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Broadening applications and insights into the cross-paramedian forehead flap over a 19-year period

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Summary *Background:* Forehead flap reconstruction of large nasal defects can be challenging. The senior author has used a paramedian forehead flap modification using the supratrochlear artery on the contralateral side of the defect.
Methods: A 9-year retrospective review (2008–2016) was performed for patients undergoing nasal reconstruction with the cross-paramedian forehead flap. Outcomes were analyzed by comparing our previous reviews, which allows us to analyze patient outcomes for over 19 years.
Results: Fifty-three patients were identified. The aasal defect was most frequently due to basal cell carcinoma (n = 37, 69.8%). Twenty-three (43%) patients were smokers, and nine (17%) had diabetes. The mean defect size was 12.9 cm^2, involving an average of 2.6 nasal subunits. One-third of the patients had cartilage defects (n = 18) and mucosal lining defects (n = 19). Periorbital involvement was present in five patients. Complications included partial flap loss (n = 6), donor site dehiscence (n = 4), flap dehiscence (n = 2), and postoperative infection (n = 1). Only two of the partial flap losses were considered significant, as they required additional reconstructive procedures for soft tissue coverage. Complications were 12 times as likely as those in diabetes (OR = 11.97, p = 0.007, 95% CI 1.94–72.44), six times as likely as those in cartilage defects (OR = 6.4, p = 0.007, 95% CI 1.64–24.92), and nearly five times as likely as those in mucosal lining defects (OR = 4.8, p = 1.27–18.09, 95% CI 1.27–18.09). Thirty-one patients required revisions most commonly for flap debulking (n = 16).
Conclusion: The cross-paramedian forehead flap is a reliable option in the armamentarium of the reconstructive surgeon for large and complex defects in addition to those with periorbital extension.
Summary: Coverage of distal nasal defects after tumor extirpation remains a challenge to the reconstructive surgeon. Our institution uses the cross-paramedian forehead flap for these

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defects. This flap is based on the supratrochlear artery on the contralateral side of the defect and is oriented obliquely across the forehead for additional length and an improved donor site scar at the level of the eyebrow. The technique and outcomes were published in 2009, and this manuscript serves as an update on outcomes and applications during the past 9 years. By including all our data, we can analyze outcomes for over 19 years. During the past 9 years, 53 patients underwent the cross-paramedian forehead flap technique between 2008 and 2016. These patients were found to have an average defect size of 12.9 cm^2 and an average loss of 2.6 nasal subunits. Cartilage defects were present in 34.6% ($n = 18$) and mucosal defects were present in 36.5% ($n = 19$) of patients. Five patients had periorbital reconstruction with the forehead flap, of which three patients underwent a single-stage islandized forehead flap reconstruction. Given the large defect size, additional local flaps were frequently used, including nasolabial flaps ($n = 16$) and cheek rearrangement ($n = 11$). Complications included partial flap loss ($n = 6$), donor site dehiscence ($n = 4$), and postoperative infection ($n = 1$). Only two of these partial flap losses were considered significant, as they required additional reconstructive procedures to address areas of soft tissue loss. Increased rates of complications were associated with the presence of diabetes and defect characteristics, which reflects increased complexity including mucosal and cartilage loss. When comparing with our prior review of this technique, the more recent population have had increasing complexity of the nasal defects with a large surface area involvement. Overall, the cross-paramedian forehead flap is a reliable option in the armamentarium of the reconstructive surgeon for large and distal nasal defects.
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Introduction

The paramedian forehead flap has gained popularity in the reconstruction of nasal defects greater than 2 cm because of its reliability and tissue similarities to the nasal skin. It is an axial flap with the pedicle based on the supratrochlear artery. Most commonly, the supratrochlear artery on the same side of the defect is used. This can be problematic when attempting to cover distal nasal defects because of the difficult arch of rotation, which results in an unsightly triangular-shaped scar just superior to the brow, and it often requires inclusion of the hair-bearing tissue, particularly in patients with low hairlines. Attempts to alter the traditional design to attain flap length can be traced back over nearly a century. Starting in the 1920s, contemporaries of Kazanjian began to orient their flap obliquely and horizontally both for greater length and to fold the flap to reconstruct the nasal lining.[1] At the same time, Gilles created the "*U*"-shaped flap, in which the ascending component was based on the ipsilateral supratrochlear artery and the descending arm was based on the contralateral supratrochlear artery.[2] While this later flap design fell from favor because of its donor site morbidity, it displayed early attempts to overcome the shortcomings of the traditional design.

