

The Most Current Algorithms for the Treatment and Prevention of Hypertrophic Scars and Keloids: A 2020 Update of the Algorithms Published 10 Years Ago

Rei Ogawa, M.D., Ph.D.

Tokyo, Japan



Background: In 2010, this *Journal* published my comprehensive review of the literature on hypertrophic scars and keloids. In that article, I presented evidence-based algorithms for the prevention and treatment of these refractory pathologic scars. In the ensuing decade, substantial progress has been made in the field, including many new randomized controlled trials. To reflect this, I have updated my review.

Methods: All studies were evaluated for methodologic quality. Baseline characteristics of patients were extracted along with the interventions and their outcomes. Systematic reviews, meta-analyses, and comprehensive reviews were included if available.

Results: Risk factors that promote hypertrophic scar and keloid growth include local factors (tension on the wound/scar), systemic factors (e.g., hypertension), genetic factors (e.g., single-nucleotide polymorphisms), and lifestyle factors. Treatment of hypertrophic scars depends on scar contracture severity: if severe, surgery is the first choice. If not, conservative therapies are indicated. Keloid treatment depends on whether they are small and single or large and multiple. Small and single keloids can be treated radically by surgery with adjuvant therapy (e.g., radiotherapy) or multimodal conservative therapy. For large and multiple keloids, volume- and number-reducing surgery is a choice. Regardless of the treatment(s), patients should be followed up over the long term. Conservative therapies, including gel sheets, tape fixation, topical and injected external agents, oral agents, and makeup therapy, should be administered on a case-by-case basis.

Conclusions: Randomized controlled trials on pathologic scar management have increased markedly over the past decade. Although these studies suffer from various limitations, they have greatly improved hypertrophic scar and keloid management. Future high-quality trials are likely to improve the current hypertrophic scar and keloid treatment algorithms further. (*Plast. Reconstr. Surg.* 149: 79e, 2022.)

In 2010, this *Journal* published my review on hypertrophic scars and keloids and the treatment and prevention algorithms for these

refractory scars.¹ Since then, many randomized controlled trials on pathologic scar management and guidelines²⁻⁵ have been published. To reflect these considerable advancements, I have reprised my review and the algorithms (Figs. 1 and 2).

From the Department of Plastic, Reconstructive and Aesthetic Surgery, Nippon Medical School.

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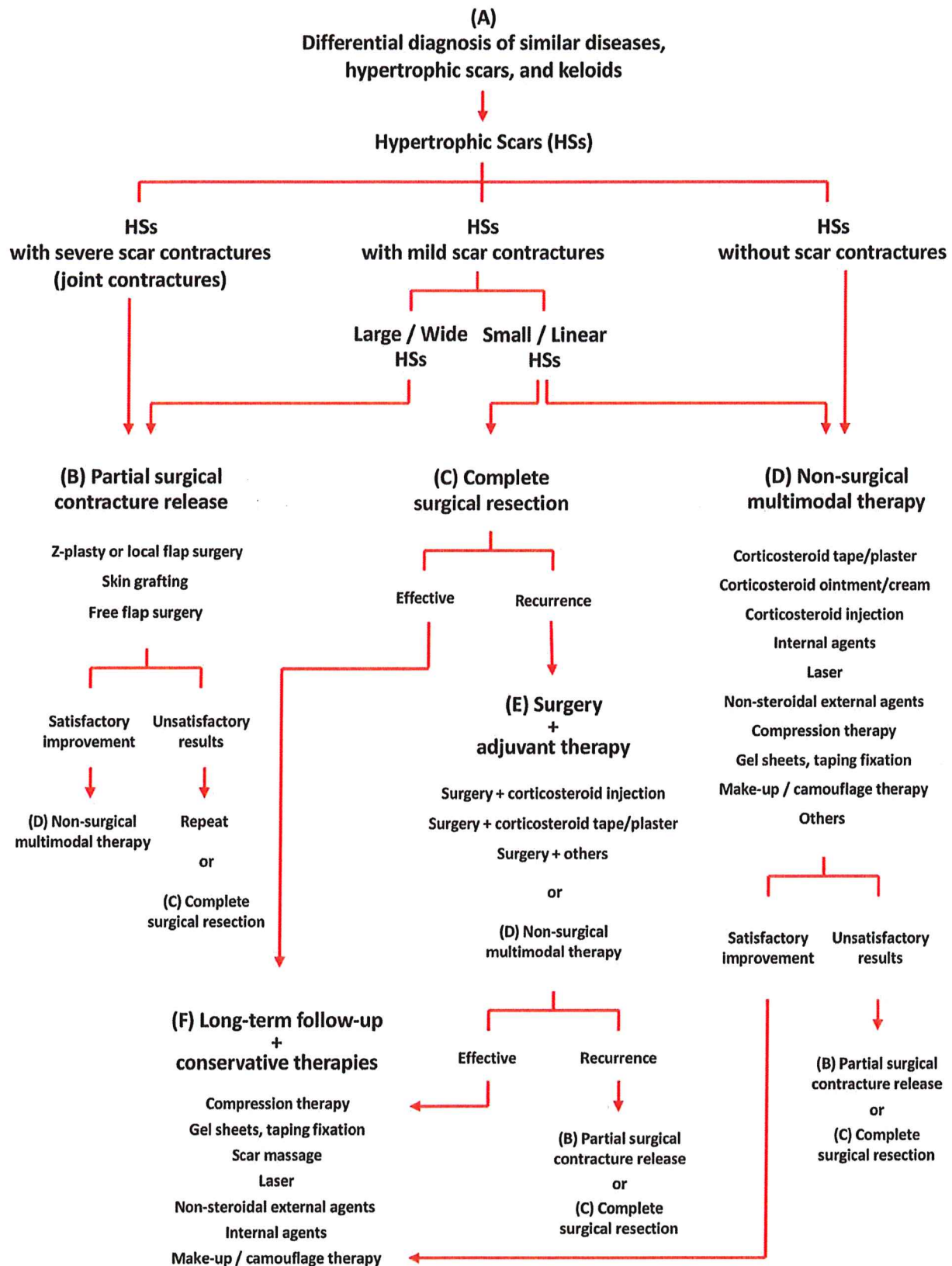


Fig. 1. Treatment algorithm for hypertrophic scars (HSs). The scar should first be assessed for the degree of scar contracture. If the contracture is severe, surgery that releases the contracture is the first choice. If the contracture is mild, the scar can be resected completely; however, nonsurgical multimodal therapy is also a choice.

