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Reconstructive

# Versatility of the Latissimus Dorsi Free Flap during the Treatment of Complex Postcraniotomy Surgical Site Infections

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**Background:** Some intractable cases of postcraniotomy infection, which can involve compromised skin, an open frontal air sinus, and residual epidural dead space, have been reported. In such cases, reconstructing the scalp and skull is challenging.
**Methods:** Between 2009 and 2016, the author treated 12 patients with recalcitrant postcraniotomy surgical site infections with latissimus dorsi (LD) free flaps. The patients' ages ranged from 37 to 79 years (mean, 63.5 years), and their underlying diseases included subarachnoid hemorrhaging (n = 5), brain tumors (n = 4), and cerebral arteriovenous malformations (n = 3).
**Results:** The LD free flap was used for scalp reconstruction in 3 cases, scalp reconstruction and separation of the intracranial and nasal cavities in 5 cases, and the obliteration of epidural dead space in 4 cases. Debridement followed by staged cranial reconstruction was carried out in 8 cases, and single-stage cranial reconstruction was conducted in 2 cases. The bone defects of the other 2 cases, which were small, were filled with LD musculo-adipose free flaps. The postoperative local appearance of the wounds was acceptable in every case, and no complications occurred.
**Conclusions:** The LD free flap is a versatile tool for the treatment of complex postcraniotomy surgical site infections. This vascularized muscle flap is useful for controlling local infections because of its abundant vascularity. Moreover, its variety of uses means that it can resolve several problems in cases involving complex cranial wounds. *(Plast Reconstr Surg Glob Open 2017;5:e1355; doi: 10.1097/GOX.0000000000001355; Published online 13 June 2017.)*

## INTRODUCTION

It has been reported that free flaps are useful for treating complex postcraniotomy surgical site infections. Various free tissue flaps can be used for covering wounds and reconstructing bone defects.[1–5] However, in addition to scalp defects, there are several issues associated with cranial reconstruction that need resolving, including open frontal sinuses and residual epidural dead space. The author has treated complex postcraniotomy surgical site infections by exclusively using latissimus dorsi (LD) free flaps for various purposes. In this article, the author describes the versatility of the LD free flap for treating complex surgical site infections that arise after craniotomy.

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## PATIENTS AND METHODS

Between 2009 and 2016, 12 patients with postcraniotomy surgical site infections were treated with LD free flaps. The LD free flaps were used for scalp reconstruction, separation of the nasal and intracranial cavities, and the obliteration of dead epidural space. The patients' ages ranged from 37 to 79 years (mean, 63.5 years), and their underlying diseases included subarachnoid hemorrhaging (n = 5), brain tumors (n = 4), and cerebral arteriovenous malformations (n = 3). The study was performed according to the institutional ethical guidelines and patients provided consent.

## RESULTS

The results of this study are summarized in Table 1. The LD free flap was used for scalp reconstruction in 3 cases, scalp reconstruction and separation of the nasal and intracranial cavities in 5 cases, and the obliteration of dead epidural space in 4 cases. The superficial temporal vessels were the recipient vessels in every case except one,

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**Table 1. Patient Summary**

| No. | Age/Sex | Original Disease | Debridement (Timing: Y/Mo) | Cranioplasty (Timing: Y/Mo; Material) | Transferred Flap | Role of the Flap (Timing of Transfer) | Recipient Site | Complications | Follow-Up (Mo) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 79/M | SAH | 2009/6 | 2009/9; HA | LD M flap with STSG | Scalp reconstruction, separation from NS (debridement) | STAV | No | 82 (Died of another disease) |
| 2 | 60/F | BT | 2010/8 | 2010/11; HA | LD M flap with STSG | Scalp reconstruction (debridement) | FAV | No | 72 |
| 3 | 37/F | AVM | 2011/4 | 2011/7; HA | LD M flap | Obliteration of ES (cranioplasty) | STAV | No | 64 |
| 4 | 73/F | AVM | 2014/4 | 2014/7; HA | LD M flap with STSG | Scalp reconstruction (debridement) | STAV | No | 28 |
| 5 | 51/M | AVM | 2014/12 | 2015/2; HA | LD Mflap | Obliteration of ES (cranioplasty) | STAV | No | 21 |
| 6 | 75/F | SAH | 2014/12 | 2015/3 HA | LD M flap | Obliteration of ES (cranioplasty) | STAV | No | 20 |
| 7 | 67/F | SAH | 2015/2 | 2015/4 Titanium | LD M flap with STSG | Scalp reconstruction (debridement) | STAV | No | 19 |
| 8 | 53/M | BT | 2015/8 | No | LD MA flap with STSG | Scalp reconstruction, separation from NS (debridement) | STAV | No | 15 |
| 9 | 73/F | SAH | 2015/10 | 2016/1 Titanium | LD MA flap with STSG | Scalp reconstruction, separation from NS (debridement) | STAV | No | 10 |
| 10 | 66/M | BT | 2016/3 (Single-stage cranioplasty) | Titanium | LD M flap with STSG | Scalp reconstruction, separation from NS | STAV | No | 8 |
| 11 | 64/M | SAH | 2016/5 | No | LD MA flap with STSG | Scalp reconstruction, separation from NS (debridement) | STAV | No | 6 |
| 12 | 65/M | BT | 2016/5 (Single-stage cranioplasty) | AC | LD MA flap | Obliteration of ES | STAV | No | 6 |