The forehead is supplied by a rich vascular network, which involves the dorsal nasal, supratrochlear, supraorbital, and superficial temporal arteries.[3] While there are dominant vascular supplies to each specific region of the forehead, there is a rich anastomotic network between these arteries.[3] This robust blood supply to the skin territory allows for modification in flap design.

Given the need for more reliable coverage of large and distal nasal defects and the rich vascular network of the forehead, the senior author has adopted the cross-paramedian forehead flap in practice. As described in our institution's previous paper, the cross-paramedian design uses the contralateral supratrochlear artery and is oriented more obliquely across the forehead with extension along the inferior hairline (Figure 1).[4] This extension provides additional flap length without involving the hair-bearing scalp. This design also offers an improved arc of rotation, which allows a thinner pedicle to be designed, and, consequently, a shorter and more aesthetic donor site scar, which can be concealed in a glabellar crease. This paper serves as a follow-up to this institution's 2009 review of the cross-paramedian technique to assess broadening applications and outcomes of the flap during an additional 9 years in comparison to our initial experiences with this flap.

Methods

We performed a 9-year retrospective review of the cross-paramedian forehead flap at Plastic Surgery Department, Wake Forest Baptist Medical Center, between 2008 and 2016. Current procedural terminology (CPT) codes specific for paramedian forehead flaps were collected through the I2B2 database for patients enrolled at our institution from 2008 to 2016. Fifty-three patients who underwent a cross-paramedian forehead flap were identified. Patient demographics, comorbidities, cause of the nasal defect, nasal defect characteristics, procedures, number of revisions, and outcomes were assessed. Standard univariate statistical analysis and chi-square tests were performed on nasal defect characteristics, comorbidities, and complications. These data were then compared to the data in our existing patient database from our previous retrospective review conducted from 1996 to 2007, allowing us to analyze a total of 147 patients who had cross-paramedian flaps during the last 19 years.

While our surgical approach was described in the initial paper, we will review this and our more recent flap