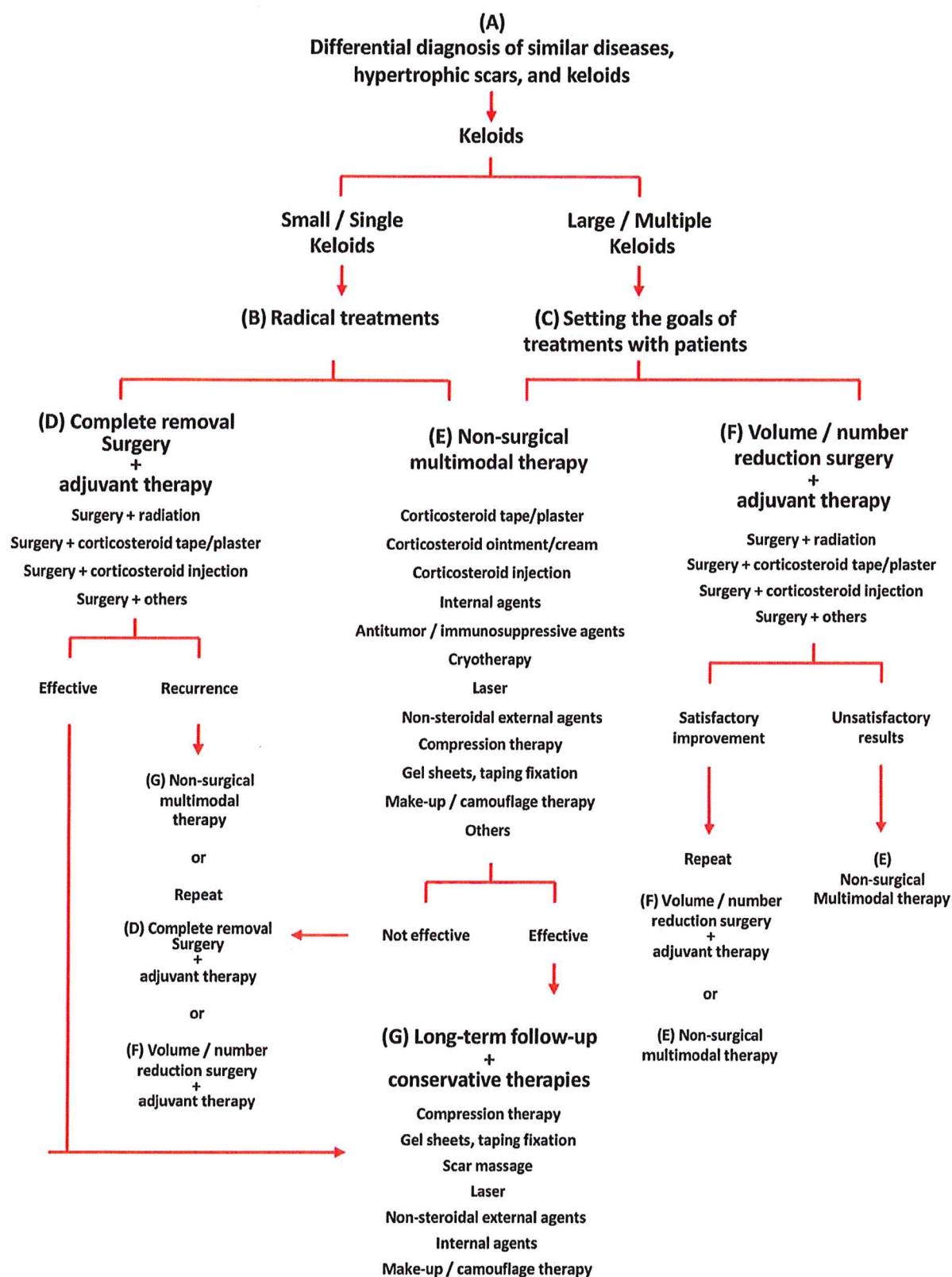


Fig. 2. Treatment algorithm for keloids. The selected treatment method for keloids depends on whether the keloids are small and single or large and multiple. Small and single keloids can be treated radically by surgery with adjuvant therapy (including radiation therapy); alternatively, they could be treated with nonsurgical multimodal therapy. For large and multiple keloids, volume- and number-reduction surgery is a choice.

NEW DEVELOPMENTS IN THE PAST DECADE

The past decade has seen a remarkable growth in our understanding of how hypertrophic scars and keloids develop and progress. Consequently, hypertrophic scars and keloids are now known to be caused by chronic inflammation in the reticular dermis. Risk factors associated with hypertrophic scar and keloid development and aggravation have been identified, thereby aiding treatment optimization and effectiveness. Several major advancements in preventing and treating hypertrophic scars and keloids have been made, as follows. First, deprodone propionate (a stronger steroid) plaster was found to both prevent and treat hypertrophic scars and keloids very effectively. Second, surgical methods have been optimized for each body region, thereby improving cosmetic and functional outcome, safety, and recurrence rates. Third, the postoperative radiotherapy protocol has been fine-tuned, making it safer while remaining equally effective. The previous algorithm has been greatly improved by the inclusion of these modalities. I anticipate that further high-quality evidence for these modalities, and additional new modalities, will emerge in the next decade.