AC, alumina ceramics; AVM, arteriovenous malformation; BT, brain tumor; ES, epidural space; F, female; FAV, facial artery and vein; HA, hydroxyapatite; LD M, latissimus dorsi muscle; LD MA, latissimus dorsi musculo-adipose; M, male; NS, nasal space; SAH, subarachnoid hemorrhage; STAV, superficial temporal artery and vein.

in which the patient had previously undergone a rectus abdominis muscle transfer for skull base reconstruction, and so the facial vessels were used instead. Debridement followed by staged cranial reconstruction was carried out in 8 cases, and single-stage cranial reconstruction was performed in 2 cases. The materials used for the cranioplasty were hydroxyapatite in 6 cases, titanium mesh in 3 cases, and alumina ceramics in 1 case. The bone defects in the other 2 cases, which were small, were filled with LD musculo-adipose free flaps. The reconstruction of the skin defects and the separation of the nasal and intracranial cavities were performed after debridement. On the other hand, the obliteration of dead epidural space was carried out during cranioplasty. The 3 of 4 patients in whom LD free flaps were used to obliterate dead epidural space had developed infections following previous cranioplasty procedures, which were performed with reduced curvature cranial implants. In case 12, a frontal bone defect was reconstructed with a normal curvature implant due to aesthetic considerations. The mean duration of the postoperative follow-up period was 30 months (range, 6–82 months).

## CASE REPORTS

### Patient 1

A 79-year-old man underwent a bifrontal craniotomy for a subarachnoid hemorrhage. After temporary external decompression, the craniotomy site was reconstructed with titanium mesh. The patient presented with an epidural abscess and a forehead skin ulcer due to delayed-onset frontal sinusitis 20 years after the initial craniotomy. The frontal sinusitis was caused by obstruction of the frontal sinus outflow tract due to improper treatment of an open frontal sinus during the initial craniotomy. The patient had a large forehead skin defect, which contained exposed titanium mesh and purulent discharge. Surgical debridement, cranialization of the frontal sinus, elimination of the obstructed frontal sinus outflow tract, and reconstruction of the forehead skin were carried out using an LD free muscle flap with a split-thickness skin graft (STSG). The superficial temporal vessels were used as recipient vessels. Separation of the nasal and intracranial cavities was performed using the caudal side of the muscle flap. Secondary cranioplasty with a custom-made hydroxyapatite implant was successfully carried out while leaving part of the muscle over the frontal skull base (Fig. 1).

### Patient 9

A 73-year-old woman underwent bifrontal craniotomy for a subarachnoid hemorrhage, and a previously inserted autogenous bone flap was replaced during the procedure. The patient's postoperative course has been uneventful for 3 years. Before being referred to our hospital, the patient suffered from swelling of the forehead and a high fever. A radiological examination showed an epidural abscess and infection of the forehead skin and underlying soft tissue. A computed tomography (CT) scan showed that the frontal sinus had been cranialized, and the frontal sinus outflow tract had closed due to ossification. Surgical debridement, drilling of the bony surface of the base of the sinus, and the filling of the epidural space with an LD free musculo-adipose flap were performed. The superficial temporal vessels were used as recipient vessels.


