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The superficial temporal artery: A meta-analysis of its prevalence and morphology

Mateusz Koziej[1] | Jakub Wnuk[1] | Jakub Polak[1] | Marek Trybus[2] | Przemysław Pękala[1,3] | Jakub Pękala[1] | Mateusz Hołda[1] | Bogusław Antoszewski[4] | Krzysztof Tomaszewski[3,5]

[1]Department of Anatomy, Jagiellonian University Medical College, Kraków, Poland

[2]Second Department of General Surgery, Jagiellonian University Medical College, Kraków, Poland

[3]Faculty of Medicine and Health Sciences, Andrzej Frycz Modrzewski Kraków University, Kraków, Poland

[4]Plastic, Reconstructive and Aesthetic Surgery Clinic, Medical University of Lodz, Łódź, Poland

[5]Department of Orthopedic Surgery, Scanmed St. Raphael Hospital, Kraków, Poland

Correspondence
Mateusz Koziej, Department of Anatomy, Jagiellonian University Medical College, Kopernika 12, Kraków 31-034, Poland.
Email: mk.holda@uj.edu.pl

Abstract

Introduction: The superficial temporal artery (STA) is a terminal branch of the external carotid artery. It supplies the regions of scalp and face. The morphometrical data concerning STAs are not consistent; therefore, in this systemic review and meta-analysis, we aimed in this to provide an up-to-date data on its anatomic features.

Material and methods: In order to do this, PubMed, Embase, ScienceDirect, and Web of Science were searched. We followed the Preferred Reporting Items and Review and Meta-Analyses guidelines for the meta-analysis. Studies that reported the prevalence and anatomical data regarding STA were included in further analyses.

Results: Out of 1,446 studies initially evaluated, 21 were included in the meta-analysis (874 patients/donors). The STA diameter was 1.5 mm (95% confidence interval [CI]: 1.47–1.53 mm). The frontal and parietal branches of the STA were present in 97.6% (95% CIs: 94.6–99.5%) and 96.4% (95% CIs: 93.5–98.5%) of the cases, respectively. The STA bifurcation point was located above the zygomatic arch in 79.1% (95% CI: 68.0–84.3), below the zygomatic arch in 6.7% (95% CI: 2.4–12.1), and on the zygomatic arch in 11.1% of the cases (95% CI: 5.4–17.5). There was no bifurcation of the STA in 3.1% of the cases (95% CI: 0.4–7.3).

Conclusion: The most comprehensive analysis of STA morphological features is presented. The results from this evidence-based anatomical study will improve understanding of the clinical STA anatomy, which in turn has major implications for understanding the STA in clinical practice.

KEYWORDS

carotid artery, external, meta-analysis, plastic, prevalence, reconstructive surgical procedures, surgery.

1 | INTRODUCTION

The superficial temporal artery (STA) is the terminal part of the external carotid artery and the largest artery among the scalp vessels (Figure 1). Its main divisions are the frontal and parietal branches. Embryological origin of the STA, such as the whole external carotid artery, originates from the third aortic arch, and the artery develops as a result of regression of three separate arterial segments. The artery supplies the parotid gland and temporomandibular joint in addition to the skin and muscles of the lateral parts of the face and in the scalp (Standring, Ellis, Healy, & Johnson, 2008; Thorne et al., 2013). Moreover, it provides blood to the temporoparietal fascia and can be applied as a recipient vessel for free-flap reconstructions. The STA is accompanied by corresponding veins and the

