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# The complete anatomy of the transverse facial artery: a computed tomography angiography analysis

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*Background:* *The transverse facial artery (TFA) supplies blood to various structures of the lateral face, including the parotid gland, parotid duct, masseter muscle, and facial skin. Knowledge about its anatomy is of utmost importance in various plastic and reconstructive procedures.*
*Material and methods:* *The results of 55 (110 hemifaces) consecutive patients who underwent head and neck computed tomography angiography (CTA) in the Department of Radiology of the Jagiellonian University Medical College, Cracow, Poland, were evaluated in July 2022.*
*Results:* *The TFA was found to originate from the STA (superficial temporal artery) in 84 of the cases (95.5%), whereas from ECA (external carotid artery) only in 4 of the cases (4.5%). The median length of the TFA was found to be 43.39 mm (LQ = = 38.53; UQ = 46.37). The median TFA diameter, at its origin, was established at 2.26 mm (LQ = 1.93; UQ = 2.54). The median TFA cross-sectional area, at its origin, was found to be 2.54 mm (LQ = 1.67; UQ = 3.10).*
*Conclusions:* *The TFA plays an important role in the arterial blood supply to the face, and the present study has demonstrated its stable prevalence in the lateral face region. The most frequent origin of the artery was from the STA; however, it also originated from the ECA in some cases. Moreover, the topographic relationships between the TFA and nearby arteries and anatomical landmarks were measured and analysed.* (Folia Morphol 2024; 83, 3: 639–646)

**Keywords: transverse facial artery, face, plastic surgery, perforator flap, surgery**

## INTRODUCTION

The transverse facial artery (TFA) originates most commonly as a singular vessel from the superficial temporal artery (STA), within the parotid gland. It traverses the face in a superficial manner, passing over the masseter muscle. Its course is approximately a finger's breadth below the zygomatic arch (Fig. 1, 2). Subsequently, the artery divides into multiple branches, which provide blood supply to various structures, including the parotid gland, parotid duct, masseter

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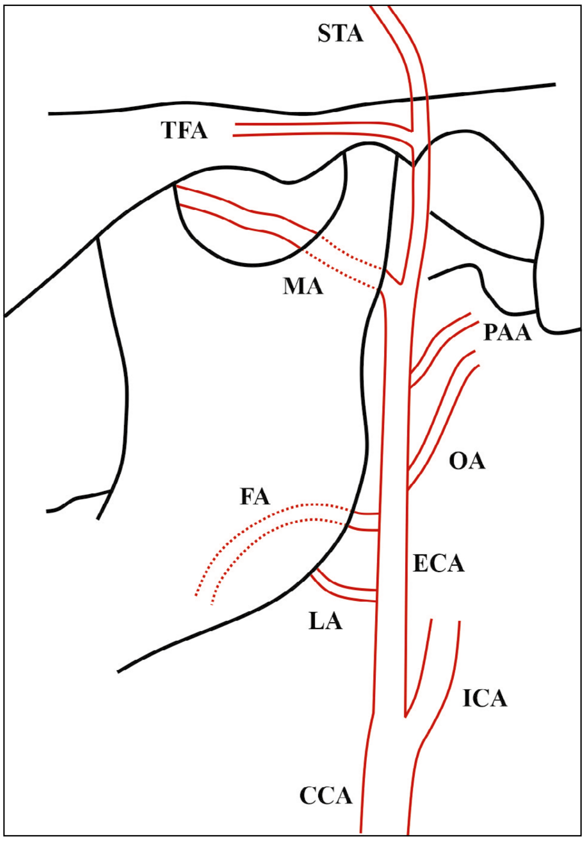


**Figure 1.** Scheme, presenting the arterial anatomy of the region in which the measurements were taken. CCA — common carotid artery; ECA — external carotid artery; FA — facial artery; ICA — internal carotid artery; LA — lingual artery; MA — maxillary artery; OA — occipital artery; PAA — posterior auricular artery; STA — superficial temporal artery; TFA — transverse facial artery; UQ — upper quartile.

muscle, and facial skin. Additionally, it forms anastomoses with branches of the facial artery (FA) [9].

Numerous studies have demonstrated the variability in the anatomy of the TFA [7, 16]. As mentioned earlier, the TFA is said to originate from the STA; however, reports have shown that the artery may also arise from the external carotid artery (ECA) or its terminal bifurcation in up to 35% of the cases [4]. Moreover, a study by Yang et al. [16] demonstrated that the number of TFAs is also variable. ranging from one to three arteries. The spatial association between the TFA and nearby structures has also been analysed, especially between the said artery and the branches of the facial nerve [16].