HYPERTROPHIC SCAR AND KELOID DIAGNOSIS

Differential Diagnosis

Hypertrophic scars and keloids are fibroproliferative disorders in the reticular dermis layer; this layer exhibits continuous inflammation,⁶ excessive angiogenesis, and abundant collagen accumulation. Compared to classic hypertrophic scars, classic keloids spread aggressively, rarely resolve spontaneously, and, at the histologic level, contain keloidal collagen, whereas hypertrophic scars only have nodules. However, many scars bear the clinical and pathologic features of both classic keloids and hypertrophic scars. This suggests that classic hypertrophic scars and keloids are polar manifestations of the same skin disorder, between which lies a spectrum of intermediate scars.

The clinical and histologic differences between classic hypertrophic scars and keloids probably reflect differences in the intensity and duration of reticular dermis inflammation. These differences in turn may reflect the presence and severity of local, systemic, genetic, and lifestyle risk factors.^{6,7}

International Differences in Hypertrophic Scar and Keloid Diagnosis

Classic keloids are strongly driven by genetics.^{8–13} This partly explains ethnic differences in keloid susceptibility: keloids are common in Africans (5 to 10 percent are affected), less common in Asians (0.1 to 1 percent), and rare in Europeans/North Americans (<0.1 percent).¹⁴

These ethnic differences mean that physicians in certain regions have more experience with keloids than others. It is my impression, gained through attending many international scar conferences, that this can influence physician diagnoses. Thus, in Western countries, most abnormal scars are classic hypertrophic scars; consequently, Western physicians often diagnose scars as keloids if they exhibit minor spreading. However, African physicians see many patients with classic keloids; consequently, they often diagnose all scars as hypertrophic scars unless they grow rapidly. This should be taken into account when reviewing international literature.

Differential Diagnosis of Hypertrophic Scars and Keloids from Similarly Appearing Diseases

Hypertrophic scar and keloid diagnosis is often based on clinical features alone. However, malignant tumors such as dermatofibrosarcoma protuberans^{15–18} and giant-cell fibroblastoma¹⁹ can be misdiagnosed clinically as keloids.²⁰ Moreover, analysis of 378 hypertrophic scars and keloids showed that 1.06 percent were other diseases.²⁰ Thus, biopsy is warranted if malignancy is suspected.^{20–22}

PREVENTION OF POSTSURGICAL HYPERTROPHIC SCARS AND KELOIDS

Patients with a hypertrophic scar and keloid history are at high risk, as are patients with one or more of the following risk factors (special care must be taken during and after surgery).

Risk Factors

Local

Hypertrophic scars and keloids occur frequently on sites that are frequently stretched by daily body movements, including the major joints, anterior chest, scapula, and lower abdomen.²³ By contrast, hypertrophic scars and keloids occur rarely on the scalp and anterior lower leg, where stretching tension is low.²³ This is because stretching a wound prolongs and worsens its

inflammation, thereby provoking hypertrophic scar and keloid formation.^{24–26}

To prevent hypertrophic scar and keloid formation after surgery on susceptible body regions, surgical techniques that limit dermal tension should be used, namely, flaps, Z-plasties, and subcutaneous and deep fascial tensile-reduction sutures. Moreover, postsurgical wound stretching should be limited by fixation materials such as paper tape, gel sheets, gels, or compression bandages and garments. All are supported by meta-analyses/randomized controlled trials. Regarding paper tape, a randomized controlled trial²⁶ demonstrated that paper tape fixation reduced the hypertrophic scar risk after cesarean section by 13.6-fold. Regarding gel sheets, a meta-analysis on 20 trials²⁷ concluded that silicone gel sheets may prevent hypertrophic scar and keloid formation in scar-prone people with newly healed wounds; however, they commented that trial quality was poor.²⁷ A recent review on 10 trials had similar conclusions.²⁸ Regarding gels, a randomized controlled trial²⁹ showed that silicone gel reduces sternotomy scar pigmentation, erythema, hardness, height, and pain and itchiness. This was confirmed by a review.²⁸ Regarding compression therapy, a meta-analysis of 12 trials confirmed that 15- to 25-mmHg compression therapy reduces burn scar thickness, erythema, and hardness.³⁰

All patients undergoing surgery on susceptible body areas should be monitored closely for hypertrophic scars and keloids for 3 to 12 months. If induration is observed, steroid tape and plaster should be started and replaced with steroid injection if the induration prevails.

Systemic

Systemic factors include the female hormone estrogen³¹; a large cross-sectional study showed that keloids may predominate in women.³² Moreover, estrogen-induced vasodilation could worsen wound and scar inflammation: indeed, hypertrophic scars and keloids worsen during pregnancy^{33,34} and improve after delivery. Another systemic factor is hypertension, which may aggravate hypertrophic scars and keloids.³⁵ Moreover, hypercytokinemic diseases (e.g., Castleman disease) can greatly worsen hypertrophic scars and keloids.^{36,37} Thus, surgery on pregnant, hypertensive, and hypercytokinemic patients should be conducted with the surgical and wound fixation techniques described above, followed by close monitoring.

Genetic

As mentioned, keloids are often strongly underpinned by genetic factors, including ethnic¹⁴ and

familial genes: multiple cases of keloid-susceptible families have been reported.^{38,39} Moreover, several single-nucleotide polymorphisms associate with keloids^{40–42}: four promote keloidogenesis⁴⁰ and one associates with severe keloids.⁴¹

Several genetic diseases associate with keloidogenesis, including Rubinstein-Taybi syndrome^{43,44}: a cross-sectional study⁴⁴ reported that 24 percent of such patients had spontaneously growing keloids. Multiple hereditary exostoses also associate with keloidogenesis.⁴⁵

These risk factors cannot be obviated. Thus, patients with familial history and genetic diseases should be treated carefully during and after surgery. The relatively low frequency of keloid-associated single-nucleotide polymorphisms means that testing for them is impractical.

Lifestyle

Several lifestyle factors could exacerbate surgery-induced wound and scar inflammation, including strenuous wound-stretching physical activity. Athletes and manual laborers should rest their wounds. Certain diets and hot baths could aggravate surgery-induced inflammation⁴⁶; my experience with thousands of patients suggests they often experience itch and pain after consuming hot and spicy foods or taking hot baths.

