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Original Article

Anatomical Mapping of the Supratrochlear Artery Pedicle: Defining a Surgical Danger Zone for Paramedian Forehead Flap Elevation

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ABSTRACT

Variability in the anatomy of the supratrochlear artery (STA) carries implications for the use of a paramedian forehead flap in facial reconstruction. While prior reports have documented STA branching configurations and the vessel's separation from the midline, the STA pedicle itself has received no systematic description. The present work set out to triangulate the STA pedicle against familiar anatomical landmarks and map a danger zone that could help surgeons construct viable tissue flaps. A total of 38 cadaveric donors underwent bilateral dissection of the upper facial territory. Values were captured for the distances spanning from the supraorbital neurovascular bundle, the orbital rim, and the medial canthus to the STA pedicle. Results were tabulated and evaluated with statistical methods. For each measurement, mean, range, and standard deviation were derived; comparison by side revealed no significant discrepancies ($P > 0.05$). Across all metrics collected from male and female donors alike, statistically significant sex differences were detected. By mapping a surgical danger zone specific to the STA pedicle in the context of a paramedian forehead flap, this investigation brings to light notable sex-based variations within that zone—differences that surgeons should heed to steer clear of pedicle breach, bolster operative success, and achieve the greatest possible flap length and mobility.

Keywords: Paramedian forehead flap, Supratrochlear artery, Danger zone, Surgery, Facial surgery, Ophthalmic artery

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Introduction

The circulatory network of the face is intricate, and the way terminal vascular sources anastomose makes each pattern distinct. Two end-branches of the ophthalmic artery account for the majority of forehead perfusion [1, 2]: the supraorbital artery and the supratrochlear artery (STA). A precise working knowledge of the STA's trajectory through the layered planes of the forehead is indispensable in reconstructive facial surgery, as it equips surgeons to more reliably preserve the STA pedicle when separating the muscular tissues situated medial and lateral to the vessel. Average STA dimensions cited in the literature include a diameter approximating 1.00 mm [3-5], a depth measured from the overlying skin of 1.50 mm, and a length extending 51.1 mm from the point of branching off the occipital artery to its passage beyond the supraorbital rim [6]. The point at which the STA perforates the orbital septum sits 1.70–2.20 cm lateral to the midline, after which the artery pursues a paramedian upward route that averages 1.50–2.00 cm from the midline [2]. Thorough investigation into STA branching has indeed brought to light a dense web of vascular interconnections across the nasoglabellar territory, fed by the angular artery, the terminal segment of the facial artery, the supraorbital artery, the STA, and the corresponding arteries of the contralateral side [1-3, 7].

Given that this arterial network blends tributaries of both internal and external carotid origin, the possibility of reversed flow through these anastomotic linkages remains open even under various adverse vascular conditions [2-4].

Rebuilding facial defects demands considerable skill, requiring surgeons to juggle the preservation of facial identity with the resolution of the presenting clinical problem. For mid-facial defects of moderate extent, reconstruction leans on regional flaps, meaning donor tissue is mobilized while retaining a vascular tether but not obliged to lie immediately next to the wound. A contemporary survey of the techniques deployed for midfacial restoration itemized 12 flaps as the prevailing choices for that anatomical region: the bilobed flap, the rhomboid flap, flaps based on the facial artery (nasolabial flap, island composite nasal flap, and retroangular flap), the cervicofacial flap, the paramedian forehead flap, the frontal hairline island flap, the keystone flap, the Karapandzic flap, the Abbé flap, and the Mustardé flap [5]. Those 12 configurations can be further categorized by transfer mechanism (rotation, transposition, advancement, or a combined approach) and the targeted midfacial subunit (upper lip, nose, cheek, etc.) [5]. Among this list of 12, the paramedian forehead flap is a rotation flap with a principal indication for nasal defect closure [5-9]. The advantages of paramedian forehead flaps are considerable: they can deliver a generous volume of tissue, yield a robust and reliable flap, and minimize donor-site complications [5-10]. Most often, the paramedian forehead flap is staged across two or three operations [11], the later procedures serving to sever the vascular pedicle and then further carve the relocated tissue toward a closer imitation of the native anatomy. Flaps sourced from the contralateral side are standard practice, since they lessen the chance of pedicle kinking and the attendant threat to blood flow; the trade-off is that the flap must then span a greater distance to cover the defect. In the effort to fashion and elevate the paramedian forehead flap safely, most surgeons follow a prescribed sequence of technical steps to maximize flap survival **(Figure 1)**. Division of the pedicle is deferred until three to four weeks after the initial transfer, providing adequate time for neovascularization to establish [10-12]. The gap left at the pedicle base is then repaired. Later, further thinning and contouring revisions may be considered to achieve closer harmony with adjacent structures and a more favorable aesthetic result.

