Elegant Solutions for Complex Paramedian Forehead Flap Reconstruction

Nathan Todd Nelson Schreiber, MD,
Steven Ross Mobley, MD*

Elegant solutions are frequently sought by both artists and engineers. In dance, for example, elegance is defined by the minimum amount of motion that results in the maximum visual effect. Similarly, engineers strive to provide simple and practical solutions to their challenges while efficiently balancing the demands of time, materials, and other constraints. The confluence of art and engineering is never more intertwined than it is in complex multistage nasal reconstruction. The surgeon must draw on both the practical and scientific qualities of an engineer and the creativity of an artist. Experienced surgeons can quickly identify challenges, craft efficient solutions, and optimize reconstructive benefits for their patients with each surgery. In short, experienced surgeons reconstruct complex nasal defects with the most elegant of solutions.

The basic principles and techniques of facial reconstruction have been in use and relatively unchanged for a surprising number of years. As early as the fourth century, a Byzantine physician named Oribasius described advancement flaps, recognized the importance of tension-free closure, and warned of complications in poor wound healers, the elderly, and individuals in generally poor health.[1] Because the human eye can perceive asymmetries of only millimeters, the modern facial plastic surgeon must be creative and precise to recreate facial symmetry as much as is humanly possible.

In evaluating a patient for facial reconstructive surgery, the reconstructive ladder of increasing complexity and surgical involvement must always be discussed and patients must be guided to the surgical option that best suits their needs and goals. A skin defect can be closed primarily, allowed to heal by secondary intention, repaired with a split or full-thickness skin graft, or reconstructed with a local, regional, or free flap. This article describes refinements in the technique of paramedian forehead flap (PMFF) nasal reconstruction by the senior author (SRM) over his years of practice in a university setting.

PREOPERATIVE PLANNING

There are several factors to consider before initiating any discussion of reconstructive options for a specific patient. In patients undergoing Mohs surgery, the margins should be pathologically clear before reconstruction. If there is a significant risk of recurrence, methods of reconstruction may be suggested that allow for easy monitoring, such as skin grafting. In such a case, a more cosmetically

acceptable definitive reconstruction can be deferred to a later date.

Certain patient populations have poor peripheral circulation, putting them at risk for flap necrosis. Risk factors that cause endothelial dysfunction and impaired neoangiogenesis include tobacco use, poorly controlled diabetes, and irradiation.[2,3] Tobacco use, in particular, increases the risk of flap necrosis and skin slough, and this has been well documented in patients who have undergone rhytidectomy.[4,5] A study in patients undergoing breast reconstruction with a transverse rectus abdominis muscle flap suggests the results are best when a patient abstains from smoking for at least 4 weeks both preoperatively and postoperatively.[6] We also advise our patients to abstain from smoking for a minimum of 4 weeks both preoperatively and postoperatively. However, because many Mohs reconstructions present with little forewarning, the smoking status of the patient must be factored into a safe reconstructive plan, with the performance of a delayed PMFF often the method of choice in a patient who smokes.

THE DELAY PHENOMENON

The practice of surgical delay improving a flap's viability has long been noted. Surgical delay seems to cause several mostly transient effects, including division of sympathetic nerves causing initial release and then depletion of adrenergic factors from nerve endings, vasodilation occurring parallel to the long axis of the flap, ischemic conditioning, blunted release of vasoconstrictive metabolites, and, later, neoangiogenesis. Animal studies have reported maximally increased blood flow at the distal ends of random pattern flaps in as few as 4 days and lasting as long as 14 days.[7–11] Most relevant human studies have investigated breast reconstruction and generally endorse best results with a delay of 7 to 14 days.[12,13] We currently recommend a delay of 7 to 10 days and have a low threshold to perform a delay stage before reconstruction for at-risk patients. It is often difficult for both the surgeon and the patient to commit to surgical delay because of the additional stage of reconstruction that is required. However, we strongly believe that the addition of a delay stage before a given reconstruction can significantly decrease the chances of a flap-related complication. As otolaryngologists, many of us were taught, "If you think of a tracheotomy, perform a tracheotomy"; as facial plastic surgeons, we offer the perspective, "If you think of a delay stage, perform a delay stage." The additional cost of a delay stage is worth the prevention of distal flap necrosis and the multiple surgeries often required for its repair.

SURGICAL TECHNIQUE
General Principles

It is important to think of the face in terms of aesthetic subunits and to approach each reconstruction with these in mind. As much as possible, incisions should be placed at the borders of aesthetic subunits where they are least noticeable. Generally, a scar within a subunit is more obvious than a scar located at a border between subunits. As a result, the best reconstruction may involve removing additional tissue and rebuilding an entire subunit if the defect involves 50% or more of that subunit.[14] However, there are some exceptions, and a blind adherence to the 50% rule should be no substitute for an artistic reconstructive eye. For example, with lighter skin color, such as Fitzpatrick type I or II, a scar may be placed across a subunit without being noticed as much as with darker skin color. In addition, in contrast to thinner nasal skin, thicker sebaceous nasal skin can be a poor match with the forehead. In this situation, a PMFF might not be the best choice for reconstruction, and one may wish to avoid excising the remaining portion of a subunit if it would make the difference in requiring a pedicled flap for coverage.[15]

PMFF

The PMFF is extremely useful for nasal defects with a diameter larger than 1.5 cm because it can provide a significant amount of nasal coverage with minimal donor defect and is usually an ideal color match for the nose. The flap is centered on the supratrochlear vessels at the medial canthus and should be about 1.2 cm in width at its base. A foil template should be created to match the defect and outlined at the forehead with adequate length to reach the defect in a tension-free manner. The flap can then be elevated and inset. The pedicle can be safely divided and inset 3 weeks later. For full-thickness defects that involve the intranasal lining, the PMFF can be folded over to close the intranasal defect as an alternative to full-thickness skin grafting or a mucosal flap.[16–18] In this situation, a 3-stage operation can be performed at 3-week intervals with delayed placement of a large auricular cartilage batten graft in stage 2. A large cartilage graft, preferably from the septum, abutting the nasal sidewall is often used to provide extra support and prevent collapse.

