Restoring the Failed Cranioplasty: Nonanatomical Titanium Mesh with Perforator Flap

Hugo St.-Hilaire, M.D., D.D.S.
Suhail K. Mithani, M.D.
Jesse Taylor, M.D.
Oliver P. Simmons, M.D.
Navin Singh, M.D.
Eduardo D. Rodriguez, M.D., D.D.S.
Baltimore, Md.

The calvaria is covered by a thin, well-vascularized soft-tissue envelope, providing a rich environment for a variety of local and regional flaps.[1] Composite cranial vault restoration aims to protect the brain and restore cranial form. Primary reconstructions result in good outcomes, provided there is adequate quality and quantity of soft tissue. The complexity also increases with the size and thickness of the defect, and the predictability and durability decrease with attenuating factors. Local and systemic factors such as malnutrition, extensive zone of injury from radiation therapy, and multiple surgical explorations play a pivotal role and potentially complicate routine options. Thus, composite calvarial defects within a field of multiple surgical interventions or radiation therapy result in less predictable outcomes.

Secondary cranioplasty in the setting of an attenuated soft-tissue envelope presents a unique challenge. The purpose of this article is to present a novel alternative for managing the failed cranioplasty with associated soft-tissue deficit that includes distant tissue transfer in the form of perforator-based flaps in addition to a nonanatomical titanium mesh cranioplasty, ensuring rigid brain protection and durable tissue coverage.

PATIENTS AND METHODS

A retrospective review of patients who underwent secondary cranioplasty using nonanatomical titanium mesh cranioplasty and perforator free flap reconstruction was conducted at R Adams Cowley Shock Trauma Center and Johns Hopkins Hospital from 2002 to 2008. Charts were reviewed and data collected, including age, gender, type and size of defect, reconstructive procedures, outcome, and length of follow-up.

Surgical Technique

Preoperative evaluation was performed to assess the availability of the superficial temporal vessels by means of palpation or handheld Doppler. The area of devitalized skin was identified, marked for excision, and sent for pathologic analysis. Dissection was carried in a subpericranial plane. Débridement of nonviable bone was performed with curettes and rotary instruments to ensure bleeding bony margins. The dura was débrided and repaired when indicated. The bony margins were beveled to allow positive seating of the titanium

From the Division of Plastic, Reconstructive, and Maxillofacial Surgery, R Adams Cowley Shock Trauma Center, University of Maryland School of Medicine and Johns Hopkins School of Medicine.
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mesh. The patient's head was turned from a decubitus position toward the midline to evaluate dural expansion. At least 1 hour was allotted to allow the dura to expand fully before adapting the titanium mesh. An adipocutaneous perforator flap was raised during this time. A nonanatomical cranioplasty was performed to minimize the intracranial dead space, relying on the bulk of the free tissue transfer to reestablish contour. The perforator-based free flap was inset and microvascular anastomosis performed in standard fashion. To preserve hair-bearing scalp and natural appearance, flaps were deepithelialized preferentially and inset under the skin envelope. In the setting of compromised overlying skin, the tissue was débrided and the flap inset without deepithelialization.

RESULTS

A total of 10 patients who underwent revision of failed cranioplasty with a combination of perforator flap and titanium mesh cranioplasty were identified. There were eight men and two women, with a mean age of 48.5 years. The initiating events were a combination of trauma and craniotomy for malignancy or cerebrovascular hemorrhage. All underwent multiple attempts at cranioplasty (range, two to four) with subsequent failure and two underwent radiation therapy. The average calvarial defect was 175.6 cm^2 and the average flap size was 266.2 cm^2. Eight anterolateral thigh flaps, one deep inferior epigastric artery perforator flap, and one ulnar artery flap were used in this series. Five of the anterolateral thigh donor sites were closed primarily, whereas the remaining donor sites required skin grafting. The superficial temporal system was used for recipient vessels in six cases and the facial vessels were used in the remaining patients. There were no flap losses, but there were one major and two minor complications. One flap was found to have venous congestion on postoperative day 1 that responded to leech therapy followed by the development of a small hematoma that required surgical drainage. There was no loss of tissue and the patient went on to an uneventful postoperative course thereafter. There were two minor complications. A seroma developed at the anterolateral thigh donor site that resolved following aspiration. Also, a small area of titanium mesh became exposed, which was trimmed and subsequently covered by means of local tissue rearrangement. The mean follow-up was 13.8 months. All patients were satisfied with their reconstruction and none requested secondary recontouring (Figs. 1 through 5). Also **see Figure, Supplemental Digital Content 1,** which shows a