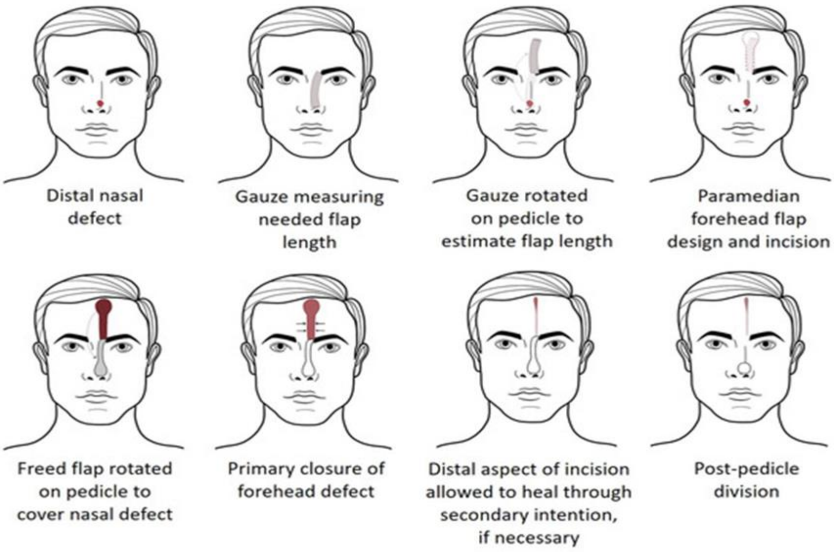

Figure 1. Operative sequence for the paramedian forehead flap, with stages advancing from left to right and top to bottom. The nasal defect is located and debrided, and the margins of healthy viable tissue are fashioned. A template is cut from pliable material (such as gauze) reaching from the defect to the contralateral pedicle base. The template is rotated medially onto the face along the axial plane to gauge the required flap length. An incision follows the confines of the template, and dissection of the tissue proceeds from distal toward proximal, preserving the pedicle untouched. The flap is pivoted around its pedicle into the defect, and the forehead wound is closed primarily. The pedicle is divided later, according to patient-specific needs. Surgical sequence and figure adapted from Mellette and Ho [11] (8 pictures) and Correa *et al*. [12] (9 steps).

Although published work confirms that the STA runs up the forehead 1.50–2.00 cm away from the facial midline [2], no further surface cues have been put forward to help pinpoint the vessel's position. This data shortage is even sharper when the goal shifts to localizing the STA pedicle itself, a step on which the avoidance of ischemic injury, necrosis, and total flap loss hinges. Reece *et al*. [13] recommended leaving a continuous block of tissue measuring 7 mm above the supraorbital rim as a vascular buffer, a guideline based on measurements from five cadaveric heads. The study reported here extends those measurements considerably and highlights additional anatomical landmarks to be consulted during the planning and elevation of paramedian forehead flaps, with the broader purpose of reducing the risk of vascular injury and improving postoperative outcomes.

