The arteries of the central forehead: implications for facial plastic surgery

Mateusz Koziej, MD, PhD; Jakub Polak, MD(c); Jakub Hołda, MD(c); Marek Trybus, MD, PhD; Mateusz Hołda, MD, PhD; Piotr Kluza, MD; Artur Moskała, MD, PhD; Anna Chrapusta, MD, PhD; Jerzy Walocha, MD, PhD; and Krzysztof Woźniak, MD, PhD

Abstract

Background: The forehead has substantial importance as an aesthetic unit. The central and supraorbital parts of this area are supplied by the supratrochlear (ST) and supraorbital (SO) arteries as well as the recently defined paracentral (PA) and central arteries.

Objectives: The authors aimed to assess the morphometry of the vessels of the forehead in the context of plastic surgery and minimally invasive cosmetic procedures.

Methods: This research included 40 cadavers directed for forensic autopsy and subjected to postmortem computed tomography angiography. In total, 75 hemifaces were examined for the course and location of arteries relative to the bones and surrounding structures.

Results: The arteries were observed as follows: ST in 97.3%, SO in 89.3%, and PA in 44.0%. The PA can be expected in the 13-mm-wide zone starting 2 mm laterally from the midline. The ST should be expected in the 10-mm-wide area extended laterally from the tenth millimeter from the midline, and the SO should be expected in the slightly wider (11 mm) area extending laterally from the 20th millimeter from the midline. For the proximal main trunks of the ST and SO arteries, we observed no overlap between the zones of occurrence, whereas the zones for the PA and ST main proximal trunks did overlap. No distinctive central artery was observed in the midline region of the forehead, but instead a network of small vessels in the midline region was visible.

Conclusions: The ST is the main and most conservative artery of this region and the PA is the most variable. A unique and detailed anatomical map was created to better understand the vasculature of the forehead area.

Editorial Decision date: October 10, 2019; online publish-ahead-of-print October 25, 2019.

The vascular supply of the forehead is a compound system of arteries. The central region of the forehead is mainly vascularized by the supratrochlear artery and the supraorbital artery, which branches from the ophthalmic artery. Laterally, the forehead is supplied by the frontal branch of the superficial temporal artery. The above-mentioned arteries are

Dr Koziej is a Research Assistant and Plastic Surgery Trainee, Dr Hołda is a Research Assistant, and Dr Walocha is a Professor and Department Head, Department of Anatomy; Dr Trybus is a Professor and Plastic Surgeon, Second Department of General Surgery; Mr J. Hołda and Mr Polak are Medical Students; Drs Kluza and Moskala are Research Assistants and Forensic Specialists and Dr Woźniak is an Associate Professor and Forensic Specialist, Department of Forensic Medicine; Jagiellonian University Medical College, Kraków, Poland. Dr Chrapusta is an Associate Professor, Plastic Surgeon, and Head of the Department, The Malopolska Center for Burns and Plastic Surgery, The Ludwik Rydygier Hospital, Kraków, Poland.

Corresponding Author:
Dr Mateusz Hołda, Second Department of General Surgery, Jagiellonian University Medical College, Kopernika 50, 30-001 Kraków, Poland.
E-mail: mt.ujcm@gmail.com
not the only arteries that participate in central forehead nutrition. The presence of the paracentral and central arteries is often overlooked, and their presence is typically not mentioned in the main anatomical textbooks. The paracentral artery originates as continuation from the angular artery on the forehead or from the communicating branch with the supratrochlear artery. The central artery originates from the dorsal nasal artery.1–4

The forehead region has substantial importance as an aesthetic unit.5,6 Deformations or disturbances that might occur in the forehead, such as acquired or inborn deformities, oncological disorders, or aging signs, are highly visible, and these patients often consult with a plastic surgeon. Moreover, the forehead is one of the most frequent locations for neuromodulators and soft-tissue filler applications.7 The key point of aesthetic surgery is to perform an effective and safe procedure that best fits the patients’ needs.8 Knowledge of anatomy is crucial to increase the number of treatment options and decrease risk of complications during surgery.