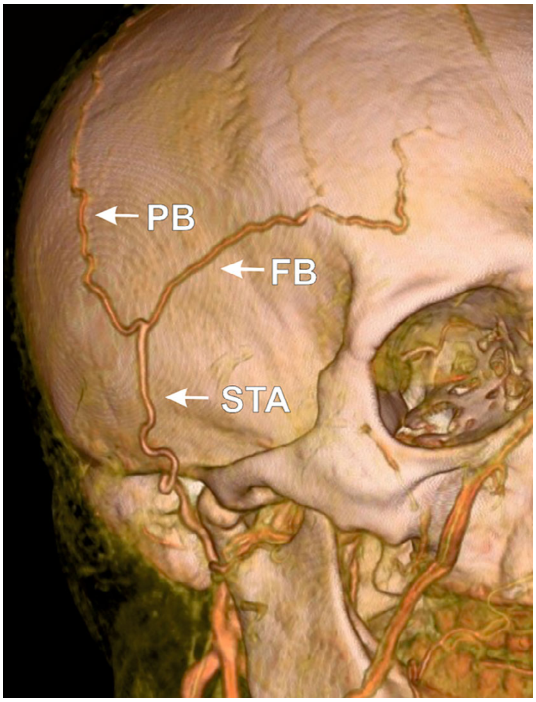

FIGURE 1 Computed tomography angiography three-dimensional reconstruction showing the superficial temporal artery (STA) with parietal and frontal branches (PB and FB, respectively) [Color figure can be viewed at wileyonlinelibrary.com]

auriculotemporal nerve, a branch of the mandibular nerve. The latter lies posterior to the artery.

The accurate knowledge of the anatomy, course, and variability of this clinically important artery is of great importance in plastic surgery, as it allows the selection of a better and safer surgical technique in patients. Nevertheless, morphometrical data regarding the STA are not consistent. Using a systematic review and meta-analytical approach, we aimed to provide an up-to-date prevalence rate of STA in addition to data concerning its anatomical features in order to establish its true prevalence and morphometric characteristics in the population.

2 | PATIENTS AND METHODS

2.1 | Search strategy

Major electronic databases, including PubMed, Embase, ScienceDirect, and Web of Science, were used to perform searches for eligible article up to December 2018 with respect to reporting data concerning variations in the STA. The following search terms were employed: STA OR *arteria temporalis superficialis* AND *anatomy* OR *variations* OR *variant* OR *anomalies* OR *branching* OR *course* OR *division* OR *pattern* OR *aberrant*. No date or language restrictions were applied during the search. An additional search through the references of the identified studies was conducted. Throughout the meta-analysis, Preferred Reporting Items and Review and Meta-Analyses (PRISMA) guidelines were strictly followed.

2.2 | Eligibility assessment

The eligibility assessment for the inclusion into this meta-analysis was conducted by two independent reviewers. Peer-reviewed imaging, cadaveric and intraoperative studies that reported the prevalence and anatomical data of STA were included into this meta-analysis. Conference abstracts, letters to the editor, reviews, and studies providing incomplete or duplicated data were excluded from the study. Studies in languages other than English were translated by medical professionals fluent in the original publication language and English. In the case of any disagreement between the reviewers during the eligibility assessment, a decision was made via a consensus process among the review team.

2.3 | Data extraction

Studies that met inclusion criteria were extracted by two independent researchers. Demographic data, including sample size, study type, and geographic location in addition to a prevalence of variants and morphometrics of the STA morphology were extracted. If any discrepancies in the study data were observed or further details were needed, the authors of the original articles were contacted.

2.4 | Statistical analysis

A meta-analysis was performed using MetaXL version 5.3 (EpiGear International Pty Ltd, Wilston, Queensland, Australia) in order to calculate multi-categorically pooled prevalence estimates for STA presence and branching patterns. A random-effects model was performed in all analyses. Heterogeneity was assessed by the χ^2 test and Higgins I^2 statistic (Higgins et al., Higgins & Green, 2011; Meireles, Natour, Batista, Lopes, & Skare, 2014). Authors considered a p value of <.10 for Cochrane Q for the χ^2 test to be an indicator of significant heterogeneity between studies. For the I^2 statistic, values of 0–40% were considered as "might not be important," 30–60% as "might indicate moderate heterogeneity," 50–90% as "may indicate substantial heterogeneity," and 75–100% as may represent considerable heterogeneity. Confidence intervals (CIs) were used to determine statistically significant differences between two or more groups. In the case of overlap, differences were considered statistically insignificant.

3 | RESULTS

3.1 | Study identification

A total of 1,446 studies were initially evaluated, and 66 of them were included for a more detailed evaluation. Out of these 66 studies, two were excluded for being case reports, and one was excluded as a duplicate report. Of the remaining 63 studies, 42 were excluded due to their failure to report the required data. Finally, 21 studies (874 patients/donors) were included in our analysis (Figure 2).