Materials and Methods

Cadaveric donors

Access to 38 cadavers—some intact, others decapitated—was granted through the Gift Body Program at Kansas City University (KCU) and the Deeded Body Program at the University of Nebraska Medical Center (Institutional Biosafety Committee, #1819182-1). Formalin preservation had been applied to 35 whole-body subjects; the three remaining donors consisted solely of frozen-fresh heads. Limitations imposed by both the embalming procedure and the terms of the body donation agreements rendered vascular latex injection unfeasible. Both sides of each donor were dissected whenever possible, with unilateral dissection restricted to cases in which the opposing side was unusable (n = 4), yielding a total of 72 individual pedicles available for measurement. The STA pedicle values from the right and left sides of a given donor were treated as independent specimens and documented accordingly. The demographic parameters collected alongside the measurements encompassed sex, age, weight, and height.

Dissection approach

Three anatomical structures served as the key reference points for localizing where the STA pedicle emerges: the bony orbital rim, the supraorbital neurovascular bundle, and the medial canthus. A digital caliper (General Ultratech, San Jose, CA, USA) was employed bilaterally to capture the spans that separate the supraorbital neurovascular bundle, the bony orbital rim, and the medial canthus from the STA flap pedicle, thereby permitting triangulation of a danger zone encircling the pedicle. For purposes of control, the gap between the facial midline and the STA pedicle—a dimension already described in the literature as measuring 1.50–2.00 cm—was likewise recorded [2].
Positioning of every cadaver was supine, and the investigator who carried out the full set of procedures took up a stance at the cranial side of the dissection table, thereby reproducing the vantage point of the operating surgeon. Before making the first incision, each specimen underwent measurement and marking to generate a pre-dissection blueprint for a paramedian forehead flap, resembling what would be mapped out intraoperatively **(Figure 2)**. A single dotted line traced the facial midline (informed by the nasal septum, the philtrum, and, when identifiable, the chin cleft) and functioned as the reference for all ensuing measurements. Bilateral placement of a mark 1.70 cm outward from the facial midline was carried out to estimate the ascending path of the STA. The intended flap width was then indicated by adding marks set 0.70 cm on either side of that STA mark. These two outermost marks were continued superiorly from the eyebrow up to the hairline, demarcating the prospective length of the flap. One further mark, positioned 2.50 cm lateral to the midline, was made to facilitate the raising of a secondary flap whose purpose was to help disclose the supraorbital neurovascular bundle. This generous lateral offset enabled safe dissection without risking inadvertent breach of the supraorbital neurovascular bundle beyond the point where the supraorbital margin transitions. All markings and measurements were executed bilaterally on each cadaveric specimen before any tissue dissection; the first author performed all of them using the same digital caliper to promote consistency and curb potential variability.

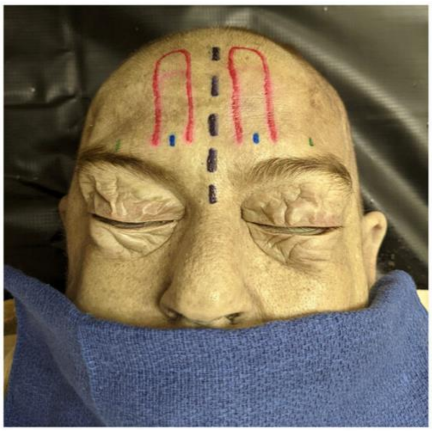

Figure 2. Pre-dissection diagram and measurements. The black mark indicates the facial midline. The blue mark is set 1.70 cm from the midline and signifies the expected STA position. The red marks extend 0.70 cm to either side of the blue mark, framing the flap width. The green mark is placed 2.50 cm from the midline, reflecting the typical position of the supraorbital neurovascular bundle.