Surgical Instrumentation

In our experience, the 6900 Beaver blade (Becton, Dickinson and Company (C), Waltham, MA, USA) is a very useful instrument for soft tissue reconstruction of the face and has several applications in PMFF surgery. Unlike the more common 11 and 15 blades, the 6900 Beaver blade is not as widely used. Surgeons who may not be familiar with this particular blade are encouraged to experiment with its use. In soft tissue work, the surgeon can stab into the tissue similar to using an 11 blade. The 6900 Beaver blade, however, is narrower and allows for the creation of precisely sized pockets for the cartilage grafts often used in PMFF nasal reconstruction. In addition, the 6900 Beaver blade is similar in feel to the 15C blade with the added advantage of being able to cut in all directions. Because the 6900 Beaver blade cuts on all sides, it does not need to be continually reinserted when creating a cartilage graft pocket, thereby promoting operative efficiency. The qualities of this blade allow the surgeon to hold it much like a pencil or paintbrush and paint through the soft tissue with artistic precision, cutting with both forward and backward strokes as well as delicate stabbing advancements. We have found this blade particularly helpful in creating tight pockets to receive the alar rim grafts commonly used in PMFF surgery (**Fig. 1**).

The 6900 Beaver blade is also an excellent instrument for thinning flaps, which is important for achieving a well-contoured final result. The senior author (SRM) originally thinned flaps after their elevation from the forehead using sharp serrated scissors.[19–22] However, we have found it more efficient to thin the PMFF as it is initially raised from the forehead. In this situation, as the flap is being raised off the frontalis musculature, there is extra tension along the flap that, combined with the 6900 Beaver blade, provides an excellent opportunity for flap thinning as it is initially raised. In this technique, the perimeter of the flap is created with either 11 or 15C blade scalpels. Small double-pronged skin hooks are then placed along the edge of the flap for upward tension while the surgeon sits at the head of the bed with the patient's forehead positioned such that both the surface and the immediate underside of the flap can easily be viewed with a simple shift of the surgeon's gaze. In this manner, the 6900 Beaver
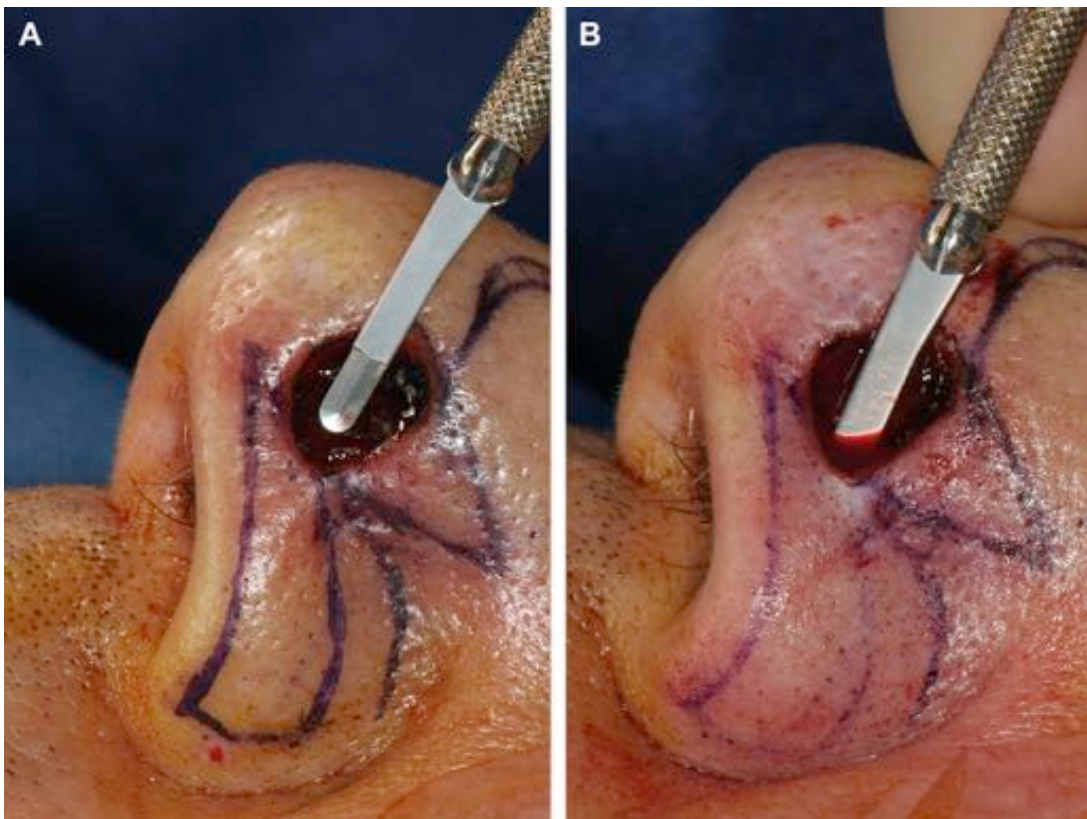

Fig. 1. The 6900 Beaver blade is able to cut on all sides (*A*) and can be used to create a pocket for an alar rim cartilage graft (*B*).
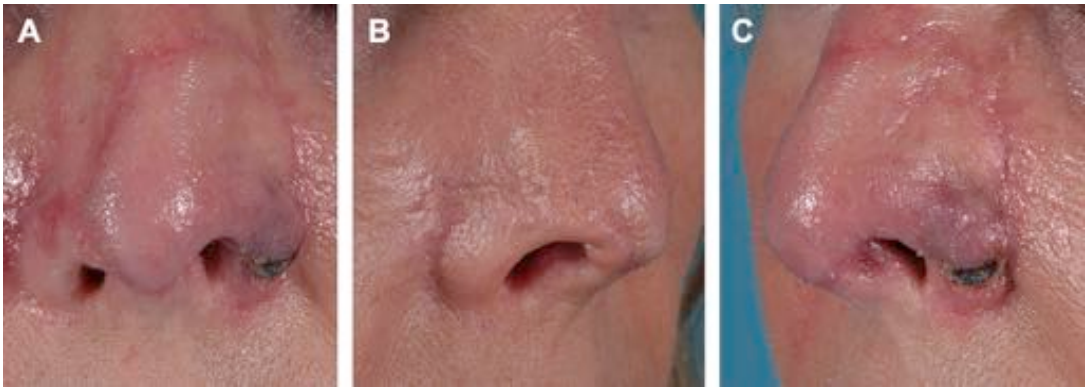
Fig. 2. Asymmetry from distal necrosis of PMFF reconstruction of the left alar rim is shown in frontal (*A*), right three-quarter (*B*) and left three-quarter (*C*) profile views.

