The Midline Central Artery Forehead Flap
A Valid Alternative to Supratrochlear-Based Forehead Flaps

Callum Faris, FRCS; Paul van der Eerden, PhD; Hade Vuyk, PhD

IMPORTANCE This study clarifies the pedicle geometry and vascular supply of a midline forehead flap for nasal reconstruction. It reports on the vascular reliability of this flap and its ability to reduce hair transposition to the nose, a major complicating factor of previous forehead flap designs.

OBJECTIVE To compare the vascular reliability of 3 different pedicle designs of the forehead flap in nasal reconstruction (classic paramedian, glabellar paramedian, and central artery flap design) and evaluate hair transposition rates and aesthetic results.

DESIGN, SETTING, AND PARTICIPANTS Retrospective analysis of patient data and outcomes retrieved from computer files generated at the time of surgery, supplemented by data from the patient medical records and photographic documentation, from a tertiary referral nasal reconstructive practice, within a secondary-care hospital setting. The study population included all consecutive patients over a 19-year period who underwent primary forehead flap repair of nasal defects, with more than 3 months of postoperative follow-up and photographic documentation.

INTERVENTIONS Three sequential forehead flap patterns were used (classic paramedian flap, glabella flap, and central artery flap) for nasal reconstruction over the study duration.

MAIN OUTCOMES AND MEASURES Data collected included patient characteristics, method of repair, complications, functional outcome, and patient satisfaction score. For cosmetic outcome, photographic documentation was scored by a medical juror.

RESULTS No forehead flap had vascular compromise in the first stage. Partial flap necrosis was reported in subsequent stages in 4 patients (1%), with no statistical difference in the rate of vascular compromise between the 3 flap designs. Hair transposition to the nose was lower in the central artery forehead flap (7%) compared with the classic paramedian (23%) and glabellar paramedian (13%) flaps (P < .05). Photographic evaluation in 227 patients showed that brow position (98%) and color match (83%) were good in the majority of the patients.

CONCLUSIONS AND RELEVANCE In this series, the central artery forehead flap was as reliable (in terms of vascularity) as the glabellar and classic paramedian forehead flap. Its use resulted in a statistically significant reduction in transfer of hair to the nose in our series.

LEVEL OF EVIDENCE 3.
Nonmelanoma skin cancer (NMSC) is the most common malignant condition in the white population, with basal cell carcinoma (BCC) representing 75% and squamous cell carcinoma (SCC) 20% of all skin cancer cases. In our series of more than 2000 facial skin tumors, the nose has been affected in approximately 50% of the cases.

By far, the most common method to resurface middle to large nasal defects (>1.5 cm) is the forehead flap. It provides excellent color and texture match with acceptable donor site morbidity. The extremely robust blood supply supports a variety of flap and pedicle designs. The paramedian flap design has been advocated by D. Ralph Millard Jr, MD, Gary Burtget, MD, and Frederick J. Menick, MD. This pedicle design has become the dominant forehead flap geometry for nasal reconstruction. In our experience, a large proportion (23%) of nasal reconstructions using the classic paramedian forehead flap resulted in transfer of scalp hair to the nose.

To overcome this problem, adaptations to the design were initiated to achieve more effective length for nasal reconstruction (to reduce hair transposition) while maintaining the robustness of the vascular supply. The pedicle design evolved over a 20-year period through 2 adaptations, the glabellar paramedian flap and finally the central artery forehead flap. This retrospective case series primarily analyzes the vascularity (flap necrosis rate) and hair transfer rate of the 3 forehead flap pedicle designs used for complex nasal reconstruction. Secondary outcomes of cosmesis of reconstruction and complications are also reported.

Numerous previous studies have analyzed the blood supply to the paramedian forehead region. The supratrochlear artery has reliably been shown to exit the superomedial orbit 1.7 to 2.2 cm from the midline to supply the paramedian forehead region.