Measurement of STA pedicle to anatomical landmarks

With the paramedian forehead flap design laid out, a #10 scalpel blade was guided along its perimeter, slicing through the full thickness of all five scalp layers. Once freed, the tissue flap was gently lifted with forceps to expose the periosteum. Elevation of the periosteum proceeded under a freer elevator, advancing from the cephalic end toward the caudal **(Figure 3a)**. As the plane of dissection encroached upon the STA pedicle, instrument movements were deliberately kept to a minimum to leave the pedicle's origin undisturbed. The moment the pedicle could be adequately inspected, its origin was annotated. The first author then used a digital caliper to measure from the facial midline to the pedicle mark **(Figure 3b)**. After this, the pedicle was intentionally taken down to permit more extensive mobilization of the paramedian forehead flap. Once the flap could be reflected without restriction, the span bridging the STA pedicle mark and the medial canthus was noted **(Figure 3c)**. For those specimens in which flap thickness obstructed a clear line of measurement, the entire flap was resected with a #10 scalpel blade. Commencing at the 2.50 cm mark, a vertical incision was extended through roughly the lower half of the forehead; this vertical cut was then linked to the lateral flap incision by a short horizontal cut placed at approximately the mid-forehead level. Upon detaching the second flap, forceps were used to lift the tissue, allowing the periosteum to be visualized. A free elevator was once again directed cephalad to caudad to separate the periosteum **(Figure 3d)**. Identification of the supraorbital neurovascular bundle was followed by measuring the interval between its origin and the STA pedicle mark **(Figure 3e)**. While this bundle cannot be directly seen during live surgery, it was incorporated as an internal confirming landmark for pedicle location. To finish, any remaining soft tissue overlying the supraorbital region was reflected with forceps and a freer elevator until the bony orbital rim was fully exposed. The most direct linear distance from that bony rim to the pedicle mark was then documented **(Figure 3f)**.