Fig. 1. A 32-year-old patient had undergone a left temporal lobectomy 14 years earlier as a result of a motor vehicle accident. Subsequent anatomical cranioplasty with methylmethacrylate and mesh was complicated with exposure and infection that led to eventual removal. The patient presented to our clinic with a severe temporoparietal contour deformity (*left*). (*Right*) The cranioplasty skin flap is reflected anteriorly with nonanatomical placement of titanium mesh.

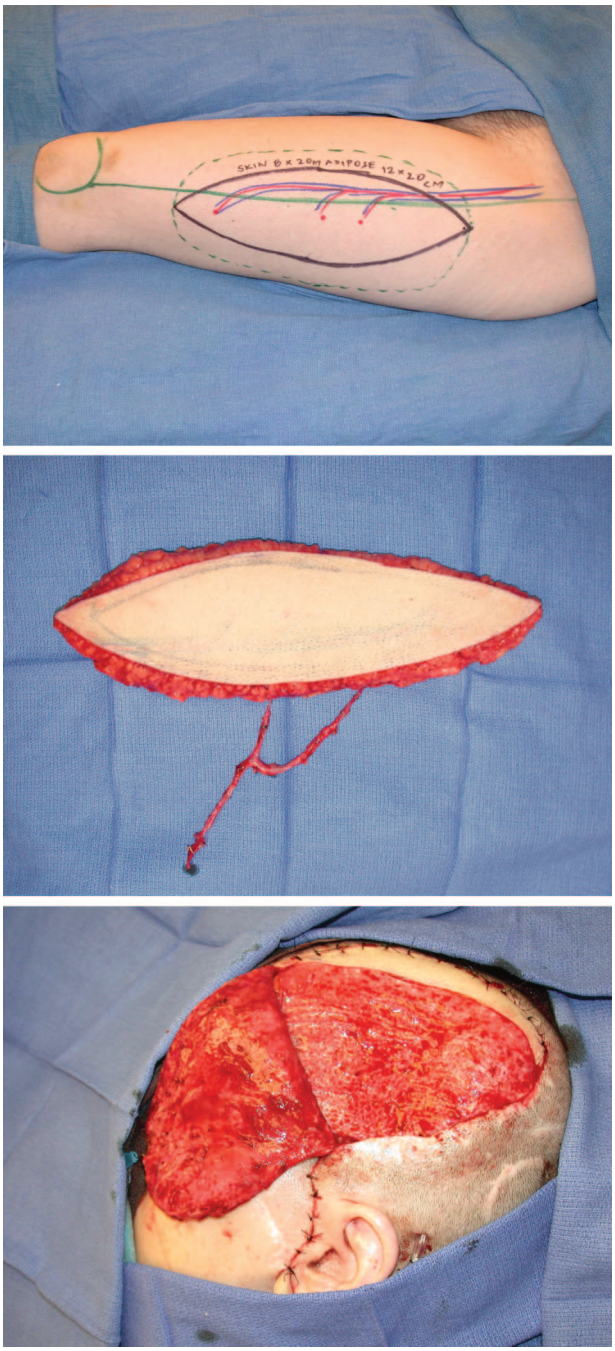

Fig. 2. The defect was reconstructed with an adipocutaneous anterolateral thigh flap. (*Above*) The flap outlined. Note the extended adipose tissue incorporation into the flap beyond the margin of the skin paddle. (*Center*) Elevated flap before inset. (*Below*) Flap deepithelialized and inset.

92-year-old man who had undergone cutaneous tumor resection and methylmethacrylate cranioplasty with resultant alloplast hardware, ***http://links.lww.com/A1174***. Because of his hair distribution and destruction of overlying skin, reconstruction was performed using an anterolateral thigh flap

Fig. 3. Results of nonanatomical titanium mesh cranioplasty with vascularized tissue. There is significant improvement of contour deformity 12 months postoperatively.

