Microvascular Repair of Heminasal, Subtotal, and Total Nasal Defects with a Folded Radial Forearm Flap and a Full-Thickness Forehead Flap

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Background: The site, size, and depth of tissue loss, irradiation, or composite injury to adjacent cheek and lip may make local tissues inadequate or unavailable for the repair of major nasal defects.

Methods: In 13 patients, a single, folded, horizontal radial forearm flap was used to line the vault and columella, with an incontinuity fasciocutaneous extension to resurface the nasal floor, with or without primary dorsal support. Later, excess external forearm skin was turned over to adjust the nostril margin and alar base positions. Delayed primary cartilage grafts completed subunit support. A three-stage full-thickness forehead flap provided covering skin. Three-dimensional contouring of the midlayer framework was performed over the entire nasal surface, during an intermediate operation, before pedicle division.

Results: Good to excellent aesthetic and functional results were obtained in total and subtotal defects in five operations over 8 months, including a late revision. Partial necrosis of the folded columellar lining (n = 2) and dehiscence of unilateral alar lining (n = 1) were salvaged at forehead flap transfer by hinging over excess external forearm skin (n = 2) or by folding the extension of the forehead flap for columellar lining (n = 1). Indolent cartilage infection necessitated débridement (n = 4) and partial support replacement (n = 3). No free flaps were lost or required to salvage a complication.

Conclusions: The approach is reliable, efficient, and applicable to varied defects and has the ability to correct design errors and complications before pedicle division. An unscarred lining sleeve, defined three-dimensional contour, and thin conforming skin cover are restored. (Plast. Reconstr. Surg. 127: 637, 2011.)

The site, size, and depth of tissue loss, irradiation of residual tissues, or a composite injury to the adjacent cheek and lip may make local tissues inadequate or unavailable for nasal repair. A regional forehead flap can provide covering skin, but distant tissue, transferred as a microvascular flap, will be required to line the nose.

Despite Gillies and Millard’s admonition to employ “like” tissue, distant skin for lining, bulky rib grafts for support, or a thick, flat forehead flap for external cover is “unlike” the normal. These disparate donor materials must be modified into “nasal-like tissues” and integrated together to restore each anatomic layer and, ultimately, a normal-looking and functioning nose. We present our experience using a single folded radial forearm flap to line the nasal vault, columella, and nasal floor, staged subunit support for contour, and a three-stage full-thickness forehead flap for cover.

The approach is applicable to varied defects. It establishes a seamless, unscarred, and vascularized lining sleeve. During subsequent stages, a temporary external excess of folded forearm skin is available to correct imperfections, errors in design, or significant complications. Early dorsal and later-staged subunit support grafts establish an ideal midlayer framework, which is aesthetically modified, over the entire nasal surface during the intermediate sculpting operation of a three-stage full-thickness forehead flap, before pedicle division. Vascular supple lining, a contoured midlayer support framework, and thin conforming skin flap to line the nasal vault, columella, and nasal floor, staged subunit support for contour, and a three-stage full-thickness forehead flap for cover.
cover are restored, successfully repairing these complex defects.

**PATIENTS**

Between 2004 and 2009, complex injuries were presented due to cancer (six cases), trauma (two cases), cocaine abuse (three cases), congenital deformity (one case), or infection (two cases). Defects included total (five cases), subtotal (six cases), and heminasal (one case) defects and an intranasal lining defect with an associated full-thickness columellar (one case) loss.

Four patients presented with failed forehead flap reconstructions, lined with skin grafts, nasolabial flaps, intranasal lining flaps, or a three-paddle radial forearm microvascular flap. Four patients had been irradiated. Patients were between 12 and 71 years of age.

In 13 patients, a folded radial artery forearm flap was used to line the vault, columella, and the nasal floor (four cases), the vault and columella (six cases), the vault and floor (one case), vault and floor and full-thickness columella (one case), and a heminasal vault (one case). Forehead expansion was employed in six patients.