Normality in anatomy can be considered relative (linked to a specific set of assumptions) and is inferred from numerous repeated observations [19]. Having appropriate knowledge of the anatomy of the TFA is of immense importance in plastic and reconstructive

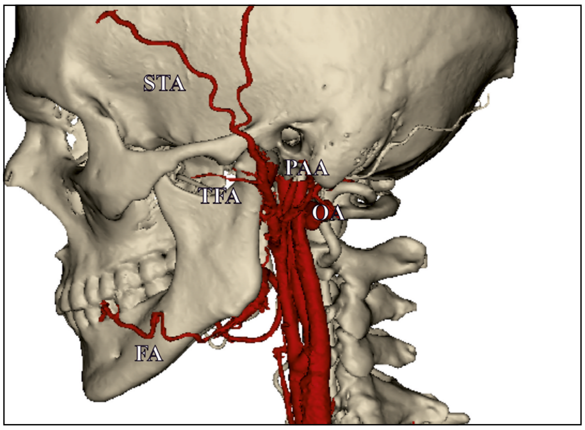


**Figure 2.** Three-dimensional reconstruction of one of the analysed computed tomography angiographies. Some of the arteries were removed to provide the best possible quality of the image. FA — facial artery; OA — occipital artery; PAA — posterior auricular artery; STA — superficial temporal artery; TFA — transverse facial artery.

surgery. In recent decades, the utilisation of fillers and botulinum toxin to enhance facial features and improve the jawline has gained significant traction. However, the elevated frequency of injections may give rise to infrequent yet severe complications, notably an emerging trend of blindness reported in the literature [2, 3, 12]. The underlying mechanism behind this debilitating complication involves the injection of the toxin into an artery, such as the TFA in the lateral face, subsequently leading to the obstruction of the central retinal artery. Consequently, this occlusion disrupts the blood supply to the optic nerve, resulting in impaired vision and potential blindness [13]. Furthermore, TFA perforator flaps have been utilised in reconstructions of the zygomaticofacial region after tumour resections [18]. Hence, knowing the topographical anatomy of the TFA is of incredible importance. Therefore, the main goal of the present study was to analyse the complete anatomy of this artery and provide surgeons with useful morphometric data between the TFA and nearby structures. It is hoped that the present study may help physicians with localising the TFA efficiently during various aesthetic and reconstructive procedures and, with that, decrease the potential of iatrogenic injury to this vessel.

## MATERIALS AND METHODS

### Approvement of the Bioethical Committee

The research protocol was submitted for evaluation and approved by the Jagiellonian University Bioethical

Committee, Cracow, Poland (1072.6120.51.2022). The study was carried out according to the allowed criteria during the next stages.

**Study group**

The results of 55 consecutive patients who underwent head and neck computed tomography angiography (CTA) in the Department of Radiology of the Jagiellonian University Medical College, Cracow, Poland, were evaluated in July 2022. Each CTA was evaluated bilaterally; therefore, a total of 110 hemifaces were initially evaluated. Exclusion criteria were established as follows: (1) head, neck, or thoracic trauma affecting the course or the morphometry of the TFA or its close anatomical area; (2) significant artifacts that prevented accurate and precise imaging and/or measurement of the TFA or its close anatomical area; (3) low-quality and illegible images; and (4) significant lack of filling the whole arterial system with contrast. In cases where only a segment of the CTA exhibited any of the mentioned abnormalities, without impacting the opposite side, the assessment of the other TFA was conducted. A substantial majority (20 cases) of the omitted hemifaces were ineligible for analysis due to prominent artifacts. The other 2 instances were disregarded to ensure data impartiality owing to their subpar image quality. Finally, 88 hemifaces fulfilled the stipulated inclusion criteria.

**Results acquisition**

All head and neck CTA were performed on a 128-slice scanner CT (Philips Ingenuity CT, Philips Healthcare). The main CT imaging parameters were the following: collimation/increase: 0.625/0.3 mm; tube current: 120 mAs; field of view: 210 mm; matrix size: 512 × 512.

All patients received intravenous administration of contrast material at a dose of 1 mL/kg (standard dose). A non-ionic contrast medium (CM) containing 350 mg of iodine per ml was used (Jowersol 741 mg/ /mL, Optiray®, Guerbet, France). The acquisition of CT data was initiated using a real-time bolus tracking technique (Philips Healthcare) with the region of interest (ROI) placed in the ascending aorta. CM was injected intravenously using a power injector at a flow rate of 5 mL/s. This was immediately followed by an injection of 40 mL of saline solution at the same flow rate. Following injection of CM and saline, image acquisition was automatically started with a 2 s delay when the attenuation trigger value reached a threshold of 120 Hounsfield units (HU). Scanning was performed in the caudocranial direction. The CTA examination was started at the level of the aortic arch up to the circle of Willis.

