Radiation-Induced Scalp Malignancies Following Childhood Treatment for Tinea Capitis: Clinical Experience and a Skin-Sparing Surgical Approach

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ABSTRACT In the 1950s, ionizing radiation to the scalp was commonly used in Israel as a treatment for tinea capitis. Decades later, epidemiological studies identified an increased incidence of head and neck malignancies, particularly basal cell carcinoma, as well as intracranial tumors such as meningiomas among individuals who underwent this therapy in childhood. In addition to the oncologic risk, irradiated scalp skin presents significant reconstructive challenges due to chronic skin atrophy, hypovascularity, fibrosis, and impaired wound healing. In this study, we present our clinical experience with a modified, skin-sparing surgical protocol for managing reconstruction post excision of non-melanoma skin cancer of the scalp in patients previously irradiated for tinea capitis. The surgical strategy is tailored according to lesion size, depth, periosteal involvement, and scalp tissue quality. It incorporates components of the reconstructive ladder as appropriate. We present three representative cases highlighting key surgical challenges and considerations in this complex population.

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Tinea capitis is a contagious fungal infection of the scalp, which was historically treated with ionizing radiation during the 1950s [1]. In Israel, this treatment was implemented on a large scale under the auspices of the Ministry of Health and was administered to more than 20,000 individuals, mostly children, many of whom were recent immigrants from North Africa and, to a lesser extent, the Middle East [2].

The most commonly used technique was the Kienbock-Adamson method, delivering radiation across five overlapping scalp fields to ensure comprehensive coverage [3]. Due to the spheroid shape of the scalp, this method resulted in significant overlap between fields, and certain areas received 2–2.5 times the intended dose. On average, the scalp was exposed to approximately 1.4 Gy (range 1.0–6.0 Gy), thyroid tissue to 0.09 Gy (range 0.04–0.5 Gy), and breast tissue to only 0.016 Gy [4].

Although effective against the fungal infection, radiation therapy for tinea capitis was later found to be associated with increased long-term risk of malignancies, particularly basal cell carcinoma (BCC) [5].

In addition to skin cancers, cranial irradiation for tinea capitis has also been associated with an increased incidence of intracranial tumors, particularly meningiomas, reflecting the multifocal oncogenic potential of ionizing radiation.

Today, oral terbinafine is the treatment of choice, with a cure rate of approximately 95% within 10 weeks [3]. In this article, we describe the long-term implications of radiation-induced skin cancer following childhood treatment for tinea capitis and present a skin-sparing surgical approach based on clinical experience from our institution.

NON-MELANOMA SKIN CANCER IN IRRADIATED SKIN

Ionizing radiation has been strongly associated with an increased risk of developing BCC, the most common malignant skin tumor [3]. Studies have shown that patients who underwent therapeutic scalp irradiation for tinea capitis in childhood have a significantly increased risk of developing BCC. The 30-year cumulative risk was estimated at 0.8 ± 0.2 %, with an annual incidence of 790 per 10,000

persons [5], compared with 2.5–3.3 per 10,000 annually in the general population. Furthermore, radiation induced BCCs tend to exhibit more aggressively and have a higher propensity for recurrence, even four decades after exposure [6,7]. Although mortality attributable to BCC is very low, the disease is responsible for considerable morbidity and a high burden on healthcare services. In the absence of early detection and treatment, local tissue destruction, and disfigurement can be extensive [6].

SURGICAL TREATMENT OF BASAL CELL CARCINOMA

Surgical treatment is currently the gold standard for BCC treatment [3]. However, incomplete excision occurs in approximately 7% of standard surgical excision cases [4], posing a risk of recurrence. Recurrence rates vary by site and are highest in areas where complete margin clearance is challenging, such as the nose, periocular and paranasal regions, and the scalp. BCCs located in the head and neck are more likely to recur than those located on the trunk and extremities [8].

RADIATION-INDUCED SCALP MALIGNANCIES POSE COMPLEX RECONSTRUCTIVE CHALLENGES, PARTICULARLY DUE TO CHRONIC SKIN ATROPHY, FIBROSIS, AND POOR VASCULARITY FOLLOWING CHILDHOOD IRRADIATION FOR TINEA CAPITIS.