EARLY DETECTION AND FIRST-LINE HYPERTROPHIC SCAR AND KELOID TREATMENT

Hypertrophic scars and keloids should be detected early because they may respond well to conservative therapy. As discussed later, the first-line conservative therapy for hypertrophic scars and keloids in the 2019 Japanese guideline⁵ is long-term/continuous steroid tape or plaster application. Strong steroid (deprodone propionate) plaster effectively extinguishes early hypertrophic scars and keloids^{5,31,47,48} but is only available in Japan.⁴⁷ Nevertheless, if applied very early and continuously, even weaker fludroxycortide tape can extinguish early hypertrophic scars and keloids.⁵

HYPERTROPHIC SCAR TREATMENT

Hypertrophic scars are detected several weeks after injury (Fig. 1). They grow for 3 to 6 months; if risk factors are minor, they then plateau and regress spontaneously. This process can be accelerated by the following conservative therapies, which reduce hypertrophic scar volume and suppress pain and itch. Hypertrophic scars rarely

require surgery unless they contract and cause joint dysfunction^{49,50}; in this case, reconstructive surgery is indicated.

Compression Therapy

A recent meta-analysis (12 randomized controlled trials) showed that 15- to 25-mmHg compression therapy improves burn and hypertrophic scar thickness, erythema, and hardness.³⁰ Compression therapy may promote wound healing by means of local vasoconstriction that limits burn-induced inflammation.

Gel Sheets

Gel sheets are soft and self-adhesive. A meta-analysis (20 trials)²⁷ reported that continuous gel sheeting improves hypertrophic scar maturation. A new meta-analysis⁵¹ on this question is currently underway; it will be of interest to learn their findings.

The type of material may not matter: a randomized controlled trial⁵² showed that silicone and hydrocolloid matrix gel sheets reduce hypertrophic scar dimensions equally well. More important may be patient education: a randomized controlled trial⁵³ on burn and hypertrophic scar patients suggests that instructional handouts and videotapes increase gel sheet effectiveness. Computer analysis suggests that gel sheets may prevent hypertrophic scar formation and promote hypertrophic scar maturation by limiting wound and scar tension.⁵⁴

Scar Massage

Randomized controlled trials on burn rehabilitation massage have conflicting results, and a meta-analysis of 10 randomized controlled trials concluded that the supporting evidence is weak.⁵⁵ I advise caution regarding massage therapy. Wound healing associates with initial inflammation that normally slowly wanes. At this point, massage may promote mature scarring. However, in patients with risk factors, inflammation rises rather than subsides. Because massage stretches the scar, it could induce and worsen hypertrophic scars and keloids. Thus, scar massage in high-risk patients should be avoided.

Corticosteroid Injection

Recent meta-analyses of four to 14 trials,^{28,56,57} a network meta-analysis of 23 trials,⁵⁸ a systematic review of 11 studies,⁵⁹ comprehensive reviews,^{60,61} and several new randomized controlled trials^{62,63} show that intralesional corticosteroid can induce

50 to 100 percent regression of both hypertrophic scars and keloids. An international expert panel recommends triamcinolone acetonide at doses of 2.5 to 40 mg/site.⁶⁴ The injections probably act by decreasing inflammatory cytokine production.⁶⁵ However, disadvantages include injection-induced pain, systemic side effects (e.g., menstrual dysfunction, adrenocortical suppression,⁶⁶ and cataracts and glaucoma), and local side effects (e.g., skin thinning and atrophy, steroid acne, capillary dilatation, and hypopigmentation).

Corticosteroid Tape and Plaster

Corticosteroid tape and plaster is a painless alternative to corticosteroid injections. When 60 hypertrophic scar and keloid patients were treated with fludroxycortide (weak steroid) tape, 20 percent of the 30 adults and 80 percent of the 30 children exhibited improved scar elevation and erythema and pruritus after 12 months. The strong pediatric response may reflect thinner skin. When the 24 nonresponsive adults were switched to depredone propionate (stronger steroid) plaster, 70.8 percent demonstrated improved scar features after 6 months.^{47,67} Other observational studies and good clinical experiences with steroid tape and plaster have caused it to become a mainstay of scar-management protocols.³¹ Consequently, a Japanese guideline⁵ recently recommended that corticosteroid tape and plaster should be the first-line hypertrophic scar and keloid therapy. [Figure 3](#) depicts a depredone propionate plaster-treated hypertrophic scar. Tape and plaster should be used continuously as early as possible⁵ for at least 3 months. If unsuccessful, it should be replaced with stronger treatments.

Corticosteroid Ointment and Cream

Randomized controlled trials on corticosteroid ointment and cream are lacking, but a case series study⁶⁸ showed that triamcinolone acetonide injections of hypertrophic scar and keloid-excision sites combined with twice-daily 6-month corticosteroid ointment application yielded keloid and hypertrophic scar recurrence rates of 14.3 percent and 16.7 percent, respectively. These outcomes and good clinical experiences recently led several Japanese burn and scar societies^{5,69} to recommend corticosteroid ointment and cream materials for superficial dermal burns⁷⁰ and hypertrophic scar prevention and treatment.⁵ However, since corticosteroid ointment and cream should be applied four times daily to

