The Laryngoscope

Successful Reconstruction of Scalp and Skull Defects: Lessons Learned from a Large Series

David C. Shonka, Jr., MD; Andrea E. Potash, MD; Mark J. Jameson, MD, PhD; Gerry F. Funk, MD

Objective: To provide a framework for the management of scalp and skull defects.
Design: Retrospective chart review.
Setting: Two tertiary care hospitals.
Patients/Intervention: Fifty-six consecutive patients who underwent reconstruction of scalp and/or skull defects with free flaps, rotational skin/fascia flaps, skin grafts, and implants. Defects closed primarily and those of the lateral temporal bone and skull base were excluded.
Results: Sixty-two reconstructions were performed. Treatment of skin cancers and intracranial tumors necessitated 31 (50%) and 22 (35%) of the reconstructions, respectively. Defects included partial-thickness soft tissue (9, 15%), full-thickness soft tissue (28, 45%), full-thickness soft tissue and skull (17, 27%), and full-thickness soft tissue, skull, and dura (8, 13%). Radiation or prereconstruction wound breakdown or infection was involved in 33 (53%) and 25 (40%) of cases, respectively. The most common method of reconstruction was free tissue transfer (27, 44%) followed by local skin (15, 24%) or fascia (9, 15%) flaps. There was a 15% (9/62) complication rate; 89% (8/9) of these occurred in radiated tissues and 44% (4/9) occurred in smokers. Seven of the nine patients with complications (78%) were managed with local wound care and/or removal of an implant, whereas 2 (22%) required a second reconstructive procedure. All patients ultimately achieved a safe outcome with no infection and no bone or dural exposure.
Conclusions: In addition to defect location and extent, availability of surrounding tissue and wound healing characteristics direct reconstruction. Patients who receive radiation therapy are at increased risk of complications. Use of vascularized tissue is critical for successful management, making local flaps and free tissue transfer the mainstay of reconstruction.
Key Words: Sinonasal, general otolaryngology.
Level of Evidence: 2b.
***Laryngoscope*, 121:2305–2312, 2011**

INTRODUCTION

Treatment of scalp and skull defects is a challenging problem for reconstructive surgeons, in part because of the relative inelasticity of the surrounding skin.[1] Despite wide undermining, only relatively small defects can be closed primarily. Galeotomies can be helpful, but the amount of actual tissue gain per galeotomy is less than 2 mm.[2] In addition, the high incidence of partial or complete skin graft loss when applied to exposed bone limits the use of full or split-thickness skin grafts in scalp reconstruction, particularly in the setting of full-thickness soft tissue defects and use of pre- or postreconstruction radiation therapy (RT).[3] Finally, the distance of the scalp from the clavicle and axilla limits the use of the pedicled pectoralis and latissimus flaps.

It is difficult to plan scalp and skull reconstruction based on a simple, generalized, defect-directed algorithm; recent articles have focused only on reconstruction with free tissue transfer or defects resulting from extirpation of malignancies.[4–12] However, scalp and skull defects can present in a variety of contexts that may be pertinent to the reconstructive approach. Patients who have had prior neurosurgical interventions may have compromise of the adjacent axial blood supply due to previous incisions and/or dissection. Patients with scalp and skull defects often have wounds complicated by the presence of foreign material, infected bone, or soft tissue abscess. The use of RT in these patients further compromises the locally available tissue and may complicate the decision making for reconstruction. The purpose of this article is to examine a large, heterogeneous series of scalp and skull reconstructions and provide a framework for management based on the extent of the defect, adequacy of adjacent tissue, wound-healing characteristics, and patient factors.

MATERIALS AND METHODS

A retrospective chart review was performed of consecutive patients who underwent reconstruction of scalp and/or skull defects at the University of Iowa and the University of Virginia. All reconstructions were performed by either G.F.F. or M.J.J.

From the Department of Otolaryngology—Head and Neck Surgery (D.C.S., M.J.J.), University of Virginia Health System, Charlottesville, Virginia, U.S.A; Department of Otolaryngology—Head and Neck Surgery (A.E.P., G.F.F.), University of Iowa Hospitals and Clinics, Iowa City, Iowa, U.S.A.

Editor's Note: This Manuscript was accepted for publication April 21, 2011.

Presented at the Combined Sections Meeting of the Triological Society, Scottsdale, AZ, January 28, 2011.

The authors have no financial disclosures for this article.

The authors have no conflicts of interest to disclose.