Early in the series, after cocaine or traumatic injury, scarred external nasal skin was transposed to resurface the nasal floor (one case) or line the columella (one case), in combination with a folded radial flap for other lining deficiencies. In another case (n = 1), the vault and floor were replaced with a folded flap without a columellar extension. Later at the time of forehead flap transfer, the external folded forearm skin, which covered the vault lining, was hinged over secondarily, to create a lining for the columella. Today, we

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**Fig. 1.** A single paddle distal radial forearm flap is harvested to supply nasal vault and columellar lining and to resurface the nasal floor. Thin ulnar skin is pinched together in the midline to create a “columella,” and the lateral distal tips (*) of the forearm flap are folded under and sutured to the midline of the defect (*) to line both nasal vaults. A skin extension is designed distal to the point of the future infolding of cover and lining (dotted lines). It spontaneously rotates medially to resurface an accompanying nasal floor defect.
Fig. 2. Eccrine carcinoma recurred in this 66-year-old woman after initial radiation therapy. A subtotal nasectomy, anterior maxillectomy, partial parotidectomy, and medial cheek excision were performed. The defect was immediately repaired with a right forehead flap, remnants of septal and inferior turbinate lining, and ear and septal cartilage grafts. On presentation, the nose is flat and shapeless. The airways are stenotic. Scalp hair has been transferred to the distal nose. The right lower eyelid is malpositioned and the cheek sunken. The forehead is severely scarred. The upper lip is retracted inward due to the loss of the nasal floor.

Fig. 3. The subtotal nasal defect is recreated and an osteocartilaginous rib graft is positioned to provide dorsal support.

Fig. 4. Thin ulnar forearm skin is folded inward to line the nasal vault and provide a columellar “backing” for a future forehead flap. The septal partition is not reconstructed. The skin extension is positioned in continuity with the vault lining, distal to the area of future infolding, and turns inward to resurface the nasal floor deficiency. More proximal radial skin, with the radial vascular pedicle, is turned back over the infolded vault lining to provide external covering skin and a vascularized pocket for the dorsal graft. The columella is sutured in the midline of the nasal floor to the deepithelialized surface of the skin extension. Expanders are placed under the forehead and scalp. More proximal forearm skin is harvested and deepithelialized to cover additional rib grafting of the cheek. A subsequent dermis fat graft was later added to further augment cheek contour.
satisfy all tissue requirements for the vault, columella, and floor with a single folded free flap. Adjacent cheek and lip defects were repaired with cheek and lip flaps, additional deepithelialized fasciocutaneous extensions of the radial forearm flap, dermal grafts, or bone grafts to replace missing skin and soft and hard tissue. During preliminary operations, the nasal airways were opened with nasolabial island flaps from adjacent scarred cheek (one case), or the medial maxillary buttress and the orbital floor was reconstructed with fibular and dorsalis pedis osteocutaneous flaps (one case) to restore the facial platform (performed elsewhere).

**METHODS**

**Operation 1**

A pattern of the lining defect is positioned on the forearm and face to verify the flap’s size, outline, orientation, pedicle length, area of folding, and the position of the skin extension for the nasal floor. A single, horizontally oriented paddle of forearm skin (8 to 10 cm in width and 6 to 8 cm in height) is outlined on the distal forearm, with or without a proximal extension, to line the nasal vault and columella and to resurface the nasal floor according to the needs of the defect (Fig. 1). The flap can be raised as a skin flap, maintaining fasciocutaneous connections only over the radial vessels. We now, however, limit primary fascial excision to maintain maximum blood supply.

The proximal extension for the nasal floor is designed vertically, in continuity with the primary flap, just distal to the future site of infolding. This positions the skin extension to resurface the floor when the primary flap is turned inward for lining. Because the single skin paddle is placed distally on the forearm, a 12- to 15-cm arterial pedicle and a longer venous pedicle (extended through the communicating vein from the vena comitans to the cephalic vein) are available. We prefer large, high-flow recipient vessels and routinely use the first branch of the external carotid artery and the internal jugular vein or external jugular vein as recipients. The superficial temporal artery and external jugular vein or facial vessels are used in the short fat neck. In subtotal and total defects (Fig. 2) requiring dorsal support, an osteocartilaginous rib graft is fixed to the residual nasal or frontal bones within the soft-tissue pocket established by folding of the forearm skin (Fig. 3).