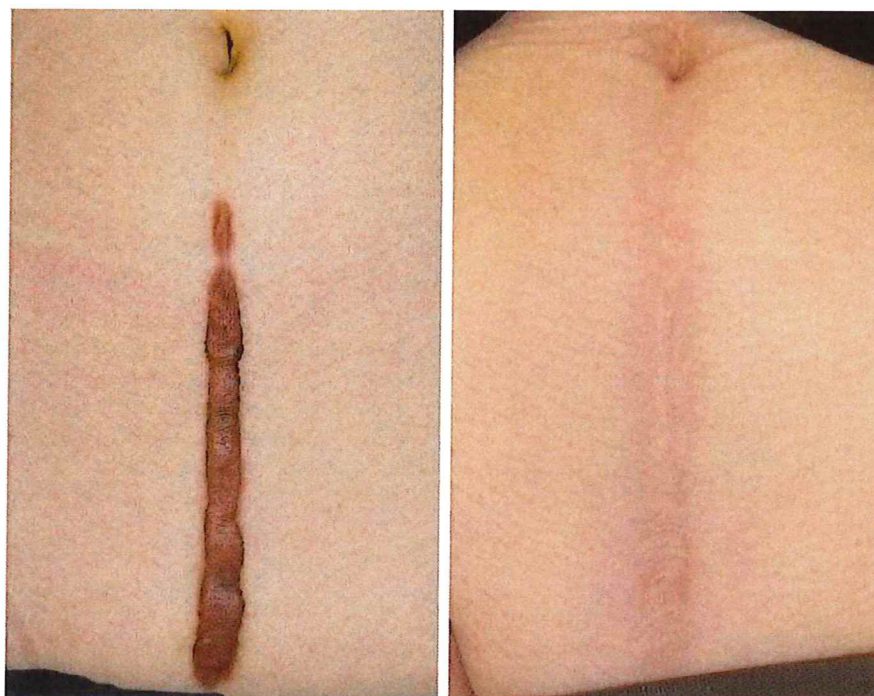


Fig. 3. Treatment of hypertrophic scars with deprodone propionate plaster. (Left) Pretreatment view. (Right) Three years after starting deprodone propionate plaster. A 50-year-old woman had several hypertrophic scars as a result of cesarean delivery. She was provided with deprodone propionate plaster and told to apply it 24 hours per day until further notice. She was instructed to peel it off while taking a bath and then reapply it. When the plaster lost its adhesiveness, it was replaced by a new plaster. After 6 months, the scar became soft. After 3 years, the scar became completely flat and its tone was close to that of the surrounding skin.

generate steroid tape and plaster effects,⁶⁷ patient education is necessary.

Laser

Two reviews^{70,71} and a meta-analysis⁷² showed that pulsed-dye laser significantly reduces hypertrophic scar erythema and pruritus^{73–77} because its wavelength (585 to 595 nm) reaches the hypertrophic scar angiogenic region: its heat reduces hypertrophic scar blood flow and therefore inflammation. Neodymium:yttrium-aluminum-garnet laser (532/1064 nm) has similar effects, as shown by a review,⁷¹ a meta-analysis,⁷² case-series studies,^{48,78} and a randomized controlled trial.⁷⁹ Randomized controlled trials showed that nonablative/ablative carbon dioxide fractional lasers have no beneficial effects.^{80,81} Fully ablative laser therapy is not recommended for pathologic scars because of high recurrence.^{82,83}

Surgery

When hypertrophic scars occur near or on a joint, their contraction can induce joint

dysfunction. Such scar contractures should be released surgically. This also accelerates maturation of surrounding hypertrophic scars. Small and linear hypertrophic scars can be treated by complete resection. All hypertrophic scar operations should involve tension-releasing techniques,⁵ including Z-plasty,⁸⁴ W-plasty,⁸⁵ and local flaps.^{86–89} Figure 4 shows a Z-plasty–treated hypertrophic scar contracture.

One randomized controlled trial suggests that absorbable/nonabsorbable sutures do not differ in hypertrophic scar risk,⁹⁰ but another⁹¹ showed that nonabsorbable sutures reduce hypertrophic scar frequency. The suturing method is probably more important than the material: clinical experience⁹² suggests that tensile-reduction sutures reduce hypertrophic scar and keloid scarring and recurrence because they decrease dermal tension.^{6,92,93}

Other Hypertrophic Scar Therapies

Other therapies have been proposed for hypertrophic scars. Some may also be suitable for

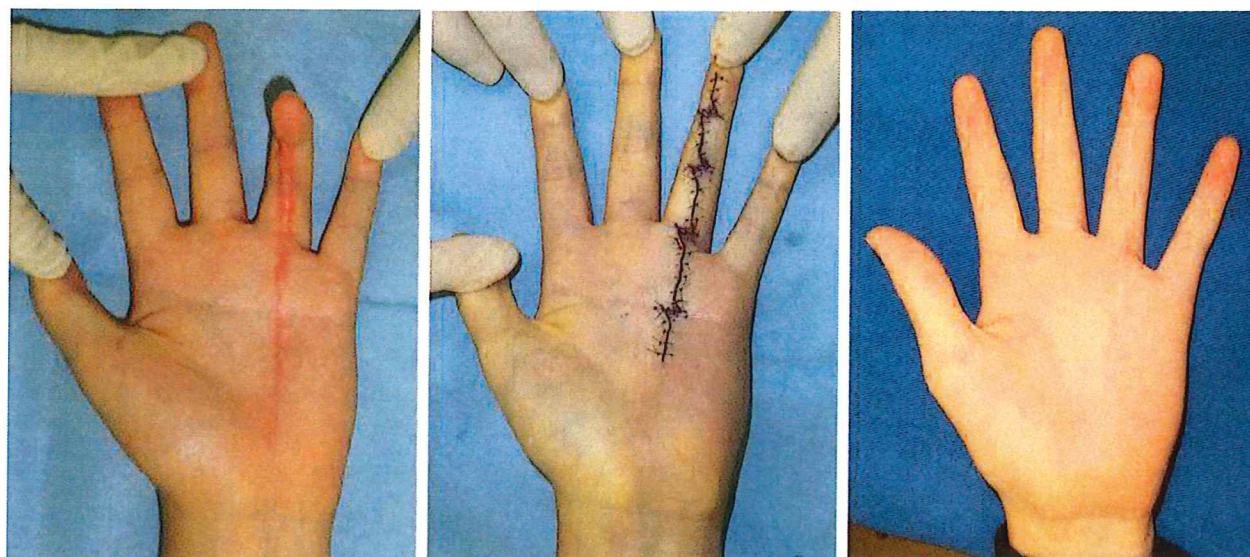


Fig. 4. Treatment of a traumatic scar contracture between the finger and palm by using Z-plasty. (Left) Preoperative view. (Center) Immediately after surgery. (Right) Eighteen months after surgery. A 10-year-old boy sustained trauma to his left ring finger and palm. A hypertrophic scar with mild scar contracture developed. Because the width of the scar was narrow, the scar could be removed completely. Thereafter, Z-plasties were placed over the joints and the main crease in the palm. After surgery, the inflammation decreased uneventfully. The scar became mature over the next year.

keloids. The evidence level is generally low. One is adipose tissue transplantation by using lipotransfer and lipoinjection techniques. A recent review⁹⁴ noted that adipose-derived stem cells can secrete trophic factors that alter fibrotic and remodeling mediator expression. The evidence is too limited to justify changes in clinical practice. A recent review⁹⁵ of case series studies showed that cryotherapy is safe and achieves good scar reduction, albeit with some adverse effects (depigmentation, recurrence, pain).