Moreover, there is a trend towards an increasing number of injection procedures, which are associated with a higher incidence of complications.9,10 The most dangerous zones for the utilization of dermal fillers are the nose and glabellar area, and the most common side effects are bruising, erythema, and swelling. Some serious, vascular-related complications, such as necrosis and blindness, can also occur.11,12 Likewise, knowledge of the underlying anatomy of the vascular components is fundamental for such procedures.

Postmortem computed tomography has been adopted as the standard examination method in selected forensic medicine centers.13 It gives the opportunity to provide high-quality images, which support the work of the forensic pathologist. The applied contrast medium and X-ray doses are mostly different (hydrophobic/oily liquid applied contrast medium and higher radiation doses than normally utilized on living patients), which is why postmortem computed tomography angiography can provide greater detailed anatomical images compared with normal low-dose computed tomography angiography or even tedious and time-consuming cadaver dissection.

Due to the distinct clinical significance of the vascularization of the forehead and concurrent lack of complete knowledge on this subject, we aimed to assess the morphometry of the central forehead arteries employing a high-resolution imaging tool in the context of plastic surgery and minimally invasive cosmetic procedures.

METHODS

The study was conducted at the Department of Anatomy as well as Department of Forensic Medicine of Jagiellonian University Medical College in Kraków, Poland from November 2018 to February 2019. The study protocol was approved by the Bioethical Committee of the Jagiellonian University (No. 1072.6120.213.2017). The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki. The methods were carried out in accordance with the approved guidelines.

Study Group

This research was a retrospective study and included 40 cadavers (34 males and 6 females) directed for forensic autopsy and whole-body postmortem computed tomography angiography (victims of suicide, homicide, and traffic accidents). Exclusion criteria were head trauma (possible damage of blood vessels), significant imaging artifacts (such as low quality or illegible images), states after craniotomy or other head and neck surgeries, incomplete cross-sections, and changes due to putrefaction. A total of 35 cadavers had their forehead vessels visualized bilaterally and 5 cadavers unilaterally, which provided a total of 75 hemispheres included in the final analysis (right = 37, left = 38).

Postmortem Computed Tomography Angiography

This study was targeted on the head and neck due to the forensic cases. Cadavers were scanned between 2 steps of conventional medicolegal examination (external and internal examination) employing 16-detector row computed tomography (Somatom Emotion, Siemens AG, Germany). Scan parameters were 130 kVp, 50 mAs, and 240 mAs; reconstructed slice thickness of 0.75 and 1.5 mm; collimation 16 × 0.6 mm; and pitch 0.85 and 0.55. Postmortem computed tomography angiography was performed with administration of oily liquid contrast medium: 6% Angiofil (Fumedica, Muri, Switzerland) paraffin oil solution via the unilateral or bilateral access to femoral (39 cases) or carotid (1 case) vessels according to the procedure applied by the Technical Working Group Postmortem Angiography Methods.13–15 The results were evaluated utilizing Horos, a free digital imaging and communication medical image viewer and open source code software program distributed free of charge under the LGPL license at Horosproject.org and sponsored by Nimble Co LLC d/b/a Purview (Annapolis, MD). Reconstructions for the current paper were based on the results of arterial phase acquisition. Three-dimensional volume rendered reconstructions were performed and assessed (Figure 1). The forehead vessels and its branches were included in the analysis, with data for both sides recorded and evaluated separately.
Measurements

In each cadaver, the arteries supplying the forehead area were identified and named and their course was recorded. The distances were measured utilizing virtual calipers as listed in Table 1. The vessel lengths were recorded until the loss of visibility. Moreover, the length of each vessel was measured along its course. To show the relationship between arteries and surrounding bone structures, we implemented a topographical reference system in the form of a coordinate system. The horizontal axis passes through the summits of superior margins of orbits, and the vertical axis corresponds to the midline axis of the body. The cross point was designated as a central point of the coordinate system.