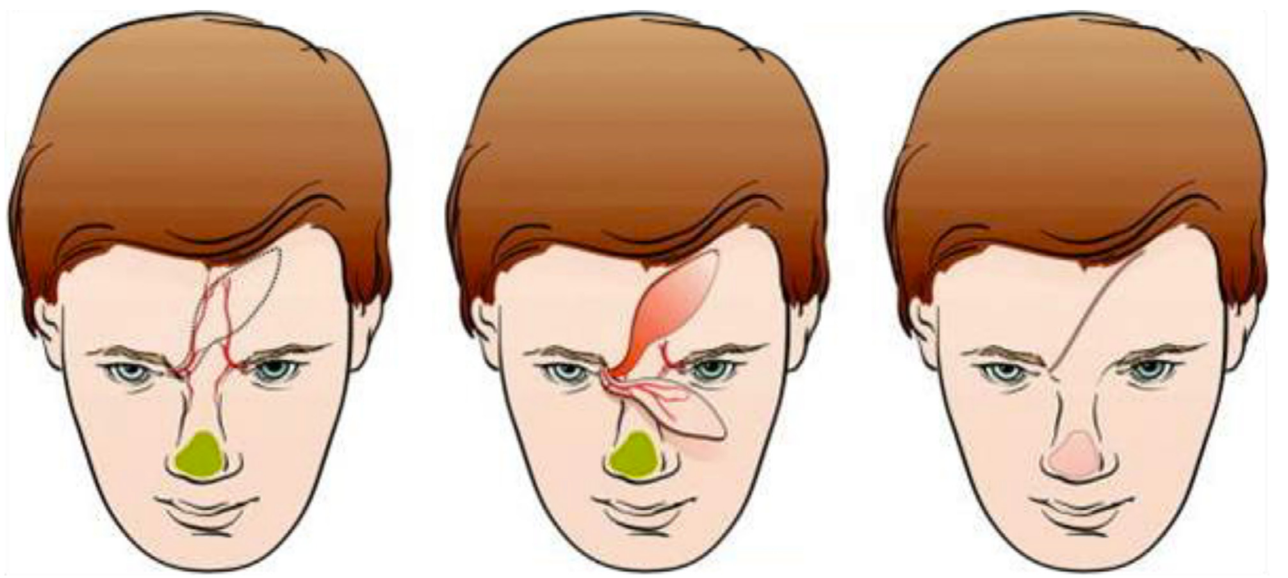

Figure 1 This illustration demonstrates the phases of cross-paramedian forehead flap reconstruction, including flap design, flap delay, and pedicle division. This is an axial flap based on the supratrochlear artery contralateral to the side of the nasal defect, and it can be oriented obliquely across the forehead for additional flap length. During pedicle division, the caudal aspect of the flap is excised, creating a linear scar within a glabellar rhytid.

modifications in this paper. A template of the nasal wound is made to approximate flap dimensions and rotated into the defect to ensure an appropriate arc of rotation. The flap is designed with an oblique tilt. The majority of the flap is ipsilateral to the pedicle, but the distal aspect is across the midline. The greater the length required, the more oblique the flap will be oriented with the option to extend the flap along the inferior hairline. The flap is dissected in the subgaleal plane from the level of the hairline toward the brow. Given the subgaleal plane, the frontalis muscle is included in the flap. If it is felt that the frontalis is contributing to excessive bulkiness of the flap, the muscle can be thinned and it can be excised entirely if there is robust bleeding to the distal aspect of the skin flap. The periosteum is incised approximately 1.5 cm above the orbit, and the dissection is deepened to the subperiosteal plane. The skin bridge of the pedicle just superior to the eyebrow is narrowed to 3–4 mm and skin flaps are raised medially and laterally just deep to the dermis, thereby preserving the subcutaneous tissues carrying the supratrochlear vessels. The underlying subcutaneous pedicle is incised at the same width as the rest of the pedicle not to disrupt the vascular pedicle. We design a narrow skin bridge so that the pedicle can be excised at the time of inset. The resulting wound at inset is closed primarily with a linear scar in the glabellar crease. This avoids a triangular flap having to be rotated upwards on the lower forehead. Only enough skin is maintained on the pedicle to facilitate dressing changes postoperatively. The flap is then rotated into the defect, and the donor site is closed primarily (Figure 2).

The second stage of flap division and inset is done at 3 weeks. The pedicle is transected, and the forehead defect is closed primarily in a glabellar crease. At this stage, a marginal amount of flap thinning is performed to ensure that flap thickness is similar to that of the surrounding skin. The flap is then inset into the nasal defect. Postoperatively, if the patients developed pin cushioning, kenalog injections are performed. If this did not improve, injections were repeated monthly until improvement was noted for up to three total injections. Once postoperative swelling of the flap had resolved, its bulk and appearance were assessed and subsequent surgical refinements were performed, if necessary.

Results

Of the 53 new patients identified, there were 37 males and 16 females. Mean age was 68 years (range 40–91 years), with a mean follow-up time of 13.3 months. All patients had nasal defects secondary to tumor extirpation. The most common diagnosis was basal cell carcinoma ($n = 37$, 69.8%), followed by squamous cell carcinoma ($n = 10$, 18.8%), melanoma ($n = 4$, 7.5%), atypical fibroxanthoma ($n = 1$, 1.8%), and angiosarcoma ($n = 1$, 1.8%). Seven patients (13.2%) had recurrent skin cancer of the nose. Within the patient population, 43% ($n = 23$) were active smokers, and 17% ($n = 9$) had diabetes (Table 1).

In terms of characterizing the nasal defects, the mean size was 12.9 cm^2 (range 2–55 cm^2). Data of defect size were not available in seven patients. Of the patients with available defect sizes, approximately one-half had defects less than 10.9 cm^2 ($n = 24$) and one-half had defects greater than 11 cm^2 ($n = 22$). On average, a total of 2.6 nasal subunits were resected during tumor extirpation. The nasal ala and sidewall were most frequently affected, including 32 (24.2%) nasal alae defects and 32 (24.2%) nasal sidewall defects. This was followed by defects of the nasal dorsum ($n = 26$, 19.6%), nasal tip ($n = 25$, 18.9%), soft tissue triangle ($n = 11$, 8.3%), columella ($n = 3$, 2.2%), and radix ($n = 3$, 2.2%). Two patients had subtotal rhinectomies, and three patients had hemi-rhinectomies following Mohs exci-