blade is gently stabbed into the tissue, leaving 1 to 3 mm of subcutaneous fat on the underside of the forehead flap. The surgeon can watch from below as the blade precisely enters the subcutaneous fat layer and then watch the skin surface of the flap as the blade causes the skin to gently rise, similar to what is seen when the tips of a face-lift scissor press on the underside of the cheek skin during wide undermining. The ability to paint this blade back and forth while gently advancing has allowed us to safely and more quickly raise nicely thinned flaps. These thinner flaps eventually result in a superior contour match. Another advantage of

this technique is that subcutaneous fat and frontalis muscle are left in place at the patient's forehead, which can more quickly provide a healthy base of living tissue on which granulation tissue can more quickly form when the forehead defect cannot be closed primarily and must heal by secondary intention.

Achieving Alar Rim Symmetry, Skin Layer

In PMFF reconstruction of the alar subunit, alar retraction is a significant complication that the facial plastic surgeon must work diligently to
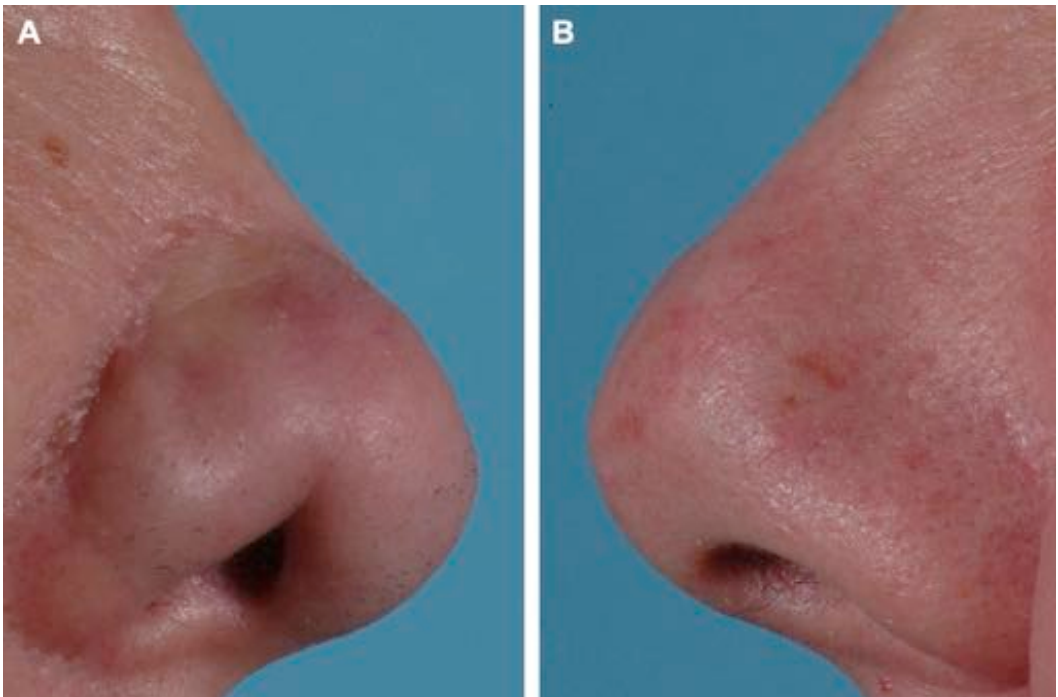

Fig. 3. Retraction after PMFF reconstruction of the right alar rim resulting in a notched right alar rim (*A*) compared to the native left alar rim (*B*).

prevent. In one published study, alar retraction was reported to occur as often as 40% of the time after alar rim reconstruction.[23] Even subtle alar retraction can significantly reduce the elegance of the final surgical result.

Achieving symmetric alar rims is made all the more difficult when a full-thickness defect that involves the alar rim must be repaired. The classic teaching for PMFF nasal subunit reconstruction has been to create a flap that exactly replaces the tissue and/or subunit that has been removed. Through a busy PMFF reconstruction practice dealing with many full-thickness defects, the senior author (SRM) prefers to use a folded PMFF for most of his full-thickness alar subunit reconstructions and has learned that it is often advantageous to leave an additional 2 to 3 mm of tissue at what will eventually be the alar rim. Leaving this tissue is particularly important when reconstructing the ala of someone with a very high aesthetic standard. The reasoning for this is that during the course of a multistage full-thickness alar subunit reconstruction, the distal part of the flap, which will be the new alar rim, is the part of the flap most vulnerable to distal ischemia and poor wound healing. If classic design of the skin paddle is followed and an exact amount of replacement skin is brought from the forehead to the missing alar subunit, the symmetry of the final reconstruction will be in serious jeopardy if there is any distal flap necrosis resulting in a paucity of tissue at the alar rim (**Figs. 2** and **3**). It is extremely difficult to add an additional 2 to 3 mm of tissue once it has been lost, and the patient can expect multiple additional operations in an effort to reconstruct the missing tissue at the alar rim.

A more elegant solution, however, is to purposefully leave 2 to 3 mm of tissue in the skin paddle in the area of the paddle that will eventually be the alar rim. One can always debulk the alar rim to create near-perfect symmetry, but it is another matter altogether to build it up if there is tissue loss and the rim retracts.

