Preface

Principles of Cancer Reconstructive Surgery is a reference text for medical and surgical oncologists, radiation oncologists, family practice physicians and dermatologists, providing an overview of reconstructive procedures. Interested residents, medical students, and health care professionals will find this an important resource designed to educate those involved with the management of cancer patients.

The disease-specific format facilitates quick reference for focusing on a single body area or disease. The most commonly occurring cancers, breast, melanoma, and head and neck, are covered in an overview chapter and in greater detail individually, with 300 color illustrations in a format that provides excellent detail and clarity.

Charles E. Butler, MD, FACS
Neil A. Fine, MD, FACS

2

The Principles of Cancer Reconstruction

Margo Herron and Michael W. Neumeister

The surgical management of various types of cancer offers some of the most challenging opportunities in reconstruction that plastic surgeons can face. Although obtaining adequate surgical margins should never compromise the gold standards of treatment, care should be taken to preserve functional and specialized tissue whenever possible, keeping the reconstruction plan in mind from the onset of the operation. The principles of cancer reconstruction are rather broad, but can be better understood by dividing them into five key points: evaluation of the defect, the surgical goals, surgical options, the operative procedure, and finally outcome analysis. It is not only the size, location, and properties of the resected tissue that are important, but also the overall health of the patient, the pre-morbid body habitus, and the potential detrimental effects on the donor site that lend information to plastic surgeons, allowing them to formulate a reconstructive option for the patient that offers the best possible outcome *(1)*.

A thorough evaluation of the defect is essential to (1) restore contour, (2) provide stable coverage at the defect, and (3) restore function *(2)*. A series of critical questions need to be answered to help identify which type of closure is best suited for any given resection (Table 2.1). There are various techniques of reconstruction that have application in the management of cancer resection. The smaller the resection defect, the more likely primary closure or local tissue rearrangement can be applied. This is seen routinely following excision of small skin cancers found on the trunk, extremities, or on the head and neck. Wounds closed under tension are prone to dehiscence or widening of the scar *(3)*. Dead space should be obliterated and all necrotic material debrided to avoid complications such as infection, hematoma, seroma, or skin and flap compromise *(4)*. If closure is to be accomplished with vascularized tissue, the various flaps need to be evaluated based on their composition, vascular supply, proximity to the wound, and movement (Table 2.2) *(1)*.

Defining the surgical goals for any given defect seems like a rather intuitive statement. Its importance, however, cannot be overemphasized. Put simply, the goals will define the type of reconstruction necessary to obtain the most appropriate closure. The "reconstructive ladder" includes

Table 2.1. Principles of Cancer Reconstruction

1. **What is missing?**
2. **What function is lost?**
3. **Does the flap need to restore everything that is lost?**
4. **Which flap will provide the best contour?**
5. **Is vascularized bone, tendon, or nerve needed?**
6. **Is sensation in the flap required?**
7. **What amount of tissue is required for the reconstruction?**
8. **What will provide the best result: local, regional, distant, or free flap?**
9. **What type of reconstruction will provide the least donor site morbidity?**
10. **Which flap is more reliable?**
11. **What is the best color match?**
12. **Is a hair-bearing flap required?**
13. **Where are the recipient vessels?**
14. **Are vein grafts or vascular loops required?**
15. **Is radiation a factor either before or after surgery?**
16. **Is a staged procedure required?**

progressively more complex procedures ranging from primary closure to skin grafts, local flaps, regional flaps, distant flaps, and ultimately to free tissue transfer. The optimal closure to restore form and function often dictates using the "reconstructive elevator," moving directly to free tissue transfer (the most complex option) at times *(1,2)*. For example, a through