**Fig. 1.** Patient 1. A preoperative local examination revealed exposed titanium mesh and that the surrounding skin was compromised (A). The obstructed frontal sinus outflow tract was extirpated after drilling the walls all the way around the tract (B). An LD muscle free flap was transferred to cover the frontal lobe dura mater as well as the frontal base. The contaminated skin was resected, and an STSG was fixed over the exposed muscle of the LD free flap (C). The postoperative appearance of the wound at 2 years after a secondary cranioplasty procedure involving a hydroxyapatite block is shown (D).

Reconstruction of the small forehead skin defect was carried out using an STSG on top of the muscle. Secondary cranioplasty was conducted with a custom-made titanium implant by dissecting the plane between the muscle and adipose tissue of the previously transferred LD flap. This procedure prevented dural tearing and reinforced the compromised forehead skin with the adipose tissue of the flap. The previously grafted skin was removed during the cranioplasty (Fig. 2).

**Patient 12**

A 65-year-old man underwent bifrontal craniotomy to extirpate a brain tumor. The patient subsequently required a frontal lobectomy due to the development of brain edema after the tumor extirpation. In addition, a ventriculoperitoneal (VP) shunt was inserted to control the patient's hydrocephalus. Secondary cranioplasty with artificial bone was unsuccessful because of the development of an epidural abscess due to remnant frontal epidural dead space. The patient was referred to our hospital, and a local examination detected a small skin fistula with purulent discharge, which was in communication with the epidural space. A CT scan showed epidural fluid and air collection in the frontal epidural space. However, no skin redness or swelling was seen, and the patient's laboratory data were normal. An intraoperative examination performed during the debridement did not detect any communication with the nasal cavity; however, a large epidural dead space remained. The patient's forehead skin was of sufficient thickness and was not infected; therefore, single-stage cranial reconstruction combined with obliteration of the epidural space with an LD free musculo-adipose flap was planned. The superficial temporal vessels were used as recipient vessels. The frontal epidural dead space was filled with the flap, and artificial bone, which was made of alumina ceramics, was sterilized intraoperatively and fixed in place in the bone defect. A bone window was created by drilling the autogenous bone, and the vascular pedicle of the flap was passed through it. A postoperative CT scan showed obliteration of the frontal epidural space with muscle and adipose tissue, and the patient's postoperative course was uneventful (Fig. 3).

## DISCUSSION

Free vascularized tissue is a useful material for reconstructing the scalp and skull in patients with compromised skin due to postcraniotomy surgical site infections.[1–5] Cranial reconstruction can require surgeons to perform scalp reconstruction, separate the nasal and intracranial cavities, and/or eliminate epidural dead space. Vascularized muscle is useful for controlling infections due to its abundant vascularity, and vascularized soft tissue can also be