Mohs micrographic surgery is considered the treatment of choice for high-risk BCCs, especially in anatomically sensitive areas like the head and neck. This technique enables precise, layer-by-layer excision with immediate microscopic margin evaluation, resulting in high cure rates and maximal tissue preservation. A large retrospective study reported a 5-year cumulative recurrence rate of 3.3% following Mohs surgery for primary BCCs [9].

EFFECT OF IONIZING RADIATION ON THE SKIN

Ionizing radiation remains an important treatment modality for a variety of malignant and benign conditions, including cancers of the head and neck, brain tumors, lymphomas, and certain dermatologic diseases [7,10]. However, it can lead to long-term damage of the scalp, including atrophy, fibrosis, and compromised tissue quality, which may impair surgical reconstruction and overall scalp integrity [6].

Radiation-induced skin injury evolves through distinct pathophysiological phases. Initially, ionizing radiation causes direct DNA damage and generates reactive oxygen species, leading to apoptosis, senescence, and inflammation in epidermal and dermal cells [11]. Acute effects, emerging within days or weeks include erythema, desquamation, edema, hyperpigmentation, and mucositis. These symptoms primarily reflect damage to proliferating basal keratinocytes and endothelial cells [12]. Chronic radiation injury, which may develop months to years post-exposure, affects multiple layers of the skin. In the epidermis, basal keratinocytes are depleted, leading to thinning and impaired barrier function. In the dermis, radiation induces fibroblast dysfunction, excessive collagen deposition, vascular rarefaction, and fibrosis. Damage to the microvasculature further impairs tissue perfusion and healing. Subcutaneous tissues may exhibit atrophy, contributing to reduced elasticity and increased susceptibility to ulceration and secondary malignancies [12,13]. Furthermore, in the scalp, chronic radiation-induced atrophy and fibrosis can lead to thinning or loss of the pericranium, increasing the risk of calvarial bone exposure following tumor excision and complicating surgical reconstruction.

Therapeutic strategies for managing radiation-induced skin injury include topical corticosteroids, antioxidants such as pentoxifylline and vitamin E, and physical therapy [14]. However, these treatments are primarily aimed at symptom relief, especially in the acute phase, and do not fully reverse the chronic structural damage induced by radiation.

The irradiated scalp presents multiple reconstructive challenges, including atrophic skin, poor elasticity, hypovascularity, and delayed wound healing [15]. These features complicate tissue advancement and flap viability and may limit the success of conventional closure techniques. Therefore, attention has focused on using skin-sparing reconstructive techniques for defect closure following excision of BCCs in adults who underwent radiation treatment for tinea capitis in childhood.

Beyond BCC, exposure to ionizing radiation during childhood has also been associated with increased risk of developing squamous cell carcinoma (SCC), but to a lesser extent, as well as with other malignancies including brain tumors (notably meningiomas), leukemia, and tumors of the thyroid and breast. These risks are dose-dependent, particularly elevated following exposure at a young age, and may persist for decades after treatment [15,16].