Send correspondence to Dr. David C. Shonka, Jr., Department of Otolaryngology—Head and Neck Surgery, University of Virginia Health System, Box 800713, Charlottesville, VA 22908. E-mail: dcs5z@virginia.edu

DOI: 10.1002/lary.22191

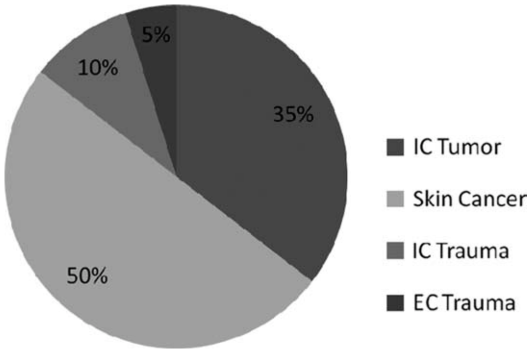

Fig. 1. The etiology of scalp/skull defects. IC = intracranial; EC = extracranial.

Defects of the lateral temporal bone and anterior or lateral skull base were excluded, as were defects repaired by primary closure.

The charts were reviewed for demographic data, including age at the time of reconstruction and tobacco use. Patients were defined as tobacco users if they reported smoking within a week of the reconstruction. The presence of prereconstruction wound breakdown or infection was obtained from review of the chart and was defined by reported purulence, bone flap osteomyelitis, or foreign body exposure. The use of RT before or after the definitive reconstructive procedure was noted as was the history of a neurosurgical procedure.

Defects were categorized as small (<10 cm^2), medium (10–50 cm^2), or large (>50 cm^2) based on the size of the cutaneous component. Defects were further categorized as partial-thickness (at least periosteum intact), full-thickness soft tissue (exposed skull bone), full-thickness soft tissue and skull (exposed dura), or full-thickness soft tissue, skull, and dura (exposed brain). The reconstructive method utilized and any planned staged procedures were recorded. Finally, any complications at the reconstructive site were identified and documented. Complications were categorized as flap related if there was partial loss of the flap used for reconstruction or wound breakdown related to the adequacy of the flap. Complications were categorized as implant related if they involved infection or exposure of an implant used at the time of the initial reconstruction or during a staged procedure.

All statistical analyses were performed using a two-tailed Fisher exact test with $P \leq .05$ considered significant. These analyses were performed using standard statistical functions in Microsoft Excel 2003.

RESULTS

Patient and Defect Characteristics

Sixty-two reconstructions were performed on 56 patients. The average age of the patients was 57.8 years, range = 16 to 94 years. Males accounted for 57% of the patients treated. The defects resulted from a variety of causes including skin cancers (31, 50%), intracranial tumors (22, 35%), intracranial trauma (6, 10%), and extracranial trauma (3, 5%) (Fig. 1). Reconstructions were performed for 30 large defects (48%), 23 medium-sized scalp defects (37%), and 9 small defects (15%).

Twenty-five reconstructions (40%) were performed for defects involving skull; 8 of these (32%) also involved the dura (Table I). Sixteen of the 25 defects (64%) involving skull in this series had cranioplasty performed either at the time of the initial reconstruction or as a staged procedure. Three of these patients (19%) had an implant-related complication.

The remaining 37 reconstructions (60%) were for defects involving the scalp only. Twenty-eight of these defects (76%) involved the full-thickness scalp with exposed bone (Table II). Nine (24%) were partial-thickness defects (Table III). Seven of the nine partial-thickness scalp defects (78%) were managed with split-thickness skin grafts, one with AlloDerm® (LifeCell, Branchburg, NJ) and one with a local rotational skin flap. There were no complications among these patients. One of the patients reconstructed with a split-thickness skin graft elected later to have a tissue expander inserted to replace the skin graft with hair bearing scalp. Thirty-three patients (53%) were treated with RT to the scalp and/or skull either before or after the reconstructive procedure. Preexisting wound breakdown or infection was present in 25 cases (40%) at the time the initial reconstruction was performed. Neurosurgical procedures were performed in 28 cases (45%) prior to reconstruction.

Reconstructive Approaches

The most common method of reconstruction was free tissue transfer. Twenty-seven free flaps were performed (44%); all were harvested from the subscapular system except one. The free flaps used were latissimus dorsi myofascial (17, 63%), latissimus dorsi myocutaneous (6, 22%), serratus anterior myofascial (2, 7%), combined latissimus dorsi and serratus anterior myofascial (1, 4%), and radial forearm fasciocutaneous (1, 4%). Other reconstructive methods included local skin (15, 24%) or fascia (9, 15%) rotational flaps.

Eighteen patients (29%) had a staged procedure; 10 of these (55%) involved insertion of a cranioplast implant for skull contouring in patients with missing bone. Six of the staged procedures involved use of tissue expanders so that previous defect sites could be resurfaced with hair-bearing scalp. Overall, 21 reconstructions (34%) utilized a prosthetic material (cranioplast, tissue expander, wire mesh, etc.) during the initial or staged procedures.