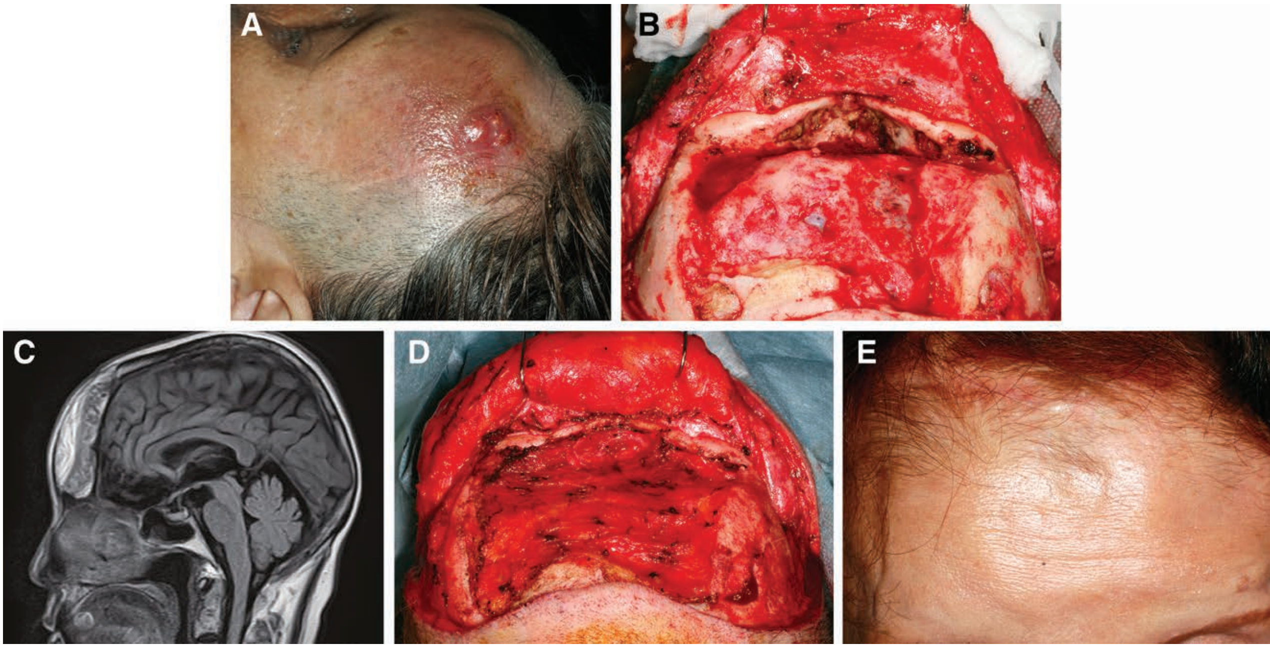


**Fig. 2.** Patient 9. A preoperative local examination revealed a forehead infection and an abscess (A). An intraoperative image acquired after debridement and drilling of the frontal sinus base is shown. The frontal sinus outflow tract had closed due to ossification (B). Postoperative sagittal T1-weighted magnetic resonance imaging showed the transplanted LD musculo-adipose free flap located between the frontal dura mater and forehead skin (C). An intraoperative image obtained during the secondary cranioplasty after dissecting the plane between the muscle and adipose tissue of the flap showed that the muscle was attached to the frontal lobe dura mater and the base of the frontal sinus (D). The postoperative appearance of the wound at 1 year after a cranioplasty procedure involving a titanium implant is shown (E).

used to obliterate dead space and reconstruct skin defects. Therefore, intractable wounds that arise after postcraniotomy infections can be reconstructed using free flaps.

### Scalp Reconstruction

Free vascularized tissue is a suitable material for reconstructing relatively large scalp defects because of its consistent vascularity and the amount of available tissue. Scalp reconstruction is most commonly conducted using an anterolateral thigh fascia cutaneous flap or a combination of an LD muscle free flap and an STSG.[4–8] According to previous studies, the use of an LD free muscle flap combined with an STSG produces aesthetically superior results compared with the use of fasciocutaneous flaps.[6–8] The thickness of skin reconstructed with an LD muscle flap/STSG matches that of the surrounding scalp well. Even when such flaps are applied to forehead skin defects, they result in a better color match than the use of a fascia cutaneous flap (e.g., patient 1). Therefore, an LD muscle free flap with an STSG is the author's method of choice for scalp reconstruction. In 6 of 8 patients who underwent scalp reconstruction in this series, the reconstructed site was located on the forehead. Another unique usage of LD free musculo-adipose flap is to reinforce the affected thin scalp by adipose component of the flap. In patient 9, the previously transferred LD free musculo-adipose flap was separated between the muscle and adipose tissue during the staged cranioplasty, and this maneuver prevented dural tearing and reinforced the compromised forehead thin skin with the adipose tissue of the flap. Regarding hair-bearing areas, the author prefers to perform tissue expansion after the transfer of a local flap and an STSG. Tissue expansion is an alternative approach, especially for scalp reconstruction of hair-bearing areas,[4,5,9] but this technique is outside of the scope of this article. Considering the alopecia caused by free flap transfers, the forehead is an appropriate site for free flap reconstruction. Although it has been mentioned that the disadvantages of the LD flap include the necessity of collecting the flap in the lateral decubitus position,[8] the author harvests the flap in the semi-lateral decubitus position and does not change the patient's position during the operation.

### Separation of the Nasal and Intracranial Cavities

Anteriorly located pericranial and galeal-pericranial flaps are the main flaps used to separate the nasal and intracranial cavities during initial craniotomy procedures.[10,11] However, this is not the case when patients suffer forehead skin defects or thinning of the skin due to infection. A part of the muscle tissue of LD free muscle flap can be utilized to separate the nasal cavity from the intracranial cavity. And simultaneous reconstruction of the forehead skin is carried out using an LD free muscle flap with a STSG like in patient 1. Secondary cranioplasty is carried out while leaving part of the muscle over the frontal skull base. Therefore, LD free muscle and musculo-adipose flap are applicable to the integrated reconstruction of the scalp and frontal skull base.