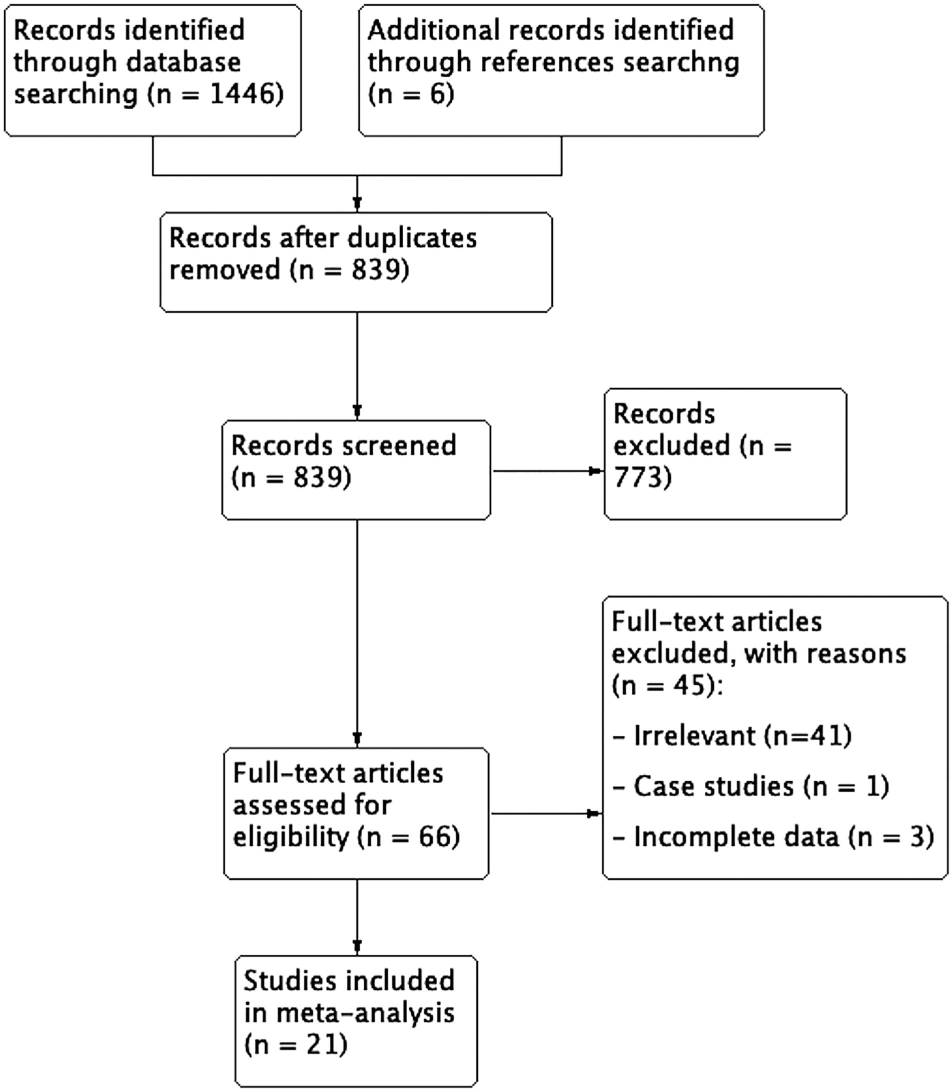

FIGURE 2 Flow diagram demonstrating the selection process of studies to be included in the meta-analysis

The characteristics of included studies are presented in Table 1. Of 21 included studies, eight were based on radiological imaging (Bettoni et al., 2018; Cobb, Galvin, & Gonzalez, 2016; Doscher et al., 2015; Kim, Jung, Chang, & Choi, 2013; Koziej et al., 2018; Kuruoglu, Cokluk, Marangoz, & Aydin, 2015; Manoli et al., 2016; Medved et al., 2015), 12 were based on cadaveric anatomical studies (Chen et al., 1999; Fan, Zhang, Yang, & Huang, 2010; Imanishi, Nakajima, Minabe, Chang, & Aiso, 2002; Kawashima et al., 2005; Kleintjes, 2007; Lee et al., 2014; Lei et al., 2005; Marano, Fischer, Gaines, & Sonntag, 1985; Mwachaka, Sinkeet, & OgengO, 2010; Pinar & Govsa, 2006; Ricbourg, Mitz, & Lassau, 1975; Tayfur, Edizer, & Magden, 2010), and one study included both methodologies (Stock et al., 1980).