The thin, distal ulnar edge of the forearm flap is pinched together in the midline, with sutures approximating its posterior raw surface. This “manufactures” a skin columella which will later provide a posterior backing for the columellar extension of the forehead flap (Fig. 4).

The septal partition is not restored. The lateral, distal tips of the flap are fixed to the midline of the lining defect, folding the distal skin under the more proximal skin flap to line both vaults. It is sutured toward each alar base, from medial to lateral, completing the lining inset. The height of the columella and dimension of the vault are adjusted and slightly exaggerated by altering the extent of infolding. As the flap folds inward to line the vault, the skin extension spontaneously rotates medially to resurface the floor. Tension, tight molding sutures, and aggressive thinning are avoided.

Proximal radial skin, with the vascular pedicle, is turned back over the infolded lining. This places the pedicle externally over the midvault, on the outer surface of the repair, out of the airway, and away from the inferior third of the nose. The external skin is sutured to the periphery of the nasal defect to provide temporary cover.

Residual rib cartilage is “banked” on the chest. The reconstructed columella is inset in the midline to the residual or resurfaced nasal floor.

Fig. 5. Several months later, after forehead and scalp expansion and wound maturation, the external forearm skin poorly matches adjacent facial skin. Nostril rim and alar base positions are imperfect. The dorsal graft supports the soft tissues centrally, but additional support grafts must be added to establish a sub-unit contour.

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Operation 2

Two months later, external radial skin, with a few millimeters of subcutaneous fat, is elevated and turned over inferiorly (Figs. 5 through 7). Excess hinged-over skin is trimmed to refine the nostril margins or reposition the alar bases, adjusting the inset as needed. The external skin surface of the columella is split in the midline. If lining for the columella or ala was not included in the initial vault design (one case) or was inadequate due to necrosis or wound separation with retraction (two cases), the external forearm excess is turned over to provide columellar or additional alar lining.

Excess subcutaneous fat and fascia are excised, protecting the radial vessels and exposing thin, supple, scarless lining. The vascular pedicle is not elevated and remains adherent to the underlying lining. The radial vessels, which perfused the folded flap through its external skin surface, are effectively “prelaminated” to the underlying lining. The lining remains perfused through the radial pedicle and by its peripheral inset to the recipient site.

Delayed primary rib supports (a columellar strut, tip graft, alar battens, and sidewall cartilage grafts) are fixed to each other and to the previously positioned dorsal graft. The base of the columellar

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**Fig. 6.** (Left) At the second stage, external forearm skin is hinged inferiorly to adjust the nostril margin or alar base position. If needed, the excess can be turned over to line an area of lining deficiency, secondary to an error in design or a complication. If columellar folding was not included in the vault reconstruction or is missing, external skin can be turned over inferiorly to provide a columellar backing for the posterior raw surface of the forehead flap. If alar lining is deficient, the external skin is hinged laterally. Excess external skin is discarded. The exposed subcutaneous fat of the folded forearm flap is then excised. The radial vessels are left adherent to the underlying lining layer and, with the peripheral margin of the healed recipient inset, continue to revascularize the transferred forearm skin lining. (Right) A subunit framework is completed to support, shape, and brace the soft tissues. The nose is resurfaced with a full-thickness forehead flap without thinning.
Fig. 7. (Above, left and center, left) The position of the radial pedicle is marked with arrows. Excess external radial skin, which will be turned over along the folded nostril margin, is marked. The external columellar skin surface will be split in the midline to provide a pocket for a columellar strut and “backing” for the columella extension of the covering forehead flap. Based on an upper lip template, the ideal positions of both alar bases are marked. The external skin, with a few millimeters of subcutaneous fat, is hinged inferiorly along the folded margin of the radial flap. The external columellar skin is hinged laterally. The lining envelope is adjusted to establish symmetric nostril margins and adequate nasal length. Excess external skin is trimmed. Laterally, the alar bases are repositioned inferiorly by reinserting the hinged over external skin (now lining) into their ideal position. (Above, right and center, right) Excess subcutaneous forearm fat is excised to the underlying supple and unscared lining. The radial vessels (visible over the midvault superior to the tip and alar battens) are protected and remain adherent to the lining.
strut is sutured to the nasal spine through a buccal incision. A full-thickness forehead flap, without distal thinning, is transferred for nasal cover.