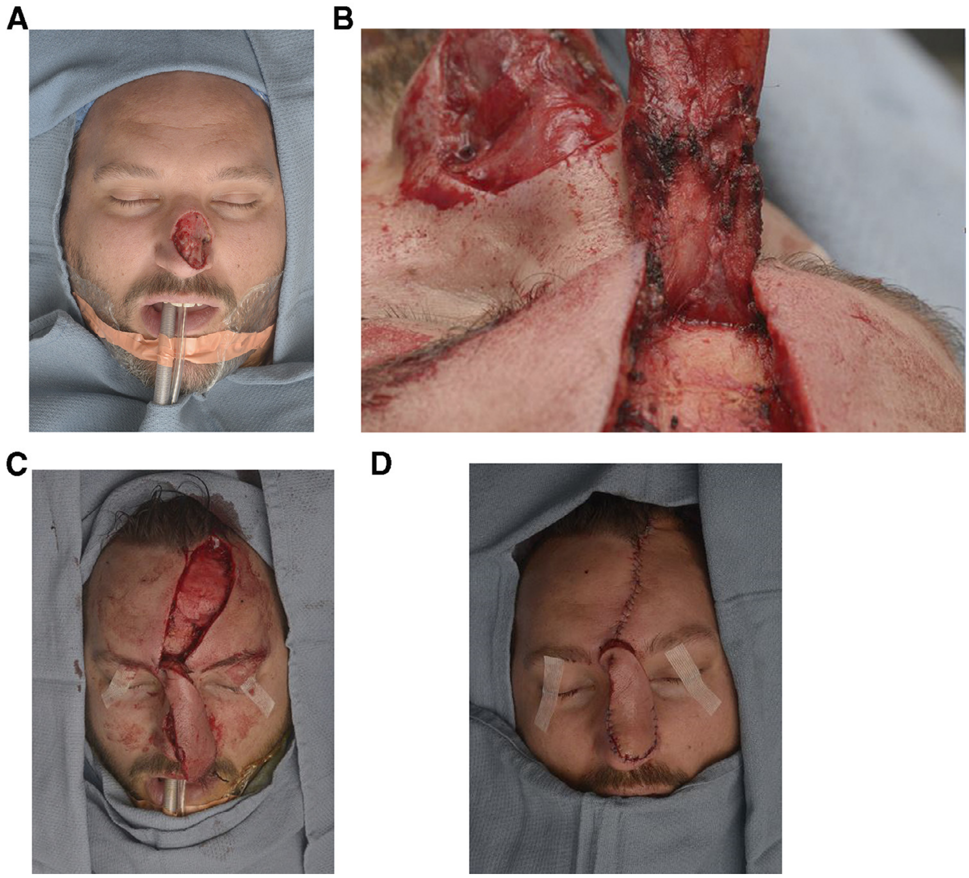

Figure 2 (A-D): A 42-year-old male with a past medical history of diabetes, who presented following Mohs excision basal cell carcinoma involving the nasal dorsum, left nasal sidewall, and left ala (A). Cross-paramedian forehead flap elevation was performed, and the subgaleal plane of dissection as it approaches the brow is demonstrated (B). The flap is designed obliquely across the forehead and is based on the supratrochlear artery on the contralateral side of the defect (C). The narrow skin bridge at the level of the brow is designed so that the pedicle can be excised at the time of inset with a residual linear glabellar scar (D).

sion. Positive margins involving the bone were present in five patients, which necessitate nasal floor resection ($n = 1$), partial septal excision ($n = 1$), and local bone excision or burring ($n = 3$). The defect involved the periorbital area in five patients. T of these involved the lower lid, three cases involving the medial canthus and one case had involvement of both. Three patients had an islandized forehead flap in which the pedicle was tunneled subcutaneously and therefore did not require a second stage for pedicle division (Table 2).