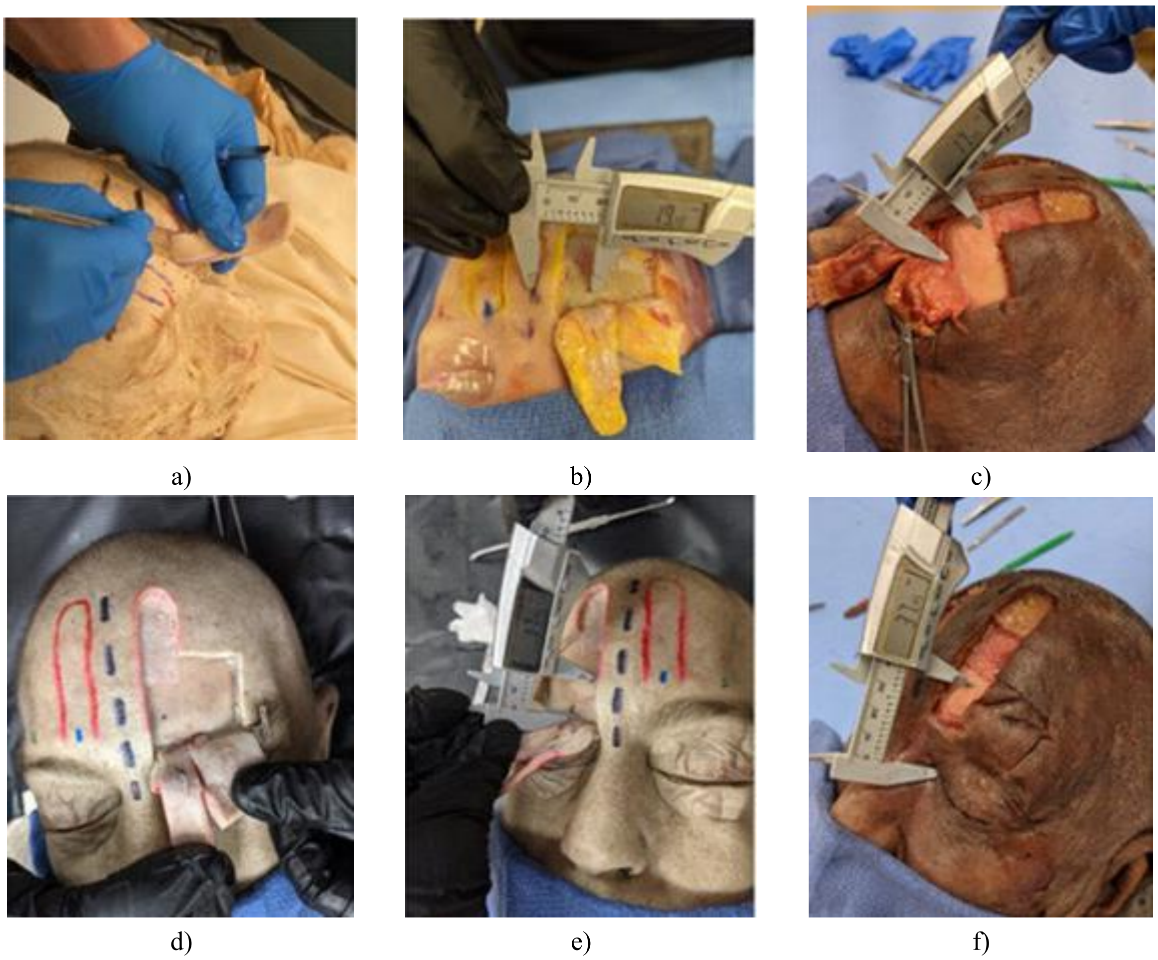

Figure 3. Measurements from the STA pedicle to anatomic landmarks: (a) The periosteum is being lifted with a freer elevator, (b) Span from the STA pedicle to the facial midline, (c) Span from the STA pedicle to the medial canthus, (d) The supraorbital neurovascular bundle was brought into view, (e) Span from the STA pedicle to the supraorbital neurovascular bundle, and (f) Span from the STA pedicle to the bony orbital rim.

Statistical analysis

All data were assembled and processed within Excel (Microsoft, Takoma, WA, USA). For each of the four variables, an independent-samples t-test was applied to determine whether the means differed significantly between right- and left-side values and between the anatomical sexes represented among the donors. To account for differences in group sizes, a Mann–Whitney U test was performed in SPSS (Statistical Product and Service Solutions, IBM, Armonk, NY, USA) to compare the means of embalmed versus fresh cadaveric specimens. No intraclass correlation coefficient was computed, given that a single observer—the first author—conducted every measurement. The cutoff for statistical significance was defined as $P < 0.05$. All results are reported as the mean ± standard error of the mean, with the range provided alongside.

Results and Discussion

The investigation drew upon 38 cadaveric donors, from which 72 pedicles were isolated and quantified. Six of those pedicles belonged to the three fresh cadaver subset, while 67 pedicles were harvested from the 35 embalmed bodies. The full cohort comprised 20 male and 18 female donors; their ages averaged 75.2 years, ranging from 44 to 103. For each parameter, the mean, standard deviation, and range were derived and tabulated.

Facial midline to the STA pedicle

The average distance recorded between the facial midline and the STA pedicle came to 1.69 cm (std. dev., 0.14; range, 1.30–2.00 cm). When values obtained on the right side were compared with those on the left, no meaningful difference emerged ($P > 0.05$); in contrast, the comparison between male donors and female donors yielded a statistically significant difference **(Table 1)**. A further significant divergence was observed when comparing fully intact embalmed bodies with fresh-head specimens **(Table 1)**.

Table 1. All measurements taken in centimeters (cm = centimeter).

Formalin-Embalmed Cadavers versus Fresh Disarticulated Head and Neck Cadavers			
Measurement	**P-value**	**Fresh cadaver (Mean ± SD)**	**Embalmed cadaver (Mean ± SD)**
Facial midline to STA pedicle	< 0.05	1.81 ± 0.10	1.68 ± 0.14
Supraorbital neurovascular bundle to STA pedicle	0.265	1.73 ± 0.73	1.48 ± 0.33
Bony orbital rim to STA pedicle	0.684	1.52 ± 0.56	1.54 ± 0.37
Medial canthus to STA pedicle	0.283	3.23 ± 0.51	3.04 ± 0.36
STA measurements in male versus female cadavers			
Measurement	**P-value**	**Female cadaver (Mean ± SD)**	**Male cadaver (Mean ± SD)**
Facial midline to STA pedicle	< 0.05	1.63 ± 0.16	1.75 ± 0.11
Supraorbital neurovascular bundle to STA pedicle	< 0.05	1.40 ± 0.36	1.58 ± 0.37
Bony orbital rim to STA pedicle	< 0.05	1.42 ± 0.35	1.65 ± 0.39
Medial canthus to STA pedicle	< 0.05	2.92 ± 0.31	3.17 ± 0.39

Abbreviation: STA = supratrochlear artery; total cadavers, n = 72 samples (male, n = 39; female, n = 33); fresh cadaver, n = 3 (6 samples); formalin-embalmed cadavers, n = 35 (67 samples); [a] Mann–Whitney U test was used to evaluate differences in the means of embalmed vs. fresh cadavers; an independent sample t-test was used to determine the significance between male and female cadavers.

