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Anatomy of the superficial temporal artery in patients with unilateral microtia

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Summary *Background:* This retrospective study evaluated the anatomical distribution of the superficial temporal artery (STA) in supply of the temporoparietal fascial (TPF) flap for use in patients with unilateral microtia undergoing reconstruction. We aimed to determine whether embryologic arrest of pharyngeal arch development would lead to aberrant STA, which impedes reliable harvest of the TPF flap in patients requiring microtia repair.
Methods: CT angiograms (CTAs) and 3D reconstruction of the face and neck of 41 patients with microtia, aged 6-21 years, were examined. The number of STA branches, branching pattern, vessel diameter, and the presence or absence of the external auditory canal atresia were documented.
Results: The STA crosses the zygoma on average 4 mm more anterior to the porion (anterior-inferior lip of the tympanic part of the temporal bone) on the side with microtia compared to the nonmicrotia side. There were no statistically significant differences between vessel caliber or STA branches between the two sides.
Conclusion: The STA is anatomically reliable for inclusion in TPF flaps, which is used for auricular reconstruction in patients with microtia. A TPF flap can be safely harvested by the routine technique; however, surgeons should be cognizant of the STA coursing more anteriorly on the microtia ear.

Introduction

Microtia is defined as a congenital malformation of the external cartilaginous ear. The estimated prevalence of microtia is 1 in 7000–10,000 live births,[1,2] with greater prevalence of 1 in 4000 in the Japanese population and up to 1 in 900–1200 in the Navajo Native Americans.[3] It presents in variable degrees of deformity and has been extensively classified by previous authors. The commonly used Marx classification system grades microtia according to the severity of the deformity: grade 1 involves a smaller ear with all normal anatomical structures; in grade 2, some anatomical structures are present, but the ear is deformed;

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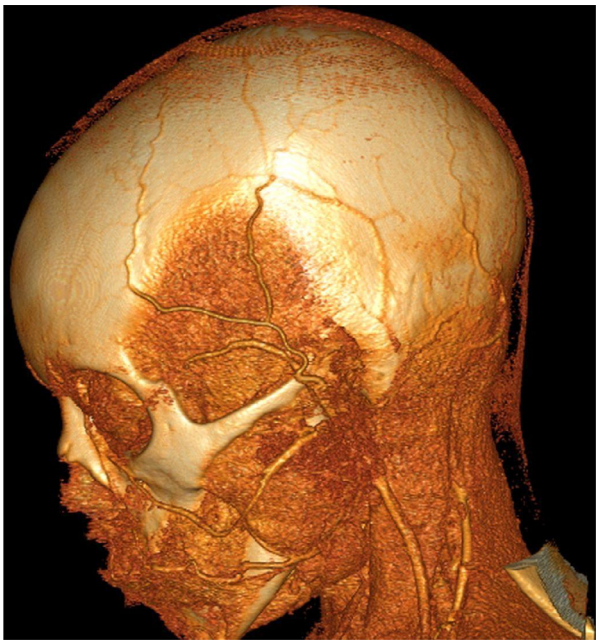

Figure 1 Three-dimensional reconstruction of a computed tomography angiogram showing the anterior (frontal) and posterior (parietal) branches of STA on a microtic ear.

and grade 3 is the classic "peanut" ear with only a vestigial lobule present.[4] Grade 4, which is the most severe grade, is anotia. The development of microtia is the result of a failure in the terminal proliferation of the first and second pharyngeal arch structures and fusion of the hillocks of His that produce the external ear. The clinical presentation of microtia may be an isolated finding, but it is commonly associated with malformation of the external auditory canal (EAC), as well as the middle ear. The majority of microtia is unilateral and isolated, but it can be associated with various syndromes at times, such as Treacher Collins syndrome (TCS), hemifacial microsomia, Goldenhar syndrome, Crouzon syndrome, and Apert syndrome to name a few. Some authors consider microtia/anotia to be a mild form of hemifacial microsomia, with Goldenhar syndrome representing the extreme end of the spectrum (Figure 1).[1,4]

The treatment of microtia is complicated for the facial reconstructive surgeon. The challenge inherent in external ear reconstruction is the reproduction of the convexities and concavities that comprise the normal ear aesthetics. The traditional Tanzer and Brent four-stage reconstruction technique is based on autologous costal cartilage harvest for placement within a subcutaneous pocket and subsequent elevation and shaping of lobule and tragus. Nagata also designed a two-stage technique using a superficial temporal artery (STA)-pedicle temporoparietal fascia (TPF) flap as the second stage. Recent innovation in operative techniques has incorporated alloplastic materials such as high-density porous polyethylene (PPE) implants. The technique of using PPE underneath a TPF flap and covering it with a full-thickness skin graft has been utilized by the senior author (T.R.) for many years with satisfactory results. This two-stage operation eliminates the need for costal cartilage harvest, decreases surgical time, and provides more predictable results among patients and surgeons.[5,6]

