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Superficial Temporal Artery: A Cadaveric Feasibility Study for Cerebral Bypass Surgery

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ABSTRACT

The superficial temporal artery (STA) is one of the most encountered vessels in neurosurgery and has a significant importance in cerebral bypass surgery. In cerebral bypass surgery, a suitable donor vessel to create the bypass graft close to the recipient artery with suitable size, is essential. The STA can be harvested easily and is readily accessible, minimizing surgical complexity. Using the STA as the donor artery has shown to have lower rates of complications compared to other graft options. It has a low risk of spasm and thrombosis, which could lead to graft failure. Additionally, harvesting the STA does not cause significant damage to surrounding tissues, reducing the risk of postoperative complications. The STA has a robust and consistent blood flow, making it an ideal candidate for grafting during cerebral bypass surgery.

Understanding the variations of the STA is important to surgeons who encounter it during an operation. In this cadaveric study, we obtained length and internal elastic lamina diameter measurements of the STA trunk and its branches. Our cadaveric internal elastic lamina diameters were consistent with the literature's as well as the STA trunk and frontal branch lengths but the parietal branch length measurements were significantly different from the related literature's. Further cadaveric studies of the STA must be conducted as a better understanding the anatomy of this vessel by cerebrovascular surgeons.

Keywords: Anatomy, Superficial Temporal Artery, Cadaveric, Cerebral Bypass Surgery

Introduction

Cerebral bypass surgery (CBS) is a multiskilled tool that helps neurosurgeons treat complex aneurysms, tumors, Moyamoya disease, cerebral perfusion problems, and also prevent strokes (1-3). A common form of CBS is superficial temporal artery to middle cerebral artery (STA-MCA) surgery, which connects the superficial temporal artery (STA) or one of its branches through the skull to the MCA in order to provide extra blood flow to a low-perfused part of a cerebrum/occluded or blocked artery distribution (4). Because STA-MCA bypass surgery is one of the most common CBS procedures, it is important that neurosurgeons have an accurate and thorough anatomical understanding of superficial temporal artery (STA) and its branches (5,6).

STA is the terminal branch of the external carotid artery (ECA) and it provides a blood supply to the face and scalp (7). The artery originates around the parotid gland and after reaching the temporal bone level, it divides into a parietal and frontal branch (8). STA-MCA bypass surgery typically utilizes one or both branches as donor vessels (9). In bypass surgery, the donor vessel has blood flow redirected to the low perfusion/occluded region (10). Conceptually, the STA can be divided into three parts: the STA trunk, the frontal branch, the parietal branch (Figure 1) The two portions of the STA that are typically used either separately or in conjunction are the frontal and parietal branches (9). However, the STA trunk has also been effectively utilized for CBS (11).

Although there have been anatomical studies that obtain results of physical characteristics of the STA, a study has not been conducted that compares data found in to literature to cadaveric data for two its essential characteristics, the length of the STA and the diameter of the internal elastic lamina (7, 12).The internal elastic lamina is a layer that is present in the outermost part of most arteries and plays a role in helping the artery deal with variations of blood flow. The goal of this study was to collect cadaveric data for the lengths of the STA and its branches along with internal elastic lamina diameters, and compare that to the data cited in the literature that showed various physical characteristics of the STA (13).

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Materials and Methods

All work in this project was carried out in University of Wisconsin Skull base laboratory where we evaluated total of 10 STAs from alcohol-fixed human cadaveric heads. All specimens were from adult men and women who had no known neurological and psychiatric history and lacked any significant pathologic changes. Neither age nor sex was considered as an exclusion criterion. The study was approved by the University of Wisconsin, Madison, Institutional Review Board (IRB- University of Wisconsin, Madison).