Few studies have focused on the clarification of the vascular supply to the central forehead region because of the incorrect assumption that the central forehead is supplied entirely by random pattern tributaries of the supratrochlear arteries. In 1985, McCarthy et al performed injections of the facial artery after ligation of the supraorbital and supratrochlear arteries. They demonstrated filling of axial vessels in the central forehead, sufficient enough to enable vertically oriented flaps in this location. These feeding vessels were termed the dorsal nasal arteries and were thought to be terminal branches of the facial artery. In 2000, Vural et al examined the central forehead with Doppler imaging and correlated the glabellar frown line (approximately 9 mm from midline) with an axial vessel thought by the authors to be the supratrochlear artery. In 2007, Kleintjes et al performed one of the most extensive cadaver studies to date on the central forehead vascular supply in 60 hemiheads. They again confirmed that the paramedian forehead is supplied by the supratrochlear artery 5 mm medial or lateral to the medial canthal line. In addition, they showed the central forehead and glabella region was supplied by additional axial vessels placed more medial to the supratrochlear artery termed the central and paracentral artery (Figure 1).

A further study has also supported this axial nature of the vascular supply to the central forehead. Reece et al studied 5 fresh cadaver heads with computed tomographic angiography. A careful analysis of the computed tomographic angiographic pictures shows that these branches (termed the nasal dorsal artery) are identical to the central artery as described by Kleintjes et al.

These studies clearly prove an axial nature of the vascular supply of the central forehead separate to the supratrochlear artery and have supported our progressive shift to more medial forehead pedicle designs.

Methods

This study does not fall within the scope of the Medical Research Involving Humans Subjects Act (WMO), which means that it does not have to be reviewed by an accredited medical ethics committee. This retrospective study included a consecutive series of patients undergoing nasal reconstruction using a forehead flap over a 20-year period. The data of patients with forehead flaps was retrieved from computerized...
files generated at the time of operation and supplemented by a retrospective review of patient medical records. Only primary forehead flaps were included. Data collected included patient characteristics (eg, etiology of defect, location of defect), method of repair, functional and cosmetic outcomes, and a patient satisfaction score. With regard to complications, we categorized infection and postoperative bleeding as minor complications, while flap necrosis, alar notching, and complete nasal obstruction were considered as major complications. For evaluating cosmetic outcome, only patients with photographic documentation and follow-up of 3 months or longer were included and evaluated by a different observer (P.v.d.E.). The photographs were evaluated for brow position, tip position, alar retraction, and flap color match.

Statistical analysis involved investigation of sample characteristics of the patients in the 3 treatment conditions using Pearson χ² test of independence. Flap necrosis and cosmetic outcome (brow position or color match) were analyzed using the Fisher exact test. Comparisons of hair transposition rates were analyzed with a z test of proportions.

**Surgical Techniques**

The forehead flap is usually a 2- or 3-stage procedure. The nasal aesthetic subunits are first drawn directly onto the nose before injection, with a mixture of local anesthesia (lidocaine hydrochloride, 1%, and bupivacaine hydrochloride, 0.5%, with 1:100 000 epinephrine).

The 3 types of forehead flap geometries have similar pedicle dimensions, pivot point, and skin paddle orientation:

- **Pedicle Dimensions**: The pedicle dimensions are maintain at 1.2 to 1.5 cm; a wider pedicle carries an increased risk of pedicle kinking and vascular compromise.

- **Pivot Point**: Pivot point is set at or below the orbital rim by precise preoperative flap measuring. Placing the pivot point at or below the orbital rim maximizes flap length and improves pedicle geometry, reducing the risk of pedicle kinking and vascular compromise.

- **Skin Paddle Orientation**: We favor a vertical skin paddle over the lower and mid-forehead to avoid the risk of elevation of the eyebrow on forehead donor site closure.

**Pedicle Location**

Pedicle location has migrated progressively medially over the years from paramedian to glabellar crease to the most recent design, the central artery flap.

**Figure 2. The 3 Forehead Flap Designs (Classic, Glabella, Central Artery)**

A. Glabellar paramedian design on the right side and classic paramedian design on the left side of a patient. B. Central artery design in the central forehead and classic paramedian design on the left side of a patient. Note this shows the central artery flap pedicle tracing toward the medial canthus. The distal portions of the flap are oriented such that the widow’s peak does not shorten the flap.

- **The Classic Paramedian Forehead Flap**: The entire vertical axis of the flap is located in a paramedian position, centered over the supratrochlear artery, 17 to 22 mm from the midline. The skin paddle extended vertically to the hairline (Figure 2A). The pedicle can be extended through the brow and if needed and possible, up to 5 mm below the brow line.