Complications

Nine reconstructive procedures (15%) had complications at the site of the defect; eight of these (89%) occurred in radiated tissues. Patients who were treated with pre- or post-reconstruction RT were significantly more likely to develop a complication than nonirradiated patients ($P = .03$). Four of the nine complications (44%) occurred in smokers, who were significantly more likely to develop a complication compared to nonsmokers ($P = .04$). Five of the complications (56%) were implant related (two tissue expander infections and three cranioplast implant infections) and four (44%) were flap related. Compared to the use of free tissue transfer, local skin or fascia flaps for reconstruction of large size defects was associated with a significantly higher risk of flap related complications ($P = .01$). Although reconstructive procedures utilizing an

TABLE I.
Full-Thickness Scalp and Skull Defects—Management and Complications.

No.	Sex	Age	Tobacco	Pathology	Size	Dura	Infection	RT	Initial Reconstruction	Staged Procedure	Complication
1	F	29	Yes	IC trauma	Medium	No	Yes	No	LD, STSG	Cranioplast implant	No
2	F	68	No	IC tumor	Large	No	Yes	Yes	LD, STSG	Cranioplast implant	No
3	M	83	No	IC tumor	Large	No	No	Yes	LD, STSG, Titanium plate	No	No
4	F	51	No	IC tumor	Large	No	Yes	Yes	Skin flap, STSG to pericranium	No	Yes—Distal flap breakdown
5	F	73	No	IC tumor	Small	No	Yes	Yes	Bone flap removal, skin flap	Cranioplast implant	No
6	F	51	No	IC tumor	Small	No	Yes	Yes	Bone flap removal, skin flap	Cranioplast implant	No
7	F	66	No	IC tumor	Medium	No	Yes	Yes	Skin flap, STSG to pericranium	No	No
8	F	47	Yes	IC trauma	Medium	No	Yes	No	LD, STSG	No	No
9	M	16	No	IC tumor	Small	No	Yes	Yes	TPF flap, cranioplast implant	No	No
10	M	53	No	IC trauma	Medium	Yes	No	No	LD, STSG	No	No
11	M	72	No	Skin CA	Large	Yes	No	Yes	LDMC	No	No
12	M	56	Yes	IC tumor	Large	Yes	No	Yes	LDMC, titanium mesh	No	Yes—Wire mesh exposure
13	F	84	No	Skin CA	Large	Yes	No	Yes	LDMC	No	No
14	M	71	No	IC tumor	Small	No	Yes	No	Free serratus, skin flap	Cranioplast implant	No
15	M	40	No	IC tumor	Small	No	Yes	Yes	LD, STSG, cranioplast implant	No	No
16	F	63	No	IC tumor	Small	No	Yes	Yes	LD, STSG	Cranioplast implant	No
17	M	43	No	EC trauma	Small	No	No	No	Pericranial flap, skin flap, bone graft	No	No
18	M	23	No	IC tumor	Medium	No	No	Yes	LD, STSG	No	No
19	F	47	No	IC tumor	Medium	Yes	Yes	Yes	LD, STSG	Cranioplast implant	No
20	F	57	No	Skin CA	Large	Yes	No	Yes	LD with serratus, STSG	Cranioplast implant	Yes—Cranioplast exposure
21	F	57	No	Skin CA	Large	No	Yes	Yes	Implant Removal, skin flap, alloderm	No	No
22	M	73	Yes	IC trauma	Large	No	No	No	LDMC	No	No
23	F	75	Yes	Skin CA	Large	Yes	No	Yes	LD, STSG, cranioplast and mesh	No	Yes—Cranioplast infection
24	F	46	No	IC tumor	Small	Yes	Yes	Yes	Free serratus, skin flap	Cranioplast implant	No
25	M	22	No	IC trauma	Large	No	Yes	No	LD, STSG	Cranioplast implant	No

RT = radiation therapy; IC = intracranial; EC = extracranial; CA = cancer; LD = latissimus dorsi myofascial free flap; STSG = split-thickness skin graft; TPF = temporoparietal fascia flap; LDMC = latissimus dorsi myocutaneous free flap.

implant had a higher incidence of overall postoperative complications, this factor did not reach statistical significance ($P = .16$).

Other potential contributing factors including presence of preoperative wound breakdown or infection, previous neurosurgical procedures or defects, type of reconstruction, and use of staged procedures did not correlate with complications. Seven of the nine patients with complications (78%) were managed with local wound care and/or removal of an implant, whereas two (22%) required a second reconstructive procedure. All patients ultimately achieved a safe outcome with no infection and no bone or dura exposure.

DISCUSSION

The purpose of this study was to examine a large series of scalp and skull reconstructions and to generate a framework for the management of these defects. As with other studies published in the literature, a simple defect oriented algorithm was not used to plan the treatment for the patients in this series and there is no simple algorithm for reconstructive technique. Instead, this study examines several factors that should be taken into consideration when planning the reconstruction of scalp and skull defects (Fig. 2).