3.2 | Meta-analysis

The prevalence of the STA was not specified in the mentioned included study articles; however, no specific data were provided on its absence in any of the cases. Taking this into account, it can be said that the STA is present bilaterally in nearly 100% of cases, and the absence of the artery (aplasia) is an extremely rare congenital condition, mainly accompanied by scalp lesions (Choi, Choi, Ki, & Jun, 2016).

The STA diameter was reported in six studies (680 arteries) and was 1.50 mm (95% CI: 1.47–1.53) (Bettoni et al., 2018; Chen et al., 1999; Kim et al., 2013; Koziej et al., 2018; Pinar & Govsa, 2006; Stock et al., 1980). There was a statistically significant difference between studies based on radiological imaging of 1.35 mm (95% CI: 1.32–1.39) and cadaveric anatomical studies of 2.19 mm (95% CI: 2.11–2.27) (Table 2).

The bifurcation point of the STA related to the zygomatic arch was determined in 10 studies (842 arteries) (Table 3) (Chen et al., 1999; Cobb et al., 2016; Kim et al., 2013; Koziej et al., 2018; Marano et al., 1985; Medved et al., 2015; Mwachaka et al., 2010; Pinar & Govsa, 2006; Stock et al., 1980; Tayfur et al., 2010). It was located above the zygomatic arch in 79.1% (95% CI: 68.0–84.3) of cases, below the arch in 6.7% of the cases (95% CI: 2.4–12.1), and on the arch in 11.1% of the cases (95% CI: 5.4–17.5). There was no division of the STA detected in 3.1% of the cases (95% CI: 0.4–7.3).

The presence of parietal branch was determined in 11 studies (898 arteries) (Table 4) (Fan et al., 2010; Imanishi et al., 2002; Kim et al.,

TABLE 1 Characteristic of included studies

Author and year	Country	Type of study	Number of patients/donors	Number of studied arteries
Bettoni 2017	France	Radiological	30	58
Kim 2013	South Korea	Radiological	35	70
Chen 1999	Taiwan	Cadaveric	26	52
Cobb 2015	USA	Radiological	25	50
Doscher 2015	USA	Radiological	14	28
Imanishi 2002	Japan	Cadaveric	15	30
Kawashima 2005	USA	Cadaveric	25	n/a
Kuruoglu 2014	Turkey	Radiological	53	n/a
Lee 2014	South Korea	Cadaveric	38	64
Lei 2005	China	Cadaveric	25	50
Manoli 2015	Germany	Radiological	38	n/a
Medved 2014	Germany	Radiological	93	93
Mwachaka 2010	Kenya	Cadaveric	30	30
Pinar 2006	Turkey	Cadaveric	14	27
Stock 1980a[a]	USA	Radiological	25	25
Stock 1980b[a]	USA	Cadaveric	15	29
Tayfur 2010	Turkey	Cadaveric	13	26
Marano 1985	USA	Cadaveric	n/a	50
Kleintjes 2007	South Africa	Cadaveric	30	60
Koziej 2018	Poland	Radiological	215	419
Ricbourg 1973	France	Cadaveric	80	80
Fan 2010	China	Cadaveric	10	19

[a]The study by A. L. Stock (Stock, Collins, & Davidson, 1980) has been subdivided in this table into two positions, because it contains both cadaveric and radiological sections.

2013; Koziej et al., 2018; Marano et al., 1985; Medved et al., 2015; Mwachaka et al., 2010; Pinar & Govsa, 2006; Ricbourg et al., 1975; Stock et al., 1980; Tayfur et al., 2010). It was present in 96.4% (95% CI: 93.5–98.5) of cases. There was no statistically significant difference between cadaveric (97.5% [95% CI: 95.1–99.2]) and radiological studies (94.7% [95% CI: 89.3–98.4]) in parietal branch prevalence. The diameter of the parietal branch was reported in six studies (622 arteries) and was 1.14 mm (95% CI: 1.12–1.17) with statistically significant larger values for cadaveric versus radiological studies (Table 5) (Chen et al., 1999; Kim et al., 2013; Koziej et al., 2018; Pinar & Govsa, 2006; Stock et al., 1980).

