

Dynamic Brow Restoration Using a Soft Tissue Expander in Adult Patients With Arteriovenous Malformation

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Background: Impaired brow function in adult patients with arteriovenous malformation is a serious disability that can even influence the field of vision. Brow reanimation techniques are used to recover a more natural appearance and brow function. Many static procedures have been set to augment brow elevation, but only dynamic procedures can lead to better functional results. In this study, the experience of a single surgeon addressing the challenge of brow restoration with dynamic procedures is presented.

Methods: A retrospective review was performed using the records of 4 adult patients who underwent dynamic procedures using a soft tissue expander for brow restoration after arteriovenous malformation excision in the unilateral site of the forehead with the expander on the contralateral side. Movement and electrodiagnostic examinations were performed postoperatively at 2 months.

Results: The patients included 3 males and 1 female (mean age, 20.5 ± 4.04 years). Brow improvement was noted in all patients. The results of the electrodiagnostic examination showed synchronous and spontaneous motor unit potentials and compound muscle action potentials with the contralateral forehead.

Conclusions: Dynamic procedures using a soft tissue expander can provide both static and dynamic functional brow elevation of the contralateral frontalis and skin.

Key Words: arteriovenous malformation, dynamic brow restoration, soft tissue expander

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Among vascular malformation subtypes, arteriovenous malformation (AVM) is considered the rarest. Arteriovenous malformation has a high-flow shunt between the feeding artery and outflow vein and an abnormal capillary network.¹ The preferred treatment of an AVM lesion has been radical excision.^{2,3} However, radical excision may cause postoperative functional and aesthetic damage, particularly when the lesion is located in the facial region. Compared with other peripheral AVMs, lesion expansion often causes deformities and can be aesthetically displeasing, leading to social problems. Sometimes, at the terminal stages, it is usually life-threatening. Resection and reconstruction may cause a deformity that is more noticeable than the original malformation.⁴

When the lesion is located in the frontal and temporal areas, it can be challenging to reconstruct the brow to provide pleasing aesthetics and acceptable functionality.⁵ Skin loss and brow lift function are some of the most important consequences of AVM excision in the unilateral or temporal forehead. Additionally, ptosis of the eyelid and brow often affects patients.

In this study, we investigated surgical treatment to repair the defects of the frontalis muscle and skin after radical resection of AVM. Restoration of the frontalis muscle both statically and dynamically has been a challenging problem for surgeons so far. There are many procedures that are designed to repair skin defects, but dynamic restoration of muscle defects has rarely been performed because it is hard to restore the frontalis muscle dynamically, and results have generally been poor. A single technique that meets all criteria has not been found yet.

The most widely used static procedure sometimes does not have long-lasting effects, although it is effective in most cases.^{6,7} At present, new dynamic techniques have been used to try to restore brow elevation by means of increasing the function of the eyebrow or substituting the frontalis muscle with other muscle units. However, experience with these techniques has been limited, and the results have been modest. Hence, the quest for the most appropriate technique for frontalis reanimation continues.

In this study, the authors attempted to expand the contralateral frontalis muscle to restore eyebrow function, a technique that has not been previously reported. Theoretically, the contralateral frontalis muscle, more than other muscles, would be suitable for eyebrow reanimation because of the following features. First, the thickness of the frontalis muscle is less, and it is hard to find a similar muscle as a substitute. Second, it is possible to achieve innervation of a piece of muscle via the contralateral temporal branch of the facial nerve to provide synergetic movement of the eyebrow. In this study, we aimed to explore the feasibility of using a tissue expander to expand the contralateral frontalis muscle to repair ipsilateral defects of the frontalis muscle.

PATIENTS AND METHODS

Patient Demographics

We retrospectively reviewed the records of 4 patients who underwent dynamic procedures for eyebrow restoration using our method between March 2011 and January 2013. The inclusion criteria were unilateral local AVM at the temporal or forehead site and inability to preserve functionality of the frontalis after resection of the lesion.

An electrophysiological examination and a detailed examination of the facial musculature were performed and well documented; the follow-up period was from 6 to 52 months. The patient demographics are shown in Table 1.