- **The Glabellar Paramedian Forehead Flap**: The pedicle lies over and includes the glabellar frown line (usually located approximately 9 mm from the midline) and should be wide enough to cover a minimum distance of 6 mm lateral to this line. The skin paddle abuts the midline (Figure 2A). Again the pedicle can be extended to 5 mm below the brow line. If the hairline contains a significant central widow’s peak that may result in hair transfer, the cranial few centimeters of the skin paddle can be gently offset to either side of the midline to avoid the lower hairline in the central portion of the forehead (Figure 2A).

- **The Central Artery Forehead Flap**: The skin paddle is located in the precise anatomic center of the forehead. However, the flap pedicle is more obliquely curved so the base of the flap is angled to a point on the side of the nose midway between the medial canthal area and the nasal dorsum (Figure 2B). Characteristically, the pedicle is normally extended 5 mm and if needed even lower (to prevent hair transfer), below the lowest part of the median brow on to the lateral nasal wall. If the hairline contains a significant central widow’s peak that may result in hair transfer, the cranial few centimeters of the skin paddle can be oriented such that any distal extensions of the flap (eg, columella portion) can be offset to either side of the widow’s peak. This can avoid the lower hairline in the central portion of the forehead in most cases (Figure 2B).

In the clinical case presented, the central artery flap is demonstrated in Figure 3. The right lateral wall defect is reconstructed by a typical contralateral central artery flap in combination with a septal flap and free conchal cartilage grafts.

Preoperative Doppler studies to locate the supratrochlear or central artery were not routinely performed. Elevation of the forehead flap starts in the subcutaneous plane, and selective thinning is performed in the distal 1.5 cm of the flap to match the recipient nasal skin thickness. For patients with extremely thin skin or significant small vessel risk factors, the skin can be elevated in a subgaleal plane with a planned intermediated stage for debulking. After the distal 1.5-cm portion of the flap has been raised, the subcutaneous plane, the
remaining skin paddle, and pedicle of the forehead flap are always elevated in the subgaleal plane.

Pedicle division takes place after a 3-week interval in a 2-stage approach. In a 3-stage approach, flap thinning, sculpting, and trimming, as well as additional cartilage grafting, is performed at 3 weeks. Six weeks following the first stage, the pedicle is divided. Of course, structural support and internal lining are reconstructed as required.

Results
A cohort of 300 consecutive patients from a 19-year period (1991 and 2010) underwent primary forehead flap repair of nasal defects by the senior author (H.D.V.). The mean follow-up was 24 months (range, 3-103 months). Most nasal defects were caused by an NMSC (n=288) treated with excision and histological evaluation using both Mohs and standard paraffin techniques. A total of 130 patients underwent an intermediate phase (3-stage approach) with final pedicle division at 6 weeks. In our practice this is primarily indicated in smokers (72%) and patients with diabetes. The subsite affected was consistent between the 3-flap designs: classic (n = 26 [67%]) vs glabella (n = 141 [72%]) vs central artery (n = 48 [72%]), for lower-third nasal defects.

Sample Characteristics
The first set of analyses compared the sample characteristics of patients in the 3 treatment conditions using the Pearson \( \chi^2 \) test of independence.\(^{46} \) No significant differences were found between treatment groups in the distribution of sex, vascular disease, diabetes, smoking, and nasal subunit primarily affected.

Vascularity
There were no instances of flap necrosis during the first stage of nasal reconstruction. Partial flap necrosis was reported in 1 intermediate-stage (glabella, 1 of 88) and 3 final-stage (glabella, 2 of 194; classic, 1 of 39) procedures. All patients with flap necrosis had 1 or more risk factors for necrosis (smoking and/or diabetes). To determine whether there were statistically significant differences in necrosis rates between treatment groups, the Fisher exact test was used. Pairwise comparisons were made between each treatment group. No significant differences in the incidence of second-stage vascular compromise or in final stage vascular compromise were found. Overall, the rates of necrosis were significantly higher among patients who had diabetes compared with all other cases (ie, those who did not have diabetes and those whose status was not known) (Fisher exact test, \( P = .02 \)).

Hair Transposition
There were no significant differences among groups with regard to defect location (\( \chi^2 = 0.692, \ P = .71 \)). Hair transposition to the nose was lowest in the central artery forehead flap (n = 5 [7%]) compared with the classic paramedian (n = 9 [23%]) and glabellar paramedian (n = 26 [13%]) flaps.

