Optimising Aesthetic Reconstruction of Scalp Soft Tissue by an Algorithm Based on Defect Size and Location

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Abstract

Introduction: Scalp soft tissue defects are common and result from a variety of causes. Reconstructive methods should maximise cosmetic outcomes by maintaining hair-bearing tissue and aesthetic hairlines. This article outlines an algorithm based on a diverse clinical case series to optimise scalp soft tissue coverage. Materials and Methods: A retrospective analysis of scalp soft tissue reconstruction cases performed at the Singapore General Hospital between January 2004 and December 2013 was conducted. Results: Forty-one patients were included in this study. The majority of defects <100 cm² were reconstructed with local flaps and were subdivided by location. Methods included rotation, transposition and free flaps. The most common type of reconstruction performed for defects ≥100 cm² was free flap reconstruction. Multistage reconstruction using tissue expanders aided in optimising cosmetic outcomes. There were no major complications or flap failures. Conclusion: By analysing our experience with scalp soft tissue reconstruction, we have developed an algorithm based on defect size and location, achieving excellent closure and aesthetic outcome while minimising complications and repeat procedures.

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Key words: Flaps, Reconstruction Algorithm, Scalp

Introduction

Full-thickness scalp soft tissue defects are common and causes include trauma, tumour resection, radiation necrosis and infection. The need for adequate coverage is important as the scalp provides protection to underlying structures such as the calvarium, meninges and brain parenchyma. Poor decision-making in reconstructive choice can lead to wound breakdown, repeated operations, exposed implants and patient distress. Factors such as a previously irradiated or infected field increase these risks.

The goal of scalp soft tissue reconstruction is tension-free, durable coverage, especially in areas where calvarium or implants are exposed. The availability of modern reconstructive knowledge and methods also demands maximising cosmetic outcomes by maintaining hair-bearing tissue and aesthetic hairlines. In some cases, this may require staged procedures and tissue expansion.

Primary closure, while providing for minimal morbidity and hairy coverage, is only suitable for defects up to 2 to 3 cm².[1] Larger defects require the use of local, regional or free flaps to provide adequate coverage. To date, the literature describes many methods of scalp soft tissue reconstruction encompassing the entire reconstructive ladder.[2-4] The appropriate choice should ultimately achieve the goals set out above, ensuring successful wound coverage, minimise donor site morbidity, and as far as possible returning a fully hair-bearing scalp to the patient.

We thus reviewed our experience with flap coverage of scalp soft tissue to determine wound factors affecting reconstructive choice. This article aims to outline our decision-making process which has helped to optimise anatomical as well as aesthetic coverage. Utilising this, we propose an algorithm for scalp soft tissue reconstruction based on defect size and location, providing a step-ladder

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guide to coverage of full-thickness scalp wounds.

Materials and Methods

A retrospective analysis was conducted on consecutive full-thickness scalp soft tissue reconstruction cases done at the Singapore General Hospital (SGH) between January 2004 and December 2013. Full-thickness defects were defined as those involving all layers of the scalp down to calvarium, cranioplasty implant or dura mater. Information was obtained from patient medical records, and data regarding patient and wound characteristics, size and location of defect, reconstructive procedure undertaken and postoperative details and outcomes were recorded and analysed. Wound sizes (cm^2) were recorded according to the surgical notes, and calculated based on surface area length (cm) x width (cm). The study was conducted under Institutional Review Board approval.

General Operative Procedure and Flap Types

All operations were conducted under general anaesthetic. In cases of malignancy, resection was done by the plastic, head and neck and/or neurosurgeons. For cases of trauma, irradiated tissue or infection, adequate debridement of all infected and necrotic tissue was done before reconstruction was considered. Where cranioplasty implants were infected or exposed, decision to remove part of or the entire implant, along with debridement, was left to the neurosurgeons. If the wound bed was deemed unsuitable, temporary dressing with negative-pressure wound therapy was instituted, along with intravenous antibiotics.