Surgical Procedure for Tissue Expansion

Tissue expansion surgery has the advantage of providing extra skin and functional muscle to cover the defects of the skin and muscle physiology. This technique has been widely used to cover skin defects. However, there have been few articles on the use of a tissue expander to expand a functional muscle. Although tissue expansion surgery is the first stage, it is an integral part of the restoration. After installing the expander, it was filled with saline by injection. The surface area of the tissue was measured after expansion. The volume of the tissue expander was selected according to the lesion area, and the tissue expander was located at the contralateral side of the forehead. Gradual filling of the expander with saline injection was performed at intervals over 16 weeks.

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TABLE 1. Patient Demographics

Patients	Age	Sex	Diagnosis	Site
1	18	Male	AVM	Right frontalis, orbitalis
2	19	Male	AVM	Right temporalis, frontalis, orbitalis
3	21	Male	AVM	Right temporalis, frontalis, parietalis
4	25	Female	AVM	Left frontalis, temporalis, parietalis

Surgical Procedures for Lesion Excision and Dynamic Restoration

The second stage involves lesion excision and dynamic restoration of the brow. The surgery is performed with the patient in the supine position under general anesthesia. First, the AVM lesion was removed radically. After prudent hemostasis, the expanded skin-muscle flap was rotated and transferred to the defect site to cover the skin and muscle defect simultaneously. All patients underwent postoperative pathological examination. Dynamic procedures to restore brow function were primarily investigated in this study. After the procedure, the patients were provided postoperative care and rehabilitation. Antibiotics and hemostatic agents were used for 1 day after the operation, the dressings were changed every 4 days, and the sutures were removed 9 days after the operation. Electrodiagnostic examination was performed postoperatively at 2 months. If the static or dynamic results were not satisfactory, the revision was performed 3 months after the initial operation. The procedure has been represented as a diagrammatic sketch in Figure 1.

Satisfaction Assessment

Clinical efficacy assessments were conducted independently by 3 plastic surgeons (doctors A, B, and C), who had no previous knowledge about the patients and did not participate in the surgery. For this, we employed standardized facial photographs obtained by a single professional photographer in a professional studio with 2 flashes. Preoperative and postoperative (3 months at least after the latest reconstructive surgery reported here) photographs of all patients were classified by 3 plastic surgeons, based on the 2 previously published outcome rating scales. A Global Aesthetic Improvement Scale (GAIS) was used to rate the results as very much improved (4 points), much improved (3 points), improved (2 points), no change (1 point), or worse (0 point). And another rating scale on the need for additional surgery was defined as category I (3 points), no refinements or surgical revisions considered advisable or necessary; category II (2 points), soft tissue contouring revisions were advisable; category III (1 point), required a considerable amount of additional surgeries (procedures not as extensive as the original

TABLE 2. Patients' Diagram

Patient	Size of the Expander	Shape of the Expander	Recurrence	Mean Score of GAIS	Need for Additional Surgery (Score)
1	80	Rectangular	Yes	3	2.3
2	100	Rectangular	No	3.3	2.67
3	80	Rectangular	No	3	2.3
4	100	Rectangular	No	3.67	3

procedure); and category IV (0 point), major craniofacial soft tissue procedure advisable, duplicating, or exceeding the original procedure.

RESULTS

All wounds achieved primary healing, and no complications, such as hematoma, infection, or wound dehiscence, occurred. The recurrence of AVM lesion occurred in only 1 patient on the margin of the upper eye lid, which was assessed carefully during the follow-up postoperatively.

All the patients could elevate their eyebrows during the follow-up. The results of the electrodiagnostic examination showed that the frontalis muscle was innervated by the contralateral temporal branch. Both static symmetry and dynamic symmetry were observed 4 years postoperation (Supplemental Digital Content 1, <http://links.lww.com/SAP/A419>).

During follow-up, a substantial frontal functional and aesthetic improvement was obtained in all the 4 patients, evaluated through preoperative and postoperative (the last one) pictures. The average objective GAIS scores for the 4 patients from 3 independent plastic surgeons with the satisfaction assessment were: 3, 3.3, 3, and 3.67, respectively, and the overall rates of surgical results ranked according to the need for additional surgery were 2.3, 2.67, 2.3, and 3, respectively. In this series, all the 4 cases obtained eyebrow dynamic movement especially the second and the fourth cases. However, the range of movement and the symmetry of the eyebrow can be further improved by surgery.

The patients' diagram is shown in Table 2 and Figures 2–6.