The dissection and measuring of the STAs started with an incision approximately 1 centimeter in front of the tragus with a 11-blade. Following this initial incision, we located the STA by further maneuvering through the subcutaneous layers with a dissection scissors. This technique was utilized until the STA was visible. Once the STA was located, both sharp and blunt dissection techniques were used to cut and follow STA from the tragus until the bifurcation point, where the STA separates into the frontal and parietal branch. Following this, the ends of each respective branch were located and made as visible as possible by removing as much subcutaneous layer as possible without damaging the branches. Once an adequate amount of skin was cut that could be folded over in order to have a better view of the STA, automatic retractors were utilized to hold the folded skin in place. Once the side branches were dissected, cut and straightened and then the STA and then the measurements of the STA were taken using an electronic caliper. Three length measurements were taken: the STA trunk, frontal branch, and parietal branch (Figure 2). STA trunk measurement was started just above the zygomatic arch and branches measurements were completed after total mobilization of the vessel. Given we aim to provide STA measurements feasible for CBS and very small calibers of the vessel are not good donor candidates, we did not measure the length of the STA branches after they became thinner than 0.8 mm.

After the completion of the length measurements, five samples were taken from each STA and placed into a 24-well plate with a corresponding label A-E. The location of each of the samples on the STA were labeled the following: Sample A - 3 millimeters before the bifurcation on trunk, Sample B - 3 millimeters after bifurcation on frontal branch, Sample C - 3 millimeters after bifurcation on parietal branch, Sample D - 50 milimeters after bifurcation on frontal branch, Sample E - 50 millimeters after bifurcation on parietal branch (Figure 2). After all of the samples were taken, we proceeded to measure the internal elastic lamina for each of the samples using a microscope.

In order to identify studies that reported lengths STA lengths and/or diameters of the internal elastic lamina of the STA, the electronic databases PubMed, Embase, and Scopus were utilized. Searches were conducted using the following keywords "Superficial Temporal Artery," "STA," "Cadaver," "Diameter," "Internal Elastic Lamina," and "Length." The date of publication of the article was not considered as we wanted to retrieve all relevant cadaveric studies of the STA.

We considered studies in any language that were published as full articles. To be included in the project, studies had to be cadaveric, report mean lengths of at least one of the three length measurements (trunk, frontal branch, parietal branch) of the STA or include mean internal elastic lamina diameters from at least one of our sample locations (A, B, C, D, E). Then we conducted statistical analyses for each separate measurement, a One-Way ANOVA through VassarStats where two independent samples were entered for each test: one sample was the cadaveric data and the other was the literature data. A p-value of 0.05 or lower was considered significant.

Results

Average STA trunk length was 32.94 mm, with the average length of the frontal branch and parietal branch length was found as 71.05 mm and 70.18 mm (Table 1). The average internal elastic lamina diameter for Sample A (3mm before the branching point on STA trunk) was 2.059 mm. For Samples B and C (3 mm away from the branching point) the average internal elastic lamina diameters were 1.470 mm and 1.609 mm, respectively. The samples for D and E had mean internal elastic lamina diameters of 1.277 mm and 1.400 mm, respectively (Table 2).

In order to compare our results with the literature 113 cadavers from six different studies provided the data that was included in the literature investigation portion of this study (Table 3,4). Three articles possessed measurements of average STA lengths and internal elastic lamina diameters. The other three articles only had average internal elastic lamina diameters.

As shown in Figure 3, three publications had at least one applicable STA length (trunk, frontal branch, parietal branch). Two studies had collected and cited mean trunk measurements, where we calculated an average length of 34.30 mm (Figure 4). Mean frontal and parietal branch measurements were also found in

Table 1: Average Lengths (mm) of the STA Taken From the 10 Cadaveric Specimens

Length Measurement	Average Length (mm) ± SD
Trunk	32.94 ± 11.86
Frontal Branch	71.05 ± 22.64
Parietal Branch	70.18 ± 15.26

Table 2: Average Diameters of Internal Elastic Lamina at 5 Sampling Points

Sample	Average Diameter of Internal Elastic Lamina (mm) ± SD
A	2.059 ± 0.515
B	1.470 ± 0.388
C	1.609 ± 0.423
D	1.277 ± 0.299
E	1.400 ± 0.420

Sample A = 3 millimeters before bifurcation, Sample B = 3 millimeters after bifurcation on frontal branch, Sample C = 3 millimeters after bifurcation on parietal branch, Sample D = 50 milimeters after bifurcation on frontal branch, Sample E = 50 milimeters after bifurcation on parietal branch, SD = Standard Deviation

two studies, where we calculated an average length of 107.10 mm and 110 mm, respectively (Figure 4).