Statistical Analysis

Qualitative features were presented as frequencies and percentages. Normal distribution was assessed employing the Shapiro-Wilk test. To verify the variance homogeneity, Levene’s test was performed. Quantitative features were characterized by the mean ± standard deviation. Quantiles (Q1, Me, Q3) were applied if a nonparametric test was performed to compare quantitative features in groups. To compare artery features between the left and right sides, a paired t test or the Wilcoxon rank test was employed, depending on whether data were normally distributed. Statistical analyses were performed with STATISTICA v13.1 (StatSoft Inc., Tulsa, OK, USA). Statistical significance was defined as $P < 0.05$.

RESULTS

The current study included 40 cadavers (34 men and 6 women; mean age, 45.5 ± 15.5 years old; range 19-79 years old). The supratrochlear artery was observed in 97.3% of cases (n = 73), with a median diameter of 1.4 mm (Q1 = 1.2; Q3 = 1.6 mm) and length of 53.2 mm (Q1 = 38.6; Q3 = 68.1 mm). The point where the artery entered the forehead was represented as a notch in 32.9% (24/73) or foramen in 13.7% (10/73); in the remaining 53.4% (39/73) there was no noticeable change in the structure of superior margins of orbit.

The supraorbital artery was detected in 89.3% of cases (n = 67), and the average diameter was 1.3 mm (Q1 = 1.0; Q3 = 1.7 mm). The median length of the supraorbital artery was 39.2 mm (Q1 = 32.5; Q3 = 53.7 mm). The supraorbital artery entered the forehead through a notch in 67.2% (45/67) or foramen in 32.8% (22/67).

The paracentral artery was noted in 44.0% of cases (n = 33) with a median diameter of 1.5 mm (Q1 = 1.2; Q3 = 1.9 mm) and length of 67.5 mm (Q1 = 49.8; Q3 = 77.2 mm). In 36.4% (12/33) the paracentral artery originated from the communicating branch with the supratrochlear, and in 63.6% (21/33) it originated from the angular artery as its continuation onto the forehead. No distinctive central artery was observed in the midline region of the forehead, but instead, a network of small vessels in the midline region was visible in 34.7% (26/75).

No statistically significant difference in supraorbital, supratrochlear, and paracentral artery diameter was detected ($P > 0.05$). When comparing the length, the
paracentral artery was the longest among all vessels, and the supratrochlear was significantly longer than the supraorbital artery ($P < 0.001$). We detected no relationship between artery lengths and courses. Neither sex (male vs female, $P > 0.05$) nor face side (left vs right, $P > 0.05$) dependent differences were found for artery lengths and diameters.

The anatomical map with measured distances is presented in Figure 2 and Table 1. Employing the proposed coordinate system and the 10th- and 90th-percentile calculations, the paracentral artery can be expected in the wide zone from the midline horizontally (2-15 mm; median 7.6 mm). The supratrochlear artery should be expected in the area extended laterally from the midline (11-21 mm; median, 15 mm), and the supraorbital artery should be expected from 21 to 32 mm (median, 27 mm). Those measurement were made for the proximal parts of arteries for their main trunks. For supratrochlear and supraorbital arteries, no overlap of zones of occurrence was observed, whereas the zones for paracentral and supratrochlear arteries did overlap (Figure 3). These are connected proximally. However, in the distal part, their course is individual, mostly in an axial pattern. The vertical extents of the arteries are presented in Table 1 and Figure 3, which were the highest for the paracentral and lowest for the supraorbital artery ($P < 0.001$).

**DISCUSSION**

The current study presents topographical dependences of the central forehead arterial supply. Despite the large clinical significance of the forehead region, its vascularization gained relatively little attention. So far, only a few small anatomopathological and imaging studies have explored features of the central forehead blood supply.2,3,16-20 However, because the forehead is the target of several surgical and less invasive operations, knowledge of the vascular bed is essential for the safety of these plastic and aesthetic procedures.11 This publication complements the cycle regarding clinically important facial arteries; in

