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Reconstruction of Extensive Scalp and Skull Defects with Dural Exposure: Report of a Series of Cases and Literature Review

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Background: Large scalp and calvarial defects pose significant challenges for reconstruction. Successful reconstruction necessitates soft tissue restoration capable of withstanding radiation following tumor resection. Free flaps allow preserving and maintaining the structural and functional status of the reconstructed area. This article presents our experience with microsurgical free tissue transfer for scalp and calvarial defects as well as a literature review on the subject.

Methods: A retrospective study was conducted to retrieve the files of all the extensive scalp/forehead defects with dural exposure treated in the plastic surgery department of Hotel Dieu de France University Hospital from September 2006 to December 2023.

Results: Twelve free tissue transfers were performed in 11 patients between 2006 and 2023. In 3 cases, a 2-stage procedure was performed with the transfer of the free flap in the first stage and the ablative surgery in the second stage 1 week later. A muscular latissimus dorsi flap was used in 9 cases. In 3 patients, the defect involved the forehead and required cutaneous flaps: 2 radial forearm flaps and 1 parascapular flap. Complications included 1 flap venous thrombosis, 2 hematomas, 1 subdural hematoma, and 2 cases of distal flap necrosis.

Conclusions: Free tissue transfer is indispensable for addressing large defects of the scalp and calvaria. A 2-stage operation is warranted for debilitated patients with a high risk of complications. The latissimus dorsi muscle flap is the flap of choice to cover extensive defects. Delayed cranioplasty is preferable in contaminated wounds.
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INTRODUCTION

Large scalp and calvarial defects pose significant challenges for reconstruction.[1] These defects may arise from tumor-related causes such as surgical resection and radionecrosis, or from traumatic injuries, severe burns, and rarely, vasculitic disorders. The extent of scalp tissue loss can range from small partial-thickness wounds to large full-thickness wounds involving bone and even dura mater, potentially resulting in cerebrospinal fluid leakage. Successful reconstruction necessitates soft tissue restoration capable of withstanding radiation and accommodating adjuvant treatments following tumor resection.[2] The choice for reconstruction depends on the size, depth, and location of the defect.[3] Although local flaps may suffice for small- to medium-sized defects of the scalp, they often prove inadequate for larger defects involving the calvaria. In such cases, only free flaps can adequately address the challenge.[3,4] Free flaps offer multiple options that allow preserving and maintaining the structural and functional status of the reconstructed area.[5] This case series evaluates the functional and aesthetic outcomes of different microvascular-based scalp reconstruction approaches.

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PATIENTS AND METHODS

A retrospective study was conducted to retrieve the files of all the extensive scalp/forehead defects with dural exposure treated in the plastic surgery department of Hotel Dieu de France University Hospital from September 2006 to December 2023.

Disclosure statements are at the end of this article, following the correspondence information.

Inclusion criteria included patients with composite scalp/forehead and skull defects with dural exposure necessitating free flaps for reconstruction. The extent of the soft tissue defect exceeded the capacity of the local and locoregional tissue for a safe coverage evaluated at 80 cm^2.

The medical charts were reviewed to record patient characteristics (sex, age, etiology of the defect, and defect location and size), flap characteristics (flap used and recipient vessel), reported complications, and follow-up period. Complications were noted as well as the functional outcome during the follow-up period (minimum of 6 months). This study was approved by the ethical review committee of Hotel Dieu de France University Hospital.

Takeaways

Question: What are the outcomes and considerations of using microsurgical free tissue transfer for reconstructing large scalp and calvarial defects?

Findings: Free tissue transfer is indispensable for addressing large defects of the scalp and calvaria. It is a heavy surgery, with a high complication rate.

Meaning: A 2-stage operation is warranted for patients with a high risk of complications. The large surface of the latissimus dorsi makes it ideal to cover extensive defects. The anterolateral thigh flap and the radial forearm flap are indicated for forehead reconstruction.

RESULTS

Twelve free tissue transfers were performed in 11 patients between 2006 and 2023. All patients but 2 were men, with age ranging from 33 to 79 years and a median age of 55 years. Five patients were heavy smokers. Table 1 summarizes the types of free flaps used, details of microvascular anastomosis, bone reconstruction, complications, and outcomes of reconstruction.