Fig. 4. Computed tomographic scan demonstrates nonanatomical placement of titanium mesh with obliteration of potential space by an adipocutaneous flap.

without deepithelialization. [(*Left*) Appearance at the beginning of the procedure. Note multiple draining sinuses and destruction of the skin envelope overlying the cranioplasty. (*Center*) Nonanatomical placement of titanium mesh. (*Right*) Three month-postoperative result.)]

DISCUSSION

Titanium is light, strong, biocompatible, heat resistant, and relatively affordable.[2,3] It does not

Fig. 5. A 24-year-old man suffered posttraumatic left periorbital and left temporoparietal deformity. He had undergone multiple reconstructions, including a left temporoparietal cranioplasty. (*Above*, *left*) Preoperative image. Note the left temporoparietal contour deformity. (*Above*, *right*) Coronal formatted computed tomographic scan. Again, soft-tissue asymmetry is apparent in the temporal region. (*Below*, *left*) Intraoperative view with craniotomy skin flap reflected anteriorly and deepithelialized anterolateral thigh flap inset. (*Below*, *right*) Appearance at 6 months postoperatively. Note improvement of temporoparietal contour.

cause hypersensitivity reactions and is minimally encapsulated by normal wound-healing mechanisms. It performs well in the face of contamination and exposure[3] and, when exposed, responds to wound care and local tissue rearrangement. From the surgical standpoint, it is relatively easy to contour and fixate with monocortical screws, providing adequate structural rigidity. Because it is an alloplast, the stability of the reconstruction is dependent entirely on the quality of the soft-tissue envelope.

Free muscle flaps have been used extensively in cranial vault reconstruction.[4,5] However, long-term flap atrophy of up to 80 percent has been

reported.[6,7] The latter led to an increased interest in adipocutaneous perforator free flaps because they consistently maintain their contour and volume over time. The unpredictable volume changes associated with denervated muscle are removed from the equation when transferring skin and fat. The long vascular pedicle offered by the perforator flaps used in this series allows for vascular anastomosis out of the zone of injury. Of additional importance is the minimal donor-site morbidity associated with perforator flaps when compared with traditional muscle flaps. The notable preservation of functional muscle units decreases overall morbidity.

The combination of mesh and perforator flaps is imperative for facilitating definitive reconstruction in the setting of failed cranioplasty, as each provides a separate but important role in the reconstruction. The mesh provides a rigid framework and protects the brain, and the adipocutaneous flap provides volume. A perforator flap alone is not desirable, as it does not provide adequate protection to the brain and has been reported to cause compression in the absence of a protective framework.[8]

Several other options are available for hardware coverage and volume after cranioplasty, namely, tissue expansion and fat grafts. In the setting of persistent failure with chronic infection after multiple cranioplasty attempts, it was felt that a single procedure to provide a definitive solution was preferable to the implantation of a tissue expander with serial expansion and later revision. Although there have been anecdotal reports of nonvascularized fat grafting as an alternative method of increasing soft-tissue bulk of thin scalp flaps,[9] volume maintenance of nonvascularized fat grafts is notoriously unpredictable,[10] especially against the background of diminished vascularity. We prefer vascularized tissue transfer as a potentially more reliable option with more predictable volume.

The combination of titanium mesh cranioplasty and adipocutaneous free tissue transfer has resulted in safe, reliable, and aesthetic reconstructions. Although our series is small, the results have been consistently good, with few perioperative or postoperative complications. Most importantly, all of the reconstructions have preserved their volume to date. The few complications encountered at the donor sites were self-limiting and managed conservatively. The combination of titanium mesh cranioplasty and perforator-based free tissue transfer has gained favor at our institution because of the ability to obtain a reliable reconstruction in the setting of an attenuated soft-tissue envelope.

Eduardo D. Rodriguez, M.D., D.D.S.
Division of Plastic, Reconstructive, and Maxillofacial Surgery
R Adams Cowley Shock Trauma Center
22 South Greene Street, Room T6R59
Baltimore, Md. 21201-1545
erodriguez@umm.edu

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