The defect involved the cartilage in 34% of patients ($n = 18$), eight of which required cartilage grafts. There were mucosal lining defects in 36% of patients ($n = 19$), with four patients requiring multiple flaps for lining reconstruction. Mucosal defects were most frequently reconstructed with nasolabial flaps ($n = 9$), followed by an extension of the forehead flap ($n = 5$), septal mucosal hinge flaps ($n = 4$), cheek musculocutaneous turnover or advancement flaps ($n = 3$), and full-thickness skin graft ($n = 1$) (Figure 3). Given the large mean defect size, 30.1% of patients required nasolabial flaps and 20.7% required cheek tissue rearrangement in addition to the cross-paramedian flap for skin coverage.

Following stage 1 of flap inset, two patients (3.7%) developed flap dehiscence. With the exception of one patient, all forehead donor sites were closed primarily. The donor site of one patient could not be closed primarily and required Integra and split-thickness skin graft placement in a staged fashion. Four patients (7.4%) had donor site dehiscence or wound breakdown, one of which required full-thickness skin graft to the donor site wound. One patient developed a postoperative infection, which was defined as postoperative hospital admission requiring IV antibiotics.

Partial flap loss developed in 11% ($n = 6$) of patients. Upon further analysis of these cases, it was found that the majority of cases were in the setting of high-risk medical comorbidities or increased surgical complexity. Of the six patients, only one patient was a non-smoker as three were current smokers and two were former smokers. Two of these patients had recurrent skin cancer of the nose. The average defect size was 15.26 cm^2, and although one patient did not have a recorded size, they were described as having a hemi-rhinectomy following Mohs surgery. The extent of flap loss was categorized on the basis of its required treatment. Four of these patients were considered to have minor flap loss, as two were treated

Figure 3 (A-F): A 77-year-old male with chronic lymphocytic leukemia, diabetes, and chewing tobacco use, who presents following Mohs excision squamous cell carcinoma of the nose involving the nasal dorsum, tip, and bilateral sidewalls. There was a cartilaginous defect at the tip and mucosal lining defects on bilateral nasal sidewalls (A–C). The cutaneous defect was reconstructed with a cross-paramedian forehead flap that was based on the left supratrochlear artery. The mucosa was reconstructed with a left mucoperichondrial flap and a right nasolabial turnover flap. A cartilage graft from the left conchal bowl was performed for the nasal tip. Given the size of the defect, the donor site on the forehead could not be closed and integra was placed over the defect. The flap was divided, and, inset, 4 weeks later, and a split-thickness skin graft was placed on the residual open donor site. The postoperative course was uneventful. These photographs were taken 4 months after flap division (D–F).

with wound care alone, whereas two patients required debridement of the distal tip of the flap during the second-stage procedure. The two remaining patients were considered to have more significant flap loss, with resultant defects requiring additional reconstruction including staged Integra and skin graft in one patient and a conchal bowl composite graft in another patient. No patients progressed to total flap loss. Whether flap loss was due to arterial or venous insufficiency was unclear, as the flap necrosis was observed on an outpatient basis between 1 and 3 weeks postoperatively; as such, the areas of flap necrosis were typically well demarcated by the time they appeared in clinic.

Revision rate was 58% ($n = 31$) following division and inset. Most frequently, this was required for flap debulking in 16 patients and scar revision in 8 patients. Eight patients with cartilage defects who did not have a cartilage graft placed during stage 1 required subsequent cartilage grafting. For flap pin cushioning, 41% of patients required postoperative kenalog injections with an average of 2.5 injections.

On further analysis of complications, it was found that patients with comorbid conditions and more complex defects were at increased risk of flap complications. Overall complications were more than 11 times as likely as those occurring if the patient had diabetes (OR = 11.97,

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Table 1 Patient demographics: demographic information about patients for the last 9 years.

Patient demographics 2008–2016	
No. of patients	53
Average age (range), y	68 (40–91)
Gender	
Female, *n*	16
Male, *n*	37
Comorbid conditions	
Diabetes, *n*	9
Hypertension, *n*	24
Coronary artery disease, *n*	11
Hyperlipidemia, *n*	14
Smoking, *n*	23
Recurrent skin cancer, *n*	7
Etiology of nasal defect	
Basal cell carcinoma, *n* (%)	37/53 (69.8%)
Squamous cell carcinoma, *n* (%)	10/53 (18.8%)
Melanoma, *n* (%)	4/53 (7.5%)
Atypical fibroxanthoma, *n* (%)	1/53 (1.8%)
Angiosarcoma, *n* (%)	1/53 (1.8%)

Table 2 Nasal defect characteristics: nasal defect size data were available for 46 patients, and the average size was 12.9 cm^2. The defects most commonly involved the ala and nasal sidewall.