Achieving Alar Rim Symmetry, Cartilage Layer

As the sixteenth century French physician Francois Rabelais once said, "Nature abhors a vacuum." There are many situations in facial reconstruction for which this tenet rings true and perhaps none quite as much as when attempting to reconstruct an alar rim. The nasal ala is actually devoid of cartilage in its lateral inferior region (**Fig. 4**). When a partial or full-thickness defect is present in this area, it is important to reconstruct the area with generously sized alar rim grafts. More importantly, when these grafts are inset along the lateral nasal
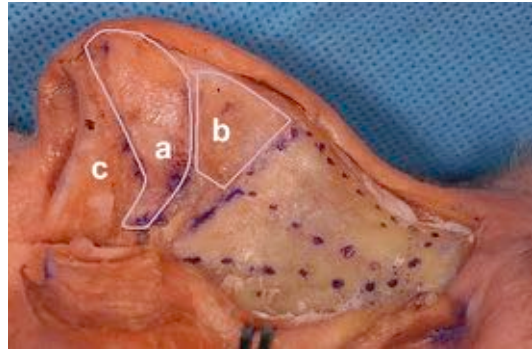

Fig. 4. Nasal dissection in a cadaver showing left lower lateral cartilage (a), upper lateral cartilage (b), and inferior lateral region of nasal ala that normally does not contain any cartilage (c).
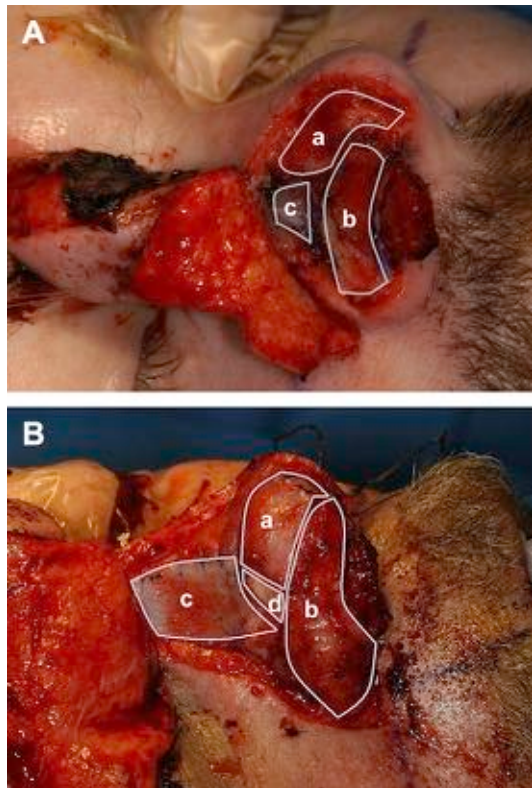

Fig. 5. Examples of abutting cartilages in PMFF nasal sidewall and alar rim reconstruction. (*A*) Native right lower lateral cartilage (a); right alar rim reconstruction with generous auricular cartilage graft, filling the area normally composed of fibrofatty tissue (b); and right upper lateral cartilage reconstruction with septal cartilage graft (c). (*B*) Right lower lateral cartilage reconstruction with auricular cartilage graft (a), right alar rim reconstruction with auricular cartilage graft (b), right upper lateral cartilage reconstruction with septal cartilage graft (c), and septal cartilage graft to eliminate dead space between cartilage grafts (d). Note how the grafts abut one another with little to no gaps.

sidewall, it is imperative that there are no soft tissue gaps between abutting edges of cartilage grafts (**Fig. 5**). If gaps are left between adjacent cartilage grafts, the sidewall can contract, obliterating the dead space and leaving behind a retracted nasal ala.

In patients with high aesthetic standards and full-thickness defects involving the alar rim, repair is planned as follows (**Fig. 6**):

1. Design folded PMFF using a template to reconstruct missing internal lining as well as alar subunit with 2 to 3 mm of additional tissue at what will be the alar rim.
2. If the patient is a smoker or otherwise perceived to be at risk for flap failure, there should be a delay stage, and the PMFF should be sutured in its original position after being raised. Wait 7 to 10 days for the next stage.
3. Raise the folded PMFF to the nose to reconstruct the internal lining and alar subunit. Reconstruct such that 2 to 3 mm of additional tissue is located at the alar rim. Wait 3 weeks for the next stage.
4. Divide the internal lining from the external skin paddle, and place delayed primary cartilage grafts to support the alar rim, nasal sidewall, tip, and so forth. Wait an additional 3 weeks for the next stage.
5. Divide the pedicle, and inset the flap. Wait 2 months for the final stage.
6. Design a symmetric alar rim and remove any excessive tissue to match the native side (**Fig. 7**).