DISCUSSION

Although associated lethal conditions, such as massive hemorrhage, may occur, AVMs are usually not life-threatening. In addition to symptoms, such as bleeding and ulceration, patients are primarily worried about cosmetic and functional disfigurements, such as ptosis of the eyebrow, skin color changes, and deformities caused by lesion expansion.⁸ Interestingly, in this study, all patients regardless of sex had

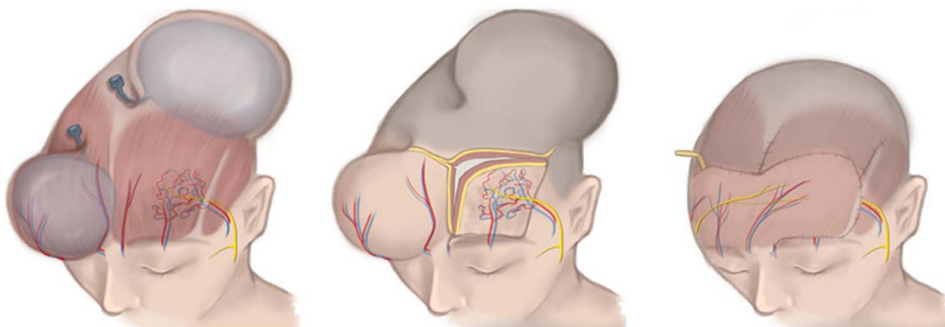


FIGURE 1. Diagrammatic sketch of the procedure. [full color online](#)



FIGURE 2. Surgery details of patient 1. A, A lesion in the temporal area and upper eyelid (March 2011). B, The lesion is removed, and the expanded musculocutaneous flap is transferred to the recipient site. C and D, The patient shows both static and dynamic symmetry. A recurrent lesion occurred at the margin of the upper lid (July 2015). [full color online](#)

cosmetic concerns. All patients were examined by angiography for differentiation and to decide the appropriate therapy.

Some reports have described the management of head and neck AVMs with ethanol embolization, but long-term results are scarce. Su et al⁹ reported that ethanol embolotherapy for head and neck AVMs was effective in 74% of patients, but there was only a short clinical follow-up. Pekkola et al¹⁰ analyzed the treatment outcomes of 19 patients with AVMs in the head and neck region after ethanol sclerotherapy. The results showed that 11 patients had complete eradication of the AVM, and 1 patient experienced recurrence, with a mean follow-up of 15 months. Regarding long-term results, Kim et al. reported the outcomes of ethanol sclerotherapy performed in 45 patients.¹¹ Total angiographic eradication of the AVMs was achieved in 17.8% of the patients, and partial resolution was achieved in 75.6% of the patients, with a mean follow-up of 56.6 months. The recurrence rate was 11.1%. As is well known, the long-term treatment outcomes could be affected by both endovascular

and surgical procedures. Meila et al¹² recently reported that complete or greater than 90% closure of head and neck AVMs was achieved in 6 of 14 patients using Ethibloc (Ethicon, Somerville, NJ) and Onyx (mean follow-up, 91 months). Regardless of the treatment modalities, a high recurrence rate of AVMs has been established by most investigators, and follow-up of 5 years is widely accepted as sufficient to allow conclusions on long-term disease control.^{3,11} Even localized lesions sometimes require surgical resection for better results. Although these studies can achieve good results for lesions and the skin, there are also worries about the facial nerve and mimic muscle injured by the ethanol.

Although AVM occurs in the temporal area or frontalis muscle, it usually causes eyebrow ptosis after radical resection of the lesion. Because the frontalis muscle is flat, it is hard to find a similarly thin muscle for substitution. Regarding therapeutic outcome, there are no previous reports that have shared experiences similar to ours. It remains a challenge for surgeons to restore eyebrow elevation after local AVM radical



FIGURE 3. Surgery details of patient 2. A, A lesion in the temporal area and frontalis muscle (September 2011). B, The lesion is removed, and the expanded musculocutaneous flap is transferred to the recipient site. C and D, The patient shows both static and dynamic symmetry (September 2015). E, The lesion is removed intraoperatively. [full color online](#)