Defect Anatomy

The first factor that should be taken into consideration is the anatomy of the defect. Defects can generally be categorized as small (<10 cm^2), medium (10–50 cm^2), or large (>50 cm^2). Small defects can usually be closed primarily.[12] Defects closed primarily were excluded from this study; however, not all defects that involve <10 cm^2 of the scalp should be closed primarily. Some of the patients in this series had small scalp defects overlying infected bone flaps or implants (Table I). Removal of the bone flap and primary closure would leave the approximated skin edges over dura. We managed these patients with local skin or fascia flaps or free tissue transfer in order to place vascularized tissue over exposed dura

TABLE II.
Full-thickness scalp defects—management and complications.

No.	Sex	Age	Tobacco	Pathology	Size	Infection	RT	Initial Reconstruction	Staged Procedure	Complication
26	F	51	No	IC tumor	Large	Yes	Yes	Skin flap, skin graft to pericranium	No	No
27	F	71	No	Skin CA	Medium	Yes	Yes	LD, STSG	No	No
28	F	63	No	IC tumor	Medium	Yes	Yes	LD, STSG	Tissue expander	Yes—Two infected expanders
29	F	75	Yes	Skin CA	Medium	No	Yes	TPF, STSG	No	No
30	F	60	No	Skin CA	Medium	No	No	Skin flaps, TPF flap, STSG	No	No
31	F	38	No	IC tumor	Large	No	Yes	TPF, STSG	No	Yes—Partial flap loss
32	F	38	No	IC tumor	Large	Yes	Yes	RFFF	No	No
33	M	78	No	IC tumor	Medium	Yes	No	Skin flap	No	No
34	F	41	No	Skin CA	Medium	No	No	TPF flap, alloderm	Tissue expander, SF	No
35	M	49	Yes	Skin CA	Large	No	Yes	TPF flap, STSG	No	Yes—Wound breakdown
36	M	73	No	Skin CA	Medium	Yes	No	Skin flap	No	No
37	M	75	No	Skin CA	Large	No	Yes	Porcine graft	STSG	No
38	M	40	Yes	Skin CA	Large	No	No	Alloderm	Tissue expander, SF	Yes—Infected expander
39	M	74	No	Skin CA	Medium	Yes	Yes	Skin flap, STSG to pericranium	No	No
40	M	79	No	Skin CA	Large	Yes	No	Skin flaps	No	No
41	F	79	No	Skin CA	Medium	No	No	Skin flap, STSG to pericranium	No	No
42	M	24	No	EC trauma	Large	No	No	LD, STSG	Tissue expander, SF	No
43	F	63	No	IC tumor	Large	No	Yes	Temporalis and TPF, skin flaps	No	Yes—Wound breakdown
44	F	94	No	Skin CA	Large	Yes	Yes	Three stage juri flap, STSG	Juri flap	No
45	F	50	No	IC tumor	Small	Yes	No	FB removal, skin flap	No	No
46	M	76	No	Skin CA	Large	No	Yes	LD, STSG	No	No
47	M	50	No	EC burn	Large	No	No	Debridement, vigilon, wound vac, then STSG	Tissue expander, SF	No
48	M	20	No	IC trauma	Medium	No	No	Skin flap, STSG to pericranium	No	No
49	M	83	Yes	Skin CA	Large	No	No	Temporalis rotation, STSG	No	No
50	M	52	No	Skin CA	Large	No	No	LDMC, STSG	No	No
51	M	60	No	Skin CA	Large	No	No	LDMC	No	No
52	M	74	No	Skin CA	Large	No	No	LD, STSG	No	No
53	M	73	No	Skin CA	Large	No	No	LD, STSG	No	No

RT = radiation therapy; IC = intracranial; EC = extracranial; CA = cancer; LD = latissimus dorsi myofascial free flap; LDMC = latissimus dorsi myocutaneous free flap; RFFF = radial forearm free flap; SF = skin flap; STSG = split-thickness skin graft; TPF = temporoparietal fascial flap; FB = foreign body.

despite the small size of the scalp defect (Fig. 3). We encountered no complications with this approach.

Large defects require more soft tissue than is available from local scalp tissue unless tissue expansion and staged reconstruction is performed.[5] In our study, nine reconstructive procedures used local skin or fascia flaps for large defects and four (44%) of these reconstructions resulted in flap-related complications, two of which required a second reconstructive procedure to create a safe wound with no bone exposure. However, none of the patients with large defects who were managed with free tissue transfer had flap-related complications, demonstrating the superiority of free tissue transfer over local skin or fascia flaps for reconstruction of large scalp defects. Our series also demonstrates that defects in the medium size range can be successfully reconstructed with either local flaps or free tissue transfer: no flap-related complications occurred when medium-sized

TABLE III.
Partial-Thickness Scalp Defects —Management and Complications.