The CTAs were analysed on a dedicated workstation in the Anatomical Department of Jagiellonian University Medical College, Cracow, Poland. To ensure the highest possible quality of the visualisations and measurements and minimise potential bias, Materialise Mimics Medical version 21.0 software (Materialise NV, Leuven, Belgium) was used. Three-dimensional (3D) reconstructions of each scan were developed, employing a set of settings adjusted to each scan. A volume rendering opacity range oscillated from 25 to 75 HU for the lower limit and up to 135 HU for the upper limit. The range was individually adjusted to each TT after a visual investigation.

**Evaluation and measurements**

At the commencement of each assessment, each TFA was carefully visualised. Subsequently, a series of measurements was recorded within each TFA by 2 distinct researchers working individually. Then the average was computed, considering both sets of findings. All measurements were rounded off to 2 decimal places. Morphometric features of the TFA and/or its associated anatomical area were assessed in 26 categories, listed in Table 1.

**Statistical analysis**

Statistical analysis was performed with STATISTICA v13.1 (StatSoft Inc., Tulsa, OK, USA). The frequency and percentages presented qualitative features. The Shapiro-Wilk test was used to assess the normal distribution. Quantitative characteristics were presented as medians and upper and lower quartiles (UQ, LQ), as well as means and standard deviation (SD), depending on the verified normality of the data. Statistical significance was defined as $p < 0.05$. Mann-Whitney and Wilcoxon signed-rank tests were used to establish potential differences between groups. The Spearman rank correlation coefficient was used to determine possible correlations between the parameters.

## RESULTS

The general characteristics of the patient group are presented in Table 2. The TFA was found to originate from the STA in 84 of the cases (95.5%), whereas from the ECA only in 4 of the cases (4.5%). The median length of the TFA was found to be 43.39 mm (LQ

**Table 1.** Overall results of the measurements. The results were established in millimetres [mm/mm$^2$].

| Category | Median | LQ | UQ | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|---|---|
| TFA length | 43.39 | 38.53 | 46.37 | 30.50 | 64.26 | 43.43 | 6.46 |
| TFA diameter (at its origin) | 2.26 | 1.93 | 2.54 | 1.14 | 3.32 | 2.25 | 0.47 |
| TFA cross-sectional area (at its origin) | 2.54 | 1.67 | 3.10 | 0.63 | 5.97 | 2.50 | 1.04 |
| TFA branching angle [deg] | 74.55 | 59.09 | 89.70 | 30.40 | 149.38 | 75.24 | 21.80 |
| STA diameter at the TFA origin | 3.14 | 2.76 | 3.49 | 1.56 | 4.00 | 3.08 | 0.51 |
| STA cross-sectional area at the TFA origin | 5.33 | 4.24 | 6.15 | 1.47 | 10.19 | 5.30 | 1.66 |
| CCA diameter (just before bifurcation) | 8.02 | 7.37 | 8.82 | 4.62 | 11.78 | 8.11 | 1.31 |
| CCA cross-sectional area (just before bifurcation) | 41.44 | 35.12 | 49.46 | 13.80 | 77.26 | 42.47 | 12.24 |
| ECA diameter (just before bifurcation into STA and MA) | 4.10 | 3.70 | 4.53 | 2.48 | 5.56 | 4.11 | 0.67 |
| ECA cross-sectional area (just before bifurcation STA and MA) | 10.02 | 8.09 | 11.62 | 3.45 | 21.32 | 10.19 | 3.31 |
| ECA diameter (just before its first branch) | 5.15 | 4.59 | 5.72 | 3.77 | 7.57 | 5.19 | 0.89 |
| ECA cross-sectional area (just before its first branch) | 15.89 | 12.47 | 19.99 | 8.58 | 34.21 | 16.94 | 5.76 |
| MA diameter (at its origin) | 3.38 | 3.09 | 3.63 | 1.76 | 4.50 | 3.32 | 0.51 |
| MA cross-sectional area (at its origin) | 6.25 | 5.28 | 7.58 | 1.34 | 11.22 | 6.29 | 1.79 |
| PAA diameter (at its origin) | 2.55 | 2.28 | 2.91 | 1.42 | 3.73 | 2.54 | 0.47 |
| PAA cross-sectional area (at its origin) | 3.22 | 2.47 | 4.13 | 1.25 | 5.97 | 3.27 | 1.12 |
| OA diameter (at its origin) | 2.91 | 2.49 | 3.17 | 1.51 | 5.08 | 2.85 | 0.61 |
| OA cross-sectional area (at its origin) | 4.25 | 3.34 | 5.62 | 1.13 | 8.46 | 4.43 | 1.54 |
| FA diameter (at its origin) | 3.24 | 2.91 | 3.63 | 1.99 | 5.00 | 3.26 | 0.58 |
| FA cross-sectional area (at its origin) | 6.00 | 4.59 | 7.31 | 2.19 | 14.17 | 6.12 | 2.10 |
| Distance from the origin of the MA to the origin of the TFA (over the surface of the ECA/STA) | 6.36 | 5.11 | 8.04 | 3.08 | 18.02 | 6.82 | 2.35 |
| Distance from the origin of the TFA to the origin of the STA (over the surface of the ECA/STA) | 51.81 | 35.90 | 65.06 | 22.20 | 103.33 | 52.11 | 18.38 |
| Distance from the origin of the OA to the origin of the TFA (over the surface of the ECA/STA) | 46.48 | 39.33 | 52.54 | 20.48 | 81.59 | 46.74 | 10.69 |
| Distance from the origin of the FA to the origin of the TFA (over the surface of the ECA/STA) | 47.74 | 43.59 | 53.36 | 31.14 | 66.78 | 48.30 | 7.78 |
| Distance from the origin of the PAA to the origin of the TFA (over the surface of the ECA/STA) | 23.14 | 17.22 | 27.14 | 7.90 | 44.21 | 22.82 | 6.67 |
| Distance from the origin of the TFA to the lower border of the zygomatic arch | 24.16 | 21.94 | 27.38 | 12.13 | 36.07 | 24.63 | 4.10 |