Recent meta-analyses and reviews²⁸ show that 5-fluorouracil injections are effective as a monotherapy but reduce hypertrophic scar and keloid elevation and erythema better when combined with triamcinolone acetonide injections. Intralesional botulinum toxin type A (Botox; Allergan, Inc., Dublin, Ireland) injections may improve and prevent hypertrophic scars and keloids by suppressing scar tension and fibroblast activities.⁹⁶ Recent randomized controlled trials^{97,98} show that post-surgical Botox injections prevent hypertrophic scar development. A meta-analysis of 14 studies⁵⁷ showed that, compared to placebo, Botox injections significantly improved hypertrophic scar and keloid appearance and width.

A meta-analysis⁹⁹ of five trials showed that bleomycin injections improved hypertrophic scars and keloids more effectively than triamcinolone acetonide and/or 5-fluorouracil injections. A 14-study review on topical onion extract gel

(a nonsteroidal antiinflammatory drug) reported that 11 detected beneficial effects on hypertrophic scars and keloids.¹⁰⁰

Oral tranilast (an antiallergic drug) improves inflammatory diseases with few adverse effects. It has long been used in Japan to treat hypertrophic scars and keloids.^{5,101–103} Randomized controlled trials showed that tranilast improved hypertrophic scars and keloids and reduced the redness of new postsurgical hypertrophic scars.¹⁰⁴

KELOID TREATMENT

Keloid treatment starts with determining the keloid number and size (Fig. 2): this indicates the strength of the patient's keloid risk factors.¹ If there is one keloid or the keloids are small, skin tension is probably the cause. However, if there are multiple or large keloids, genetic and systemic factors should be considered, especially when keloids are on different body regions. Single or small keloids can be treated with conservative therapy. Thick, large, multiple keloids should be assessed for surgery plus adjuvant therapy because they respond poorly to topical drugs. Physicians must carefully discuss therapeutic options with the patient and establish treatment goals.

Keloid inflammation generally worsens over time. Because scar massage, ablative lasers, and surgical monotherapy provoke inflammation and worsen keloids, they should be avoided.

Gel Sheets

The meta-analysis of O'Brien and Jones²⁷ showed that silicone gel sheets alone can reduce keloid thickness and erythema.

Corticosteroid Injection

Many studies show that intralesional corticosteroid injections induce keloid regression.^{58–63} However, combining corticosteroid injections with 5-fluorouracil, pulsed-dye laser, or cryotherapy has better outcomes than corticosteroid injections alone.⁷⁰

Corticosteroid Tape and Plaster

As with hypertrophic scars, corticosteroid tape and plaster is the first-line keloid therapy in the 2019 Japanese guideline.⁵ Its long-term, continuous application softens and then flattens the mass. It also reduces pruritus and erythema.^{47,67} Figure 5 shows a steroid plaster-treated keloid. However, in my experience, rapidly growing keloids cannot be stopped by steroid tape and plaster alone, and this therapy must be combined with triamcinolone acetonide injections or other methods. The greatest advantages of steroid tape and plaster are its painlessness and few side effects. Strong steroid (deprodone propionate) plaster, which is available only in Japan, is more effective than fludroxycortide tape. It should become available worldwide for treating pathologic scars.

Corticosteroid Ointment and Cream

Case series studies showed that multiple daily corticosteroid cream applications had excellent

to good effects on existing keloids¹⁰⁵ and reduced recurrence to 14.3 percent when applied postoperatively.⁶⁸ However, a limitation is that the cream is easily rubbed off.

Cryotherapy

Recent reviews^{56,106} showed that cryotherapy (monotherapy or with triamcinolone acetonide injection) effectively reduces keloid size. Cryotherapy methods include direct contact,¹⁰⁷ sprays,^{107–109} and intralesional needles.^{109,110} However, supporting evidence is limited to case series studies.¹⁰⁶

Antitumor and Immunosuppressive Agents

Recent meta-analyses, reviews, and new randomized controlled trials^{58–60} show that intralesional 5-fluorouracil injection is an effective keloid monotherapy and reduces postoperative recurrence.^{58–60} They also show that 5-fluorouracil effectively reduces keloid elevation and erythema when combined with triamcinolone acetonide injections.^{58–60} A meta-analysis⁹⁹ reported that bleomycin injections improve keloids more effectively than triamcinolone acetonide and/or 5-fluorouracil injections.

Surgery

Small keloids can be radically resected. Large and multiple keloids may be suitable for partial and core excision that reduces the thick, hard areas or the number of keloids. Radical resection should always be combined with adjuvant therapies (e.g., radiation therapy) because surgery alone results in 45 to 100 percent recurrence



Fig. 5. Treatment of keloids using deprodone propionate plaster. (Left) Pretreatment view. (Right) Three years after starting deprodone propionate plaster. A 40-year-old woman developed a keloid on her left shoulder as a result of folliculitis. She was treated with deprodone propionate plaster for 24 hours/day. The patient changed the tape every day and continued to use it for 3 years. Six months after starting this therapy, the scar became soft. In the ensuing 3 years, the scar became almost flat.

rates.⁶⁴ Surgery should involve tension-reducing techniques, namely, subcutaneous and deep fascial tensile-reduction sutures,^{31,92,93} Z-plasties,^{111–113} and local-flap transfer.¹¹⁴

Tensile-reduction sutures elevate the wound edges smoothly and relieve dermal tension.^{31,92,93} Our clinical experience¹¹² suggests that they help reduce recurrence rates.