Although the anatomy of STA has been widely investigated, the documentation of its variation in patients with microtia has been lacking. The purpose of this study was to document the anatomy of STA in patients with microtia using computed tomography angiograms (CTAs) and 3D reconstruction of the head and neck and to determine whether the terminal branches of the external carotid system (derived from the first to third aortic arches) are affected by the same developmental arrest that produces microtia. The importance of this study is to provide information and understanding on STA variation associated with microtia. It is also paramount to operative planning when the use of the TPF flap in both single- and multi-stage microtia reconstruction is crucial. These data, along with detailed imaging, can help minimize postoperative complications such as implant exposure and infection. We hypothesized that the STA would be unaffected by developmental deviations that produce microtia based on prior successful operations.

Methods

In total, 41 patients with congenital microtia who presented to the senior author's (T.R.) private practice between 2007 and 2017 were considered for the study. Only 23 of those with preoperative CTA and 3D reconstruction were included as the final subjects. Patients were excluded from the study if the CTAs did not have adequate contrast to evaluate the external carotid system or if motion or amalgam artifact made the vessel measurements inaccurate or with a history of STA-based flap and deforming auricular trauma. The CTA and 3D reconstructed images were evaluated using GE Centricity ™ PACS on both the microtic and contralateral nonmicrotic ears. The parameters measured include as follows: (1) the number of STA branches, (2) the branching pattern of the STA in relation to the zygomatic arch, (3) the distance from the superior border of EAC meatus to the point where STA crosses the zygomatic arch, (4) the diameter of STA after branching from the external carotid artery, and (5) the presence or absence of the EAC atresia.

Each measurement was taken in duplicate, and the mean value was used for data analysis. Two-sample *t*-test was used to analyze numerical variables, with a *p*-value of <0.05 being statistically significant.

Results

A total of 22 patients met inclusion criteria and were used in this study. Forty-four ears and their respective STAs were examined. Demographically, the average age of the patients was 11.5 years (range 6–21 years) with the mode being 6 years. The male-to-female ratio of patients with microtia was 3.4:1 (17 males and 5 females). The majority of the subjects had unilateral microtia with a right-sided preponderance. Two patients had bilateral microtia, with one of them diagnosed with TCS. The right to left ear microtia involvement ratio was 1.8:1 (right: 14, left: 8, 1 bilateral). Seven out of 44 ears (15.9%) had only a single STA branch (missing posterior branch), with five of them from microtia side and two from nonmicrotia side. However, the difference was not statistically significant.

The branching of the STA into its posterior parietal and anterior frontal branches occurred above the zygomatic arch in 27/44 ears (61.4%), below the arch in 7/44 ears (15.9%), and at the level of the arch in 3/44 ears (6.82%). In the ears affected by microtia, 14 branched above the arch, three below the arch, and two at the level of the arch. The patient with TCS had missing zygomatic arch and posterior branches bilaterally. In the normal ears, 13 branched above, four below, and one at the level of the arch.

The distance (cm) from the anterior-superior lip of the bony EAC, or the porion, to the crossing point of the STA over the zygomatic arch was measured. In the case of EAC atresia, this distance was measured from the anterior-superior lip of the tympanic part of the temporal bone. In all ears, the average distance was 1.36 $\pm$ 0.48 cm (0.54–2.58 cm). In ears with microtia, the average distance was 1.54 $\pm$ 0.60 cm (0.54–2.58 cm), whereas that of nonmicrotia ears was 1.16 $\pm$ 0.27 cm (0.64–1.54 cm). The difference demonstrated statistical significance with $p = 0.01$.

The average diameter (mm) of the STA, after the branching of the internal maxillary artery from the external carotid artery, was 1.80 $\pm$ 0.56 mm (0.29–2.9 mm). The average diameter of the STA in ears with microtia was 1.75 $\pm$ 0.68 mm (0.29–2.9 mm), whereas the average diameter of the STA in nonmicrotia ears was 1.86 $\pm$ 0.46 mm (0.97–2.5 mm), with $p = 0.548$.

Discussion

The study of microtia has generated significant interest in the medical community, in part because of the multidisciplinary management that includes pediatricians, otologists, plastic surgeons, embryologists, and geneticists. The deformity of microtia is thought to be an arrest or disruption in the development of the first and second pharyngeal arch derivatives. The etiology of the arrest in development is not definitively known; proposed causes include vascular insult, embryological signaling abnormalities, genetic or hereditary aberrations, and intrauterine infections.