Reconstructive methods used were divided into local flaps, free flaps or multistage reconstruction with tissue expansion. Local flaps were raised in the subgaleal plane and included transposition, unilateral (Fig. 1A) and bilateral rotation flaps in a 'Yin-Yang' pattern (Fig. 1B). In selected cases, galeal scoring perpendicular to the direction of closure was done to aid mobility of the flaps.

For free flaps, the superficial temporal vessels were invariably used as recipient vessels. These vessels are located in the pre-auricular area just anterior to the root of the helix. When these were not available, the neck vessels such as the facial or superior thyroid vessels were used as recipients, with interpositional saphenous vein grafts if pedicle length was insufficient.

For cases where tissue expansion was used, there was an interval of at least 6 months between the initial operation and expander insertion. The expanders were inserted in the subgaleal plane, and incision lines were made away from the site of the wound respecting aesthetic hairlines. All wounds were closed without tension to ensure adequate wound healing.

Results

Patient characteristics and reconstructive choice are summarised in Table 1. Forty-one patients were identified including 24 males and 17 females, with a mean age of 53 years (range, 26 to 87 years). The commonest cause of full-thickness scalp defects in our patients was malignancy followed by exposed or infected cranioplasty implants (Fig. 2). Mean scalp defect area was 98.0 cm^2 (range, 2 to 750 cm^2). Location of defects included the vertex (n = 20),

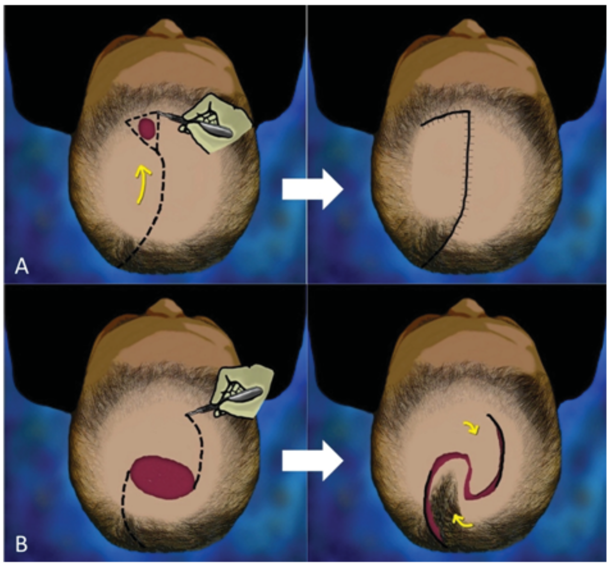

Fig. 1. In A, a unilateral rotation flap is shown while B exemplifies bilateral rotation flaps ('Yin-Yang').

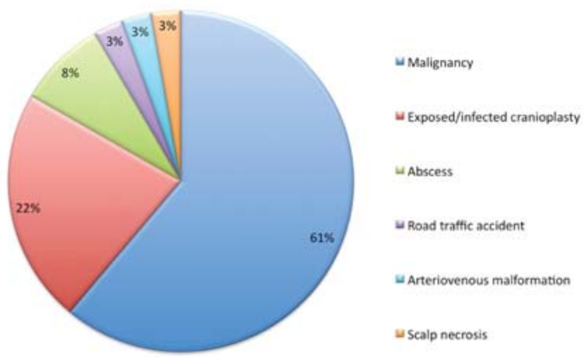

Fig. 2. Pie chart showing the breakdown of scalp defect aetiology.

Table 1. Patients with Full-thickness Scalp Defects Requiring Soft Tissue Reconstruction (n = 41)