No.	Sex	Age	Tobacco	Pathology	Size	Infection	RT	Initial Reconstruction	Staged Procedure	Complication
54	M	23	No	IC tumor	Medium	No	Yes	Skin Flap	No	No
55	F	56	No	Skin CA	Medium	No	No	AlloDerm®	No	No
56	F	42	Yes	Skin CA	Medium	No	No	STSG	Tissue expander, SF	No
57	M	25	No	Skin CA	Large	No	Yes	STSG	No	No
58	M	64	No	Skin CA	Large	No	No	STSG	No	No
59	M	72	No	Skin CA	Medium	No	No	STSG	No	No
60	F	75	No	Skin CA	Medium	No	No	STSG	No	No
61	M	48	Yes	Skin CA	Medium	No	No	STSG	No	No
62	M	72	No	Skin CA	Medium	No	No	STSG	No	No

IC = intracranial; CA = cancer; RT = radiation therapy; SF = skin flap; STSG = split-thickness skin graft.

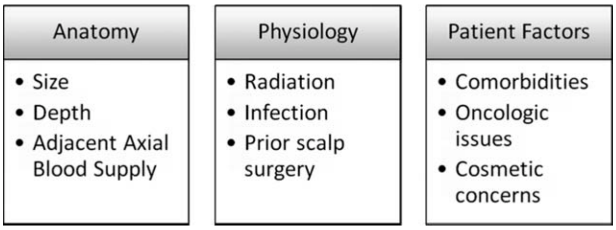

Fig. 2. Framework for the evaluation of scalp and skull defects. Each of these factors should be considered when planning defect reconstruction.

defects were managed, regardless of the approach. In this size range, the selection of reconstructive technique should be based on other factors.

In addition to the size of the scalp defect, the depth is an important aspect of the defect anatomy. Defects can be categorized as partial-thickness scalp, full-thickness scalp, full-thickness scalp and skull, or full-thickness scalp, skull, and dura. Dural defects can be addressed with artificial patches or autologous fascia in radiated patients.[4] All eight defects involving dura in this series were reconstructed with an artificial patch and covered with a free flap. No cerebral spinal fluid (CSF) leaks or dural implant-related complications occurred in these patients. The three complications that occurred in this group were related to the cranioplast implant.

Not all skull defects need to be addressed with cranioplasty. Indications for skull reconstruction include protection against trauma, restoration of cosmesis, and treatment/prevention of "syndrome of the trephined."[13] In general, defects less than 5 cm in diameter can be treated with soft tissue coverage alone, but larger defects are best managed with formal cranioplasty. In the present series, 3 (18%) of the 16 cranioplasties developed implant-related complications that required removal of the cranioplast material; all of these occurred in patients who were treated with RT. Two of these complications occurred when cranioplasty was performed at the time of the initial reconstruction and nonosteointegrative material was used. Interestingly, all three complications occurred when RT was delivered after the cranioplasty was performed, creating a situation where an implant was in a poorly vascularized bed. Thus, our series demonstrates that cranioplasty can be safely performed with a relatively low complication rate but suggests that staging these procedures, using an osteointegrative material, and covering the implants with vascularized tissue that has not been radiated may increase the likelihood of success.

In patients with defects involving scalp only, the difference between full-thickness defects with exposed bone and partial-thickness defects with at least pericranium intact is critically important. Partial-thickness defects of any size can be successfully reconstructed with split-thickness skin grafting; 78% of the partial-thickness defects in this series were managed with split-thickness skin grafting with no complications. Tissue expansion and subsequent excision of these skin grafts can be performed for cosmetic purposes at a later date; when reconstruction is performed after cancer resection, this may allow for more effective surveillance until the risk of recurrence is low. Full-thickness defects in this series were approached with the assumption that skin grafts applied directly to exposed bone have a high incidence of partial or complete graft loss and resulting bone exposure;[14] none of the 28 full-thickness defects were managed with skin grafting alone. Twenty-five of 28 (89%) were managed with free tissue transfer or local

Fig. 3. Reconstruction of a full-thickness soft tissue and skull defect (no. 9). The soft tissue component of the defect is small (A), with only a small portion of the underlying wire mesh exposed (B). The wire mesh was removed, the dura was intact, and a cranioplast implant was placed and covered with a temporoparietal flap (C). The patient had good contour and no implant exposure at 6 months (D). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