The normal development of the external ear has been well described in literature. The pharyngeal arches are a series of bulges that develop on the lateral surface of the embryo between the third and fourth weeks of gestation. Each arch is externally covered by ectoderm and internally by endoderm, with the intervening tissue comprising mesenchyme and neural crest cells.[7] The auricle begins its development in the third to sixth weeks of gestation and is usually complete by the 12th week. Mesenchymal proliferations in the first and second pharyngeal arches, termed as the auricular hillocks, develop around the dorsal ends of their respective arches and then fuse to become the complex architecture of the external ear.[8] The first three hillocks, formed from the first arch, later become the tragus, helical root, and the helix. The three hillocks derived from the second arch become the antitragus, antihelix, and lobule.

Accompanying each pharyngeal arch is an artery that arises from the associated aortic arch system. The aortic arches develop from the aortic sac and are located within the mesenchyme of each pharyngeal arch. The first aortic arch degenerates by the fourth week of gestation, but its remnant persists as the mandibular artery and its terminal branches. The second aortic arch forms the hyoid and stapedial arteries, which also disappear by the fourth week and again partially persist as branches of the internal maxillary artery. The third aortic arch becomes the common carotid artery and parts of the internal and external carotid arteries. As a result, the interaction of the first, second, and third aortic arches leads to the development of the terminal branches of the external carotid artery system, including the STA. This complex embryologic development of the arterial system, in addition to the genesis of the auricle, raises a concern for a potentially nonviable TPF flap secondary to aberrant anatomy. The TPF extends from the subcutaneous musculoaponeurotic system inferiorly and continues with the galea aponeurotica superiorly. It is a thin sheet of vascularized fascia based off the posterior branches of the STA of the external carotid system, which has a wide application in reconstructive surgery.

The modern approach to microtia reconstruction can be traced back to Tanzer who first described the four-stage reconstruction using autologous carved costal cartilage.[9] The subsequent evolution and refinement of the technique by Brent[10] and later Nagata[11] have produced the two-stage surgery with the use of TPF flap. Concerns with the adverse effects of autologous costal cartilage harvest include unpredictable aesthetic outcome; prolonged surgical time; and donor site morbidity such as pneumothorax, chest wall deformity, and scarring. This has led to the development of alloplastic implants. Silicone was the first alloplastic implant attempted,[12] but the technique was plagued by implant exposure and rejection. High-density PPE, on the other hand, allows for integration with the host tissue and has shown greater resistance to infection and exposure.

The TPF flap is used for both coverage of the costal cartilage grafts in Nagata's technique and coverage of the PPE alloplastic implant.[13] The TPF flap is ideally suited for this operation for multiple reasons. First, its end-arterial supply from the STA provides viability and resistance to infection. Second, it is conveniently located in the preauricular soft tissue and the overlying scalp, thus allowing for ease of dissection with a single surgical site. Finally, the thinness of the flap when placed over the graft or implant provides adequate coverage yet without effacing the intricate conformation of the auricular subunits (Figures 2 and 3).

On the basis of our intraoperative experience with doppler confirmation of the STA, we hypothesized that the development of STA would be unaffected by the ipsilateral microtia. The findings of this study supported our hypothesis. The statistically significant difference in the distance from porion to the crossing point of STA over the zygoma between microtia and nonmicrotia ears can be further explained by the associated canal atresia in 23/24 microtia ears studied. The observed canal atresia causes a dimpling in the tympanic bone and a remnant of the external auditory meatus, thereby resulting in the difference in vessel location.

Historically, the anatomy of STA is quite variable. The vessel diameter between the two groups, as measured in the current study before any branching of the STA, was similar and showed no statistical difference ($p = 0.5$), although a previous study on Malaysian subjects showed that the STA diameter on the microtia side was smaller than that in the normal side.[14] This finding supported our hypothe-