	Patient No.	Defect Location	Size* (cm^2)	Reconstructive Method	Hair-bearing Scalp?
≤100 cm^2	1	Vertex	12	Unilateral rotation flap	Y
	2	Vertex	14	Bilateral rotation flap in Yin-Yang pattern	Y
	3	Vertex	15	Bilateral rotation flap in Yin-Yang pattern	Y
	4	Vertex	16	Unilateral rotation flap	Y
	5	Vertex	18.5	Unilateral rotation flap	Y
	6	Vertex	20	Unilateral rotation flap	Y
	7	Vertex	20	Transposition flap + SSG	N
	8	Vertex	25	Transposition flap + SSG	N
	9	Vertex	25	Bilateral rotation flap in Yin-Yang pattern	Y
	10	Vertex	28	Transposition flap + SSG	N
	11	Vertex	30	Transposition flap + SSG	N
	12	Vertex	40	Bilateral rotation flap in Yin-Yang pattern	Y
	13	Vertex	40	Unilateral rotation flap	Y
	14	Vertex	49	Bilateral rotation flap in Yin-Yang pattern	Y
	15	Occipital	12	Unilateral rotation flap	Y
	16	Occipital	22	Unilateral rotation flap	Y
	17	Occipital	90	Regional flap (trapezius)	N
	18	Temporal	6	Unilateral rotation flap	Y
	19	Temporal	20	Transposition flap + SSG	N
	20	Temporal	49	Unilateral rotation flap	Y
	21	Parietal	16	Transposition flap + SSG	N
	22	Parietal	40	Transposition flap + SSG	N
	23	Parietal	70	Transposition flap + SSG	N
	24	Parietal	96	Unilateral rotation flap	Y
	25	Forehead	56	Free radial forearm	Y
	26	Forehead	64	Free radial forearm	Y
≥100 cm^2	27	Vertex	100	Free LD	N
	28	Vertex	100	Transposition flap + SSG	N
	29	Occipital	100	SSG, tissue expansion and advancement	Y
	30	Occipital	100	Free ALT	N
	31	Parietal	120	Free ALT	N
	32	Parietal	120	Free LD	N
	33	Parietal	130	Free ALT	N
	34	Parietal	150	Free LD	N
	35	Vertex	180	Free LD	N
	36	Vertex	200	Free LD	N
	37	Vertex	200	Free ALT	N
	38	Parietal	200	Transposition flap + SSG	N
	39	Parietal	300	Free LD	N
	40	Vertex	300	SSG, Tissue expansion and advancement	Y
	41	Vertex	750	Free LD	N

*Defects <100 cm^2 are ranked according to size and location. Defects ≥100 cm^2 are ranked according to size.
ALT: Anterolateral thigh flap; LD: Latissimus dorsi muscle flap; N: No; SSG: Split-thickness skin grating; Y: Yes

Table 2. Breakdown of Reconstructive Methods Utilised

Flap Type		Total	Percentage (%)
Free flap		13	32
Latissimus dorsi	7		
Anterolateral thigh	4		
Radial forearm	2		
Transpositional flap		10	24
Unilateral rotational flap		10	24
Yin-Yang flap		5	12
Tissue expander and advancement		2	5
Regional flap		1	3

parietal region (n = 10), occipital region (n = 6), temporal region (n = 3) and forehead (n = 2).

Flap types used are summarised in Table 2. These included free flaps (n = 13), transposition (n = 10), unilateral rotation (n = 10), bilateral rotation (n = 5), regional pedicled (n = 1), and tissue expansion with advancement (n = 2). Of the free flaps, there were 7 latissimus dorsi (LD) muscle flaps with split-thickness skin graft (STSG), 4 anterolateral thigh (ALT) fasciocutaneous flaps, and 2 radial forearm flaps (RFF).

There were no reconstructive failures in our series. Three early minor complications included 2 haematomas and 1 partial wound breakdown. The haematomas were evacuated successfully without further complication, while the wound breakdown healed by secondary intention. At a mean follow-up period of 33.6 months, all patients had healed well with intact scalp coverage. In terms of a complete hair-bearing scalp, this was achieved in 19/41 (47%) of patients.

Case Examples

Case 1 (Patient 31): Reconstruction with Free ALT Fasciocutaneous Flap

A 43-year-old male sustained left extradural hemorrhage in a road traffic accident and underwent titanium cranioplasty. He developed pressure necrosis around the cranioplasty site which fistulated into the dura, and subsequently underwent plate removal and replacement. The resultant 120 cm^2 defect was reconstructed with a free ALT flap. The wound healed well with acceptable contour (Fig. 3).