Supra-Alar Crease

Through-and-through quilting sutures are an important technique for the control of contour that is necessary for complex nasal reconstruction. These through-and-through sutures can have an important and significant effect on the final nasal contour in key areas such as the supra-alar crease. Although the quilting sutures are able to apply
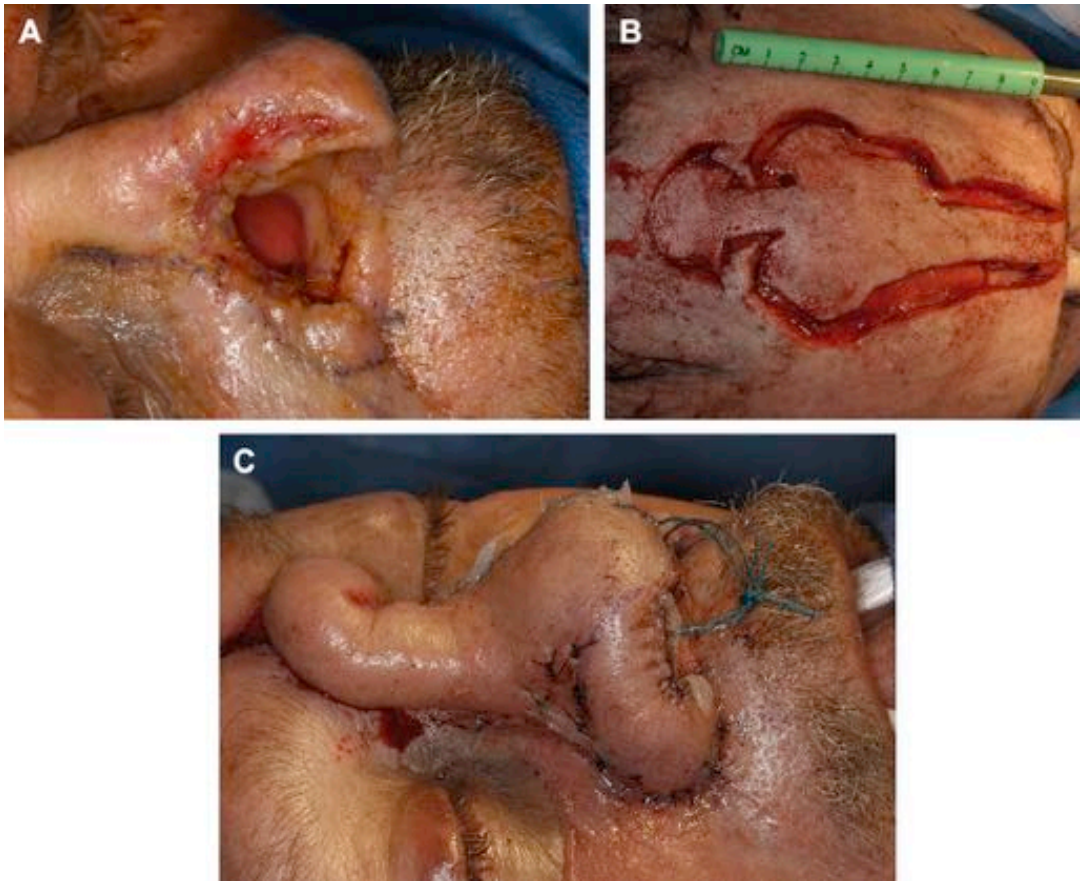

Fig. 6. Folded PMFF nasal reconstruction stage 1. Full-thickness nasal defect (*A*) and planned folded PMFF (*B*) followed by completed reconstruction (*C*) after placement of cartilage grafts and creation of supra-alar crease with quilting sutures (before use of polytetrafluoroethylene pledgets) are shown.

Fig. 7. Result of right alar rim reconstruction with PMFF before final debulking. Markings show planned location of final alar rim in the frontal (*A*) and right three-quarter (*B*) profile views. The left three-quarter profile view is shown for comparison (*C*).

pressure in a precise location, these sutures can have a cheese wire cutting effect on the skin. Alternatively, cotton bolsters have been advocated for this use to help apply broader pressure in the postoperative period without the cheese wire effect.[22] The senior author's (SRM) long-time surgical assistant, Brent Klev, RN, helped suggest an even more elegant solution to control nasal contour. This simple modification combines the benefits of applying pressure in a precise location while at the same time avoiding the cheese wire effect.

In this modification, a 5-0 black nylon is threaded over a polytetrafluoroethylene (PTFE) pledget that is used to precisely place pressure. This not only provides equal, if not superior, soft tissue compression compared with simple quilting but also prevents cheese wiring that occurs when stitches alone are used to create this crease (**Fig. 8**). In addition, the PTFE pledget has 2 ready-made perforations through which the needle can easily be passed such that equal pressure can be placed over the entire area of the pledget. PTFE pledgets
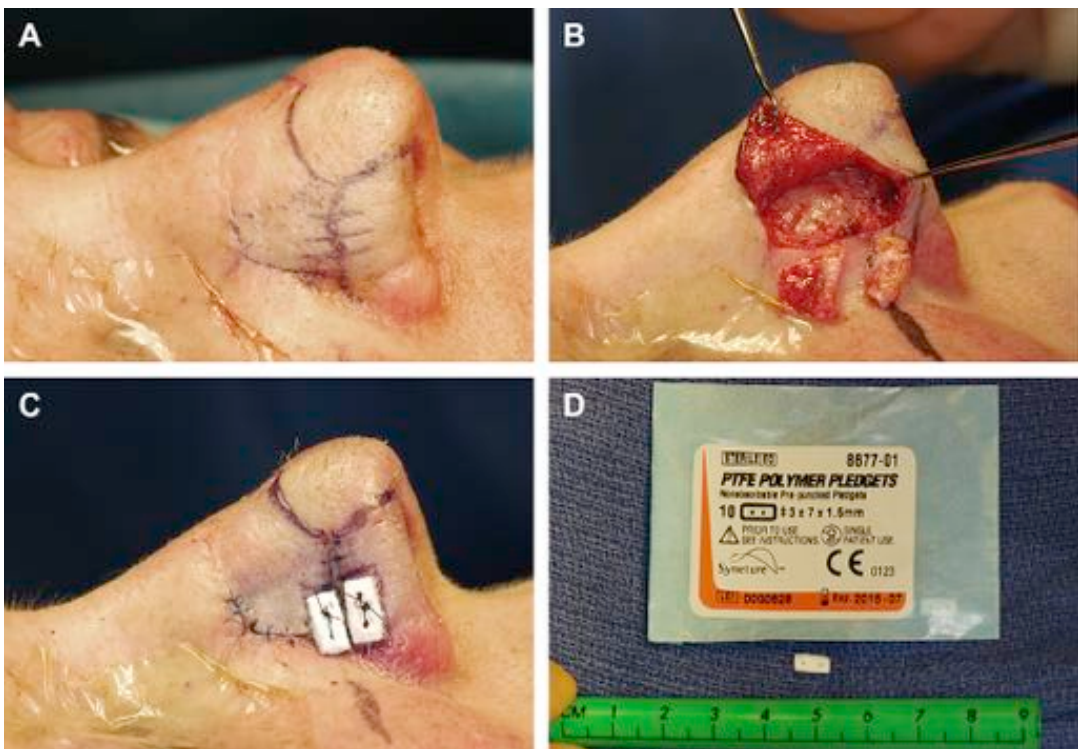

Fig. 8. Creation of supra-alar crease. Bulky supra-alar tissue (*A*) is debulked through planned incisions (*B*), and PTFE pledgets are placed to maintain pressure at the planned supra-alar crease (*C*). The dimensions of the PTFE pledget are shown (*D*).

