 0.085 mL (SD, 0.02; range, 0.04-0.12 mL). The average length was calculated as 51.75 mm (SD, 9.98; range, 35-65 mm). The average radius was calculated as 0.72 mm (SD, 0.08; range, 0.6-0.87 mm).

DISCUSSION

Facial fillers represent a versatile tool in every cosmetic surgeon’s armamentarium. With their widespread on- and off-label use and ever-increasing popularity arise the more commonly associated adverse outcomes, including edema, erythema, ecchymosis, and mild tenderness with injection. More serious sequelae can involve inflammatory or non-inflammatory granuloma formation in the dermis and skin necrosis. Among the most feared yet relatively rare complication is iatrogenic vascular occlusion, which may lead to ischemic and irreversible damage to the overlying skin and may compromise the ocular vasculature, possibly leading to blindness. To date, there are at least 98 such cases of blindness resulting from filler injections reported in the literature. Embolia cutis medicamentosa, alternatively known as livedoid dermatitis, is an injection site reaction characterized by immediate skin blanching and sharp pain that may evolve into skin necrosis and scarring. Also coined Nicolau syndrome, it was first reported by Freudenthal in 1924 and by Nicolau in 1925. The phenomenon was initially described in response to bismuth salt injections to treat syphilis. It has since been associated with several drugs, including corticosteroids, local anesthetics, non-steroidal anti-inflammatory drugs, and more recently, autologous fat injections and cosmetic facial fillers. The proposed pathophysiology is that the injected dermal filler directly occludes arterial blood flow, resulting in ischemic changes, including a red-blue mottling of the overlying skin.

Direct arterial occlusion can occur in an anterograde or retrograde fashion. In anterograde vascular occlusion, the injection pressure does not exceed systemic arterial pressure and the trapped embolus causes decreased blood flow downstream to the vascular tributaries, resulting in mainly surface changes of the skin. By contrast, retrograde vascular occlusion allows for the embolus to displace the arterial blood and travel against the arterial blood flow because of the increased injection pressure relative to the intra-arterial pressure. The embolus often traverses back to a vascular bifurcation, at which point the arterial pressure gradient stabilizes, and the embolus can then subsequently cause
anterograde occlusion at a more posterior location than the initial injection site. The arterial occlusion and subsequent non-perfusion is specifically likely to occur within distal capillaries, as demonstrated in a mouse animal model.

In the context of facial filler injections, vascular entry can occur at the supratrochlear, supraorbital, angular, and dorsal nasal arteries from injections administered in the glabella, medial midface, nasolabial folds, and nasal dorsum. In the largest global review of 98 cases of blindness secondary to facial filler injections, Beleznay et al report that the highest risk injection sites responsible for ocular complications are, in decreasing order, glabella (38.8%), nasal region (25.5%), nasolabial folds (13.3%), and forehead (12.2%). Complications are most likely to occur with autologous fat injections, attributed to the larger volumes and needle bore size necessary to overcorrect facial hollowing with a substance that is anticipated to be at least partially resorbed.

If the anterograde occlusion occurs within the central or branch retinal artery, vascular compromise to the retina can result in permanent blindness. Occlusion of the posterior ciliary arteries supplying the optic nerve can result in optic neuropathy. Further posteriorly, occlusion of the middle cerebral artery, a branch of the internal carotid artery, can occur with significant injection pressure and result in cerebral infarction. Numerous case reports have described iatrogenic vascular occlusion from cosmetic filler injections (including both absorbable and permanent substances) to the forehead, glabella, nasal dorsum, and nasolabial folds. Glabellar filler injections are most likely to cause this rare complication, given the shorter distance to the central retinal artery. In particular, the supratrochlear artery, which is itself a terminal branch of the ophthalmic artery, can be inadvertently accessed due to its superficial location at the orbit and its extensive vascular anastomoses throughout the forehead and with the adjacent supraorbital artery. Recent studies demonstrate anomalous anastomoses between the external and internal carotid systems, such as direct communication between the frontal branch of the superficial temporal artery (external carotid system) and the supratrochlear or supraorbital artery (internal carotid system), that may further facilitate entry into the ophthalmic artery.

The ability to manage a vascular occlusion is inextricably linked to the injector’s clinical identification of the occlusive event. As mentioned previously, the injection site will show lasting pallor beyond that which is transiently observed with most filler injections, and the patient often experiences a sharp, stabbing pain. The pallor may subside after a few minutes and transform into a mottled appearance with slow capillary refill. The pain can start at the skin but may simultaneously involve the globe and periorbital tissues. The patient can also suffer immediate visual loss. Prompt recognition of these symptoms and clinical stabilization is required. The injector should apply a warm compress and massage to the injection site in the attempt to dislodge the entrapped embolus and inject hyaluronidase to dissolve a hyaluronic acid-based filler and hydrodissect injection planes. Aspiration should be administered immediately to prevent clot formation but its utility has not been substantiated in the literature.