Case 2 (Patient 3): Reconstruction of Vertex Defect with Bilateral Rotational Flaps

A 38-year-old female underwent debridement of a scalp vertex abscess, resulting in a full-thickness defect measuring 5 x 3 cm (15 cm^2). Subsequently, she underwent scalp soft tissue reconstruction with bilateral rotation flaps in a 'Yin-Yang' pattern. There were no postoperative complications, and at 2-months post-op, the wound healed well and her scalp was bearing hair evenly (Fig. 4).

Case 3 (Patient 40): Reconstruction of Fronto-Parietal Scalp Defect with Tissue Expansion

A 28-year-old female with dermatofibrosarcoma protuberans underwent wide excision followed by transposition flap and STSG to the donor site. At 1-year postop, the flap was stable with no recurrence. To recruit hair-bearing tissue for the skin grafted region, tissue expansion of the left hair-bearing scalp was done. These were subsequently removed and the hair-bearing scalp was advanced. There were no postoperative complications and at 7-months review, the scalp was bearing hair with a good aesthetic outcome (Fig. 5).

Discussion

With careful planning and selection, we were able to attain 100% reconstructive success with our patients, with almost half of them maintaining completely hair-bearing scalps and aesthetic hairlines. Prior to committing to a particular method of reconstruction, care must be taken to resect all non-viable tissue, especially in cases of infection, radiation or tumour. Where infected calvarial bone graft or implants are present, adequate debridement and antibiotic treatment is paramount to prevent intracranial infection

Fig. 3. Slide A shows a patient in the preoperative stage. Note the skin necrosis around craniotomy site. Slide B shows the immediate postop with free anterolateral thigh flap. In slide C, the patient is seen 1-year postop after several flap debulking procedures. In slide D, the patient is at 5-years follow-up.

Fig. 4. In slide A, a 5 x 3 cm full-thickness scalp defect is seen at vertex. Intraop views in B; C: bilateral rotational flap raised in a 'Yin-yang' pattern and inset. In D, the scalp was bearing hair evenly at 2-months postop.