Operation 3

One month later, the forehead flap is, effectively, physiologically delayed by its elevation and transposition (Figs. 8 through 10). Forehead skin with 2 to 3 mm of subcutaneous forehead fat is completely elevated from the recipient site, maintaining an intact supratrochlear pedicle. With complete visualization, the underlying exposed subcutaneous fat and frontalis muscle are artistically excised over the entire nasal surface, including the tip and ala. Previously placed cartilage grafts are sculpted, repositioned, or augmented to shape an ideal three-dimensional support framework. Forehead skin, now with the thinness of nasal skin, is replaced on the recipient site.

Operation 4

One month later, the forehead pedicle is divided. Further debulking of the airway, by excising excess soft tissue between the lining and cartilage grafts, can be performed through nostril marginal incisions at the time of pedicle division or during a later revision.

Operation 5

Four months later, a revision defines the alar creases by direct incision, adds a secondary tip graft, trims the nostril margins or columella, or revises the forehead scar (Fig. 11). Ideally, nasal repair is completed in four stages over 4 months with a revision at 4 months (five procedures over 8 months).

RESULTS

All patients completed reconstruction with good to excellent aesthetic and functional results. These are difficult reconstructions due to smoking, past infection and repair, radiation, and large defect dimensions which require massive cartilage grafting. No complication precluded a successful outcome, but some did delay repair and necessitate additional procedures.

Partial necrosis of the folded columellar lining occurred in two early cases at the time of microvascular transfer. The lining was salvaged by hinging over excess dorsal forearm skin at the time of forehead flap transfer1 or by folding the columellar extension of the forehead flap for columellar lining.2 We attribute this to overthinning and excess tension due to inappropriate soft-tissue molding sutures.

Partial dehiscence with retraction of an unilateral alar inset, without tissue loss, occurred after free flap transfer in one massively obese smoker with methicillin-resistant Staphylococcus aureus. This was salvaged by turning over the excess external radial skin to replace the alar lining deficiency at the time of forehead flap resurfacing.

Indolent cartilage infection necessitated débridement in five patients with subsequent partial support replacement in three patients. No free flaps were lost. No additional free flaps were needed to salvage a complication.

DISCUSSION

Distant tissue has been transferred for nasal reconstruction with limited application and success.3–6 The exception is the groundbreaking work of Burget and Walton,7 who employed mul-

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**Fig. 8.** One month later, the nose is bulky. The residual forehead defect is granulating. The frontal hairline is restored.
Multiple, longitudinally oriented forearm skin paddles in 10 patients. Two or three separate skin flaps were positioned, skin inward, to individually provide future lining for the vault, columella, and nasal floor. Each paddle was vascularized separately by the underlying radial vessel, like a “string of beads.” Their external raw surfaces were covered with full-thickness skin grafts, precluding primary soft-tissue support. Later, the individual skin paddles were sutured together, thinned, supported with cartilage grafts, and resurfaced with a distally thinned two-stage forehead flap. Before pedicle division, forehead skin was elevated only over the midvault. Soft tissue was excised over the superior two-thirds of the nose, but not over the tip or ala. A second intermediate operation was performed to debulk the airways. Subsequently, the pedicle was divided and a later revision performed. Good results were obtained during six or more operations.