In 9 patients, the defect was tumor-related either following tumor resection (6 cases) or radionecrosis (3 cases). The other 2 defects were trauma-related (gunshot wound and car accident).

In 3 cases, a 2-stage procedure was performed with the transfer of the free flap in the first stage and the ablative surgery in the second stage 1 week later (Figs. 1–5). During banking, the operative site is covered by a waterproof dressing, and the flap is spread and sutured to a handmade sterile nylon sheet and secured to the periphery of the scalp with stay stitches (Fig. 2).

A duroplasty was performed in 3 cases. The calvarial defect was repaired with a polymethyl methacrylate (PMMA) implant, immediately in 3 patients and after 6 months in another case. In 1 patient, bone grafts were used in a delayed manner (Fig. 4).

A muscular latissimus dorsi (LD) flap was used in 9 cases. The muscular flap included a small skin island for monitoring, and the rest of the flap was covered with a partial thickness skin graft. In 3 patients, the defect involved the forehead and required cutaneous flaps: 2 radial forearm flaps and 1 parascapular flap (Figs. 6 and 7). Recipient vessels were the superficial temporal vessels in 6 patients and cervical vessels in 6 patients.

During the early follow-up period, we had 1 flap venous thrombosis at 1 week that was salvaged using a vein graft, 2 hematomas that needed evacuation, 1 subdural hematoma that required neurosurgical intervention, and 2 cases of distal flap necrosis with loss of 20% and 10% of the flaps, respectively, that required flap revision for advancement. One patient with PMMA cranioplasty underwent reoperation with the removal of cranioplasty material due to infection. During long-term follow-up, 2 patients died of a recurrence of their tumor at 4 months and 1 year postoperative, respectively. One patient died of lung cancer at 2 years postoperative. The other patients had a favorable course with a follow-up ranging from 1 year to 7 years with a mean follow-up period of 2.5 years.

DISCUSSION

Reconstruction of large defects of the scalp/forehead and underlying skull depends on several factors such as the anatomic involvement of the defects, the depth and size of the lesions, concomitant radiotherapy, and the general condition and comorbidities of the patient.[6] Local flaps are limited in dimensions and bulk and easily surpassed by the extent of the defect. Scarring, radiotherapy, and smoking history make them an unreliable option.[4] This makes the microsurgical transfer of free flaps the necessary choice.

Two-Stage Procedure

In case of partial or total necrosis of the free flap, meninges or brain tissues are exposed, leading to bacterial contamination, cerebrospinal fluid leak, and multiple other life-threatening complications. Servant et al[7] described a 2-stage procedure of transferring the free flap a few days before the abdominal wall resection Ray et al[8] applied this technique for large neurosurgical resections (scalp and calvaria) with the use of different free flaps. The first stage consisted of microsurgical transfer. The exact size of the skin excision was predetermined by the neurosurgeon. The free flap was harvested and transferred to the cranial site. It was folded. The second stage consisted of tumoral resection and reconstruction after several days.[8] This technique helps to successfully manage free flap complications before the cranial resection (hematoma, venous congestion, flap ischemia, and so on). We used this technique in 3 of our patients with multiple comorbidities. In 1 of our patients, distal flap necrosis occurred before definitive reconstruction (Fig. 8). This prevented meninges exposure in the event of simultaneous radionecrosis resection and flap reconstruction.

No data exist on the optimal waiting time between the 2 operations. Ray et al[8] stated that the time between the first and second procedures varied according to the extent of recovery of the patient, flap viability, and the characteristics of the second surgery. We waited 1 week before the second stage. By this time, vascular compromise and thrombosis become unlikely, and any distal flap necrosis will be well demarcated for debridement. If in 1 week the