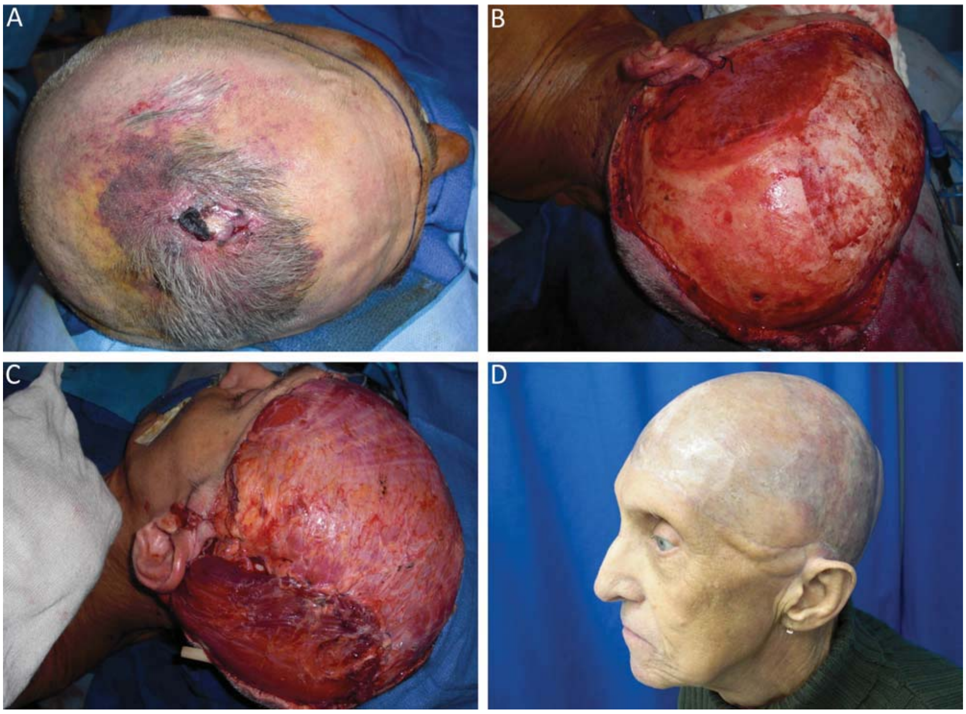

Fig. 4. Reconstruction of a full-thickness scalp defect. Patient with large scalp angiosarcoma (A). Resection necessitated wide margins and results in a near total scalp defect (B). The defect was reconstructed with a latissimus dorsi and serratus anterior myofascial flap with split-thickness skin graft coverage (C). The patient had good contour and color match 4 months postoperatively (D). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

flaps (Fig. 4); only 3 reconstructions (12%) were complicated by wound breakdown and no patients had long term bone exposure. Two of the patients with wound breakdown were successfully managed conservatively, whereas one required a second reconstructive procedure.

The final anatomic factor that should be considered is the relationship of the defect to surrounding axial blood supply to the scalp. Scalp anatomy, including vascular supply, has been extensively discussed in the past in textbooks and journal articles.[3] The dominant axial blood supply to the scalp runs on the external surface of the galea–temporoparietal fascia–frontalis–occipitalis. The axial component of the blood supply ranges from 2–7 cm from the vessel origin, beyond which the blood supply is random.[15] Thus, the use of local skin and fascia flaps should be limited to defects near the axial vessels in order to increase the reliability of the flap. This was demonstrated in the present study by the high incidence of flap-related complications (44%) when local skin or fascia flaps were used to reconstruct defects in the large size category.

Physiology

Important factors that affect wound healing physiology at the site of the defect include radiation, infection, and prior scalp surgery. Whether it is employed before or after surgery, RT alters wound healing mechanisms,[16] and was associated with a significant increase in the risk of complications in our study. Of the eight complications that occurred in patients who were radiated, four occurred when reconstructions utilized local tissue flaps and the other four occurred when implants were used. Our data support the use of free tissue transfer instead of local flaps in radiated patients and also suggests that, if implants are used, they should be covered with well vascularized, nonradiated tissue.

The presence of an infected wound has a significant impact on the planned reconstruction. In these situations, the first step is to remove any infected or foreign material present. The importance of using vascularized tissue coverage, particularly free tissue transfer, after thorough debridement in the management of these defects has been demonstrated.[17] We noted an 8% incidence of complications in reconstructions with preoperative infection present, demonstrating the effectiveness of debridement and vascularized coverage. The presence of preoperative infection also has an impact on the timing of cranioplasty.[13] Cranioplasty was delayed and performed as a staged procedure in 82% of patients with a preoperative infection; this approach was successful; none of these patients developed implant-related complications.

When evaluating a patient for scalp or skull reconstruction, it is important to note the presence and location of scars. Previous scalp incisions may transect and thereby compromise the axial blood supply to the scalp (Fig. 5). This may limit the use of certain local flaps in patients with prior scalp surgery. In the present study, when patients had undergone prior scalp surgery, flap-related complications occurred in 3 of the 14 reconstructions (21%) where local skin or fascia flaps were used and in 0 (0%) of the reconstructions when free tissue transfer was used. This suggests that free tissue transfer may be superior to local flap reconstruction in patients with a history of prior scalp surgery. Certainly, local fascia or skin flaps should only be utilized if there is no risk that the axial blood supply to the flap has been violated by prior incisions.