CCA — common carotid artery; ECA — external carotid artery; FA — facial artery; LQ — lower quartile; MA — maxillary artery; OA — occipital artery; PAA — posterior auricular artery; SD — standard deviation; STA — superficial temporal artery; TFA — transverse facial artery; UQ — upper quartile.

**Table 2.** Qualitative results of the data analysis.

| Category | N | Percentage [%] |
|---|---|---|
| *Patients' sex* | | |
| Females | 42 | 47.7 |
| Males | 46 | 52.3 |
| *Patients' side* | | |
| Left | 44 | 50.0 |
| Right | 44 | 50.0 |
| *TFA origin artery* | | |
| STA | 84 | 95.5 |
| ECA | 4 | 4.5 |

ECA — external carotid artery; STA — superficial temporal artery; TFA — transverse facial artery.

= 38.53; UQ = 46.37). The median TFA diameter, at its origin, was established at 2.26 mm (LQ = 1.93; UQ = 2.54). The median TFA cross-sectional area, at its origin, was found to be 2.54 mm (LQ = 1.67; UQ = 3.10). The median TFA branching angle was found to be 74.55 degrees (LQ = 59.09; UQ = 89.70). The median distance between the origin of the MA and the origin of the TFA was found to be 6.36 mm (LQ = 5.11; UQ = 8.04). The median distance between the origin of the TFA and the origin of the STA was found to be 51.81 mm (LQ = 35.90; UQ = 65.06). The median distance between the origin of the OA and the origin of the TFA was established at 46.48 (LQ =

= 39.33; UQ = 52.54). The median distance between the origin of the FA and the origin of the TFA was found to be 47.74 mm (LQ = 43.59; UQ = 53.36). The median distance between the origin of the PAA to the origin of the TFA was established at 23.14 mm (LQ = 17.22; UQ = 27.14). The median distance between the origin of the TFA to the lower border of the Zygomatic Arch was found to be 24.16 mm (LQ = 21.94; UQ = 27.38). All the results mentioned above, and more detailed ones in all categories, can be found in Table 1. Statistically significant differences between females and males were found in 16 categories. There was a statistically significant difference in the length of the TFA between females and males. However, this difference was not found regarding the origin of the TFA at its origin. More detailed results with respect to the patient's sex and the performed measurements are shown in Table 3.

Lastly, differences between patients' sides and correlations between parameters and patients' age were studied. However, there were no statistical differences between patients' sides in any of the parameters. Furthermore, no statistically significant correlation between any of the parameters and patients' age was found.