Table 1. Patients Included in This Case Series

Age, y	Sex	Comorbidities	Etiology	Flap	Recipient Vessels	Site of Reconstruction	Dural Reconstruction	Two-Stage Reconstruction	Bone Reconstruction	Result	Follow-up
72	M	HTA	Radionecrosis	Lat dorsi	Sup temp	Frontal, parietal	Y	Y	Y, immediate PMMA	Venous thrombosis D7	100% take (ok at 5 y)
33	F	Smoking	Gunshot	Parascapular	Cervical (facial artery, facial vein)	Frontal	N	N	N	Partial necrosis	75% take (ok at 7 y)
66	M	No	Epidermoid carcinoma	Lat dorsi	Cervical (facial artery, external jugular vein)	Parietal	N	N	Y, immediate PMMA	Wound dehiscence	90% take (death at 6 mo)
70	M	HTA, smoking	Radionecrosis	Lat dorsi	Cervical (facial artery, external jugular vein)	Occipital, parietal	N	Y	N	Hematoma D1	100% take (lost to follow-up)
36	M	No	Epidermoid carcinoma	Lat dorsi	Cervical (facial artery, external jugular vein)	Frontal	Y	N	N	Recurrence of carcinoma	100% take
			Recurrent epidermoid carcinoma	Lat dorsi	Cervical (lingual artery, facial vein)	Frontal	N	N	N	DFD at 1 y	100% take (death at 1 y)
54	M	Smoking	Epidermoid carcinoma	Lat dorsi	Cervical (facial artery, external jugular vein)	Frontal	N	N	N	Subdural hematoma D14	100% take (death at 2 y)
63	M	Smoking, HTA, diab, dysl	Radionecrosis	Lat dorsi	Sup temp	Parietal	N	N	N	Favorable at 2 y	100% take (ok at 2 y)
46	M	Smoking	Dermatofibrosarcoma	Radial forearm	Sup temp	Frontal, parietal	N	N	Y, delayed PMMA	Favorable	100% take (ok at 18 mo)
75	M	HTA, diab, dysl	Epidermoid carcinoma	Lat dorsi	Sup temp	Frontal, parietal	N	Y	Y, immediate PMMA	Infection recipient site	100% (Ok at 1 y)
36	F	No	Trauma	Radial forearm	Sup temp	Frontal	Y	N	Y, delayed bone graft	Favorable at 1 y	100% (ok at 1 y)
79	M	HTA, diab	Basocellular carcinoma	Lat dorsi	Sup temp	Frontal, parietal	N	N	N	Hematoma donor site	100% (ok at 1 y)

D, day; DFD, death from disease; Diab, diabetes; Dysl, dyslipidemia; F, female; HTN, hypertension; Lat dorsi, latissimus dorsi flap; M, male; N, no; PMMA, polymethyl methacrylate; Sup temp, superficial temporal; Y, yes.

Fig. 1. A 72-year-old patient presenting with radionecrosis in the frontoparietal area. Photograph showing a 4×3 parietal defect due to radionecrosis with a surrounding area of severe radiodistrophy. A 2-stage procedure was planned.

Fig. 2. Latissimus dorsi muscle flap was harvested and sutured to a handmade nylon drape before ligating the pedicle.

demarcation line is not clear, and if the size of the flap allows a generous debridement beyond the questionable part of the flap, we still prefer performing the second stage at this time. If this is not feasible, the banking period may be extended for a few days until the demarcation is more precise but with the increased risks of a longer hospital stay and the higher risk of maceration and infection

Fig. 3. Flap transferred to the cranial site. Anastomosis to superficial temporal vessels. The flap was spread over the area of radionecrosis and secured with temporary stitches. Muscle was covered with a split-thickness skin graft. The photograph was taken before covering the pedicle and temporal area with a skin graft.

Fig. 4. Excision of the irradiated scalp with resection of necrotic bone and bone reconstruction with PMMA.

of the lesion underneath the flap. By covering the operative site with a waterproof dressing, we reduce the risk of contamination of the flap. Additionally, by spreading the flap and securing it at its periphery, we reduce its natural tendency for contracture.

However, a longer total time is spent in the hospital. It might be used for patients at high risk of complications. The LD flap is more suitable for a staged surgery. The flap can cover a very wide area, anticipating a possible wider defect during the second stage. Another possible 2-stage scalp-free flap reconstruction[9] consists of recipient vessel dissection during the first stage and the flap harvest and microvascular anastomoses during the second stage.