Regarding Z-plasty, case series studies of anterior chest wall keloids¹¹¹ and upper-arm keloids¹¹³ showed that excision, tension-reduction suturing, Z-plasty, and radiotherapy led to respective recurrence rates of 10.6 and 5.3 percent, at 24 months. All recurrences were readily extinguished by steroid plaster and injections. **Figure 6** depicts a Z-plasty–treated chest wall acne keloid.

Flap choice depends on the affected region. A case series study showed that none of 10 huge

anterior chest wall keloids recurred after partial or total resection and flap reconstruction.¹¹⁴ Flaps are superior to skin grafts: the latter do not expand postoperatively and can yield pathologic scars encircling the skin graft. When using flaps, the donor-site must undergo multimodal therapy to prevent new keloids.¹¹⁴ **Figure 7** shows a hatchet flap–treated scapular keloid.

A special region is the ear. Wedge excision is recommended for earlobe keloids.⁵ A case series study^{112,115} of earlobe keloids showed that wedge excision and radiotherapy yielded 4.7 percent recurrence at 18 months. Core excision is recommended for auricular cartilage keloids.⁵ A case series study¹¹⁶ showed that core excision of earlobe and auricular keloids plus steroid injections yielded 9.5 percent recurrence rate at 22 months. Similarly, another case series study¹¹⁷ showed that

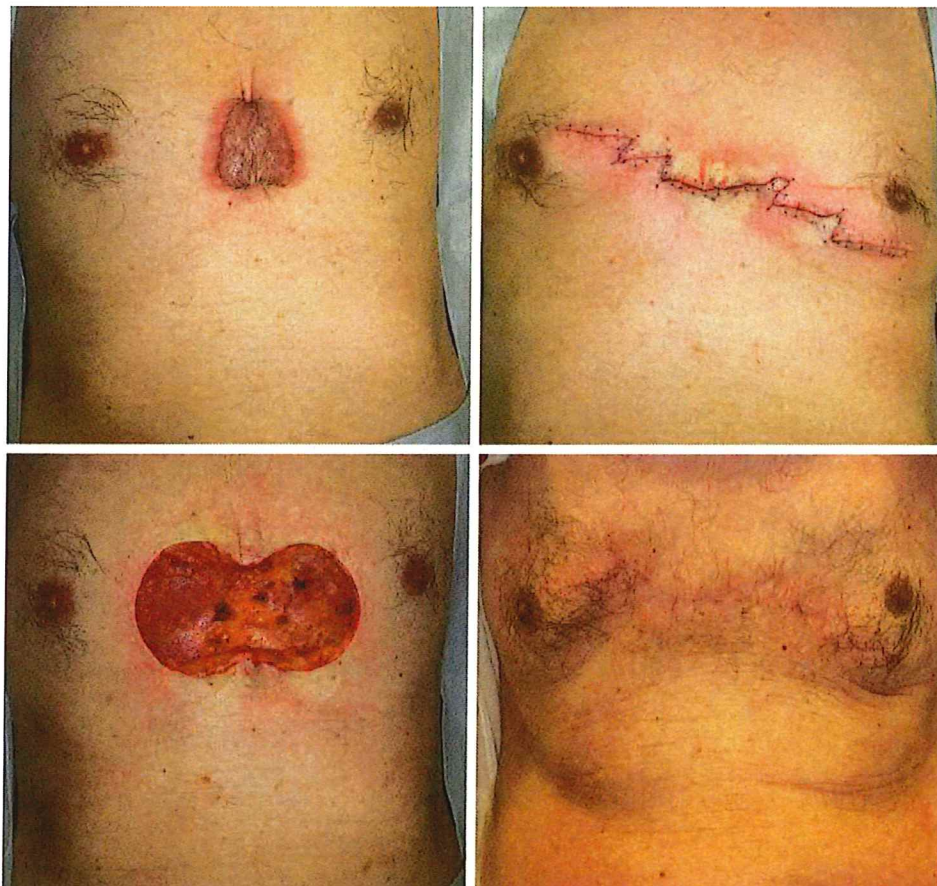


Fig. 6. Treatment of a chest wall acne keloid by using Z-plasty and postoperative radiotherapy. (Above, left) Preoperative view. (Above, right) Immediately after total keloid excision. (Below, left) Immediately after surgery. (Below, right) Two years after surgery. A 60-year-old man developed a chest-wall keloid as a result of acne. It was excised completely and the wound was closed with Z-plasties to release the tension on the scar. The surgery was followed with electron beam radiotherapy (18 Gy, in three fractions, over 3 days). The inflammation dropped uneventfully and the scar became mature over 18 months.



Fig. 7. Treatment of a scapular folliculitis keloid by using a hatchet flap and postoperative radiotherapy. (Above, left) Preoperative view. (Above, right) Immediately after total keloid excision and flap design. (Below, left) Immediately after surgery. (Below, right) Two years after surgery. A 70-year-old man developed scapular keloids. They were excised completely and reconstructed by using a hatchet flap. After surgery, the scar was irradiated (18 Gy, in three fractions, over 3 days). The inflammation fell uneventfully and the scar became mature over 18 months.

total and core excision led to 8.1 and 0 percent recurrence, respectively. [Figure 8](#) depicts a core excision–treated auricular keloid.

Radiation Therapy

Radiotherapy effectively treats or prevents keloids by suppressing angiogenesis and therefore inflammation.¹¹⁸ Radiation monotherapy should be reserved for older patients or those with huge keloids because large radiation doses are needed. It immediately reduces pain and itch and slowly ameliorates scar color and thickness in the next year.³¹

Radiotherapy is particularly effective as a surgery adjunct. Recent meta-analysis of 72 studies¹¹⁹ showed that surgery plus radiotherapy is associated with fewer recurrences (22 percent) than radiation monotherapy (37 percent). Notably, this surgery plus radiotherapy rate is higher than the rate in our center (<10 percent).¹¹² This may reflect the fact that the meta-analysis examined studies published from 1957 to 2014.¹¹² Refinements in surgery, radiotherapy, and postoperative care techniques probably all contribute to our low recurrence rate.