The presence of frontal branch was described in 14 studies (1,072 arteries) (Table 4) (Fan et al., 2010; Imanishi et al., 2002; Kim et al., 2013; Kleintjes, 2007; Koziej et al., 2018; Lee et al., 2014; Lei et al., 2005; Marano et al., 1985; Medved et al., 2015; Mwachaka et al., 2010; Pinar & Govsa, 2006; Ricbourg et al., 1975; Stock et al., 1980; Tayfur et al., 2010). It was present in 97.6% (95% CI: 94.6–99.5) of cases, and no statistically significant difference between cadaveric and radiological studies was observed. The diameter of the frontal branch was determined in seven studies (686 arteries) (Chen et al., 1999; Kim et al., 2013; Koziej et al., 2018; Lee et al., 2014; Pinar & Govsa, 2006; Stock et al., 1980). Its mean diameter was 1.2 mm (95% CI: 1.18–1.23 mm) with statistically significant larger values for cadaveric than radiological studies (Table 5). The frontal branch diameter was significantly larger than parietal branch diameter.

TABLE 2 Diameter of superficial temporal artery (STA)

Category	Number of studies (number of arteries)	Pooled mean diameter (mm): % (95 confidence interval [CI])	I^2: %
Overall	7[a] (680)	1.5 (1.47–1.53)	98.7
Cadaveric studies	3[a] (108)	2.19 (2.11–2.27)	94.7
Radiological studies	4[a] (572)	1.35 (1.32–1.39)	96.0

[a]The study by A. L. Stock (Stock et al., 1980) has been subdivided in this table into two positions, because it contains both cadaveric and radiological sections.

4 | DISCUSSION

The clinical significance of the STA anatomy in the field of plastic surgery is immensely wide, especially in reconstructive surgery and microsurgery in addition to aesthetic procedures that use invasive

TABLE 3 Level of the superficial temporal artery (STA) division (above/below/on the zygomatic arch)

Category	Number of studies (number of arteries)	Above arch: % (95 CI)	Below arch: % (95 CI)	On arch: % (95 CI)	No division: % (95 CI)	I^2: % (95 CI)
Overall	10 (842)	79.1 (68.0–84.3)	6.7 (2.4–12.1)	11.1 (5.4–17.5)	3.1 (0.4–7.3)	83.3 (70.8–90.5)
Cadaveric studies	5 (185)	81.2 (60.7–93.6)	8.2 (0.0–20.6)	8.0 (0.0–20.3)	2.5 (0.0–10.6)	86.4 (70.4–93.8)
Radiological studies	5 (657)	77.0 (61.3–86.1)	5.3 (0.3–13.8)	14.2 (5.2–25.4)	3.5 (0.0–11.1)	89.2 (77.6–94.8)
Computed tomography angiography studies	3 (539)	82.8 (63.4–97.5)	5.9 (0.0–18.9)	7.8 (0.0–22.2)	3.5 (0.0–14.3)	93.4 (84.1–97.3)
Digital subtraction angiography studies	2 (118)	60.7 (35.8–82.8)	6.0 (0.0–19.9)	27.9 (8.5–51.9)	5.4 (0.0–18.9)	78.7 (7.5–95.1)
Asia	4 (175)	81.1 (58.8–91.9)	10.2 (0.7–25.0)	6.8 (0.0–20.3)	1.9 (0.0–8.8)	84.4 (60.9–93.8)
Europe	2 (512)	65.9 (40.4–85.7)	8.1 (0.0–23.1)	14.6 (1.2–35.4)	11.3 (0.0–28.1)	94.2 (81.6–98.1)
North America	3 (125)	84.4 (63.3–99.2)	2.1 (0.0–12.3)	11.1 (0.0–29.3)	2.5 (0.0–13.2)	86.5 (61.0–95.3)