Flap Choice

In very large defects, the LD muscle or myocutaneous free flap is the flap of choice.[10] The LD is the largest,

Fig. 5. Thirty months postoperatively, the patient shows a very acceptable aesthetic result, with spontaneous atrophy of the muscle and good skin coverage.

Fig. 6. A 46-year-old patient with a recurrent sarcoma of the forehead. Tumor resection was performed, and a radial forearm free flap was used for reconstruction. A delayed PMMA cranioplasty.

Fig. 7. Final result 1 year postoperatively.

Fig. 8. A 70-year-old patient presenting with radionecrosis of the occipital area. A 2-stage procedure was performed: a latissimus dorsi flap was harvested and transferred to the cranial site. Anastomosis to the facial artery and external jugular vein. The pedicle was passed behind the ear for better reach. Limited distal flap necrosis occurred before the flap inset. The second stage consisted of radionecrosis resection and flap inset.

most expendable muscle in the body. This muscle flap can cover defects up to 25 × 35 cm.[11]

We prefer raising muscle-only flaps with subsequent skin grafting to allow primary closure of the donor site. A skin island can be taken for surveillance if an implanted Doppler is not available. Adjuvant postoperative radiotherapy can be delivered to split-thickness skin grafts without significant complications if placed on well-vascularized healthy tissues.[12] The reconstruction is not covered by hair but can be easily camouflaged if needed. As a muscle flap, it can be used for large contour defects. It can also be used if no cranioplasty is planned after bony resection.[3,13] Because of denervation, the muscle will atrophy with time, achieving excellent cosmetic

results without the need for debulking.[10] The LD covered by a partial thickness skin graft is more suitable than the anterolateral thigh (ALT) for very large areas because of its larger area size, the possibility to close the donor site without skin grafts, and the ability of the muscle to atrophy and thin down with time.

Smoking appeared to be a risk factor for major complications with the LD flap.[10] In our series, patients with peripheral necrosis were smokers as well as having postoperative venous thrombosis.

The forehead and scalp have separate aesthetic requirements, determined by tissue color and bulk. In the case of a forehead defect, we find the skin flap aesthetically more appropriate. We had 2 excellent results with a radial forearm free flap. Despite a slight color mismatch, the radial forearm flap gave very satisfactory results in our series. The radial forearm skin flap has proved to be one of the preferred techniques for the reconstruction of head and neck defects that require thin soft tissue.[14] It is associated with few complications requiring surgical intervention and a shorter duration of hospitalization.[15] It is used for relatively small defects and when a long pedicle is required for microsurgical anastomosis in the neck.[16] The flap pedicle length is likely the largest one that may be obtained from any free flap. Both the radial artery and cephalic vein have a large diameter, which is extremely dependable for anastomoses.[14] Sensation of the cutaneous segment may be recovered from direct neurotization through nerve sprouting from adjacent tissue or anastomosing the lateral antebrachial cutaneous nerve to a sensory recipient nerve.[17]

In the case where a parascapular flap (reconstruction of the whole forehead) was used, we had a partial necrosis of its distal part, and the thickness of the flap required serial defatting before a satisfactory result was achieved. However, stable long-term results and little donor site morbidity with good aesthetic outcomes and shorter operation time have been reported with the use of parascapular flap for scalp reconstruction.[18]

The use of a thin anterolateral thigh flap would be also an excellent choice in this situation: however, excessive bulk may be a drawback in some patients.[19] The ALT flap tends to descend toward the eyebrows over time and presents a significant color mismatch.[20] Van Driel et al[5] noted that ALT and parascapular flaps can be bulky, and color-match varies dependent on the genetic and ethnic background of the patient. Another option is the use of a spread gracilis muscle flap covered with split-thickness skin graft, which shows a great color match in the long term but is limited in dimensions.[20]

Recipient Vessels

Superficial temporal vessels are the logical best option with proximity to the defect and ease of access. Their use was possible in only 6 cases. Because of scarring, surgical resection, previous surgery, and inadequate size of the superficial temporal vessels, we had to rely on the cervical vessels for anastomosis in the other cases.

Because we always try to avoid vein grafts due to the higher rate of complications,[5] the flaps had to be tailored and elevated in a way to cover the extra distance to the neck. For this reason, we recommend starting by exploring the recipient vessels before tailoring and elevating the flap.