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Abbreviation on map (Figure 2)</th>
<th>Median (lower and upper quartiles), mm</th>
<th>10th percentile</th>
<th>90th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>The horizontal distance between the central point and point where the paracentral artery crosses the supraorbital rim</td>
<td>A</td>
<td>7.6 (4.8; 11.8)</td>
<td>1.8</td>
<td>15.4</td>
</tr>
<tr>
<td>The horizontal distance between the central point and point where the supratrochlear artery crosses the supraorbital rim</td>
<td>B</td>
<td>15.1 (13.1; 17.3)</td>
<td>10.7</td>
<td>20.6</td>
</tr>
<tr>
<td>The horizontal distance between the central point and point where the supraorbital artery crosses the supraorbital rim</td>
<td>C</td>
<td>26.5 (24.4; 29.4)</td>
<td>20.7</td>
<td>31.8</td>
</tr>
<tr>
<td>The horizontal distance along the horizontal line between supraorbital and supratrochlear arteries</td>
<td>D</td>
<td>9.2 (6.6; 12.6)</td>
<td>5.0</td>
<td>14.9</td>
</tr>
<tr>
<td>The vertical extent of the paracentral artery</td>
<td>E</td>
<td>62.6 (42.4; 71.1)</td>
<td>30.2</td>
<td>73.6</td>
</tr>
<tr>
<td>The vertical extent of the supratrochlear artery</td>
<td>F</td>
<td>48.1 (36.4; 59.6)</td>
<td>21.4</td>
<td>71.2</td>
</tr>
<tr>
<td>The vertical extent of the supraorbital artery</td>
<td>G</td>
<td>35.8 (25.2; 52.8)</td>
<td>20.6</td>
<td>60.9</td>
</tr>
<tr>
<td>The distance between the central point and point where the supratrochlear artery crosses the supraorbital rim</td>
<td>H</td>
<td>17.4 (15.5; 18.7)</td>
<td>12.9</td>
<td>20.6</td>
</tr>
<tr>
<td>The distance between the central point and point where the supraorbital artery crosses the supraorbital rim</td>
<td>I</td>
<td>26.5 (23.1; 28.5)</td>
<td>20.3</td>
<td>31.3</td>
</tr>
<tr>
<td>The distance from the center of the medial orbital rim to the point where supratrochlear artery crosses supraorbital rim</td>
<td>J</td>
<td>14.4 (12.6; 16.3)</td>
<td>11.5</td>
<td>18.6</td>
</tr>
<tr>
<td>The distance from the center of the medial orbital rim to the point where supraorbital artery crosses supraorbital rim</td>
<td>K</td>
<td>22.4 (20.4; 23.7)</td>
<td>18.4</td>
<td>25.6</td>
</tr>
</tbody>
</table>
previous works the vascularization of the remaining floors of the face was discussed.21-23 The paracentral and smaller central arteries have exceptional significance in the vascular supply of the central forehead, as well as their axial nature, which was specified by other authors.2,24 The above-mentioned arteries are ignored in the majority of the anatomical textbooks and atlases. On the other hand, the glabellar region is the most common site of necrosis following filler injections in the forehead area, which emphasizes the importance of these neglected vessels.9 In the present study, the paracentral artery was observed in 44.0% of cases. This observation is similar to the only morphometrical study evaluating the paracentral artery by Kleintjes et al, who dissected 60 hemifaces and found the paracentral artery in 35% of cases.2 Moreover, these authors have shown bilateral
anastomoses between the paracentral artery and adjacent arteries of the forehead. Interestingly, the central artery was observed in 71.7% and always originated from the dorsal nasal artery. The central artery supplied the inferior and middle transverse thirds of the central forehead along with the glabella. In the current study, a distinctive central artery was not visible, probably due to its small caliber and insufficient resolution of the computed tomography.

Nasal reconstruction is the oldest and commonly performed surgical procedure involving the central forehead. The axial orientation of the arteries requires the surgeon to perform the flap in such a manner to achieve both optimal cosmetic and functional results while minimizing procedure stages and resection of healthy tissue. In a study conducted by Faris et al, the classic paramedian, glabella, and central artery flaps were compared for nasal reconstruction based on the analysis of 300 patients. These authors show that the central artery flap is reliable in terms of vascularity and its design statistically reduced in the transfer of hair to the nose. Also, Balc et al suggested a flap based on the central perforator. After harvesting and dissecting, the flap is rotated 180° (in a propeller-like manner), which allows both the defect and the glabella to be covered. Employing these techniques, a defect of the nasal dorsum and medial canthal region can be reconstructed in a single-stage method without dog-ear deformity or eyebrow asymmetry.