Fig. 9. Preoperative (*A*), intraoperative (*B*), and postoperative (*C*) images of nasal vestibular stenosis repair. Note that in the middle image the senior author (SRM) had not yet adopted the use of PTFE pledget, and, instead, a bulky sponge was used. (*Modified from* Daines SM, Hamilton GS, Mobley SR. A graded approach to repairing the stenotic nasal vestibule. Arch Facial Plastic Surg 2010;12:336. Copyright © 2010 American Medical Association. All rights reserved; with permission.)

are specifically designed to prevent the suture from tearing through the tissue and are used most often in cardiothoracic and vascular surgeries. As a result, otolaryngologists and facial plastic surgeons may not have been widely exposed to the utility of PTFE pledgets in the operating room. PTFE pledgets are best used for this purpose by tying them such that they are just held in place with just the smallest amount of initial tissue compression. That way, in the days after surgery, the compression becomes more appropriate as normal postoperative edema enters the tissues in the days after the flap surgery. A short learning curve can be anticipated by surgeons learning to use PTFE pledgets for soft tissue contour compression. We routinely leave these pledgets in for 5 to 8 days postoperatively and have not seen postoperative complications from excessive compression or cheese wire cutting of tissue. In a minority of cases, the sutures may tighten, causing the pledgets to excessively depress the skin with postoperative edema. If this situation occurs, the pledgets may be removed sooner than the 5 to 8 days they are normally left in place.

Nasal Vestibular Stenosis

Nasal vestibular stenosis can occur to varying degrees after full-thickness repair of nasal ala defects with folded PMFFs and is best prevented by using large autologous grafts in the area of the nasal sidewall and ala. However, despite a surgeon's best efforts, this complication may still occur. Nasal vestibular stenosis in the setting of trauma can be difficult to repair, has a high rate of recurrence, and can often result in significant functional impairment.[24] The senior author (SRM) has had success repairing nasal vestibular stenosis using a batten graft to support the inherently weak nasal ala and a thermoplastic splint for 2

weeks (**Fig. 9**).[25] Alar vestibular stenosis caused by burns and other trauma are less common but can be corrected using the same technique.

POSTOPERATIVE CARE
Topical Nitroglycerin

Flap necrosis is a difficult complication that can significantly delay final repair and lead to

Fig. 10. Topical nitroglycerin used on the distal portion of a PMFF.

Fig. 11. Injection of triamcinolone to treat pincushion edema of a nasal flap.

radicals that cause both arterial and venous vaso-dilation (**Fig. 10**). Topical nitroglycerin has shown efficacy in improved skin flap survival in several animal models.[26–29] Importantly, a single postop-erative treatment with topical nitroglycerin showed no benefit over placebo in flap necrosis for Mohs reconstruction in the only published clinical study to date.[30] Our patients are instructed to use topical nitroglycerin every 4 to 6 hours if their flaps show signs of inadequate perfusion postoperatively. Patients are asked to continue this application for 4 to 6 days or until a more stable flap color is observed. The senior author (SRM) has used this technique for several years in a variety of patients with a spectrum of comorbidities without any significant cardiovascular complications. Patients are instructed to apply a pea-sized amount of paste, about 1 mm thick, over the pale or con-gested flap and must be warned that most people experience an annoying but tolerable headache. Anecdotally, this method seems to work slightly better for arterial insufficiency as opposed to venous congestion.

Triamcinolone

Pincushioning is often the result of edema and inadequate flap thinning and can reduce recon-struction camouflage. Triamcinolone injections that are intradermal or immediately subdermal can help reduce pincushioning through the use-ful side effects of lipolysis and inhibition of lipogen-esis. Before these injections, however, the patient must be informed of possible complications, such as telangiectasias, hypopigmentation, and skin breakdown.[31] These complications tend to occur

a prolonged course caring for an open wound. One technique that has been useful for the senior author (SRM) is the use of nitroglycerin paste, which is absorbed topically, creating nitric oxide
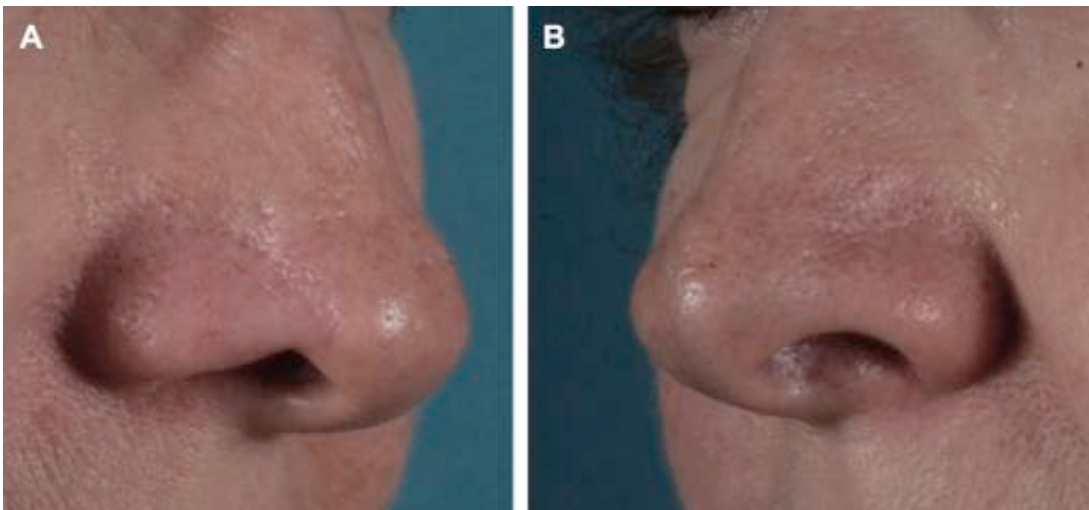

Fig. 12. Opposing three-quarter views allow comparison of nasal ala. A small amount of alar retraction can be seen at the reconstructed right alar rim (*A*) compared to the left (*B*).