Four studies found in the literature calculated the average diameter of the internal elastic lamina of the STA 3 mm before the bifurcation on the STA trunk (Sample A). The mean calculated from these studies was 2.142 mm. Five publications cited diameter averages of the proximal frontal branch (Sample B). The average diameter found from these publications was 1.670 mm. Four publications included average diameters of the proximal parietal branch (Sample C), and the average calculated from these studies was 1.548 mm. These results are seen in Table 5. No studies found in the literature collected internal elastic lamina diameters for the distal frontal or parietal branches (Sample D and Sample E).

Statistical Analyses: When the cadaveric data and literature data for trunk lengths were compared through a One-Way ANOVA test, a p-value of 0.890346 was calculated, which did not meet our 0.05 cutoff for significance (Figure 4). A p-value of 0.05 was obtained when comparing our cadaveric frontal branch lengths with the literature, which also did not meet our cutoff (Figure 5). Our threshold for significance was met for the parietal branch measurement, which yielded a p-value of 0.005513. The p-values that compared our cadaveric internal elastic lamina diameters with the literature for Samples A, B, and C were 0.782117, 0.417898, and 0.810635, respectively. Each of these p-values did not meet our significance threshold. As stated earlier, there were no publications found that measured the internal elastic lamina diameters of the distal frontal or parietal branch (Samples D and E). Therefore, no literature comparisons could be made for Samples D and E.

Discussion

The STA is an essential vessel for CBS; therefore, having a universal anatomical understanding of this artery is important in medicine. The study conducted by Kim et al. only used Korean cadavers and produced different parietal branch lengths than our study (2014). This suggests that parietal branch lengths may vary across races; therefore further cadaveric STA studies should collect data on a racially diverse group of patients and observe if this variation exists. The p-value for frontal branch measurements exceeded our 0.05 cutoff, suggesting consistency between our cadaveric data and the literature.

However, it must be emphasized that further studies must be conducted regarding the lengths of the frontal branch due the lack of literature data found for this measurement. The 0.890346 p-value obtained for the trunk length strongly suggests that our data was consistent with the literature's for this measurement.

We could only compare the internal elastic laminas diameters that we measured for Samples A, B, and C

Table 3: Summary of Studies with STA Measurements

Source	Cadaver Information	Usable Measurements Obtained	Results
Tayfur et al., The Journal of Craniofacial Surgery, 2010	13 formalin-fixed adult cadavers	Lengths: FB, PB Diameters (Samples): B, C	Mean Lengths: FB: 115 mm, PB: 114 mm Mean Diameters: B: 2.0 mm, C: 1.8 mm
Pinar & Govsa, Surgical Radiological Anatomy, 2006	14 adult cadavers	Lengths: None Diameters: (Samples): A, B, C	Mean Lengths: None Mean Diameters: A. 2.73 ± 0.51 mm B: 2.14 ± 0.54 mm C: 1.81 ± 0.45 mm
Lee et al., Surgical Radiological Anatomy, 2015	38 fixed Korean cadavers	Lengths: T Diameters: (Samples): B	Mean Lengths: T: 36.9 ± 14.24 mm Mean Diameters: B: 1.8 ± 0.6 mm
Chen et al., Plastic and Reconstructive Surgery, 1999	26 adult cadavers (4 women, 22 men)	Lengths: None Diameters (Samples): A, B, C	Mean Lengths: None Mean Diameters: A. 2.14 ± 0.45 B: 1.61 ± 0.19 C: 1.68 ± 0.21
Ma et al., Journal of Craniofacial Surgery, 2015	10 cadaver heads were fixed with 10% of formaldehyde and immersed in 75% alcohol	Lengths: None Diameters: (Samples): A, B, C	Mean Lengths: None Mean Diameters: A: 1.50 ± 0.14 B: 0.80 ± 0.08 C: 0.9 ± 0.09
Marano et al., Neurosurgery, 1985	50 cadavers of various sexes and ages	Lengths: T, FB, PB Diameters (Samples): A	Mean Lengths: T: 31.7 mm FB: 99.2 mm PB: 106.0 mm Mean Diameters: A: 2.2 mm