Limitations, however, are apparent. Elevating three separate paddles for the vault, columella, and nasal floor is technically tedious and leaves a short proximal vascular pedicle for anastomosis. Injury to the vascular pedicle during elevation, or kinking during positioning of these multiple paddles, could jeopardize blood flow. The vascular pedicle to each paddle is also exposed to injury during subsequent stages, which may compromise vascularity limited by the scars between the skin islands. This may be exemplified by their need for a second free flap to remedy a columellar lining necrosis that occurred after a revision. The cutaneous scars between each paddle may lead to skin contraction or limit the suppleness of the lining. Because primary support cannot be placed under the initial external skin grafts, soft-tissue collapse and skin shrinkage may occur. Most importantly, no excess tissue is available to salvage an imperfection in flap design or a complication.
Fig. 10. The visual units of the nose are marked on the forehead flap surface. Forehead skin, with 2 to 3 mm of subcutaneous fat, is elevated over the entire nasal surface, maintaining an intact supratrochlear pedicle. The underlying excess subcutaneous forehead fat and frontalis are marked and are excised to define the dorsal lines, alar creases, and tip contour over the distal most aesthetic nose. The previously placed subunit support framework has healed to the underlying lining, creating a rigid three-dimensional midlayer framework. Support grafts can be sculpted or augmented to provide further contouring, if needed. Thin supple forehead skin is repositioned on the recipient site. One month later, the pedicle is divided, the nostril margins are thinned, and the airways are debulked through marginal rim incisions. Four months later, the alar creases are recreated by direct incision.
The use of a two-stage forehead flap, with an intermediate operation, was originally suggested by Millard. He combined traditional distal thinning of a forehead flap with an additional operation before pedicle division. The forehead flap was elevated over the midvault as a bipedicle, maintaining the proximal supratrochlear pedicle and the tip, alar, and columellar inset. The superior two-thirds of the nose was reshaped by soft-tissue excision.

However, this forehead flap approach, which combines initial distal thinning of the forehead flap and subsequent midvault debulking, has several disadvantages. Initial distal excision of frontalis muscle may decrease the overall blood supply to the forehead flap. It is also more difficult to create a thin uniform skin flap when the forehead flap is thinned in stages. During the intermediate operation, precise contouring of the midvault is impeded by the bipedicle flap, which limits expo-

Fig. 11. Postoperative result. The patient looks normal and her airways are widely open. The subtotal nasal defect was repaired with a folded distal horizontal forearm flap for lining with an extension to resurface the nasal floor, staged primary and delayed primary support, and a three-stage full-thickness forehead flap. This integration of distant tissue for lining and regional tissue for cover permitted intraoperative modifications during multiple stages to correct imperfections in lining, cover, and support. The cheek was repaired with a proximal deepithelialized extension of the forearm flap for soft-tissue fill, rib bone grafts, and a dermis fat graft. The lower lid ectropion was corrected with a tensor fasciae latae sling.
sure. Most importantly, the contour of the distal inset—the most aesthetic part of the nose—is fixed. The shape of tip, ala, and columella cannot be altered after initial forehead flap transfer. Folding a flap to create an inside and outside is not new. As classically illustrated by Converse’s folding of a scalping flap, a two-stage forehead flap has been folded for cover and lining. Its proximal ex-

Fig. 12. (Above) Recurrent squamous cell carcinoma in this 70-year-old patient necessitated excision of a prior left heminasal forehead flap reconstruction, total nasectomy, and bilateral cheek excisions with underlying medial maxilla. The cheek defects were repaired with split-thickness skin grafts. Postoperative radiation was administered. A total nasal defect with absence of the nasal floor is present preoperatively. (Below) Postoperative result at 4 months after forearm folded lining, staged support, a full-thickness forehead flap, and late revision to recreate the alar creases in five operations over 6 months. Overall nasal form and function are good. The nostrils are widely patent.
ternal surface vascularizes its distal lining extension. But extensive or complex support cannot be placed, resulting in a shapeless, collapsed nose.

Menick,\textsuperscript{12-14} realizing the impact of surgical staging on blood supply, primary and delayed primary support, and the opportunity for intraoperative manipulation of materials during staged procedures, modified the traditional folded forehead flap method to permit a three-staged thinning of cover and lining and the placement of a complete support framework. This modified folded approach is highly effective in the repair of small and moderate full-thickness nasal defects. Could a distant microvascular flap be folded to provide a lining foundation, with subsequent midlayer support and forehead resurfacing, for the repair of large subtotal and total defects?