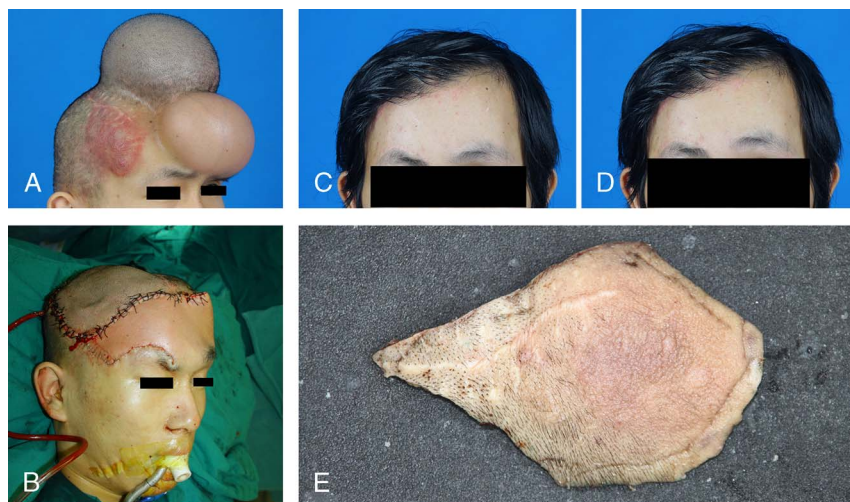


FIGURE 4. Surgery details of patient 3. A, A lesion in the temporal area and frontalis muscle (May 2011). B, The lesion is removed, and the expanded musculocutaneous flap is transferred to the recipient site. C and D, The patient shows both static and dynamic symmetry (November 2011). E, The lesion is removed intraoperatively. [full color online](#)

resection. Our technique attempts to redirect elevatory force to the eyebrow after local AVM radical resection by transposing and trimming an expanded frontalis skin-muscle flap from the contralateral side. Overall, the technique can achieve clinically significant static and dynamic brow elevation. The technique is associated with few complications and has a low reoperation rate. These results compare favorably with other static lifting studies,^{7,13–15} and the procedure can achieve spontaneous and symmetric elevation of the eyebrow.

This procedure may not provide enough elevation for patients in the first few weeks postoperatively. Patients undergoing rehabilitation for several months will develop better eyebrow elevation function. Some patients require a secondary surgery to adjust the elevation direction and position of the eyebrow, and scars can be trimmed at the same time.

Several other limitations of this study exist. First, the sample size was quite small (only 4 patients); therefore, a greater number of cases is needed to gain experience. Second, this procedure needs longer follow-up to confirm its long-term effect.

Furthermore, considering the safety during musculocutaneous flap expansion and harvest, it is vitally important to avoid damaging other important structures, such as the temporal branch of the

contralateral facial nerve. Nevertheless, unexpected anatomical variations should always be anticipated; thus, the importance of proceeding cautiously cannot be overemphasized. As stated earlier, a nerve stimulator may be of great aid to confirm the nerve that should be harvested and to maintain the integrity of the others. Nonetheless, what should be seriously considered in the raising of this flap is the skin incision and surgical approach. When we perform the expanded skin-muscle flap rotation, the pedicle of the flap should always be in the temporalis region to avoid injury to the contralateral facial nerve branch. Accordingly, we used a monopolar dissector and optical retractor to dissect the skin-muscle flap on its deep aspect all the way, visualizing the layer during the process.

In addition, it needs to be considered that a healthy well-vascularized pedicle is critical to ensure “flap survival,” and when to harvest the flap during the secondary surgery should also be taken into account to avoid scarring and capsule formation and to not damage the pedicle too much.

Another issue is that it is necessary to determine if the surface area of the expanded flap is sufficient. According to previous experiences, injection of 4 mL of saline can expand an extra 1 cm² of skin.