The geometry of the central artery flap reduces the distance to the nasal tip, as the pedicle location is medial and inferior to that of the paramedian-located pedicle. This more favorable geometry explains that the central artery flap will result in an equivalent or lower rate of hair transposition. A \( z \) test was therefore used to test the null hypothesis against a directional alternative hypothesis that the central artery forehead flap had a lower rate of hair transposition. The difference in hair transposition between the central artery and the classic paramedian was statistically significant at \( P < .05 \) (1 tailed).

Cosmetic Outcome
The cosmetic outcome could be evaluated in 227 of the patients (76%), with a minimal follow-up of 3 months. Brow position was rated as good in classic paramedian (33 of 34 [97%]), glabellar (12 of 140 [99%]), and central artery (52 of 53 [98%]). Tip position was rated as good in classic paramedian (30 of 34 [88%]), glabellar (135 of 140 [96%]), and central artery (52 of 53 [98%]). Alar retraction was rated as absent in classic paramedian (31 of 34 [91%]), glabellar (135 of 140 [96%]), and central artery (53 of 53 [100%]).

Pairwise comparisons between groups using the Fisher exact test did not find significant differences with regard to brow position or color match between the groups (\( \chi^2 = 0.914, \ P = .62 \)). Most of the patients, over 99% (297 of 300), were satisfied with their nasal appearance as recorded in the patients’ files. Four patients required unplanned thinning of the skin flap, and 1 patient received scar revision. Two patients with large, full-thickness defects needed major surgical revisions.

Complications
There was an overall 1% (4 of 300) major complication rate (flap necrosis, alar notching, and complete nasal obstruction). There
were 8 minor complications (infection and postoperative bleeding). Six patients had postoperative infections successfully treated with antibiotics. There was no significant difference in occurrence of major complications between the groups using the Fisher exact test in a pairwise manner (glabella [2 of 194] vs classic [1 of 39] vs central artery [0 of 67]). None of the pairwise comparisons attained significance at the .05 level.

Discussion

The origin of the nasal reconstruction is veiled by time but can be traced back to 1 particular text—the Sushruta Samhita (600 BC). The median flap/classic Indian forehead flap was however popularized in the United States by Blair in 1925 and Kazanjian in 1946. In the latter part of the 20th century, the paramedian forehead flap based on the supratrochlear artery (found 17-22 mm from the midline) became the dominate pedicle geometry. Burget and Menick popularized and further refined the classic paramedian forehead flap dimensions by reducing pedicle width to 12 mm. This improved mobility of the pedicle, reduced foreshortening of the flap with flap rotation, and subsequently led to an increase in effective length. Although almost all skin paddle orientations have been described, the vertical skin paddle orientation on the forehead is strongly preferred. Oblique forehead skin paddle designs, although successful, are often associated with more obvious donor scar on the forehead and an increased risk of brow asymmetry. This classic paramedian forehead flap (based on the unilateral supratrochlear vessels) had been the senior author’s initial preferred geometry. Precise preoperative measurements of required flap length are used to always set the pedicle pivot point at or up to 5 mm below the orbital rim to maximize flap length and minimize pedicle kinking. Despite this, we still observed a significant rate of hair transposition in 23% of our cases. This hair transposition was significantly troublesome for our patients with repeated laser or electrolysis treatments needed, which are frequently not covered by insurance.

Therefore, we initiated changes in pedicle location in an attempt to reduce hair transposition while still maintaining the vertical skin paddle and robust vascular supply.

Because the hairline cannot be altered and skin paddle orientation (vertical) was purposely maintained, we migrated the pedicle inferomedially to reduce the distance to the nasal tip. The senior author’s first adaption moved the pedicle medially from its lateral position centered 17 to 22 mm from the midline (classic paramedian forehead flap) to a position centered over the glabellar frown line 9 mm from the midline (the glabellar forehead flap). This was based on what was understood at the time from the anatomical studies of McCarthy et al., and later confirmed by Vural et al., that there were axial vessels medial to the understood 17- to 22-mm position of the supratrochlear artery. Despite this, modification hair transposition still occurred in 13% of our cases.