The folded forearm flap for lining has been found to be a reliable, efficient microvascular design, applicable to varied defects\textsuperscript{14} (Fig. 12). Elevation is straightforward. The distal position of the horizontal skin paddle, based on the radial vessels, provides a long pedicle. A single, distal, horizontally oriented radial artery flap lines the vault and columella, with a proximal incontinuity skin extension to resurface the nasal floor, according to the needs of the defect. Thin ulnar skin along the distal free margin is folded inward to line both vaults and columella and to resurface the nasal floor. The missing septal partition is not recreated, limiting intranasal bulk. A无缝, unscarred arching lining envelope is restored, turning a full-thickness defect into a more superficial (and simple) one, requiring only support and cover. The more proximal forearm skin, with the radial vessels, is turned backward over the lining to provide temporary cover, which can revascularize a primary dorsal support graft, minimizing collapse, scar contracture, and skin shrinkage in larger de-

\textbf{Fig. 13.} (Left) This 13-year-old Somali girl presented with a subtotal nasal loss, airway stenosis, and severe lip retraction after suffering a "noma-like" infection several years before in Africa. (Right, above and below) A single paddled distal radial forearm flap was folded to provide lining for the vault and columella. During a preliminary operation, the nasal floor had been resurfaced with bilateral nasolabial subcutaneous island skin flaps to release the upper lip and open the airway stenosis, eliminating the need for a skin extension of a folded forearm flap to resurface the nasal floor. Postoperatively, necrosis of the folded columella occurred, secondary to aggressive subcutaneous thinning of the forearm flap and tight columellar "molding" sutures. The necrotic columella was débrided.
effects. The radial pedicle is positioned over the midvault where it is less vulnerable to injury during later stages.

At the second stage, excess external skin is hinged downward to adjust nasal length and modify nostril rim and alar base position and symmetry. The exposed subcutaneous fat and fascia are excised over the lining surface. Delayed primary cartilage grafts are combined with the initial dorsal graft to complete the support framework. The radial vessels, positioned over the midvault away from the tip, are protected from injury and permanently perfuse the underlying lining. The nose is resurfaced with a full-thickness forehead flap, maintaining its cutaneous, myocutaneous, and axial blood supplies.

Inevitably, errors in operative design, malposition of the folded nostril margin, alar base asymmetry, scar contracture, necrosis, or dehiscence of the flap’s inset requires correction after the first stage. In the event of a partial lining deficiency, the excess external forearm skin can be hinged inferiorly or laterally, at the time of forehead flap transfer, to replace a columellar or alar lining shortage without delaying or jeopardizing the final result (Figs. 13 through 15).

Later, at the intermediate operation, the forehead flap’s blood supply is augmented by the delay phenomenon. Maintaining only the proximal supratrochlear pedicle, forehead skin and a few millimeters of subcutaneous fat are elevated over the entire forehead inset, creating thin, conforming, uniform cover. With complete exposure, the underlying subcutaneous fat and frontalis muscle are excised. The entire nasal surface, from the radix to the base of the columella and ala, is modified by reshap-
ing, repositioning, or augmenting the previously placed support grafts. This permits refinement of the distal, most complexly contoured tip and ala, before forehead pedicle division.

CONCLUSIONS

The result of any reconstruction is determined by the choice of donor materials, methods of tissue transfer, flap design, and the capacity to modify tissues to the needs of the defect. The ability to adjust the dimension, outline, and thickness of donor materials for each anatomic layer and to correct imperfections or salvage complications is vital. This blending of distant folded radial forearm skin for lining, timed subunit rib graft support, and a regional three-stage full-thickness forehead flap for cover permits the integration of “unlike” tissues. It can restore a nose which looks and functions normally. It is reliable, efficient, and reproducible. Good results—an attractive nose with patent airways—can be obtained in the repair of complex heminasal, subtotal, and total injuries.

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PATIENT CONSENT

Patients and parents or guardians provided written consent for the use of their images.
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