In our experience, a better reach was achieved by choosing the facial artery and the external jugular vein as recipient vessels. The facial artery was dissected distally behind the submandibular gland when needed, and the external jugular vein was also dissected toward the retromandibular vein in the parotid gland. The LD provided the best reach due to its large dimensions and long pedicle. The choice of superficial temporal vessels aligns with the choice of other authors.[18,21]

Preoperatively, the presence of a superficial temporal artery can be evaluated by direct palpation or Doppler imaging if a pulse is not easily identified.[22] Lipa and Butler[23] stated that if the superficial temporal vessels can be palpated preoperatively, they are consistently reliable with regard to their adequate caliber. Several authors stated that computed tomography angiography is helpful for planning free flap surgery.[13,24]

Cranioplasty

Cranial reconstruction is not always necessary. Reconstruction depends on the size and location of the bone defect.[5] Cranioplasty should be considered for restoration of aesthetic appearance, protection against trauma, and treatment of the syndrome of the trephined.[13,25] Van Driel et al[5] favor vascularized rib grafts or prosthetic material for large defects (>7–10 cm). For smaller defects, reconstruction should be considered for the forehead (cosmetic sensitive) and the occiput (pressure sensitive). Chao et al[26] performed calvarial reconstruction whenever the defect was greater than 3 cm in any dimension or greater than 6 cm^2 in area. In contrast, in a series of 23 patients with composite defects of the scalp and neurocranium, osseous reconstruction was not performed in any case because patients were rather old and the defect was located above the hat brim.[13]

Cranioplasty is associated with a high complication rate (up to 30%).[27] Main complications include bone resorption and infection.[28] In our case series, 5 patients underwent cranioplasty; 1 case was infected with the removal of the PMMA implant. The other patients had a favorable course.

There are reports of using bone grafts or flaps for calvarial reconstruction but alloplastic materials, including hydroxyapatite cement, polyether ether ketone, titanium mesh, and polyethylene, are more widely used.[29] Vascularized bone flaps can help overcome infection concerns.[2,21] Bas et al[30] reported good outcomes using titanium mesh as an alloplastic material in 7 cases. In contrast, van Driel et al[5] favored bone grafts and vascularized ribs for reconstruction in 12 patients necessitating bone reconstruction.

Finally, the timing of cranioplasty must be considered. We performed 3 cranioplasties immediately along with scalp reconstruction and 2 cranioplasties in a delayed manner. We lost 1 of the immediate cranioplasties due to infection.

Table 2. Comparison of Free Flap Options for Scalp Reconstruction in the Literature and Associated Flap Failure and Complications

Study	No. Free Flaps	Flap Used	Total Flap Failure, %	Major Complication, %
Lutz et al[37]	30	LD (10), RF (15), RAM (1), other (4)	6.6	16.6
Ioannides et al[1]	31	LD (27), RF (3), scapular (1)	3.2	6.4
Hussussian et al[2]	37	LD (17), RAM (5), RF (4), scapular (2), other (9)	0	32.4
McCombe et al[38]	32	LD (13), rectus abdominis (2), parascapular (3), ALT (2), omentum (1), RF (6), other (5)	6.3	34.3
Newman et al[16]	28	RAM (16), LD (11), RF (1)	3.6	17.9
Wang et al[34]	24	LD (9), ALT(7), RAM (3), RF (3), VR (1), scapular (1),	0	29.2
van Driel et al[5]	88	LD (38), ALT (24), scapular (7), RF (7), RAM (4), TDAP (4), other (4)	5.7	11.4
Chang et al[3]	12	ALT (9), DIEP (1), RAM (2)	0	8.3
Chao et al[26]	138	LD (81), ALT (21), serratus (9), RAM (9), RF (7), other (11)	2	7.2
Fischer et al[33]	33	ALT (17), LD (16)	3	12
Ehrl et al[20]	15	ALT (8), gracilis (7)	0	20
Weitz et al[18]	17	LD (8), parascapular (9)	6	35
Ray et al[8]	9	LD (7), ALT (1), other (1)	0	11
Bas et al[30]	14	LD (7), ALT (5), VL (1), RAM (1)	0	29
Innocenti et al[39]	10	LD (8), ALT (2)	0	30
Strübing et al[10]	43	LD (43)	2.3	37
Present study	12	LD (9), RF (2), parascapular (1)	0	58.3

ALT flap, anterolateral thigh flap; DIEP flap, deep inferior epigastric perforator flap; LD flap, latissimus dorsi (musculocutaneous or muscle) flap; RAM flap, rectus abdominis myocutaneous flap; RF flap, radial forearm flap; TDAP, thoracodorsal artery perforator; VL, vastus lateralis; VR, vertical rectus.