Further movement of the flap pedicle inferomedially and including an offset pedicle extended below the brow onto the lateral side wall (as in the central artery forehead) held the promise of further reductions in hair transfer. The vascular study by Kleintjes et al. clarified the more precise location and nomenclature of the axial vascular supply to the medial forehead (now termed the central artery and paracentral artery). This latter study supported us to adopt a more geometrically advantageous design by effectively tracing the central artery and paracentral artery proximally toward lateral nasal wall (Figure 2B and Figure 3B). We have termed this the central artery forehead flap. We do not suggest to have invented any new flap design. This article, however, presents a clarification or refinement of pedicle dimensions of historical flap designs (of Dieffenbach and Labat) based on recent anatomical studies.

All 3 types of forehead flaps were clinically well vascularized. Partial flap necrosis occurred in 4 patients (glabella, 2 of 194; paramedian, 1 of 39; and central artery, 0 of 67) (P > .05). The overall rate of partial necrosis (1%) compares favorably with published series reporting necrosis rates ranging from 0% to 13%.

The second question of this study explored whether the forehead flap adaptations lead to reductions in hair transposition. Although retrospective, all surgical procedures were performed by a single surgeon, where the technique of forehead flap reconstruction has changed only because of the pedicle location. The other factors—pedicle dimensions (1.2-1.5 cm), pivot point at or below the orbital rim, vertical skin paddle—have all been maintained through the 3 flap designs. When this is combined with the consistency of defect location with the highest risk for hair transfer (tip, columella,alar) of 67% (classic) vs 72% (glabella) vs 72% (central artery) between each group, we believe that one can make a useful comparison between the differing flap designs and hair transfer in this study despite its retrospective design. Hair transposition rates showed a stepwise reduction as the pedicle migrated medially and inferiorly from 23% in the classic paramedian to 13% in the glabellar flap and to 7% in the central artery forehead flap. The observed difference in hair transposition between the central artery and the classic paramedian was statistically significant at P < .05 (1 tailed). This observed difference may be secondary to a geometric advantage of the central artery forehead flap over a classic paramedian forehead flap.

The proximal pedicle of the central artery forehead flap extends below the brow, thus lowering the pivot point of the flap and effectively lengthening the flap. For every 5 mm the pedicle is extended below the brow, a gain of 10 mm in effective length results (5 mm from increased length and 5 mm from the lowered pivot point) (Figure 1 and Figure 2). We also similarly extend the pedicle of the classic paramedian forehead flap below the brow when required for up to 5 mm, also in an attempt to gain more length. However, despite this maneuver the pivot point remains at the orbital rim, as this is the point of exit of the supratrochlear artery. With the pivot point fixed, any 5-mm increase in flap length will lead to a corresponding 5-mm gain in effective length only; no additional gain in length is observed because the pivot point is fixed.

Pythagoras theorem may also help explain some of the observed differences in hair transposition. The pedicle of the central artery flap can be manipulated if required so that its pivot point is vertically above a nasal tip defect. This allows the short-
The many faces of squamous cell carcinoma.

While maintaining the other previously discussed advantages, this did not induce any vascular compromise. With no significant difference observed in brow position between the 3 pedicle locations in our series, these minor adaptations when necessary did not seem to harbor the same degree of risk of deleterious elevation of the eyebrow (frequently encountered with oblique forehead flap designs).

In our more recent experience, we have begun to extend this incision to 10 mm below the brow without any instances of flap loss. However, we believe that the transposed flaps seem to need more time to recover from the vasoconstrictive effect of the epinephrine before showing good color and refill. However, the 10-mm extension below the brow may now possibly produce 20 mm of increased effective length of the flap (by lowering the pivot point), which may in the future be able to address the problem of hair transfer in patients with a low forehead. Kishi et al used a similar midline flap design based solely on the angular artery and its terminal branches with division of the supratrochlear artery in the orbit. They reported a series of 5 patients in whom the pedicle was extended onto the nasal sill and past the level of the medial canthus without any incidence of vascular compromise. This study supports the extension pedicle of midline forehead flaps based on the central artery and angular artery below the brow and onto the lateral nasal side wall by more than 10 mm. However, due to the limited number of patients in this study, it is our current belief that pedicle extension more than 10 mm below the brow should still be considered experimental.

Conclusions

In one of the largest reported series of forehead flaps for nasal reconstruction in the literature, we have found that the central artery forehead flap design was as reliable as the glabellar and classic paramedian forehead flap. In our experience it resulted in statistically significantly lower rates of transfer of hair to the nose; however, further clinical studies are required to confirm this effect.