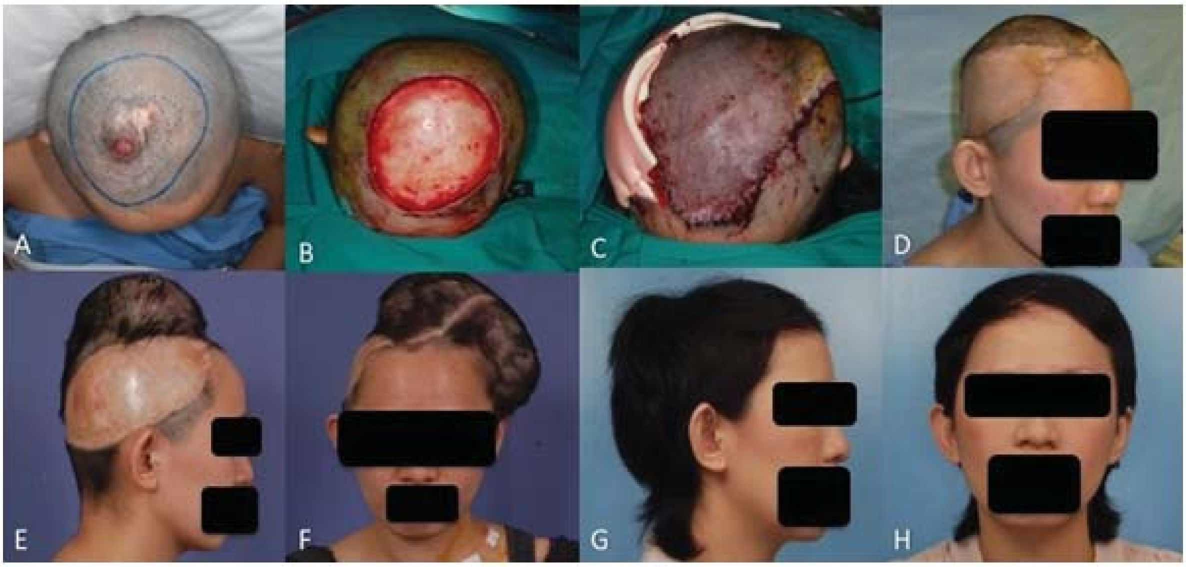

Fig. 5. In slide A, dermatofibrosarcoma protuberans at fronto-parietal region and in B and C, wide excision followed by transpositional flap and temporising skin graft. In D, patient is at 1-year postop prior to insertion of tissue expander. Slides E and F depict the expander insertion and expansion. At G and H, patient is shown 7 months after removal of tissue expander. Scalp was bearing hair with excellent aesthetic outcome.

and complications, and close collaboration with the neurosurgeons may be necessary.

As much as possible, scalp soft tissue defects should be covered with local flaps to maintain hair-bearing tissue. Knowledge of scalp vascular anatomy is key to planning these flaps, with the inclusion of at least 1 of the 5 paired major arteries (supratrochlear, supraorbital, superficial temporal, postauricular and occipital) supplying the scalp.[2] Furthermore, due to muscular and ligamentous attachments and the ovoid shape of the skull, mobility of soft tissue varies over different areas of the scalp. Over the vertex and occiput, the scalp is tensioned by the frontalis and occipitalis muscles, leading to limited mobility compared to the more mobile peripheral regions of the scalp.[5]

On analysis of our results, a distinctive pattern of flap selection can be seen at a cut-off defect area of 100 cm^2 (Table 1). The majority of defects <100 cm^2 could be covered with local flaps and recruitment of hair-bearing tissue was the primary consideration, which was achieved with unilateral or bilateral local rotation flaps in a 'Yin-Yang' pattern. For defects of this size, transposition flaps with donor site skin graft coverage were reserved for wounds ≥20 cm^2 in the less mobile vertex region or for larger wounds in the peripheral regions. In these patients, excision of the skin grafts with or without tissue expansion are options for future cosmetic improvement. When required, undermining of surrounding tissues in the subgaleal plane can help in closure, as can galeal scoring perpendicular to the line of closure at 1 to 2 cm intervals, with each cut earning 1.67 mm of elongation.[6] However, limitations of local tissue transfer include large defects, previous irradiation or surgery, and a skin grafted donor site in the case of transposition flaps. In the forehead region, the aponeurotic layer adheres to the pericranium leading to minimal scalp mobility. For the 2 defects we encountered in this area where hair-bearing tissue was not an issue, the free radial forearm flap provided the best contour and texture match, and is consistent with the most widely used flap in the literature for reconstruction of forehead defects.[7]

Where more local tissue is required for maximal aesthetic outcomes, and when immediate, permanent wound coverage is not essential, tissue expansion represents an excellent option. One limitation is in cases where postoperative irradiation is contemplated, as prolonged expansion may result in unacceptable delays in oncologic treatment. In these patients, the wound can be temporised with local flaps and skin grafts until remission, whereby expansion can be done for completion of reconstruction (Fig. 5). In a normally hair-bearing area of the scalp, tissue expansion and rotation flaps represent the best choice for reconstruction. Tissue expansion does require a stable calvarial base and adequate expandable tissue (>50% of scalp), as well as a patient who is able to remain compliant to prolonged expansion and staged procedures.[4,8]

In cases where defects were large (>100 cm^2) and there was insufficient local tissue for recruitment, microsurgical reconstruction with free flaps enabled the transfer of large amounts of composite tissue to the scalp.[9] In these cases, due to the size of the defects and exposed underlying structures expedient durable coverage is the aim and hair-bearing tissue should no longer be a primary consideration. Free tissue transfer is also indicated in salvage of patients with radiation or local flap failure.[10]