Table 2.2. Classification of Flaps

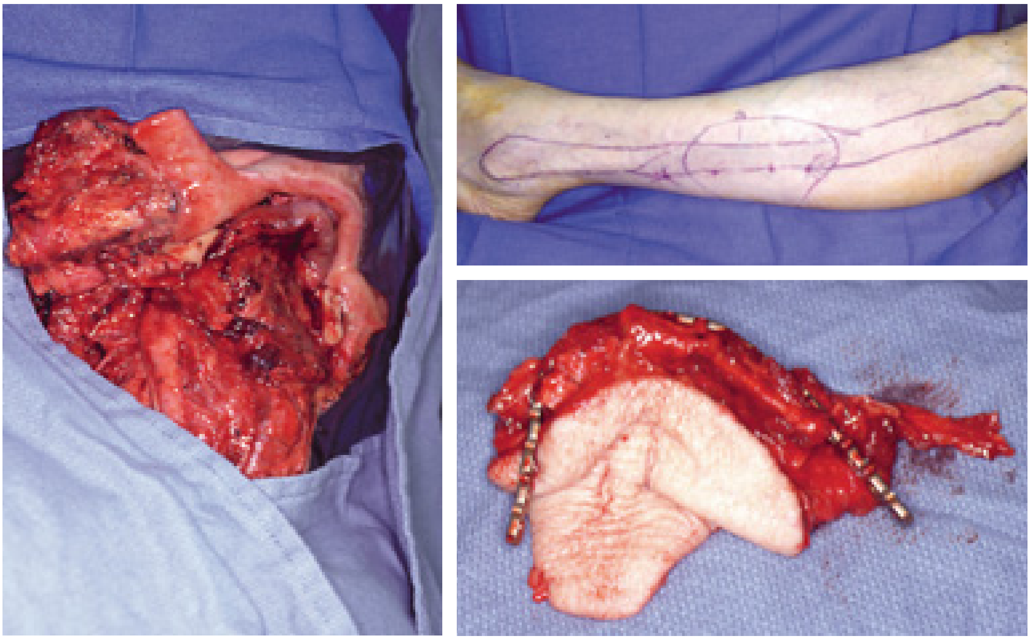
Composition	Proximity to Wound
Fasciocutaneous	Local
Musculocutaneous	Regional
Osseocutaneous	Distant
Fascial	
Muscle	**Movement**
Osseous	Advancement
Bowel	Transposition
Omentum	Rotation
	Interpolation
Vascularity	Neurovascular pedicle
Random pattern	Free flap
Axial	
Antegrade/retrograde	
Island flap	
Free flap	
Perforator	

and through defect of the cheek and oral commissure may be readily closed with a folded, pedicled pectoralis major flap, but would leave a bulky, poorly contoured reconstruction. Alternatively, a free radial forearm harvested with the palmaris longus tendon would permit a better contour with commissure reconstruction. The palmaris longus tendon acts as a sling to support the commissure, preventing oral incontinence (Figure 2.1) *(5)*. Goals, therefore, should include closure, restoration of function, contour and symmetry balance, color match, and reliability. Another aspect of closure involves the concept of restoration of all tissues that have been resected *(1,2)*. It may not be necessary or advisable, in many cases, to reconstruct all of the missing tissues, including muscle, nerves, tendons, bone, or other specialized organs. The reconstruction of these tissues may in fact be detrimental to the patient, as it may only lead to donor site morbidity with scarring and loss

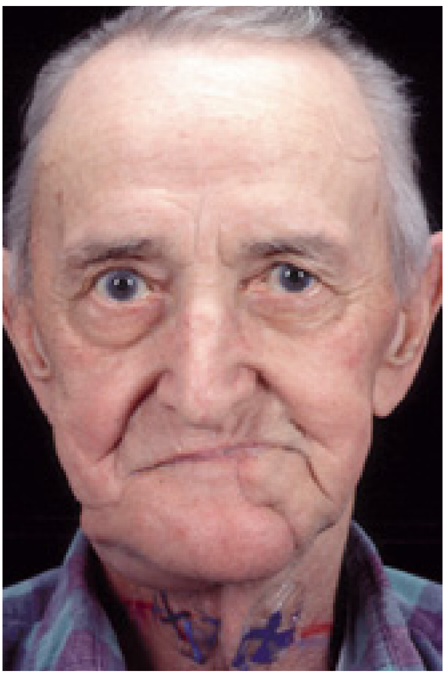
Figure 2.1. (**A**) A defect on the lateral aspect of the commissure requires soft tissue and support. (**B, C**) An appropriate flap that is thin and pliable that can be supported with the palmaris longus tendon is the radial forearm flap.