Supraorbital neurovascular bundle to the STA pedicle

A mean value of 1.50 cm (std. dev., 0.37; range, 0.60–2.70 cm) characterized the interval from the supraorbital neurovascular bundle to the STA pedicle. Right-left comparisons uncovered no significant departures for this distance. Sex-stratified analysis did, however, reach statistical significance **(Table 1)**, whereas the embalmed-versus-fresh contrast failed to do so **(Table 1)**.

Bony orbital rim to the STA pedicle

The gap spanning from the bony orbital rim to the STA pedicle averaged 1.53 cm (std. dev., 0.38; range, 0.60–2.20 cm). Lateralized evaluation again produced no significant inter-side differences. A significant separation of male and female values was apparent **(Table 1)**. Embalmed and fresh cadaver groups did not differ meaningfully on this measure **(Table 1)**.

Medial canthus to the STA pedicle

For the distance extending from the medial canthus to the STA pedicle, the mean was registered at 3.05 cm (std. dev., 0.37; range, 2.30–3.80 cm). No significant right-to-left discrepancy materialized. Sex-based differences attained significance **(Table 1)**, yet the comparison between fully intact embalmed cadavers and fresh-head cadavers did not **(Table 1)**.

Though modest in scale, the STA pursues an abbreviated, unwavering course. It merges into a lush anastomotic plexus woven among itself, the supraorbital artery, the angular artery, and the terminal reaches of the facial artery [1-3, 14]—vessels that collectively form the dominant supply to the scalp and nourish each of the five constituent layers of the forehead. As the STA climbs the medial forehead, it sequentially pierces the periosteal covering of the cranial vault, a loose areolar tissue sheet, the epicranial aponeurotic layer, a bed of dense subcutaneous connective tissue, and finally the cutaneous envelope [14-16].

A substantial body of work has focused on delineating the spectrum of STA branching morphologies and the architecture of the forehead's vascular arcade, repeatedly situating the STA's paramedian ascent at 1.50–2.00 cm [2]. What has remained uncharted, however, is the specific position of the STA pedicle not simply with respect to the midline but in relation to a broader set of surgically pertinent anatomical landmarks. The present work was undertaken to provide additional navigational cues that reconstructive surgeons might incorporate when fashioning paramedian forehead flaps, with the intent of reducing inadvertent injury to the flap's perfusion source and the complications that follow. Based on the collected data, we constructed a surgical dissection danger zone centered on the STA pedicle **(Figure 4)**. This zone traces the pedicle's forehead ascent, using landmarks that are either externally visible or palpable, marking the territory where a surgeon's dissection should proceed with deliberate restraint.

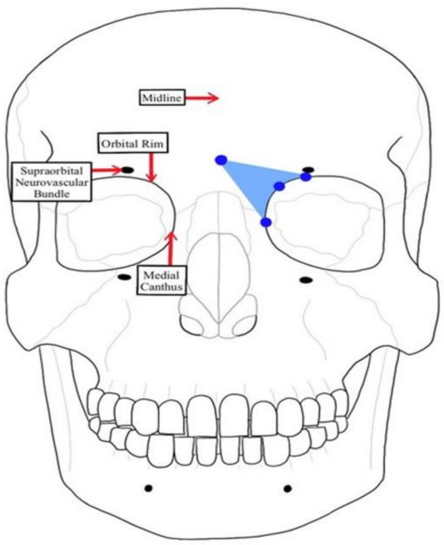

Figure 4. Surgical dissection danger zone. Graphic of the STA pedicle danger zone (blue triangle), which connects the external or palpable anatomical landmarks (blue dots) and represents the region where reconstructive surgeons should dissect with caution (shaded triangle).