Mukherjee et al[31] reported that the period in which they observed the least complication rate was between 4 and 8 months in cases where they performed secondary cranioplasty with titanium mesh. Reasons to delay cranioplasty include concerns for local recurrence, the need for postoperative radiotherapy, and the risk of complications. However, free flap scalp reconstruction and cranioplasty can be combined without increasing complications even with multiple risk factors in uninfected situations.[26,32,33] By reconstructing both soft tissue and osseous components in a single operation, a second surgery is avoided. In addition, preoperative and postoperative radiation was not found to be significantly associated with the development of recipient site complications in simultaneous scalp and calvarial reconstructions.[26] A staged approach remains the more conservative treatment, particularly in a grossly contaminated wound.[26]

Complications

Repairing extensive defects of the scalp and forehead is a high-risk surgery, with a high rate of complications. Table 2 summarizes flap choice for scalp reconstruction in the literature and the associated flap failure and major complication percentage. The most common complications include total or partial flap necrosis, venous thrombosis, wound infection, and donor site complications.[5,34,26]

No flap loss was reported in our series. Seven patients underwent reoperation due to complications. Our complication rate is significantly higher than the ones reported in the literature. This can be attributed to the small size of the series, the characteristics of the patients, and the method of detecting and reporting the complications. We reported as major complication all the complications that required a return to the operating room regardless of the severity of the complication. In only 3 cases, however, was the complication truly severe and life-threatening (1 vein thrombosis, 1 neurosurgical complication, and 1 cranioplasty material infection). It is also probable that opting for the large LD muscle flap and harvesting it completely (as we have done) exposes the patient to higher risks of complications. These complications include hematoma at the donor or recipient sites, as well as necrosis of the most distal part of the flap. However, this approach can provide better reach and wider coverage. This accounts for about half of our complications.

Factors previously linked to complications include radiation, chemotherapy, defect size, patient age, and smoking.[35] However, van Driel et al[5] did not find a significant association between the occurrence of complications and patient age, risk factors, defect location and size, previous operations and radiotherapy, flap type, full-thickness bone or dura defect, bone and dura reconstruction, or postoperative radiotherapy. The use of vein grafts was the only factor associated with the occurrence of postoperative recipient-site complications. To reduce the risk of complications, we avoided the use of vein grafts in our series (except for the salvage of the venous thrombosis in our patient). Free flaps appear to be tolerant to radiotherapy without increasing recipient site complications.[2,34,26,36]

In an analysis of late recipient-site complications (occurring after 30 days), patients with a history of peripheral vascular disease as well as patients who received both preoperative and postoperative radiotherapy were at increased risk.[26] The complication rate appears to be equivalent with the LD free flap and ALT flap.[26,33]

Limitations of the study include its retrospective design and the limited number of patients.

CONCLUSIONS

Free tissue transfer is indispensable for addressing large defects of the scalp and calvaria. A 2-stage operation is warranted for debilitated patients with a high risk of complications. The large surface of the LD muscle and its ability to atrophy with time makes it the flap of choice to cover extensive defects. The anterolateral thigh flap and the radial forearm flap are indicated for forehead reconstruction. The use of superficial temporal vessels is preferred when available. Cranioplasty, if warranted, can be performed concurrently, although with the drawback of prolonging operative time. Delayed cranioplasty is preferable in contaminated wounds. Despite the frequent occurrence of complications, free flaps typically enable successful reconstruction of these defects, yielding favorable aesthetic and functional outcomes.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

ETHICAL APPROVAL

Institutional review board approval was received from Hotel Dieu de France University Hospital before the beginning of the study.

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