Nasal defect characteristics 2008–2016	
Average surface area of defect	12.9 cm^2
Defect size	
1–10.9 cm^2, *n*	24
11–20.9 cm^2, *n*	13
21–30.9 cm^2, *n*	6
Greater than 31 cm^2, *n*	3
Average number of subunits involved	2.6
Total number of nasal subunits involved	132
Ala, *n* (%)	32/132 (24.2%)
Sidewall, *n* (%)	32/132 (24.2%)
Dorsum, *n* (%)	26/132 (19.6%)
Tip, *n* (%)	25/132 (18.9%)
Soft tissue triangle, *n* (%)	11/132 (8.3%)
Columella, *n* (%)	3/132 (2.2%)
Radix, *n* (%)	3/132 (2.2%)
Bone involvement, *n* (%)	5/53 (9.4%)
Periorbital involvement, *n* (%)	5/53 (9.4%)
Cartilage involvement, *n* (%)	18/53 (34%)
Mucosal involvement, *n* (%)	19/53 (36%)

$p = 0.007$, 95% CI 1.94–72.44). A larger average defect size of 14.9 cm^2 was found in those patients who developed complications in comparison to the average defect size of 11.7 cm^2 in those who did not. Patients were more than six times likely to develop complications if they had cartilage defects (OR = 6.4, $p = 0.007$, 95% CI 1.64–24.92) and nearly five times as likely to develop a complication with mucosal lining defects (OR = 4.8, $p = 1.27$–18.09, 95% CI 1.27–18.09).

When combining our more recent data with the data of our prior analysis, a total of 19 years of experience with the cross-paramedian forehead flaps including 147 patients was reviewed. Of these patients, there was a 2% ($n = 3$) flap incisional dehiscence rate and 3.4% ($n = 5$) donor site dehiscence rate. There were no cases of total flap loss, but partial flap loss developed in 7.4% ($n = 11$) of patients. Furthermore, postoperative infection developed in 2% ($n = 3$) and airway obstruction in 6.8% ($n = 10$) (Table 3).

Table 3 Complication rates: total complication rates for the total population of 147 patients over the last 19 years.

Total complication rates for 147 patients	
Partial flap loss	11
Airway obstruction	10
Donor site dehiscence	5
Recipient site dehiscence rate	3
Infection	3
Total flap loss	0

Discussion

The paramedian forehead flap remains the primary technique for the reconstruction of large nasal defects. Although there have been many refinements in the surgical technique described, the senior author has favored the use of the cross-paramedian approach during the past 19 years.[5-9] Experience has shown that this technique offers both functional and esthetic advantages. Extending the flap along the inferior hairling provides additional length and avoids hair-bearing scalp tissue. The linear division of the pedicle allows the forehead scar to hide in a glabellar crease and avoids the unsightly triangular-shaped scar frequently used in the traditional paramedian flap.

On reviewing our results during the past 9 years in comparison to our prior review, we have discovered several changes in the use of this flap. First, we have seen a progression toward more complex nasal defects requiring reconstruction. The increasing defect complexity is likely secondary to the improved reconstructive capabilities of the Mohs surgeons, who serve as our referral base with plastic surgery consultation reserved for more challenging cases. With more experience, the referring physicians frequently reconstruct their own nasal defects by performing forehead flaps, cartilage grafts, and minor mucosal reconstruction. In general, our practice will only receive consultation for patients in the setting of extensive mucosal involvement, extensive cartilage involvement, and/or hemi-rhinectomy. In comparison to our previous study, patients, during the past 9 years, have had defects involving more nasal subunits (2.6 vs. 1.6 nasal subunits), more mucosal defects (36% vs. 22%), and more cartilaginous defects (34% vs. 17%) (Table 4). Furthermore, our more recent patient population was two and a half times more likely to have cartilage involvement (OR 2.5, $p = 0.02$, 95% CI 1.14–5.48). The large average defect size of 12.9 cm^2 has necessitated additional local flaps to

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Table 4 Comparison of nasal defects: nasal defects in patients from our prior review (1996-2007) were compared with those of our more recent patient population (2008-2016). With progression of time, the defects have become more complex, including more subunits in addition to more cartilage and nasal lining defects.