That a single investigator—the first author—was responsible for capturing all four measurement sets bolsters the trustworthiness of the dataset, as it nullifies inter-operator technique discrepancies and narrows the scope for human error. The midline-to-pedicle figures we report across 72 samples align broadly with the anatomical work published by Shumrick and Smith [2], placing the pedicle at a mean of 1.69 cm from the midline. Yet the range we document spans 1.30-2.00 cm, thereby exceeding the previously cited 1.50–2.00 cm bracket and underscoring the need for a gentle surgical approach along the flap's medial border.

Across all four anatomical reference points, the absence of significant right-left asymmetries attests to the STA's consistent bilateral trajectory as it feeds the neighboring tissues and ascends the forehead. Two of the four measurements showed significant differences between formalin-embalmed cadavers and fresh, disarticulated head-and-neck donors **(Table 1)**. One possible explanation resides in the fixation and preservation process itself, which may alter the spatial interplay among anatomical landmarks. This interpretation must, however, be weighed against the stark imbalance in group sizes—the fresh subset being far outnumbered by the embalmed group—and the added confound that every fresh donor arrived as a detached head and neck. In contrast, all embalmed donors were whole-body preparations. It seems probable that the small fresh-cadaver count underlies the observed statistical significance, especially given that earlier literature indicates no appreciable disparity between fresh and embalmed tissues [17].

Statistical significance was likewise observed for all measurements when male and female cadaveric values were compared **(Table 1)**. Coupled with the absence of any meaningful right–left discrepancies across the dataset, this outcome underscores the imperative of meticulous surgical dissection, as the mean values recorded for female donors were consistently smaller than those of male donors. Such a finding sits comfortably within established knowledge, as sex-linked differences in facial morphology have long been investigated and are widely recognized. It is generally accepted that an individual's facial architecture is shaped by a confluence of influences, among which biological sex figures prominently [18]. The archetypal male face tends toward greater width and length, a more pronounced supraorbital ridge, and a more rectangular overall silhouette. The typical female face, by contrast, leans toward a rounder contour with softer, less sharply angled features. With this foundational understanding already embedded in the literature, the statistically significant male–female divergences documented in the present study offer further corroboration. This finding assumes particular weight in light of the previously established reference bracket of 1.50–2.00 cm reported by Shumrick and Smith [2], which was derived from a sample limited to five cadavers [2]. Set beside that earlier work, our examination of 72 hemifaces not only enlarges the sample size by a considerable margin but also extends the reference range outward to 1.30–2.00 cm.

For plastic and maxillofacial surgeons tasked with rebuilding nasal defects—most frequently following excision of nasal malignancies—the paramedian forehead flap remains an attractive surgical option [5, 6]. Although raising the flap initially leaves a conspicuous forehead wound, this resolves over time through successive tissue remodeling and yields long-term cosmetic outcomes that are favorably assessed by both the patient and the surgeon [19]. The paramedian forehead flap offers several additional benefits: it provides generous tissue volume to resurface sizable defects and can be used for both congenital anomalies [20] and acquired lesions [9, 21, 22]. Beyond this, the flap can be redeployed to address residual defects [23, 24] and possesses the innate plasticity to be tailored by the reconstructive surgeon to harmonize with patient-specific midfacial features [8, 22, 25]. Most critically, when dissected and executed with proper technique, these flaps are linked to durable, positive long-term outcomes [9].