Fig. 13. Comparison of preoperative (*A–D*) and 4-year postoperative (*E–H*) PMFF reconstruction results for a large full-thickness right alar rim defect. This patient developed alar retraction with a notched appearance similar to that in **Fig. 3**, requiring additional reconstructive procedures.

with higher concentrations of triamcinolone, such as 40 mg/mL. Telangiectasias may appear a month or more after injection and can even enlarge for up to 6 months.[32] Hypopigmentation related to steroid injection appears in multiple case reports, mainly in the orthopedic literature in which steroid doses are significantly higher than those used by the senior author (SRM).[33] This effect is caused by decreased melanocyte function and is usually temporary and rarely permanent.[34] Nevertheless, hypopigmentation can be particularly disconcerting and especially noticeable in darker-skinned individuals. The risk of skin breakdown, which is especially high in patients with thin skin, is reduced by starting with low concentrations of triamcinolone. With the concentrations we use, we have seen a few cases of telangiectasias and a little hypopigmentation but no skin breakdown.

We usually begin with triamcinolone at a final concentration of 2.5 mg/mL (mixed with lidocaine and bicarbonate for patient comfort) in 0.1-mL aliquot injections from a 1-mL tuberculin-type syringe for each approximate 5 mm^2 of edema. The first injection is administered at 3 to 6 weeks postoperatively to the deep dermis or top layer of subcutaneous fat. When injected intradermally, the surgeon should see skin blanching (**Fig. 11**). The patient is followed up for 4 weeks, and, if no appreciable effect is noticed, an increased triamcinolone concentration of 5 mg/mL can be injected, continuing with 0.1-mL aliquots per each approximate 5 mm^2 of persistent tissue edema. There is a definite art to this technique, and the learning surgeon is advised to proceed slowly, spreading treatments over longer intervals, perhaps 6 weeks initially, until comfort is gained with how much edema resolves with a given injection. The possibility of injecting more triamcinolone at a later time is a particularly important concept with this technique.

REPORTING RESULTS
Photography

It would be difficult to overstate the importance of photography in facial plastic surgery. Standardized and consistent photographs allow each surgeon to more accurately assess and report their forehead

Fig. 14. Comparison of preoperative (*A–D*) and 5-year postoperative (*E–H*) reconstruction results for a superficial right alar defect repaired with a melolabial flap and a large full-thickness left alar rim defect repaired with a PMFF. This patient's reconstruction was complicated by distal necrosis of the PMFF, shown in **Fig. 2**, requiring additional reconstructive procedures.

flap reconstruction results to the professional community at large. Ideally, photographs are taken of a patient without makeup or expression; after removing jewelry, hats, and other accessories; and at well-defined angles.[35] In addition, nonadherence to standard practices in photography can lead to the publication of possibly misleading results. For example, variations of only 10° from standard camera angles can shorten or lengthen various facial features to a significant degree, resulting in distorted assessment.[36] Nasal skin cancer reconstruction photos, and especially those involving the alar rim, can fall victim to publication of nonstandardized photography results. To ensure the most accurate assessment of a given postoperative result, the contralateral ala should always be shown juxtaposed to the reconstructed ala. Without showing the unaffected side, subtle amounts of alar rim retraction, which are quite noticeable on direct observation, can be blinded to the observer of the published photo. We encourage all nasal reconstruction results involving repair on or near the ala to be published or presented with the contralateral ala opposite to the reconstructed result (**Fig. 12**). The adoption of this standard will ensure that the results of given reconstructive techniques are more objectively presented.
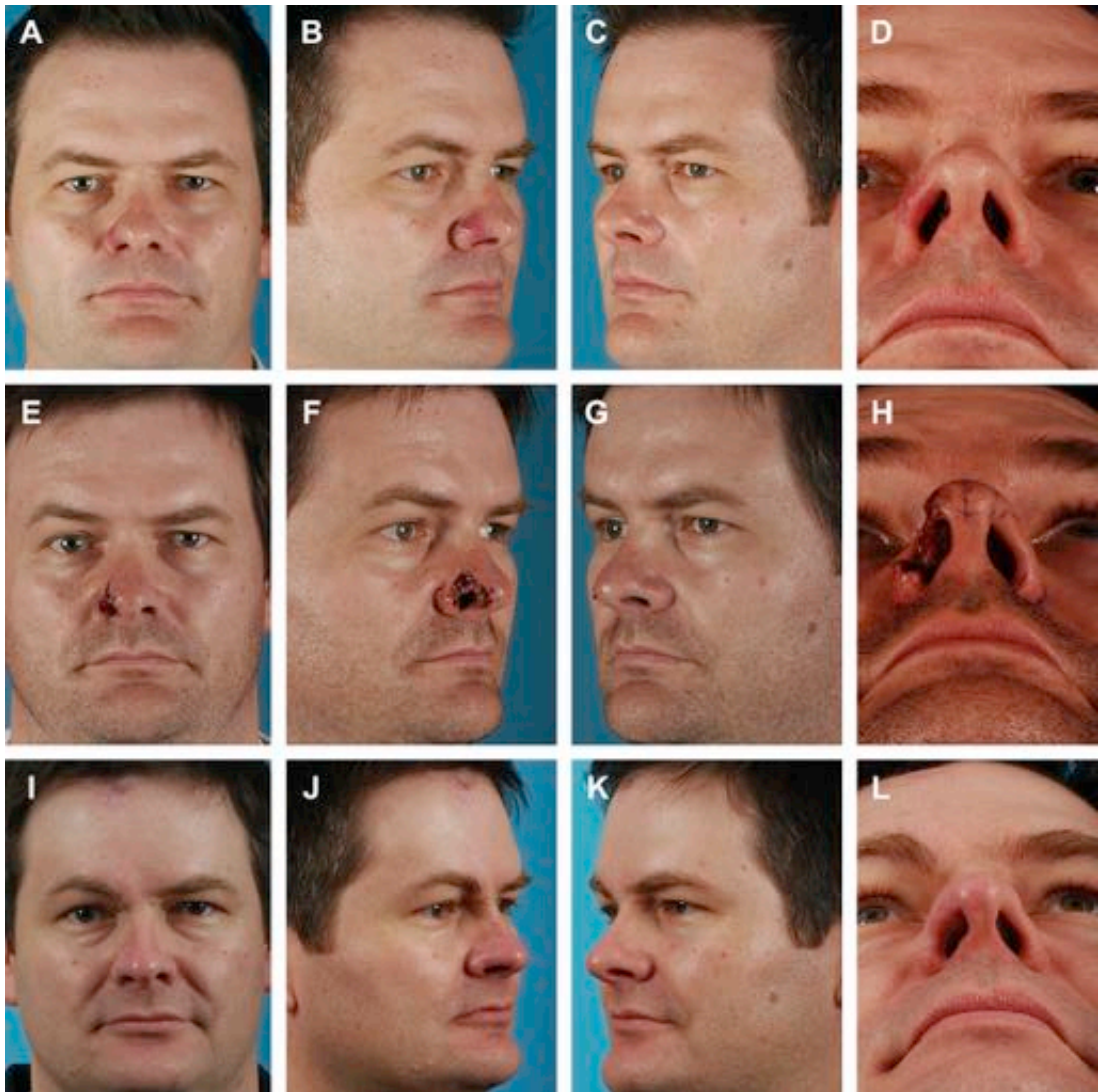