Comparison of nasal defects		
	1996-2007	2008-2016
Average number of subunits involved	1.6	2.6
Percentage of cartilage defects	16% (16/94)	34% (18/53)
Percentage of nasal lining defects	22% (21/94)	36% (19/53)

avoid tissue expansion and included nasolabial flaps in 30.1% and cheek advancement flaps in 20.7% of patients.

The cross-paramedian forehead flap may also serve to reconstruct periorbital defects. The contralateral position provides a more favorable arc of rotation into defects of the medial canthus or lower lid. This is particularly useful in patients with nasal dorsum or sidewall defects, which are contiguous with periorbital defects as the cross-paramedian forehead flap can be used to reconstruct both subunits. In our review, five patients successfully underwent periorbital reconstruction. In the setting of these defects, we found that limited flap length was required, and thus, the orientation can be linear rather than oblique. Three of these patients had a single-stage islandized cross-paramedian forehead flap, in which the supratrochlear pedicle was de-epithelialized and tunneled to the contralateral defect. While delayed and tunneled paramedian forehead flaps for periorbital defects have been described in the literature, the success of the cross-paramedian forehead flap for this purpose has not been previously analyzed.[9,10]

New challenges have also been encountered during this study period. We have found increased rates of distal flap necrosis during our more recent review in comparison to our initial publication. In our more recent review, we determined there to be 11% ($n = 6$) of patients with partial flap loss in comparison to 3% ($n = 3$) partial flap loss previously. However, when analyzing the treatment of the flap loss, only two patients had flap loss significant enough to require additional reconstructive procedures. The remaining patients only required wound care or distal flap debridement at stage 2. Furthermore, these patients were at high risk for complications, as three were active smokers and two were former heavy smokers. The nasal defect also put these patients at increased risk, with an average surface area of 15.26 cm^2, and five patients had cartilage and mucosal lining defects, respectively. Comparing the outcomes of our technique with those of the traditional paramedian forehead flap is challenging. Most of the plastic surgery literature on the paramedian forehead flap is based on technique description rather than outcome. However, of the limited number of articles discussing outcomes, the rates of flap loss are 1.4-6%.[11-13] With regard to nasal defects, these articles do not document the surface area that the defect involves, and given the large size of the defects in our population, it is difficult to conclude whether the outcomes can be clearly compared.

Regarding postoperative revision procedures, the more recent patient population underwent a slight increase in the subsequent revision procedure rate of 58% ($n = 31$) in comparison to that of 50% ($n = 47$) in our prior review. The majority of revision procedures were performed for flap debulking ($n = 16$) followed by scar revision ($n = 8$) and cartilage grafting ($n = 8$). We attributed this increased rate of revisions to the increase in size and complexity of the defects reconstructed. The high rates of revision for flap debulking are also likely secondary to the utilization of a two-stage rather than a three-stage procedure. As such, there is only a limited amount of flap thinning, which can be performed during division and inset to avoid flap necrosis.

Understandably, concerns have been raised about the use of the cross-paramedian forehead flap technique in high-risk patients given the potential need for bilateral forehead flaps in patients with cancer recurrence or flap failure.[5] The concern is that in performing bilateral cross-paramedian flaps, the blood supply to the distal portion would encounter the scar from the previous flap and become random rather than axial, leading to increased rates of distal flap failure. A cadaveric vascular study by Reece et al. has shown that the subdermal plexus supplies the distal flap rather than the supratrochlear artery.[14] Once the flap crosses the midline, it becomes a random flap rather than an axial flap. Consideration can be given to delay the random cross-midline portion of the flap if a large enough flap is required. We have not found this necessary in our group of patients to date.

Conclusion

The cross-paramedian forehead flap modification remains a reliable surgical technique that our institution has utilized for over 19 years. This technique offers functional and aesthetic benefits in comparison to the traditional flap design. It offers additional length with an oblique pedicle design that can extend along the inferior hairline and a well-hidden linear forehead scar within a glabellar crease. This flap can be used in large and complex defects.

Conflict of interest statement

None of the authors have any conflicts of interest to disclose.

Financial disclosures

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