### Obliteration of the Epidural Space

There is no definite consensus regarding the necessity of obliterating dead epidural space. There have been

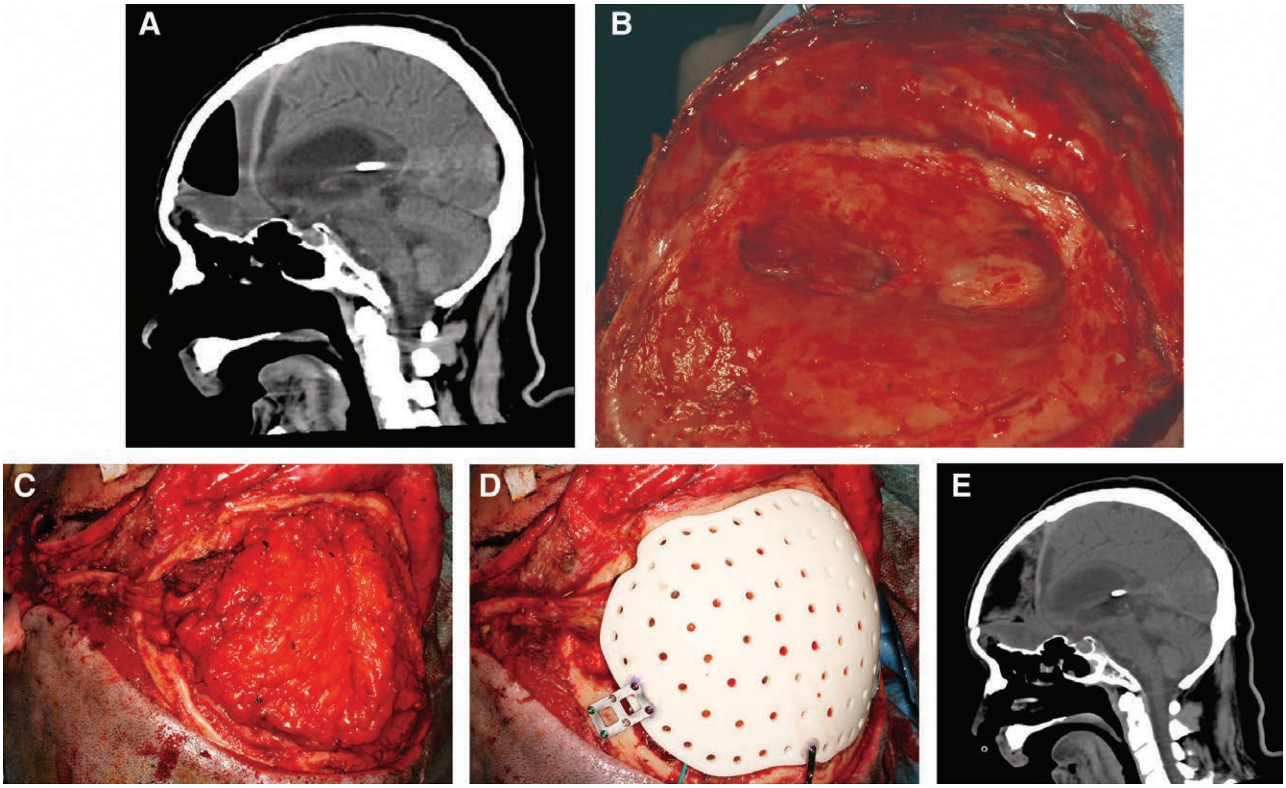


**Fig. 3.** Patient 12. A preoperative sagittal CT scan showed epidural air and fluid collection in the frontal epidural space (A). An intraoperative image obtained after debridement showed a large epidural space surrounded posteriorly by the frontal lobe dura mater and inferiorly by the frontal base. The epidural space was not in communication with the nasal cavity (B). The frontal extradural space was filled with an LD musculo-adipose free flap. Microvascular anastomosis was carried out in front of the auricle (C). A cranial implant (made of alumina ceramic) was sterilized intraoperatively and fixed in place in the bone defect without interrupting the vascular pedicle (D). A sagittal CT scan obtained at 4 months after the operation showed the complete obliteration of the frontal epidural space by the LD musculo-adipose free flap (E).