The supratrochlear and supraorbital arteries are considered as the main vessels of the forehead, and their anatomy is relatively well understood. A comprehensive dissection study was conducted by Cong et al on 12 cadavers, where the supraorbital and supratrochlear arteries were injected with colored latex. The authors show that these arteries are divided into 2 branches depending on their location relative to the frontalis: more common superficial branches (up to 100%) and less frequent deep branches (55%), which for the supratrochlear artery was not always present. Interestingly, the paracentral and central arteries were observed in 20% of cases only in the group where the deep branch of the supratrochlear artery was present and they supplied the superficial aspect of the frontalis muscle. The supraorbital artery runs parallel with the large ascending veins only in the medial canthal region. Several small veins branch out from those veins, forming a subdermal pylogonal venous network in the glabellar area.

Among the vessels of the forehead, the supraorbital and supratrochlear arteries are the most likely to be involved in complications leading to blindness. The most common locations of filler injections that lead to vision changes were the nasal region and the glabella. To highlight this serious side effect, the Food and Drug Administration issued a safety communication about the risk of unintentional intravascular injection with soft tissue fillers. Injectors must be aware of procedures to treat potential complications. The retrograde propagation of a foreign body can lead to vision loss. The concept of blindness following soft tissue filler injections is related to the retrograde propagation of the filler to the ophthalmic artery from supratrochlear and supraorbital arteries. We suggest that the paracentral artery should also be considered in this phenomena as indirect connection with the ophthalmic artery through the angular or supratrochlear artery.

A useful and noteworthy technique to maximize safety during hyaluronic acid injections in the glabella and the supraorbital region was described by Scheuer et al, who recommended performing dermal injections into wrinkles utilizing a low-gauge filler and serial puncture technique. Moreover, pressure with digits applied over the artery can be made to occlude supraorbital and supratrochlear arteries along the supraorbital rim to obviate filler to backflow through the artery even when the vessel is punctured.

The axial nature of the paracentral and supratrochlear arteries, as well as their anatomical localization (overlapped zones of vertical proximal trunk occurrence), suggests that their occlusion or damage during the procedure might lead to skin necrosis in the glabellar region. Several techniques were described to decrease the chance of skin necrosis, such as aspiration, lower injection volumes, injecting in superficial layers, or tenting skin while injecting. Nevertheless, there is no gold standard procedure that can prevent all complications when performing minimally invasive injectable procedures in the forehead region. Nonetheless, here we present an anatomical map that will be helpful when making clinical decisions. The presented vertical and horizontal extents of the arteries show an average location of the vessels, which can aid in the planning and performing of safe procedures. Anatomical knowledge, in combination with appropriate training, familiarity with potential pitfalls, and clinical experience (including how to cope with complications), contribute to the effectiveness and safety of surgical procedures.

This study is not without limitations, which result mainly from the choice of imaging technique. First, we were unable to investigate the depth of position of forehead arteries in relation to the frontal layers employing postmortem computed tomography angiography. Second, the presence and course of veins, which can also contribute to complications in plastic and aesthetic procedures, were not evaluated. Moreover, no associations between the arteries’ course and surrounding soft tissues or nerves were investigated. On the other hand, a notably higher than usual contrast dose, which was applied to visualize arteries, allowed us to visualize vessels more accurately than is possible with clinically performed computed tomography angiography. Finally, the proposed anatomical map should not be employed as a universal tool because anatomical variations can occur in
individual patients. Specifically, cadavers with craniofacial deformities were not included in this study, and the above results cannot be considered transferable to this group.

CONCLUSIONS

The arterial vascularity of the central forehead has an axial character. Here we present a unique and detailed anatomical map that was created to better understand the vasculature of the forehead area, which might be supportive for plastic surgeons in planning facial surgical and minimally invasive cosmetic procedures. Three major forehead arteries were identified. The supratrochlear artery is the main and most conservative artery of this region, and the paracentral artery is the most variable.

Disclosures

The authors declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Funding

The authors received no financial support for the research, authorship, and publication of this article.

REFERENCES