Superficial or orthovoltage x-rays (photons) were once used,^{120,121} but many institutions now

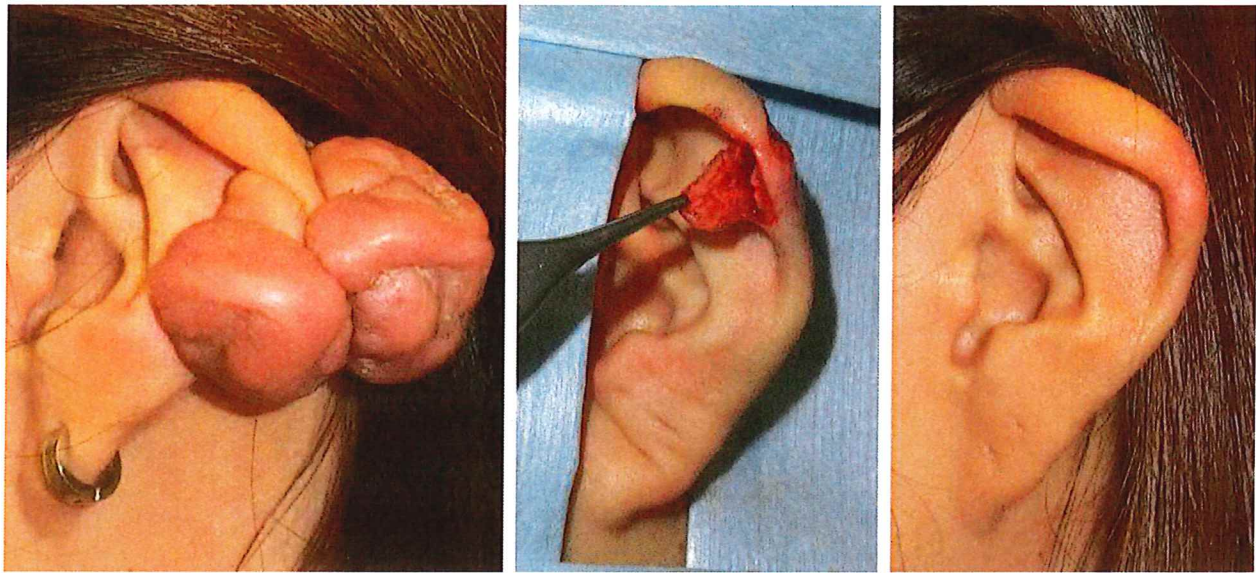


Fig. 8. Treatment of an auricular keloid by using the core excision method and postoperative radiotherapy. (Left) Preoperative view. (Center) The flap made on the keloid after the core was removed. (Right) Two years after surgery. A 20-year-old woman developed auricular keloids. A flap was designed on the anterior side of the keloid and the core was removed. The flap was sutured using 6-0 polypropylene sutures. After surgery, the site was irradiated (15 Gy, in two fractions, over 2 days). The inflammation dropped uneventfully and the scar became mature over 18 months.

prefer electron beam (β -ray) instruments because of fewer internal organ side effects.^{122–124} High-dose-rate brachytherapy (mainly γ -rays) is increasingly used,^{125,126} but its safety for internal organs should be studied further.

The maximal biologically effective dose for keloids is 30 Gy.^{127–129} Doses exceeding this have no gains in efficacy and only increase the secondary carcinogenesis risk. Given that body sites vary in recurrence susceptibility, a 30-Gy biologically effective dose is not always necessary. Our facility exploits this to further decrease the secondary carcinogenesis risk: we apply body site-specific postoperative irradiation for keloids, namely, 18 Gy in three fractions over 3 days (biologically effective dose, approximately 30 Gy) to high-recurrence sites, 8 Gy in one fraction over 1 day to earlobes, and 15 Gy in two fractions over 2 days to other body sites.¹¹²

Over 70 years, there has been a small handful of case reports of malignant carcinogenesis after keloid radiotherapy.^{129–134} Mostly, it is unclear whether these are true secondary carcinogenesis cases. Moreover, a survey¹³⁵ of radiation oncologists worldwide showed that greater than 90 percent considered keloids to be an acceptable radiotherapy indication. Thus, before excluding the possibility of keloid radiotherapy, surgeons should discuss the issue with radiation oncologists.¹²⁹

LONG-TERM POSTTREATMENT FOLLOW-UP OF HYPERTROPHIC SCARS AND KELOIDS

Treated hypertrophic scar and keloid patients should be educated about scar management and followed-up over the long-term. Close follow-up allows early detection and treatment of small recurrences that respond well to steroid tape, plaster, or injection. Thus, patients should be followed up for greater than 18 to 24 months. Follow-up can stop when the scar is flat and soft.

Hypertrophic scar and keloid patients often experience psychological stress that may aggravate their scars. They may benefit from makeup or camouflage therapies^{136–139} because they improve cosmetic appearance and promote beneficial physiologic changes.

CONCLUSIONS

In the past decade, many high-quality studies have been conducted, and the level of evidence for many treatment or prevention regimens has strengthened. As reflected in my reprised review here, these changes have led to pathologic scar management strategies that now effectively and safely prevent, eliminate, or ameliorate these pernicious scars. However, given ethnic differences in pathologic scar propensity, prevention and treatment algorithms should be optimized

for each human race by means of international collaboration.

Rei Ogawa, M.D., Ph.D.

Department of Plastic, Reconstructive,
and Aesthetic Surgery
Nippon Medical School
1-1-5 Sendagi Bunkyo-ku
Tokyo 113-8603, Japan
r.ogawa@nms.ac.jp

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