with the literature because diameters for Samples D and E were absent in the literature. None of the cadaveric samples that we were able to compare with the literature data met our significance cutoff because the p-values were all greater than 0.05. This suggests that our data for the internal elastic lamina diameters at these locations proximal to the bifurcation were consistent with the literature, which is the opposite of what we predicted. Future cadaveric studies that include diameters of the internal elastic lamina of the STA should also include diameters taken from samples further down the branches. This is because arteries be smaller further away from the heart (14). This tendency is depicted in our data as 66.7% of the STAs used for the cadaveric study had a greater internal elastic lamina diameter for Sample B than D, and 77.8% had a greater internal elastic lamina diameter for Sample C than E. Also we limited the length measurements of the STA branches with minimum diameter of 0.8 mm given the feasibility concern for CBS.

Once the studies of the STA were stratified by measurement design – cadaveric or radiographic – an interesting trend emerged: cadaveric mean diameters were significantly larger than their radiographic counterparts (15-21).

From a design perspective, we posit that the cadaveric diameters may be larger for two reasons: (1) the measurement process, being external to the artery, includes the vessel walls and (2) the preservation process involves the injection of dye-containing material into the vessel, likely artificially expanding

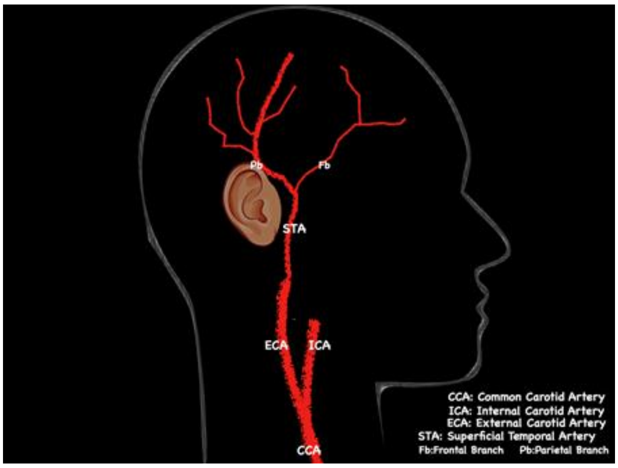

Fig. 1. The illustration demonstrates a detailed depiction of the superficial temporal artery, including its point of origin, branching pattern, and approximate location in relation to the human skull. Originating from the external carotid artery, the superficial temporal artery is shown ascending in the preauricular area and bifurcating into its two main branches: the anteriorly oriented frontal branch and the posteriorly directed parietal branch

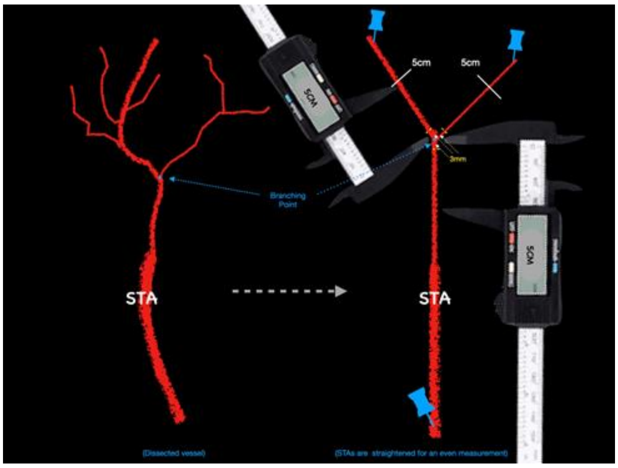

Fig. 2. illustration depicts the measurement methodology employed in this study. Initially, the dissected superficial temporal artery is straightened (left image). Subsequently, measurements are conducted using a caliper on the straightened artery (right image). Sampling point of the branches are designated at 3 mm and 50 mm distal to the bifurcation point of the artery

the vessel caliber. In contrast, the use of intravascular contrast in radiographic studies provides an in vivo measurement of the functional lumen of the vessel and has been previously been shown to be a reliable estimation of true vessel caliber (15).