Patient Factors

Medical comorbidities, oncologic issues, and cosmetic concerns are patient factors that should be

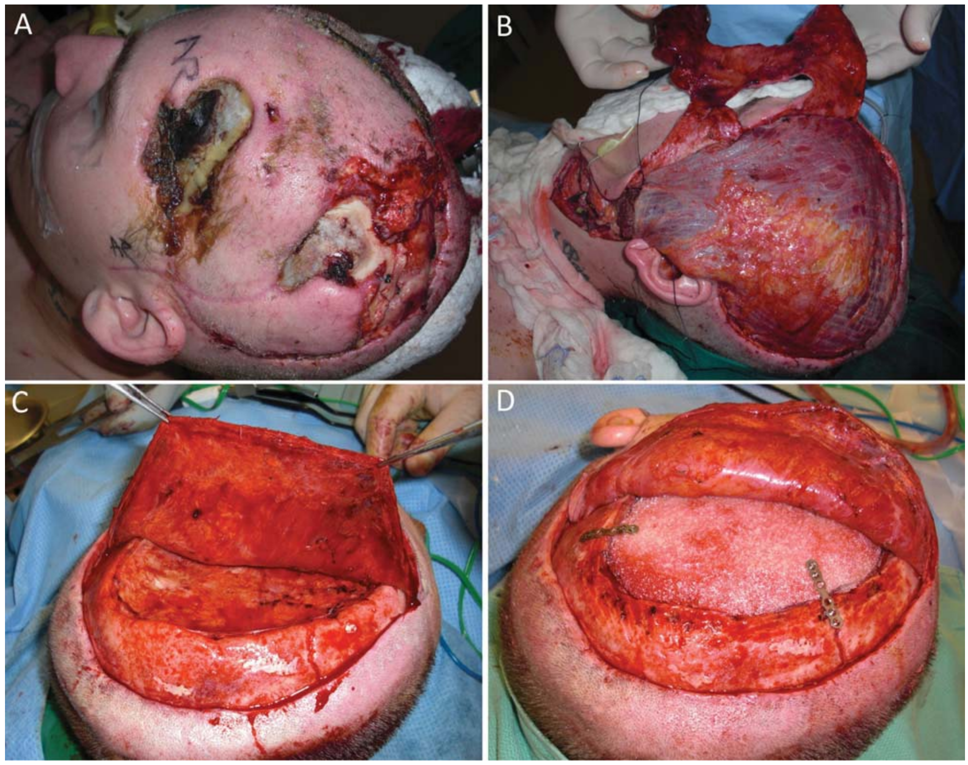

Fig. 5. Reconstruction of a full-thickness soft tissue and skull defect (no. 25). Muliple prior scalp incisions led to vascular compromise of the skin and bone flap osteomyelitis (A). The skin was debrided, the bone flap removed, and free latissimus flap was used to cover the dura (B). Four months after the initial reconstruction, the latissimus flap was elevated off the dura (C) and a cranioplasty was performed (D). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

considered when planning reconstruction of scalp and skull defects. In patients with medical comorbidities that preclude a complex reconstructive procedure, alternative reconstructive techniques have been described.[18–22] Three patients in this series with full-thickness scalp defects who had significant comorbidities precluding complex reconstructive procedures underwent placement of AlloDerm®, porcine skin, or a wound vacuum device until enough granulation tissue was present to support a split-thickness skin graft. A similar technique has been previously described in the literature.[23]

There are several oncologic issues that must be considered when planning scalp and skull reconstruction. For patients with defects resulting from excision of a malignancy, it is often preferable to perform a single definitive reconstructive procedure so that the patient can proceed more quickly to adjunctive therapy.[12] Reconstruction is occasionally delayed when there is difficulty obtaining negative margins. Tumor surveillance can be challenging when oncologic defects are covered with complicated local rotational flaps or free tissue transfer. Conversely, surgical margins may be jeopardized if a less extensive resection is performed to facilitate reconstruction such as sacrificing depth of the resection to improve skin graft survival by preserving pericranium. The patient's overall prognosis is a consideration, and a palliative oncologic surgery may direct the reconstructive surgeon toward a less complicated reconstructive procedure.

Finally, cosmesis is of greater concern for some patients than others. Staged tissue expansion and serial excisions can be performed at a later date to reintroduce hair-bearing scalp to areas initially reconstructed with nonhair-bearing tissue. Six patients in this series elected to undergo tissue expansion. There were two incidents of expander infection (33%), one of which occurred early enough to prevent adequate expansion for the necessary coverage required. Cosmetic concerns also have an impact on the decision to perform cranioplasty,[13] which can be safely performed but carries an increased risk of complication as demonstrated in this series.

CONCLUSIONS

There are several conclusions that can be drawn from this series. Large defects are best addressed with free tissue transfer instead of local scalp flaps. There is a greater risk of complication when reconstructive procedures are performed in irradiated fields. Maximizing coverage in the form of vascularized tissue is imperative in radiated patients, particularly when an implant may be used for cranioplasty. No single defect oriented algorithm is sufficient for the planned management of scalp defects due to their inherent complexity. Defect anatomy, wound physiology, and patient factors must be considered when planning scalp and skull reconstruction.