No surgical intervention is without its attendant postoperative hazards, and the paramedian forehead flap is no exception. Adverse events at the lower end of the spectrum include infection, partial nasal collapse, incomplete nasal obstruction, epidermolysis, and alar asymmetry [6, 21, 26-28]. Major complications include flap necrosis (whether complete or partial), nasal obstruction, alar notching, and frank asymmetry. Published rates of postoperative complications have fluctuated considerably from one report to the next. In the series described by Little *et al*. [27], 16.1% of patients developed a major complication during their postoperative course; within this subset, flap necrosis occurred in 5.4%, nasal obstruction in 4.9%, and alar notching in 9.8%. Necrotic flaps were further stratified into those with less than 50% necrosis and those exceeding 50%, with the former documented in nine patients and the latter in two. By contrast, Chen *et al*. [29] detail major complication indices reaching 31.7% and minor complication rates of 50.8%, singling out infection (2.9%), bleeding (1.4%), and deep vein thrombosis (< 0.5%) as the most frequently encountered issues. Taken as a whole, these figures align intermittently with the infection rate of 2.7%, bleeding rate of 8.1%, and partial flap loss rate of 2.7% communicated by Rajan *et al*. [21]. While advanced age and tobacco use are firmly entrenched as risk determinants for a broad array of medical and postsurgical complications, they have not been tied to statistically significant escalations in adverse outcomes specific to paramedian forehead flaps [30]. Necrosis of a paramedian forehead flap is a particularly grave concern, as it carries the risk of outright flap failure. The flap's vertical design, by its very nature, isolates a solitary blood supply—the STA—over the greater portion of the tissue flap's span. Consequently, any insult to the perfusion delivered by the STA can translate directly into flap necrosis and, in the worst case, total flap loss. Indeed, for patients with heightened vascular risk profiles, a three-stage surgical strategy has been proposed as a functionally and aesthetically superior alternative to the conventional two-stage approach [26].

Pinpointing the anatomical position of the STA pedicle with precision constitutes a critical competency when undertaking paramedian forehead flap reconstruction. While it is certainly true that many such flaps do not demand their maximal possible length to bridge the defect, a meaningful subset—particularly those destined for the nasal tip or columella—may require every available millimeter of reach. Given that cutaneous malignancy persists as the most frequently diagnosed cancer across the United States [31], surgical fluency in constructing paramedian forehead flaps remains indispensable, especially in scenarios involving delayed diagnosis and more deeply invasive defects. The flap's vertical configuration prevents collateral vascular contribution, leaving the STA as the sole guarantor of tissue viability. Armed with a firm command of the STA pedicle's approximate location, the reconstructive surgeon can isolate the pedicle with greater accuracy, thereby securing the maximum feasible flap length while curtailing the risk of vascular embarrassment and outright flap failure.

Multiple factors merit attention in future investigations concerning STA pedicle location. Chief among them is the observation that donors were predominantly Caucasian, thereby limiting the racial and ethnic heterogeneity of the study sample. Extrapolating the conclusions drawn here across a richly diverse spectrum of ethnic populations must therefore be undertaken with prudence. The modest number of fresh head-and-neck specimens likewise circumscribed the present work. Subsequent studies could be structured to rely exclusively on fresh cadaveric material for comparative purposes. Future lines of inquiry might also assess the presence and metric distances of these same or alternative anatomical landmarks, thereby adding further weight to the evidence base underpinning safe dissection within the context of paramedian forehead flaps.

Conclusion

The present investigation foregrounds the value of an intimate familiarity with the precise anatomical location of the STA pedicle—achieved through meticulous dissection of the surrounding surgical landmarks—as it pertains to the design and elevation of a paramedian forehead flap. The measurements presented here define an STA pedicle danger zone intended to assist facial reconstructive surgeons in addressing nasal defects with greater success and less disruption to the vascular supply. We uncovered a significant difference across all measurements when male donors were compared against female donors. In its entirety, this study provides novel insights into the STA pedicle and its role in the successful execution of paramedian forehead flap surgery.

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Conflict of Interest: Christopher Surek is a consultant for Allergan, Galderma, Revance, and Cypris Medical; all other authors have no disclosures to report.

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Ethics Statement: The cadaveric study protocol was approved by the Institutional Biosafety Committee of Kansas City University (1819182-1).
Informed consent, including permission to publish images for research and/or educational purposes, was obtained from all subjects involved in the study through their participation in the Gift Body Program at Kansas City University and the Deeded Body Program at the University of Nebraska Medical Center.

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