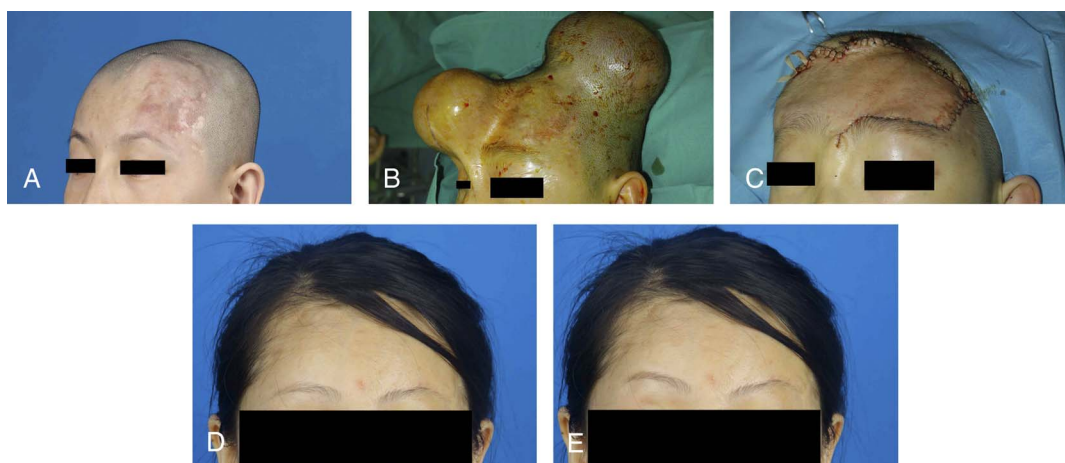


FIGURE 5. Surgery details of patient 4. A, B, A lesion in the temporal area and frontalis muscle (January 2013). C, The lesion is removed, and the expanded musculocutaneous flap is transferred to the recipient site. D and E, The patient shows both static and dynamic symmetry (August 2016). [full color online](#)

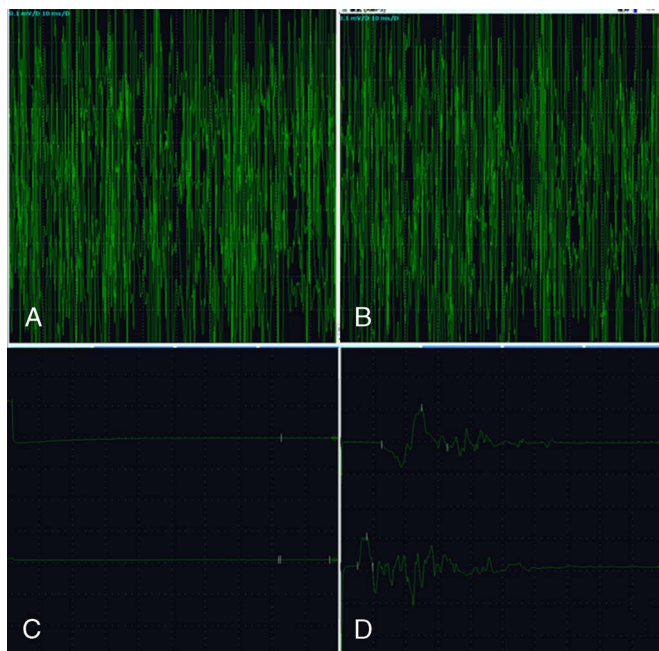


FIGURE 6. Electrodiagnostic examination results of patient 2 at postoperative 3 months. A, Motor unit potentials (MUPs) and compound muscle action potentials (CMAPs) on the ipsilateral site show that the frontalis muscle can be innervated spontaneously. B, MUPs on the contralateral site show that there is no injury to the contralateral site. C, CMAPs on both sites when stimulated by the ipsilateral site temporal branch show that there is no innervation from the ipsilateral site. D, CMAPs on both sites when stimulated by the temporal branch on the contralateral site show that both sites are innervated from the contralateral site facial nerve.

According to this rule (4:1), the amount of saline for injection can easily be calculated. Excess injections were needed for every patient to prepare for extra needs and the retraction of the expanded flap.

One important aspect to consider regarding the use of this flap is donor site morbidity. Three patients underwent temporal forehead hypesthesia, but 2 of these patients recovered after 3 months. Hypesthesia was typically located on the distal part of the expanded flap and was transitory, which was noted as bothersome and persistent in 1 patient. Intraoperatively, the contralateral facial nerve was not dissected and identified; it is usually included in the muscle flap. With experience, the authors will avoid transecting this nerve during flap formation.

Temporary hypesthesia seems to be tolerable for all patients.¹⁶ Although the benefits of this procedure seem obvious, potential disadvantages remain unknown. Further modifications may allow for fewer

adverse effects and improved results. The long-term results of this procedure remain undetermined.

CONCLUSIONS

Dynamic reanimation of the eyebrow is a vitally important goal in the treatment of eyebrow ptosis. The expanded contralateral musculocutaneous flap can be a good alternative. To minimize donor site morbidity, the use of an optical retractor and monopolar dissector is the preferred method for flap harvest. The clinical viability and effectiveness of this technique remain to be investigated.

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