BIBLIOGRAPHY

1. Hussain W, Mortimer NJ, Salmon PJ, Stanway A. Galeal/periosteal flaps for the reconstruction of large scalp defects with exposed outer table. *Br J Dermatol* 2010;162:684–686.
2. Raposio E, Santi P, Nordstrom RE. Effects of galeotomies on scalp flaps. *Ann Plast Surg* 1998;41:17–21.
3. Leedy JE, Janis JE, Rohrich RJ. Reconstruction of acquired scalp defects: an algorithmic approach. *Plast Reconstr Surg* 2005;116:54e–72e.
4. van Driel AA, Mureau MA, Goldstein DP, et al. Aesthetic and oncologic outcome after microsurgical reconstruction of complex scalp and forehead defects after malignant tumor resection: an algorithm for treatment. *Plast Reconstr Surg* 2010;126:460–470.

5. Labow BI, Rosen H, Pap SA, Upton J. Microsurgical reconstruction: a more conservative method of managing large scalp defects? *J Reconstr Microsurg* 2009;25:465–474.
6. McCombe D, Donato R, Hofer S, Morrison W. Free flaps in the treatment of locally advanced malignancy of the scalp and forehead. *Ann Plast Surg* 2002;48:600–606.
7. Hussussian CJ, Reece GP. Microsurgical scalp reconstruction in the patient with cancer. *Plast Reconstr Surg* 2002;109:1828–1834.
8. Beasley NJP, Gilbert RW, Gullane PJ, Brown DH, Irish JC, Neligan PC. Scalp and forehead reconstruction using free revascularized tissue transfer. *Arch Facial Plast Surg* 2004;6:16–20.
9. Weber SM, Kim JH, Wax MK. Free tissue transfer in the reconstruction of massive scalp defects: P027. *Otolaryngol Head Neck Surg* 2005; 133(Suppl 1):P205.
10. Upton J, Pap S. Scalp reconstruction with free flap tissue transfer: a 25-year series. *J Reconstr Microsurg* 2004;20:425–426.
11. Tanaka I, Neligan PC, Ang E, Sun T, Beausang E. Free-flap reconstruction of extensive scalp defects following tumor resection. *J Reconstr Microsurg* 2002;18:319–320.
12. Iblher N, Ziegler MC, Penna V, Eisenhardt SU, Stark GB, Bannasch H. An algorithm for oncologic scalp reconstruction. *Plast Reconstr Surg* 2010;126:450–459.
13. Baumeister S, Peek A, Friedman A, Levin LS, Marcus JR. Management of postneurosurgical bone flap loss caused by infection. *Plast Reconstr Surg* 2008;122:195e–208e.
14. Gonyon DL Jr, Zenn MR. Simple approach to the radiated scalp wound using INTEGRA skin substitute. *Ann Plast Surg* 2003;50:315–320.
15. Potparic Z, Fukuta K, Colen LB, Jackson IT, Carraway JH. Galeo-pericranial flaps in the forehead: a study of blood supply and volumes. *Br J Plast Surg* 1996;49:519–528.
16. Tibbs MK. Wound healing following radiation therapy: a review. *Radiother Oncol* 1997;42:99–106.
17. Boeckx WD, van der Hulst RR, Nanhekhan LV, De Lorenzi F. The role of free flaps in the treatment of persistent scalp osteomyelitis. *Neurosurgery* 2006;59(1 Suppl 1):ONS64–ONS67.
18. Corradino B, Di Lorenzo S, Cordova A, Moschella F. Reconstruction of full thickness scalp defects after tumour excision in elderly patients: our experience with Integra dermal regeneration template: 1110. *Eur J Clin Invest* 2010;40(Suppl 1):89–90.
19. Faulhaber J, Felcht M, Teerling G, et al. Long-term results after reconstruction of full thickness scalp defects with a dermal regeneration template. *J Eur Acad Dermatol Venereol* 2010;24:572–577.
20. Khan MA, Ali SN, Farid M, Pancholi M, Rayatt S, Yap LH. Use of dermal regeneration template (Integra) for reconstruction of full-thickness complex oncologic scalp defects. *J Craniofac Surg* 2010;21:905–909.
21. Kinsella CRJ, Grunwaldt LJ, Cooper GM, Mills MC, Losee JE. Scalp reconstruction: regeneration with acellular dermal matrix. *J Craniofac Surg* 2010;21:605–607.
22. Momoh AO, Lypka MAD, Echo A, Rizvi M, Klebuc M, Friedman JD. Reconstruction of full-thickness calvarial defect: role for artificial dermis. *Ann Plast Surg* 2009;62:656–659.
23. Komorowska-Timek E, Gabriel A, Bennett DC, et al. Artificial dermis as an alternative for coverage of complex scalp defects following excision of malignant tumors. *Plast Reconstr Surg* 2005;115:1010–1017.