## DISCUSSION

The TFA is said to originate from the STA; however, various reports have demonstrated that this is not always the case. In a study conducted by Koziej et al. [7], the TFA originated from the STA in most of the cases (91.7%). Nevertheless, it was stated that the artery also originated from the ECA (3.1%), as well as from a common trifurcation point along with the maxillary and superficial temporal arteries (4.7%). Interestingly, they also demonstrated a case in which the TFA originated from the maxillary artery. On the other hand, in the study presented by Yang et al. [16], the TFA originated from the STA in all cases. Interesting cases of the TFA were also described by Basar et al. [1], namely, the TFA originating bilaterally from a common trunk with an artery that supplied the parotid gland. In the present study, the said vessel was present in all the patients and originated most commonly from the STA (95.5%); however, an origin from the ECA was reported in 4 cases (4.5%). Moreover, the number of TFAs in the current study was constant, where only one artery was present in every patient. This differs from the results of other studies; Yang et al. [16] reported double and triple TFAs to be present in 25% and 4.5% of cadavers, respectively. On the other hand, Koziej et al. [7] reported a significantly lower frequency of double TFAs (4.7%), and no triple TFAs were observed. Interestingly, Yang et al. [16] demonstrated anastomoses between the TFA and the FA in one male cadaver; however, this was observed in our study. A possible explanation for this may be that small anastomoses between arteries may not contain as much contrast as larger vessels; hence, their visibility would be diminished on CTAs. On the other hand, the aforementioned study presented this occurrence in only one side out of 44 sides. Therefore, the overall prevalence of anastomoses of considerable size between the TFA and the FA may just be low in the general population, as this was not demonstrated in the study by Koziej et al. [7] in which 200 cases were analysed.

The relationship to nearby structures, such as the zygomatic arch and nearby arteries, has been investigated in various studies. Basar et al. [1] demonstrated that the distance between the inferior region of the zygomatic arch and the TFA ranged from 3.4 to 28.6 mm (mean: 15.49 ± 7.56 mm). Interestingly, Koziej et al. [7] presented higher results, with a distance of 20.9 ± ± 4.1 mm. The results of the present study show an even greater distance of 24.63 ± 4.1 mm. These data further prove that the TFA is located approximately a finger-width under the zygomatic arch. This may be a reliable rule for surgeons to follow during surgical procedures of the lateral face.

The dominance of the TFA over the FA has been reported in the available literature. A case of bilateral hypoplastic FAs and large TFAs was presented by Olson et al. [10]. In the case report, it was stated that the TFA supplied the whole midface region, giving off the superior labial artery, the lateral nasal artery, and terminating as the angular artery. The hypoplastic FAs gave off the inferior labial artery bilaterally. Interestingly, anastomoses between the branches of the TFA, FA, and the infraorbital artery were also observed. Koziej et al. [7] demonstrated only one case of a dominant TFA out of 200 cases. In another case study, Yotova et al. [17] reported a similar observation where a TFA provided compensation for a bilaterally underdeveloped FA. However, they noted that upon reaching the superficial face, the FA split into 2 unusual branches, ultimately terminating in the buccinator muscle. The compensatory blood flow from the TFA supported the superior labial, lateral nasal, and angular arteries. Moreover, the study did

**Table 3.** Results of the measurements with respect to the patient's sex. The results were established in millimetres [mm/mm$^2$].