TABLE 4 Prevalence of superficial temporal artery parietal and frontal branches

	Category	Number of studies (number of arteries)	Pooled prevalence: % (95% CI)	I^2: % (95% CI)
Parietal branch	Overall	12 (898)[a]	96.4 (93.5–98.5)	64.7 (34.6–80.9)
	Cadaveric studies	8 (291)[a]	97.5 (95.1–99.2)	17.7 (0.0–60.5)
	Radiological studies	4 (607)[a]	94.7 (89.3–98.4)	72.5 (22.3–90.3)
	Computed tomography angiography studies	2 (489)	94.5 (85.8–100.0)	85.3 (40.6–96.4)
	Digital subtraction angiography studies	2 (118)[a]	94.9 (83.0–100.0)	75.3 (0.0–94.4)
	Asia	5 (172)	97.2 (92.4–99.8)	44.7 (0.0–79.7)
	Europe	3 (592)	92.7 (87.9–96.4)	62.6 (0.0–89.3)
	North America	3 (104)[a]	98.3 (95.4–100.0)	0.0 (0.0–65.0)
Frontal branch	Overall	15 (1072)[a]	97.6 (94.6–99.5)	81.4 (70.3–88.3)
	Cadaveric studies	11 (465)[a]	97.2 (91.2–100.0)	85.8 (76.3–91.5)
	Radiological studies	4 (607)[a]	98.4 (97.3–99.3)	0.0 (0.0–74.1)
	Computed tomography angiography studies	2 (489)	98.9 (96.6–100.0)	40.2 (0.0)
	Digital subtraction angiography studies	2 (118)[a]	98.6 (96.1–100.0)	0.0 (0.0)
	Africa	2 (90)	88.8 (45.3–100.0)	94.9 (84.6–98.3)
	Asia	7 (286)	98.1 (94.5–100.0)	71.3 (37.7–86.8)
	Europe	3 (592)	98.5 (97.3–99.3)	2.4 (0.0–89.9)
	North America	3 (104)[a]	97.2 (92.6–100.0)	33.9 (0.0–78.3)

[a]The study by A. L. Stock (Stock et al., 1980) has been subdivided in this table into two positions, because it contains both cadaveric and radiological sections.

TABLE 5 Diameters of parietal and frontal branches of the superficial temporal artery (STA)

	Category	Number of studies (number of arteries)	Pooled mean diameter (mm): % (95 CI)	I^2: %
Parietal branch	Overall	6 (622)[a]	1.14 (1.12–1.17)	99.3
	Cadaveric studies	3 (108)[a]	1.72 (1.67–1.77)	66.5
	Radiological studies	3 (514)[a]	0.99 (0.96–1.01)	96.7
Frontal branch	Overall	7 (686)[a]	1.20 (1.18–1.23)	99.1
	Cadaveric studies	4 (172)[a]	1.66 (1.62–1.71)	89.7
	Radiological studies	3 (514)[a]	1.02 (1.0–1.05)	97.9

[a]The study by A. L. Stock (Stock et al., 1980) has been subdivided in this table into two positions, because it contains both cadaveric and radiological sections.

methods, such as injections of dermal fillers (Koziej et al., 2018). Our study is the first that provides comprehensive morphometrical data regarding the STA based on the analysis of 874 individuals.

The main advantage of the STA for its use in reconstructive procedures is the ease of access to the artery, adequate artery diameter, and predictable location (Halvorson, Cordeiro, Disa, Wallin, & Mehrara, 2009; Hansen et al., 2007). Our study shows a very high occurrence of both major STA branches (>95%). The zygomatic arch can be used as a simple orientation point for detecting the branching point of the STA, which is located above the arch in an overwhelmingly majority of cases. In our previous study, we calculated the mean distance from the center of the zygomatic arch to the bifurcation as 23.8 ± 11.4 mm (range: 2.6–65.3 mm); moreover, the location of the bifurcation point was strongly correlated with the location of the frontal branch but not the parietal branch (Koziej et al., 2018).

The use of the STA has great importance in reconstruction procedures that require utilization of a either temporalis or temporoparietal fascia flap. The successful formation and use of the those flaps depend on the anatomical features of the vascular pedicles that contain frontal or parietal STA branches (Pinar & Govsa, 2006). A study conducted by Spilimbergo et al. showed that temporalis flaps are predominantly using for either maxilla defect (46.7%) or mandible and oropharynx (14.6%) reconstruction (Spanio Di Spilimbergo et al., 2017). Since advances in microsurgery that facilitate free tissue transfer have become the preference for many surgeons in craniofacial reconstructions, other selected indications were listed for the temporalis flap use: (a) anophthalmia, (b) unilateral maxillectomy defects, and (c) facial reanimation in selected cases of facial nerve palsy (Spanio Di Spilimbergo et al., 2017).