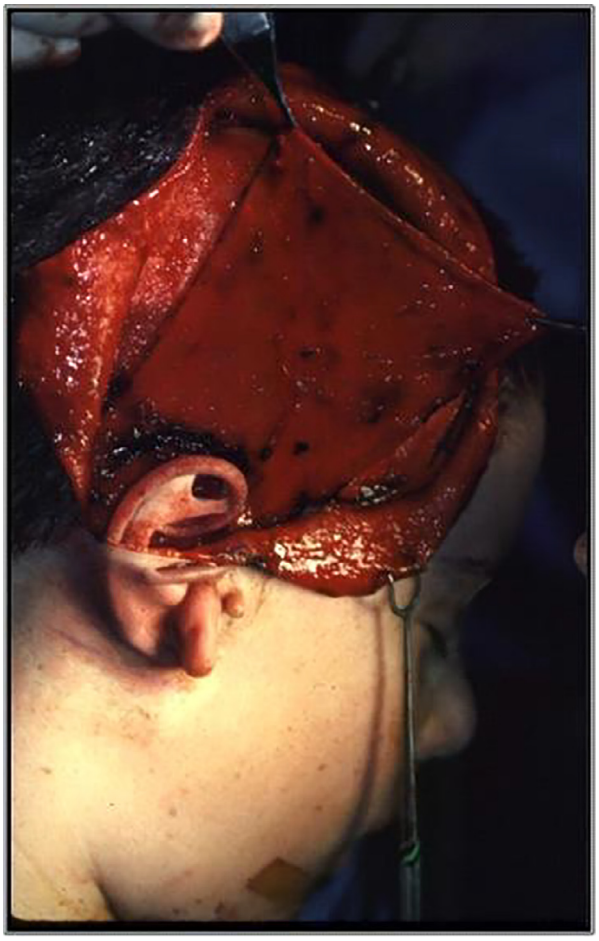

Figure 2 Image showing the elevated TPF flap. A single surgical site allows for both flap harvest and microtia repair.

Table 1 Bifurcation point of the STA in the literature (%).

Authors	Above the ZA	Over the ZA	Below the ZA
Chen et al.[15]	86.5	3.8	9.6
Stock et al.[19]	60.0	32.0	8.0
Marano et al.[14]	95.7	4.3	N/A
Pinar and Govsa[16]	74.1	22.2	N/A
Mwachaka et al.[20]	80.0	13.3	6.7
Tayfur et al.[18]	62	N/A	38
Kim et al.[17]	84.1	8.7	7.2
Current study	71.4	7.1	21.4

ZA = Zygomatic arch, N/A = not available.

sis. Finally, the branching patterns that we observed in our microtic ears and nonmicrotic ears were similar to those described by previous authors[15-20](Table 1). The present study also highlighted the use of CTA and 3D reconstructed images for surgical planning.

The main limitation of this study is the small sample size, but to our knowledge, this is the first comparison of STA anatomy between microtic and nonmicrotic ears in the United States. Future studies should focus on incorporating larger population through a multicenter study across the country.

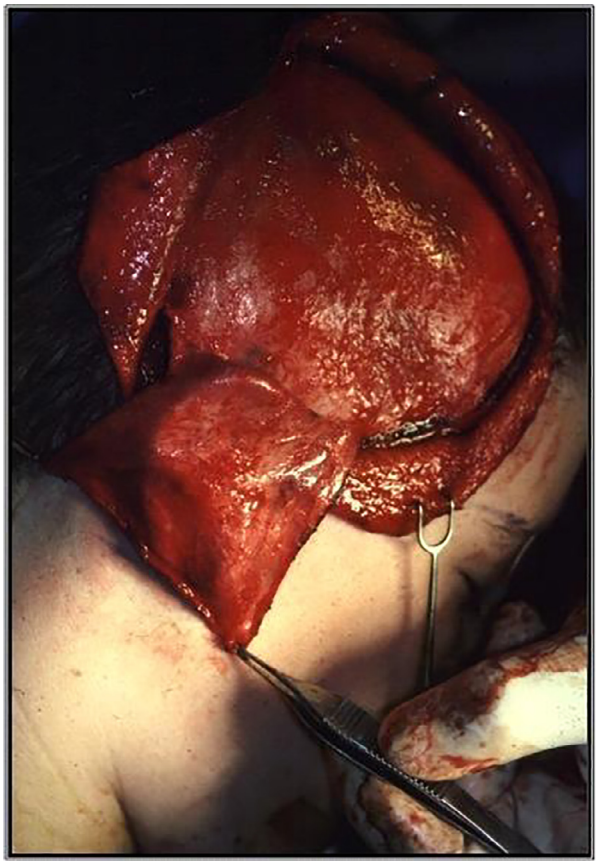

Figure 3 The flap is turned down over its pedicle to cover the exposed PPE implant.

Conclusion

The aberrant development of the first and second pharyngeal arches does not seem to affect the development of STA. Nonetheless, the anatomy of STA varies vastly; it is paramount to ascertain these variations in preoperative planning with imaging to minimize postoperative complications and failure. As the popularity of PPE implants for microtia reconstruction continues to grow, along with the advancement in technology such as 3D printed implants for auricular reconstruction, the TPF flap and its vascular integrity will continue to play a pivotal role in auricular reconstruction.

Conflict of interest

None.

Funding

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