| Category | Sex | Median | LQ | UQ | Minimum | Maximum | Mean | SD | P-value |
|---|---|---|---|---|---|---|---|---|---|
| TFA length | Females | 41.80 | 38.32 | 44.09 | 30.50 | 49.98 | 41.12 | 4.66 | 0.01 |
| | Males | 45.54 | 40.47 | 49.40 | 32.84 | 64.26 | 45.45 | 7.17 | |
| TFA diameter (at its origin) | Females | 2.16 | 1.82 | 2.50 | 1.14 | 3.15 | 2.15 | 0.44 | 0.08 |
| | Males | 2.35 | 2.04 | 2.69 | 1.45 | 3.32 | 2.34 | 0.49 | |
| TFA cross-sectional area (at its origin) | Females | 2.10 | 1.63 | 2.94 | 0.83 | 3.75 | 2.25 | 0.80 | 0.09 |
| | Males | 2.68 | 2.00 | 3.30 | 0.63 | 5.97 | 2.72 | 1.19 | |
| TFA branching angle [deg] | Females | 64.63 | 54.39 | 85.65 | 30.40 | 119.86 | 69.49 | 20.77 | 0.02 |
| | Males | 77.80 | 68.77 | 94.35 | 32.99 | 149.38 | 80.47 | 21.62 | |
| STA diameter at the TFA origin | Females | 3.01 | 2.80 | 3.24 | 1.57 | 3.97 | 3.02 | 0.50 | 0.24 |
| | Males | 3.28 | 2.68 | 3.51 | 1.56 | 4.00 | 3.14 | 0.52 | |
| STA cross-sectional area at the TFA origin | Females | 5.09 | 4.28 | 5.69 | 1.59 | 10.19 | 5.17 | 1.65 | 0.32 |
| | Males | 5.74 | 4.14 | 6.32 | 1.47 | 9.18 | 5.41 | 1.67 | |
| CCA diameter (just before bifurcation) | Females | 7.58 | 7.15 | 8.51 | 5.46 | 10.55 | 7.81 | 1.09 | 0.03 |
| | Males | 8.29 | 7.54 | 9.31 | 4.62 | 11.78 | 8.39 | 1.44 | |
| CCA cross-sectional area (just before bifurcation) | Females | 38.88 | 34.61 | 47.20 | 20.11 | 68.70 | 40.37 | 10.59 | 0.08 |
| | Males | 43.62 | 36.92 | 52.08 | 13.80 | 77.26 | 44.39 | 13.41 | |
| ECA diameter (just before bifurcation into STA and MA) | Females | 3.88 | 3.59 | 4.18 | 2.48 | 5.51 | 3.89 | 0.61 | 0.00 |
| | Males | 4.33 | 3.76 | 4.73 | 2.74 | 5.56 | 4.31 | 0.66 | |
| ECA cross-sectional area (just before bifurcation STA and MA) | Females | 9.40 | 7.81 | 11.21 | 3.45 | 15.27 | 9.25 | 2.71 | 0.02 |
| | Males | 10.75 | 8.58 | 13.14 | 4.81 | 21.32 | 11.05 | 3.60 | |
| ECA diameter (just before its first branch) | Females | 4.84 | 4.34 | 5.37 | 3.83 | 7.52 | 4.94 | 0.83 | 0.01 |
| | Males | 5.50 | 4.74 | 5.99 | 3.77 | 7.57 | 5.41 | 0.89 | |
| ECA cross-sectional area (just before its first branch) | Females | 14.97 | 11.59 | 17.23 | 8.76 | 30.80 | 15.35 | 5.12 | 0.00 |
| | Males | 17.95 | 13.61 | 22.04 | 8.58 | 34.21 | 18.38 | 5.98 | |
| MA diameter (at its origin) | Females | 3.23 | 2.79 | 3.57 | 1.76 | 4.19 | 3.19 | 0.56 | 0.04 |
| | Males | 3.51 | 3.15 | 3.65 | 2.49 | 4.50 | 3.45 | 0.42 | |
| MA cross-sectional area (at its origin) | Females | 6.23 | 4.78 | 7.51 | 1.34 | 9.12 | 6.02 | 1.91 | 0.40 |
| | Males | 6.28 | 5.63 | 7.65 | 3.22 | 11.22 | 6.54 | 1.64 | |
| PAA diameter (at its origin) | Females | 2.51 | 2.22 | 2.69 | 1.50 | 3.54 | 2.47 | 0.45 | 0.10 |
| | Males | 2.60 | 2.47 | 2.98 | 1.42 | 3.73 | 2.60 | 0.48 | |
| PAA cross-sectional area (at its origin) | Females | 2.68 | 2.10 | 3.68 | 1.25 | 5.97 | 2.93 | 1.12 | 0.00 |
| | Males | 3.67 | 3.01 | 4.26 | 1.57 | 5.38 | 3.57 | 1.05 | |
| OA diameter (at its origin) | Females | 2.65 | 2.34 | 2.96 | 1.51 | 3.85 | 2.59 | 0.52 | 0.00 |
| | Males | 3.04 | 2.69 | 3.43 | 2.03 | 5.08 | 3.07 | 0.60 | |
| OA cross-sectional area (at its origin) | Females | 3.68 | 3.06 | 4.52 | 1.13 | 6.51 | 3.74 | 1.29 | 0.00 |
| | Males | 4.97 | 3.88 | 5.78 | 2.31 | 8.46 | 5.04 | 1.50 | |
| FA diameter (at its origin) | Females | 3.04 | 2.78 | 3.37 | 1.99 | 3.82 | 3.01 | 0.47 | 0.00 |
| | Males | 3.55 | 3.08 | 3.88 | 2.29 | 5.00 | 3.49 | 0.58 | |
| FA cross-sectional area (at its origin) | Females | 5.53 | 4.00 | 6.20 | 2.19 | 7.36 | 5.17 | 1.43 | 0.00 |
| | Males | 6.72 | 5.11 | 8.08 | 3.32 | 14.17 | 6.97 | 2.26 | |
| Distance from the origin of the MA to the origin of the TFA (over the surface of the ECA/STA) | Females | 6.16 | 4.98 | 7.95 | 3.57 | 11.92 | 6.62 | 2.06 | 0.53 |
| | Males | 6.80 | 5.12 | 8.16 | 3.08 | 18.02 | 7.00 | 2.61 | |
| Distance from the origin of the TFA to the origin of the STA (over the surface of the ECA/STA) | Females | 46.90 | 29.68 | 59.07 | 22.20 | 79.97 | 46.63 | 16.45 | 0.02 |
| | Males | 54.34 | 42.52 | 70.47 | 23.25 | 103.33 | 56.74 | 18.83 | |
| Distance from the origin of the OA to the origin of the TFA (over the surface of the ECA/STA) | Females | 44.32 | 38.54 | 47.67 | 20.48 | 68.55 | 43.85 | 8.89 | 0.00 |
| | Males | 50.02 | 44.50 | 55.69 | 28.19 | 81.59 | 49.26 | 11.56 | |
| Distance from the origin of the FA to the origin of the TFA (over the surface of the ECA/STA) | Females | 45.13 | 40.35 | 48.65 | 31.14 | 57.53 | 45.16 | 6.59 | 0.00 |
| | Males | 51.26 | 45.93 | 56.52 | 32.56 | 66.78 | 51.16 | 7.73 | |
| Distance from the origin of the PAA to the origin of the TFA (over the surface of the ECA/STA) | Females | 21.81 | 16.96 | 26.55 | 12.15 | 44.21 | 22.82 | 6.96 | 0.65 |
| | Males | 23.30 | 18.01 | 27.14 | 7.90 | 34.59 | 22.82 | 6.52 | |
| Distance from the origin of the TFA to the lower border of the zygomatic arch | Females | 23.98 | 21.85 | 25.58 | 17.89 | 32.99 | 23.82 | 3.18 | 0.10 |
| | Males | 25.10 | 22.03 | 28.49 | 12.13 | 36.07 | 25.38 | 4.70 | |