several reports regarding the natural course of extradural dead space following conventional cranioplasty and fronto-orbital advancement.[12–14] Extradural space often disappears gradually without infection after conventional cranioplasty.[12,15] It seems difficult to predict whether extradural space will remain or induce an infection after cranial reconstruction. Scar contracture of the dura mater after infection and ossification of the dura mater can both affect the expansion of the brain and whether epidural space remains. Moreover, in patients with VP shunts epidural space is likely to remain after cranial reconstruction, and the resultant dead space can increase the risk of infection or hematoma.[16,17] Therefore, it is recommended that the pressure of a ventricular shunt should be maximized at least 2 days before cranial reconstruction as far as the patient's consciousness permits. Temporary ligation of the shunt tube is another option to make the brain expand sufficiently.[18,19] Kumar et al.[20] reported that based on their experience they considered that the presence of endocranial dead space of greater than 2 cm in diameter at the time of implant placement was associated with infection. They recommended that a free tissue transfer should be performed to obliterate such dead space prior to cranial reconstruction. The author's opinion is that the larger the remnant dead space is, the greater the risk of infection; however, there is no definitive method for predicting the amount of dead space preoperatively. Therefore, the author prefers to obliterate epidural space with a vascularized free flap as a second option if conventional cranioplasty fails because of the prolonged operation time and surgical invasiveness associated with a free flap transfer.[21] Of course, the installation of a cranial implant with a decreased curvature is the first priority during cranioplasty whenever extradural dead space is expected to remain after conventional cranioplasty.[19,22] In 3 of our cases, a vascularized LD muscle flap was used to fill the extradural space after conventional cranioplasty with a decreased curved cranial implant had failed. From an aesthetic point of view, an implant with a normal curvature is preferable for frontal bone reconstruction (as was performed in case 12). Moreover, the author prefers to perform simultaneous dead space obliteration during cranial reconstruction as this makes it possible to confirm that the dead space has been eliminated intraoperatively, and the use of a free flap transfer before cranial reconstruction does not always guarantee the elimination of dead space during the subsequent cranioplasty. In addition, the complete obstruction of dead space is preferable to prevent infection.[23]

**Timing of Cranioplasty**

The standard management strategy for postcraniotomy infections consists of surgical debridement followed by delayed cranial reconstruction. It has been proposed that the interval between the initial debridement procedure and cranioplasty should be approximately 6 to 12 months.[5] However, recent reports have indicated that early (after an interval of <180 days) cranioplasty is safe.[24] The author has performed cranioplasty within the first 3 months after debridement since 2002.[25] The main advantage of early cranioplasty is that it prevents syndrome of the trephined.[26,27] In all patients who underwent cranioplasty in this series, cranioplasty was conducted within 3 months without any complications. The materials used for the cranioplasty included hydroxyapatite blocks, titanium mesh, and alumina ceramics. A custom-made hydroxyapatite block is the author's material of choice because of its osteoconductivity.[28] However, the postoperative breakage of hydroxyapatite blocks has occurred in several patients, and so titanium mesh is now predominantly selected for patients with highly active daily lives.

On the other hand, the use of single-stage cranioplasty in patients who develop postcraniotomy infections is reported to result in a low infection rate.[29,30] The author considers that cranial reconstruction using porous artificial bone, which is sandwiched between well-vascularized tissues, is an alternative method for single-stage reconstruction. In this series, 2 patients (patients 10 and 12) were treated with single-stage procedures involving debridement and immediate cranioplasty. For these patients, different method to eliminate epidural dead space is applied. First, frontal cranial reconstruction with normal curved artificial implant combined with obliteration of the epidural space using a LD free musculo-adipose flap was carried out in patient 12. Second, the dead space was eliminated using titanium mesh with a reduced curvature along the dura mater combined with vascularized LD muscle on top of the titanium mesh in patient 10. The latter technique is generally reserved for the patients with temporal craniotomy rather than frontal craniotomy from the aesthetic perspective. Another option is to use a combined LD and serratus anterior muscle flap to sandwich the implant.[31,32] Immediate cranial reconstruction is especially advantageous for patients with VP shunts since their skin flaps are likely to shrink due to atmospheric pressure, which can contribute to the development of syndrome of the trephined.[26,27]

## CONCLUSIONS

The LD free flap is a versatile tool for the treatment of complex surgical site infections that arise after craniotomy. It can be used to reconstruct the skin, separate the nasal and intracranial cavities, and obliterate any dead epidural space. The combined use of alloplastic materials enables secondary or even single-stage cranial reconstruction to be performed safely while achieving acceptable aesthetic results.

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