Integrating radiological imaging data of the STA with tangible surgical or cadaveric anatomical information holds significant potential for advancing postoperative skin problem prevention and facilitating the preservation of potential cranial anastomosis surgeries in future endeavors. This synergistic approach harnesses the precision of radiological

Fig. 3. Cadaveric dissection illustrating the dissected superficial temporal artery and its branches. The left image displays the superficial temporal artery with its frontal and parietal branches. The top right image shows the measurement of the frontal branch at the distal sampling point, while the bottom right image presents the measurement at the proximal sampling point

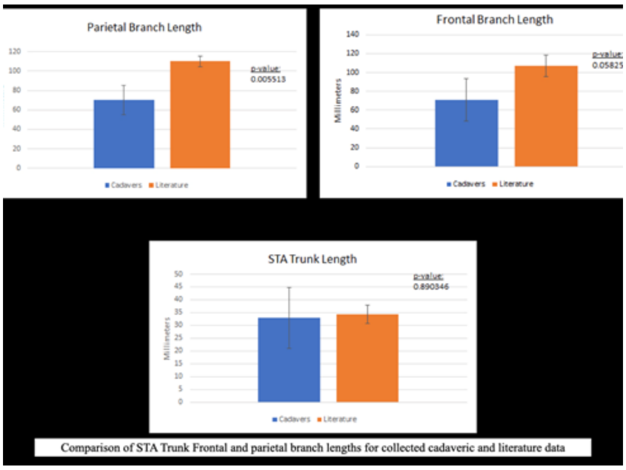

Fig. 4. Comparative analysis of the lengths of the Superficial Temporal Artery's trunk, frontal branch, and parietal branch: A correlation between our findings and published literature

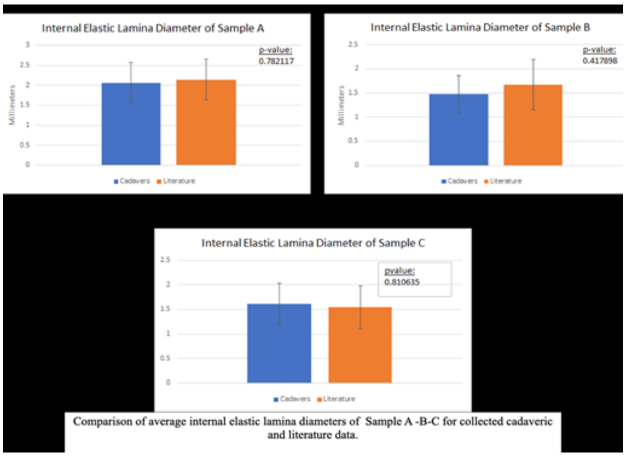

Fig. 5. Comparative analysis of Internal Elastic Lamina diameter: correlating our findings with data from published literature

imaging to enhance our understanding of the STA dynamics, thereby informing and optimizing surgical interventions. The comprehensive fusion of radiological and anatomical data not only contributes to improved postoperative outcomes by mitigating skin-related complications but also lays a foundation for enhancing the efficacy and safety of prospective cranial anastomosis procedures (22).

Based on the aforementioned reasons, we suggest that future studies of the STA and other vessels use angiographic methods to measure the vessel lumen. Employing this methodology in the future will consistently provide reliable measurements facilitating comparison of results through literature meta-analyses, as well as, giving comparable results to perioperative assessments as angiography is the golden standard method for vessel caliber measurements (23).

A limitation that may have disrupted the data in this study is the fact that we have a small sample size. Further research with more cadaveric specimens will produce more reliable data.

This study aimed to contribute to the anatomical understanding of the STA by collecting cadaveric data and comparing that data to cadaveric studies that have already been conducted. Our analyses indicated there was not a significant difference between our collected internal elastic lamina diameters and the literature's cadaveric studies. This was also the case for the trunk and frontal branch lengths. Our parietal branch lengths were statistically different from the literature, which we believed was because of the racial differences between the cadavers used in different studies. Due to the scarce amount of literature available for lengths of the frontal and parietal branches, future studies should be conducted that pay attention to whether branch lengths vary between different racial groups.

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Conflict of Interest: The author declare no conflict of interest.

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