CCA — common carotid artery; ECA — external carotid artery; FA — facial artery; LQ — lower quartile; MA — maxillary artery; OA — occipital artery; PAA — posterior auricular artery; SD — standard deviation; STA — superficial temporal artery; TFA — transverse facial artery; UQ — upper quartile.

not mention the presence of an inferior labial artery. Additionally, Tubbs et al. conducted a study reporting a remarkable specimen of a large TFA compensating for the complete absence of the corresponding FA on the left side, although it was a unilateral abnormality [14]. In the present study, the FA dominated over the TFA in all of the cases. These variations of the arterial vasculature of the face develop during embryological development. The formation of aortic arches occurs during the fourth and fifth weeks of gestation, originating from the aortic sac. Subsequently, the third aortic arch contributes to the development of the ECA, which, in turn, gives rise to the FA, and lateral to the TFA as the STA [5, 6, 8].

Having adequate knowledge about the anatomy of the TFA is of immense importance in various plastic and reconstructive procedures. The TFA has various implications in different reconstructive procedures, such as the TFA perforator flap that was extensively described by Zhang et al. [18]. In the study, 18 elderly patients with facial tumours underwent Mohr surgery, and the resection area was reconstructed using V–Y and propeller TFA perforator flaps. All of the 18 flaps survived, with proper cheek and facial symmetry, as well as proper mouth opening. Hence, the authors of the said study concluded that this reconstructive flap has a high clinical value in the treatment of zygomaticofacial tumours. Moreover, flaps that have been pedicled on the TFA have been also used for reconstructions of intraoral defects and the lower eyelid [11, 15]. Over the past few decades, there has been a growing trend in using fillers and botulinum toxin to enhance facial features and improve the jawline [12]. However, it has also raised concerns due to rare but severe complications that have been reported, specifically a concerning trend of blindness [2, 12]. These complications have been observed when the cosmetic filler or botulinum toxin is accidentally injected into an artery, such as the TFA in the lateral face. This subsequently leads to the obstruction of the central retinal artery, disrupting the blood supply to the optic nerve. The consequence is impaired vision and, in some unfortunate cases, blindness [13].

Several limitations are associated with the current study. Radiological imaging solely permits the assessment of haemodynamically proficient arteries. Consequently, this aspect could potentially introduce a considerable degree of bias when appraising anatomical deviations within the TFA and other arterial structures. Although not without limitations, our study attempts to thoroughly analyse the anatomy of the TFA using methods that meet the requirements of evidence-based anatomy.

## CONCLUSIONS

The most frequent origin of the TFA was from the STA; however, it also originated from the ECA in some cases. Moreover, the topographic relationships between the TFA and nearby arteries and anatomical landmarks were measured and analysed. It is hoped that the results of the present study can assist physicians in accurately localising the TFA during various aesthetic and reconstructive procedures. Having a comprehensive understanding of the arterial blood supply of the lateral face can play a crucial role in minimising the risk of iatrogenic injury to these vessels.

## ARTICLE INFORMATION AND DECLARATIONS

### Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### Ethics statement

The research protocol was submitted for evaluation and approved by the Jagiellonian University Bioethical Committee, Cracow, Poland (1072.6120.51.2022). The study was carried out according to the allowed criteria during the next stages.

### Author contributions

Mateusz Trzeciak — methodology, writing, measurements, analysis, literature. Alicia del Carmen Yika — methodology, measurements. Kinga Glądys — methodology, measurements. Patryk Ostrowski — writing, literature. Michał Bonczar — writing, analysis. Michał Goncerz — writing. Wadim Wojciechowski — data collection. Mateusz Koziej — analysis, methodology. Jerzy Walocha — writing. Artur Pasternak — writing.