The main considerations for free flap selection include defect size, pedicle length, and donor site morbidity. Many different types of flaps have been used, with the free LD muscle flap preferred as it is relatively thin, broad and well vascularised.[11] It is usually harvested without a skin paddle and covered with a skin graft, and as it atrophies over time usually results in a thickness that closely resembles that of the native scalp. However, this may also result in the potential drawback of calvarial or implant exposure or there is too much thinning of the flap. Other muscular free flaps described but are less commonly used include the serratus anterior and rectus abdominus flaps.[10,11] In select patients with minimal subcutaneous fatty tissue, fasciocutaneous free flaps can achieve an excellent result for scalp reconstruction. The ALT flap has been well described and is now the preferred flap for many reconstructive surgeons.[12,13] It has the advantage of a long vascular pedicle, large amount of soft tissue and skin, the ability to be harvested simultaneously with resection, and minimal donor-site morbidity. The criticism of these flaps has been their bulkiness which may require secondary debulking procedures to regulate the contour. However, advances in techniques and knowledge have now allowed elevation of ultra-thin ALT flaps which can circumvent this problem.[14] In their series of 37 patients, Fischer et al found not difference in efficacy between the free LD or ALT flaps for scalp reconstruction.[15] The main disadvantage of free flaps is that transfer of hair-bearing tissue is not possible. Hair transplants to the flap have been described but have met with limited success.[16] The use of a free flap is therefore a sacrifice of aesthetics for functionality.

A major consideration of free tissue transfer to the scalp is the choice of recipient vessels. Among the commonly described pedicles, the superficial temporal system is the closest to the scalp. However, these may not always be available due to resection, and are prone to arterial vasospasm and venous outflow sufficiency, especially in radiated fields. In these cases, the recipient vessels in the neck such as the facial and superior thyroid systems can be used. This requires either maximal flap pedicle length harvest and careful tunnelling, or the use of vein grafts.[17]

In our series, the majority of large scalp defects were reconstructed with free flaps, and we used mainly the LD muscle or ALT flaps for this purpose. The LD muscle flap with skin graft has been our workhorse flap as it provides a large surface area and contours nicely to the skull. More recently, the free ALT fasciocutaneous flap has gained favour.

The drawback of our study is that it involves solely soft tissue reconstruction. Calvarial reconstruction methods were not included, but can be significant as artificial implants have a higher rate of complications than autologous bone.[18] Also, the use of size as a cutoff in our population was limited to adult patients only. In addition, it must also be remembered that patient preoperative status and comorbidities play a role in decision-making. In selected patients who were poor candidates for free flap reconstruction, we used transpositional flaps with split thickness skin grafting for more expedient coverage and shorter intraoperative time.

Conclusion

In our experience, the common reconstructive methods for scalp soft tissue reconstruction are the unilateral rotation flap, bilateral rotation flap in a 'Yin-Yang' pattern, transposition flap with donor sites skin grafting and free flap

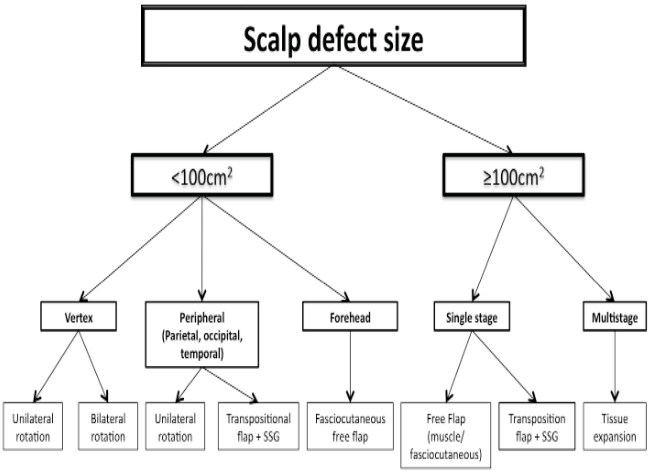

Fig. 6. An algorithm for reconstruction of full-thickness scalp soft tissue defects based on size and location.

reconstruction. By selecting the appropriate option based on size and anatomical location, we were able to achieve high reconstructive success rates while respecting aesthetic hairlines and maximising hear-bearing scalp tissue. Upon analysis of our results, we found 100 cm^2 as the "critical size" determining the tendency towards free flap reconstruction. We thus propose our algorithm to optimise full-thickness scalp soft tissue reconstruction (Fig. 6).

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