OUR APPROACH

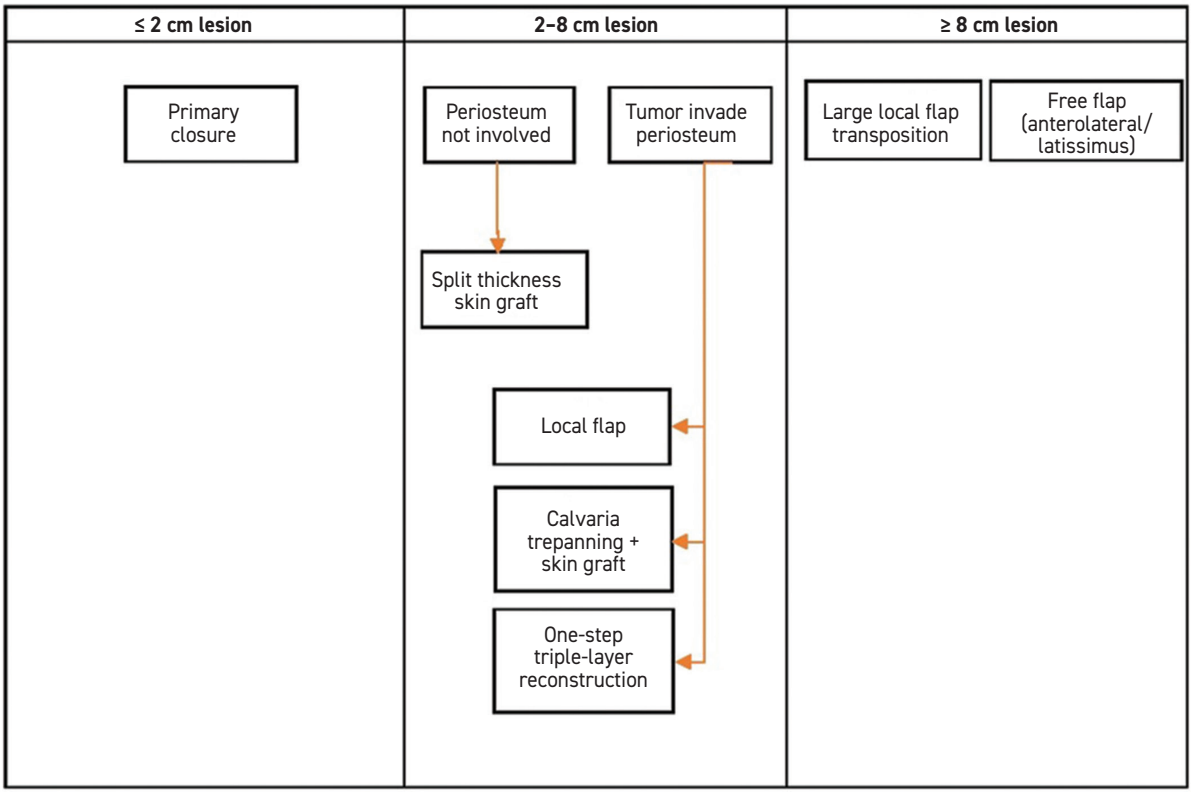
Reconstruction of scalp defects, particularly when involving exposed calvarial bone, remains a significant clinical challenge. When primary closure is not feasible, the next step in the reconstructive ladder typically involves skin grafting. If the pericranium has been

excised or deficient, resulting in a poorly vascularized calvarial surface, techniques such as burring, drilling, or other manipulation of the outer table are employed to promote graft take. Alternatively, when direct skin grafting is not possible or is inadequate, local scalp flaps may be utilized to achieve immediate coverage. At Rabin Medical Center, where a dedicated clinic for scalp and calvarial reconstruction manages a large cohort of patients previously treated with ionizing radiation for tinea capitis, the surgical strategy is based on defect size and depth, periosteal integrity, and the overall condition of the irradiated scalp tissue.

A SKIN-SPARING, ALGORITHMIC RECONSTRUCTIVE APPROACH, INCLUDING PERIOSTEAL FLAPS, DERMAL SUBSTITUTES, AND SPLIT-THICKNESS SKIN GRAFTS, CAN ACHIEVE STABLE, FUNCTIONAL, AND AESTHETICALLY ACCEPTABLE OUTCOMES EVEN IN COMPROMISED TISSUE BEDS.

Surgical excision is preferably performed using Mohs micrographic surgery or intraoperative frozen section analysis to achieve complete margin clearance while minimizing healthy tissue loss. Following excision, the choice of reconstructive technique is dictated by the defect size and the presence or absence of calvarial bone coverage. For small defects (< 2 cm in diameter), primary closure is often feasible, even in irradiated skin, although the cutoff for primary closure is more conservative compared to non-irradiated patients. For intermediate defects (2–8 cm), when the periosteum is intact, reconstruction typically involves a split-thickness skin graft (STSG) with or without the use of a dermal substitute such as MatriDerm© (Matriderm, Germany). If the periosteum has been excised or is deficient, additional measures such as calvarial burring or periosteal flap coverage are employed to prepare the bone surface and enhance graft take. For large defects (> 8 cm) reconstruction generally requires regional scalp flaps or microsurgical free tissue transfer. At our medical center, we have extensive experience with anterolateral thigh and latissimus dorsi free flaps for scalp reconstruction, achieving reliable coverage and favorable functional and aesthetic outcomes [Figure 1].