The anatomy of the STA is also crucial for harvesting the temporoparietal fascia flap, which is the thinnest flap described in the human body (Brent et al., 1985; Collar, Zopf, Brown, Fung, & Kim, 2012). The flap is used in head and neck reconstruction during procedures, such as cutaneous and mucosal oncologic defect coverage, auricle, skull base, and orbit reconstructions, hair-bearing tissue transfer, and facial augmentation (Collar et al., 2012).The reconstruction of microtia (0.83 to 17.4 cases per 10,000 births), especially, is challenging and can be performed using autogenous or porous polyethylene framework techniques (Luquetti, Heike, Hing, Cunningham, & Cox, 2012; Wilkes, Wong, & Guilfoyle, 2014). The alloplastic reconstruction methods involves usage of a temporoparietal fascia flap in which the STA pedicle is identified and preserved, and the flap is draped over the implant (Bly, Bhrany, Murakami, & Sie, 2016; Wilkes et al., 2014). However, as suggested by Farrah-Hani et al., anatomical conditions in microtic patients differ significantly from normal subjects. The comparison between the non-microtic and microtic groups showed larger STA diameters in the non-microtic versus the microtic group (larger by 0.4 mm; $p = .012$). Moreover, microtic ears were more predominantly accompanied by one-branch of the STA in contrast to the non-microtic group in which two branches of artery usually are present (Imran, Yong, Das, & Huei, 2016). The above findings may also suggest participation of the STA in microtia development.

Interestingly, the frontal branch of the STA can be used as an anatomical landmark in order to localize and preserve the temporal branch of the facial nerve during rhytidectomy, which is susceptible to injury. Lei et al. suggested that a 5 to 6 cm temporal incision in the hairline, performed 1 to 2 cm superiorly to the frontal branch, is practically safe during rhytidectomy (Lei et al., 2005). On the other hand, the presence of superficial artery branches may compromise the safety of aesthetic procedures, especially filler injections. In a notable study conducted by Lee et al., a tentative danger zone (in which the frontal branch of the STA is present and may be injured) was delineated on the lateral frontal area. This area is located near lateral border of the frontalis muscle and can easily be found by placing the radial border of a thumb on the uppermost point of eyebrow and thumb tip on a vertical line through the lateral epicanthus. The danger zone is then represented by a pad surface and should be avoided during procedure (Lee et al., 2014).

This study was limited by several aspects. Most of our results were determined by the rate of significant heterogeneity. Although a subgroup analysis was conducted, potential sources of heterogeneity could not be identified. Thus, we suspect these outcomes may be explained by different methods used in the included studies. Our analysis especially revealed a significant difference in artery diameter between cadaveric and radiological studies. Both digital subtraction angiography and computed tomography angiography were performed with use of contrast agent in order to reveal the vessel course. In those cases, imaging applies only to the vessel lumen filling with the contrast agent; therefore, the wall of the artery could not be visualized and measured. As the STA wall thickness is estimated to be 0.57–0.65 mm, the difference in visualization methods may explain the divergences in results (Bley et al., 2005; Schmidt, Kraft, Vorpahl, Völker, & Gromnica-Ihle, 1997).

Regarding geographical-related differences, this is also burdened with a potential bias, because only the geographical locations of patients and donors were analyzed without any consideration of racial and ethnic differences. The studies from Asia tended to present larger diameters of the STA and its branches, but most of those studies were cadaveric-based research. Finally, no studies originated from South America or Australia and Oceania, areas which should be covered in future studies.

5 | CONCLUSION

To summarize to date, this is the most comprehensive analysis of the morphological features of the STA and its clinical implications. The STA is a relatively invariable vessel, present bilaterally in near 100% of human beings with its bifurcation point located mainly above the zygomatic arch (80%). The frontal and parietal branches of the STA occur at a similar frequency (>95%). The frontal branch has a significantly larger diameter than the parietal branch, which suggests that the frontal branch is the main branch of the STA.

The results obtained from this evidence-based anatomy study should improve the understanding of clinical anatomy of the STA, which in turn will have major implications for understanding the STA in clinical practice.

CONFLICT OF INTEREST

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ETHICAL STATEMENT

The study does not require the consent of the bioethical committee.

ORCID

Mateusz Koziej https://orcid.org/0000-0002-2635-0776
Przemysław Pękala https://orcid.org/0000-0002-9750-2650
Krzysztof Tomaszewski https://orcid.org/0000-0001-5077-6948

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