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### Conflict of interest

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

## REFERENCES


1. Başar R, Sargon MF, Tekdemir I, et al. Accurate course and relationships of the transverse facial artery in human cadavers. Morphologie. 2004; 88(283): 191–195, doi: 10.1016/s1286-0115(04)98148-9, indexed in Pubmed: 15693423.
2. 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(4): e2173, doi: 10.1097/GOX.0000000000002173, indexed in Pubmed: 31321177.
3. Chun BoY, Kim SuY. Acute visual loss after botulinum toxin A injection in the masseter muscle. Int Ophthalmol. 2018; 38(3): 1339–1342, doi: 10.1007/s10792-017-0569-4, indexed in Pubmed: 28536763.
4. Cormack G, Lamberty B. The arterial anatomy of skin flaps. Churchill Livingstone, Edinburgh 1989.
5. Hanneman K, Newman B, Chan F. Congenital variants and anomalies of the aortic arch. Radiographics. 2017; 37(1): 32–51, doi: 10.1148/rg.2017160033, indexed in Pubmed: 27860551.
6. Koziej M, Bonczar M, Ostrowski P, et al. Termination points of the facial artery — a meta-analysis. Clin Anat. 2022; 35(4): 469–476, doi: 10.1002/ca.23817, indexed in Pubmed: 34851525.
7. Koziej M, Polak J, Wnuk J, et al. The transverse facial artery anatomy: implications for plastic surgery procedures. PLoS One. 2019; 14(2): e0211974, doi: 10.1371/journal.pone.0211974, indexed in Pubmed: 30730953.
8. Koziej M, Trybus M, Hołda M, et al. The superficial temporal artery: anatomical map for facial reconstruction and aesthetic procedures. Aesthet Surg J. 2019; 39(8): 815–823, doi: 10.1093/asj/sjy287, indexed in Pubmed: 30351355.
9. Moore KL, Dalley AF, Agur A. Clinically oriented anatomy (8th ed.). Lippincott Williams and Wilkins, Philadelphia 2017.
10. Olson C, Tan Y, Campbell M. A unique bilateral anatomical variation of the transverse facial artery: a case report. Cureus. 2022; 14(10): e30511, doi: 10.7759/cureus.30511, indexed in Pubmed: 36415375.
11. Pompei B, Pollastri G, Molteni G, et al. The new transverse-facial artery musculomucosal flap for intraoral reconstructions. Plast Reconstr Surg Glob Open. 2016; 4(3): e652, doi: 10.1097/GOX.0000000000000632, indexed in Pubmed: 27257582.
12. Toure G, Nguyen TM, Vlavonou S, et al. Transverse facial artery: its role in blindness after cosmetic filler and botulinum toxin injections. J Plast Reconstr Aesthet Surg. 2021; 74(8): 1862–1869, doi: 10.1016/j.bjps.2020.12.042, indexed in Pubmed: 33422497.
13. Townshend A. Blindness after facial injection. J Clin Aesthet Dermatol. 2016; 9(12): E5–E7, indexed in Pubmed: 28210400.
14. Tubbs RS, Salter EG, Oakes WJ. Unilateral agenesis of the facial artery with compensation by a giant transverse facial artery. Folia Morphol. 2005; 64(3): 226–228, indexed in Pubmed: 16228960.
15. Yamakawa S, Suda S, Hayashida K. A new lower eyelid reconstruction using transverse facial artery perforator flap based on an anatomical study. J Plast Reconstr Aesthet Surg. 2023; 77: 39–45, doi: 10.1016/j.bjps.2022.11.046, indexed in Pubmed: 36563637.
16. Yang HJ, Gil YC, Lee HY. Topographical anatomy of the transverse facial artery. Clin Anat. 2010; 23(2): 168–178, doi: 10.1002/ca.20880, indexed in Pubmed: 19918875.
17. Yotova N, Novakov S, Fasova A, et al. Hypoplasia of the facial artery substituted by transverse facial artery. Trakia J Sci. 2019; 17(Suppl. 2): 79–81, doi: 10.15547/tjs.2019.s.02.018.
18. Zhang S, Zhao S, Song P, et al. Application of a modified perforator flap of the transverse facial artery for zygomaticofacial skin defect repair after tumor resection. J Craniofac Surg. 2023; 34(5): 1532–1535, doi: 10.1097/SCS.0000000000009230, indexed in Pubmed: 36907836.
19. Żytkowski A, Tubbs R, Iwanaga J, et al. Anatomical normality and variability: Historical perspective and methodological considerations. Transl Res Anat. 2021; 23: 100105, doi: 10.1016/j.tria.2020.100105.