Figure 1. Our Surgical algorithm for removal of the tumor



Using this approach, we can plan safe and durable reconstructions in patients undergoing scalp defect repair following tumor excision in previously irradiated fields, despite the challenging tissue quality.

The following three cases describe patients who underwent childhood radiation therapy for tinea capitis and later developed radiation induced scalp malignancies. These cases illustrate the broad spectrum of pathologies resulting from radiation damage. All patients were treated surgically with complete tumor excision followed by tailored reconstructive procedures adapted to the quality of the irradiated scalp tissue.

REPRESENTATIVE CASES

Case 1

A 75-year-old man presented to our plastic surgery clinic with a scalp lesion. His past medical history was notable for treatment with ionizing radiation to the scalp for tinea capitis. Physical examination revealed a large, ulcerated lesion involving the frontal and vertex regions of the scalp, measuring approximately 8 cm in diameter [Figure 2]. Due to the ulcerated and exophytic nature of the lesion, both SCC and BCC were considered in the differential diagnosis. An incisional biopsy confirmed a moderately to poorly differentiated ulcerated BCC.

Surgical treatment consisted of wide excision under general anesthesia, including resection of the overlying periosteum and superficial involvement of the outer calvarial table. Three local periosteal flaps were utilized for bone coverage, and wound closure was achieved using MatriDerm© (Matriderm, Germany) and a STSG, a one-step triple-layer reconstruction. The skin graft demonstrated complete take, and the aesthetic outcome was deemed satisfactory during 18 months of postoperative follow-up.

Case 2

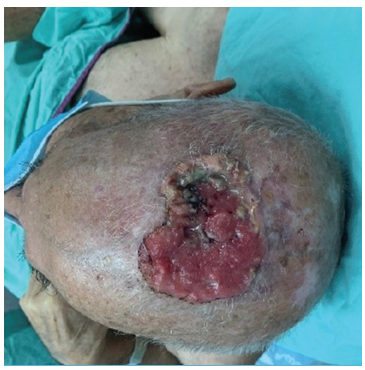
A 68-year-old woman was scheduled for resection of a meningioma by a multidisciplinary surgical team. Her past medical history was notable for treatment with ionizing radiation to the scalp region in childhood to treat tinea capitis. Five years earlier, she had undergone resection of a BCC from the left occipital scalp, which was reconstructed with a STSG. On preoperative evaluation, an area of ulceration was noted at the previous graft site [Figure 3]. Imaging revealed that the meningioma involved the left occipital bone beneath the graft. After resection of the meningioma, intraoperative frozen section analysis of the ulcerated portion of the graft revealed recurrent BCC, prompting extension of the operation to include skin resection. This procedure created a 6 cm full-thickness skin defect including the periosteal layer, which was reconstructed using double opposing rotational flaps. The postoperative course was uneventful. Follow-up was completed over a 12-month period with no reported complications.

Case 3

A 72-year-old man with a history of ionizing radiation to the scalp in childhood for tinea capitis and prior resection of a grade I meningioma from the left parietal scalp, followed by STSG reconstruction, was admitted with a new mass at the same site. Computed tomography of the head revealed a recurrent grade I meningioma, appearing as an extra-axial isodense lesion in the left parietal region mea-