Fig. 15. Comparison of preresection (*A–D*), postresection/preoperative (*E–H*) and 1-year postoperative (*I–L*) PMFF reconstruction results for a full-thickness right alar rim defect. Appearance after reconstruction but before final debulking is shown in **Fig. 7**.
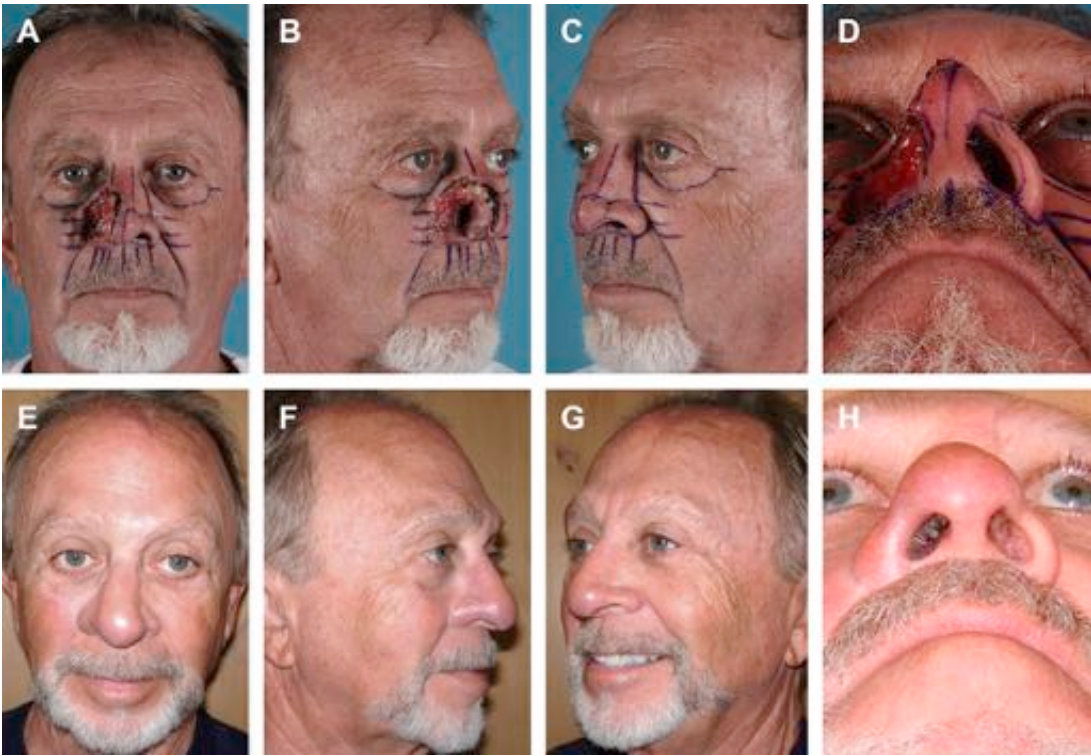
Fig. 16. Comparison of preoperative (*A–D*) and 7-month postoperative (*E–H*) PMFF reconstruction results for a large full-thickness right alar rim defect. Note that only preoperative images with surgical markings and postoperative images taken by the patient at home due to a long travel distance and inability to followup in clinic were available. Intraoperative reconstruction images are shown in **Fig. 6**.

Fig. 17. Comparison of preoperative (*A–D*) and 10-month postoperative (*E–H*) PMFF reconstruction results for a long-standing, bilateral, full-thickness alar rim and nasal tip defect.

SUMMARY

Reconstruction of nasal defects is a particularly challenging task, requiring the reconstructive surgeon to recreate facial symmetry to within millimeters to reduce detection. The techniques mentioned in this article have been refined over several years and have helped the senior author (SRM) to achieve increasingly symmetric reconstructive results while preventing complications and the need for unplanned surgeries along the reconstructive journey (Figs. 13–17). A summary of key principles is as follows:

1. Always provide choices, and help patients choose the reconstructive option that best fits their situation.
2. Consider comorbidities and have a low threshold to add a staged surgical delay.
3. Aim to reconstruct entire subunits, but use an artistic eye and do not adhere to this rule blindly.
4. Add an additional 2 to 3 mm of skin paddle when reconstructing through-and-through defects of the ala.
5. Experiment with the surgical instruments and techniques that are discussed in this article (the 6900 Beaver blade, PTFE pledgets, nitroglycerin paste, and triamcinolone injection) to enhance results.

By following these principles, we have been able to navigate our patients through a series of reconstructive stages that maximizes final aesthetic results while minimizing complications. We encourage the use of these techniques amongst facial plastic surgeons to improve reconstructive results in complex multistage nasal reconstruction and create more elegant solutions for patients.

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