Approximately 30 units of hyaluronidase has been shown to effectively dissolve 0.1 cc of various entities of hyaluronic-acid based fillers, however, the degree of dissolution is based on the three-dimensional structure and cross-linking properties of the specific filler substance, as well as the time period following the vascular event. A consensus group determined that 600 units of hyaluronidase injected to the affected area is sufficient to minimize the risk of cutaneous ischemia in an in vitro model. Tansatit et al propose directly injecting the supraorbital artery for retrograde cannulation of the ophthalmic artery to dissolve the filler substance, as demonstrated in cadaver heads. The role of hyaluronidase has been questioned in basic scientific studies that demonstrate possible propagation of filler substance into smaller arteriolar and capillary beds by causing dilation of larger proximal arteries. Oral corticosteroids can help decrease inflammation. There is no substantial evidence that other suggested therapeutic modalities, such as hyperbaric oxygen therapy, nitroglycerin paste, and vasodilator drugs, have any utility in improving the viability of the necrotic skin.

Awareness of vascular dimensions in relation to the quantity of filler injected at certain anatomical locations within the face can be instructive and may minimize the risk of unintentional adverse outcomes. For instance, superior injections on the forehead should be placed on the periosteum or in the superficial dermis, as the supratrochlear and supraorbital arteries lie more superficially in the subcutaneous layer approximately 15 to 25 mm superior to the medial supraorbital rim. Preventative considerations include: (1) aspirating before injecting to ensure the needle is not within a vascular structure, (2) injecting at a slow rate in retrograde or anterograde fashion to minimize the chances of introducing a large bolus of filler and to maintain a low pressure and flow rate, (3) providing small aliquot injections instead of large volume boluses that can directly occlude or compress a vessel, and (4) using a blunt-tipped, flexible micro-cannula that may decrease the risk of vessel perforation.

Aspiration before injection is controversial because some fillers are too viscous to effectively aspirate blood into the syringe. When 17 different filler products were aspirated in an in vitro model, only 53% of fillers demonstrated a positive aspiration test with the needle provided in the package. Successively larger needles allowed for aspiration of the fillers that failed with their manufacturer-provided needles, thus highlighting the inconsistency of this preventative technique and the additional burden it bears on the clinician-injector to use a larger needle. The topic of needle size is controversial, as a larger needle will not easily penetrate a small vessel but in the event that it does, it will propagate a bolus of filler much
more rapidly to the ophthalmic artery bifurcation against systemic arterial pressure. Conversely, a smaller needle can readily enter a vessel but may be slower to introduce filler against arterial pressure. Additionally, a smaller needle size is more likely to cause a cutaneous embolus rather than a central retinal artery embolization resulting from retrograde vascular occlusion.

Our study is limited by data obtained from only six fresh tissue cadaver heads, thus likely accounting for the ≈20% standard deviation in measured artery length. The volume and radius measurements, however, are more consistent among the heads. The calculations were obtained with the assumption that the vessel is a perfect cylinder, however, the caliber of the vessel may simulate a cone at its distal tributaries on the face and its larger proximal branches located more posteriorly. Consequently, our calculations may be less accurate at the distal and proximal ends of the harvested supratrochlear arteries. Lastly, our findings from cadaveric head vasculature may not perfectly simulate conditions of in vivo active human circulation (ie, flow characteristics, temperature) and thus account for some degree of volume discrepancy.

CONCLUSIONS

In this study, we demonstrated the dimensions of the intravascular space of the supratrochlear artery harvested anteriorly at the glabella and posteriorly toward the orbital apex. On average, this portion of the supratrochlear artery measures 0.085 mL in volume, 51.75 mm in length, and 0.72 mm in radius.

In light of our findings, injecting aliquots < 0.1 mL in the facial soft tissues can already overcome the entire volume of the supratrochlear artery from injection site at the glabella to the level of the orbital apex. This finding is consistent with the previously documented 0.1 mL as the threshold volume necessary to traverse the ophthalmic artery from a facial filler injection. The oculo-facial vasculature is thus highly sensitive to extremely small changes in volume. We hope that this study will highlight the importance of injectable safety by providing a visual and quantitative anatomical perspective so that injectors may become aware of the critical volume sufficient to cause a potentially devastating vascular occlusion.

Disclosures

Dr De Lorenzi is Medical Director for Allergan Canada (Markham, Ontario, Canada) and Merz Canada (Burlington, Ontario, Canada), and an Advisory Board Member for Kythera Biopharmaceuticals Inc. (Westlake Village, CA, USA), Suneva Medical Inc. (San Diego, CA, USA), and Valeant Pharmaceuticals (Laval, Quebec, Canada). Dr Woodward is an Advisor to Allergan, Inc. ( Parsippany, NJ, USA), Lutronic (Burlington, MA, USA), SkinCeuticals/Loreal (New York, NY, USA), Galderma Laboratories (Fort Worth, TX, USA), and Merz Pharmaceuticals (Raleigh, NC, USA). Drs Khan, Colon-Acevedo, and Mettu declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

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REFERENCES