Figure 2. Case 1

[A] Suspected lesion, 8 cm in diameter



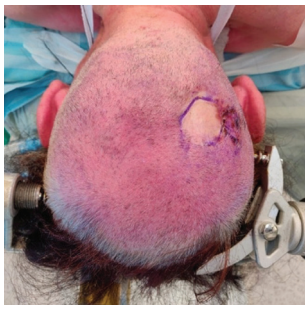
[B] Day 7 postoperative

[C] Follow-up examination at 3 weeks

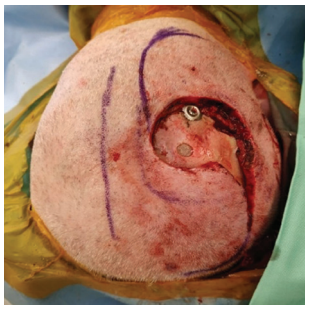
Figure 3. Case 2

[A] Area involved on the left occipital scalp

[B] Lesion margins for excision location on the left occipital scalp



[C] 6-cm full-thickness skin deficit including periosteal layer



[D] Flap is rotated to cover the deficit

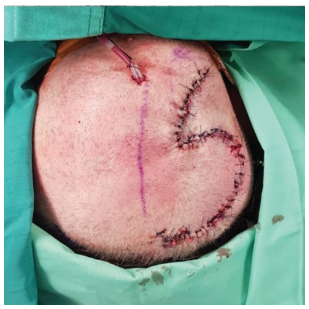


Figure 4. Case 3

[A] Surgical site on parietal scalp

[B] Titanium cranioplasty using a latissimus dorsi flap

[C] Postoperative follow-up shows aesthetic surgical result

suring 3.5 × 3.2 × 3 cm and associated with surrounding edema compressing the left lateral ventricle. The patient underwent craniotomy for tumor resection, followed by cranioplasty using a titanium mesh implant. Reconstruction was achieved using a latissimus dorsi free flap, covered with a STSG [Figure 4]. The latissimus dorsi flap and overlying skin graft demonstrated excellent integration, with a stable and aesthetically acceptable reconstruction noted during 15 months of postoperative follow-up.

DISCUSSION

Satisfactory results may be achieved using a patient-specific approach to reconstruction following malignancies that develop in cutaneous areas previously exposed to ionizing radiation for the treatment of tinea capitis. The presence of chronically irradiated, atrophic, and hypovascular skin highlights the importance of adopting the most conservative reconstructive strategies possible.

CONSERVATIVE, STAGED RECONSTRUCTION PRIORITIZING NATIVE TISSUE PRESERVATION IS EFFECTIVE IN MINIMIZING DONOR SITE MORBIDITY AND AVOIDING THE PITFALLS OF UNRELIABLE LOCAL FLAPS IN PREVIOUSLY IRRADIATED SCALP TISSUE.

We describe our clinical experience and a modified reconstructive protocol tailored according to multiple factors including lesion size, periosteal involvement, and scalp tissue quality. We outline several approaches that have been successfully implemented in our department. When treating patients with a history of cranial irradiation and the consequent poor skin quality, our primary goal is to achieve complete tumor excision while reconstructing the defect using conservative, tissue-preserving techniques whenever feasible.

Although the literature suggests that free flaps should be considered liberally in cases of previous radiation, exposed dura, multiple prior surgeries, or contaminated cranioplasty [6], our approach favors staged, size-based reconstruction that prioritizes preservation of viable native tissue and minimizes the need for free flaps.

Our algorithm involves the use of local periosteal flaps in combination with MatriDerm© and STSG, a one-step triple-layer reconstruction, which has yielded reliable coverage with minimal donor site morbidity.

By avoiding the use of traditional local scalp flaps, which in previously irradiated patients were often very thin, atrophic, and structurally unreliable, we avoided an increased risk of breakdown that could have resulted in larger defects. We were able to optimize both functional and aesthetic outcomes.

Recently, neoadjuvant therapy with vismodegib (Erivedge), a hedgehog pathway inhibitor, has emerged as an adjunctive option for locally advanced or initially unresectable BCCs. While this medical treatment rarely obviates the need for surgical excision in these cases, it can substantially reduce tumor size, allowing for more conservative resections and facilitating simpler, safer reconstructions.

In our representative patients, vismodegib was used preoperatively to minimize tumor burden, allowing for less extensive surgeries while maintaining oncologic safety.

Overall, the treatment of scalp malignancies in previously irradiated patients remains a significant reconstructive challenge, and a cautious, conservative, and individualized surgical approach is paramount to achieving optimal outcomes [14].

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Capsule

Attenuating allergic responses

Allergic responses are stimulated when immunoglobulin E (IgE) bound to its receptor, FcεRI, on mast cells is cross-linked by antigens. **Zhou** et al. found that IgE-FcεRI signaling in mouse mast cells stimulated the ubiquitin-specific protease USP5 to deubiquitylate the FcεRIγ subunit, increasing its stability and prolonging allergic responses. Inhibiting USP5 or reducing its inhibition attenuated mast cell activation and allergic responses in mice, suggesting that targeting USP5 rather than FcεRI might provide an alternative strategy for the treatment of allergic diseases.

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