of function of other body parts. Some cancer resections may only be palliative, and the morbidity of composite reconstruction may not be warranted because by the time function is restored to the operative site, the patient may have succumbed to the disease. For instance, a palliative resection of a mandible and floor of the mouth may warrant a regional flap and reconstruction plate rather than an osteocutaneous flap. The surgical oncologist and the plastic surgeon need to work as a coordinated team with similar goals and sound communication to best treat such patients. If, on the other hand in the previous case, the patient resection deficit warrants a more definitive reconstruction, then further goals need to be defined. Now, the patient requires a vascularized bone flap and intra-oral lining. If dental rehabilitation with osseointegrated implants is planned, a free osteocutaneous flap such as a fibula or iliac crest should be used to allow intra-oral lining and enough bone stock for the implants (Figure 2.2). A radial forearm osteocutaneous flap would not provide enough bone for the osseointegrated implants and would therefore be a less than optimal choice for the reconstruction *(6,7)*. Similarly, a wide resection of a sarcoma in the forearm of an elderly patient would not warrant nerve and tendon graft reconstruction along with soft tissue coverage, as the likelihood of restoration of function is essentially negligible. Expendable tendon transfers and soft tissue coverage would be more appropriate for the aforementioned patient, with less likelihood of the need for secondary procedures. The goals of the treatment are therefore defined at least in part by a number of factors intrinsic to the nature of the cancer, to the resultant defect, and to the entirety of the patient.

The evaluation of the resection defect therefore requires a logical, comprehensive approach to provide optimal results and patient satisfaction. Many times, the reconstructive efforts necessitate three-dimensional planning. The donor tissue is shaped and contoured to the defect in all planes. In head and neck cancer reconstruction, for instance, it is not uncommon for the resection to include a portion of the maxilla, the palate, the maxillary sinus, and part of the nose. The reconstructive option, then, may include a flap that requires three distinct skin paddles to provide lining for the nose, the palate, and the overlying skin (Figure 2.3) *(8)*. Other defects, on the other hand, may not need multiple skin paddles. A myocutaneous flap, used in a similar fashion, may suffice where the skin paddle is used for external skin closure and the intra-oral exposed muscle is allowed to (mucosalize re-epithelize with oral mucosa) over time. The choice of flap depends on certain characteristics and requirements of the defect and the patient, as well as the surgeon's preference. Patient factors such as available donor sites, body habitus, history of tobacco use, previous surgeries, co-morbid medical conditions, and the nature of the recipient site influence the type of flap to be used in any given situation. The surgeon's experience with certain flaps, as well as their preference, will also play a role in the type of reconstruction performed. Many times, patients may have had previous surgeries that may interfere with certain donor sites. A previous thoracotomy may prevent



A B C



D

Figure 2.2. (**A**) A defect of the mandible and the floor of the mouth. The mandibular defect was from the left parasymphseal to the right body of the mandible. (**B, C**) A fibular osteocutaneous flap is designed in contoured through osteotomies to fit the mandible defect. The skin paddle provides coverage of the floor of the mouth. (**D**) Final result providing good contour of the mandible.

the use of the latissimus dorsi (LD) flap because the incision has disrupted the thoracodorsal vessels, as well as the muscle itself *(9)*. Other scars on the recipient sites may render these flaps unreliable, and therefore an alternative flap must be chosen. The patient's body habitus also plays an important role. In extremely obese patients, certain myocutaneous and fasciocutaneous flaps may be too bulky and non-maleable. Such flaps, not only result in significant donor site contour defecits, but also the compromise the contour of the recipient site. Conversely, extremely thin patients may not have enough tissue for fasciocutaneous flaps to appropriately fill certain contour defects.

After some cancer resections, the resultant bed is well vascularized and would accept a split-thickness skin graft or a full-thickness skin graft. The decision to use such grafts is dependent on the judgment of the surgeon relative to the goals of reconstruction. For instance,

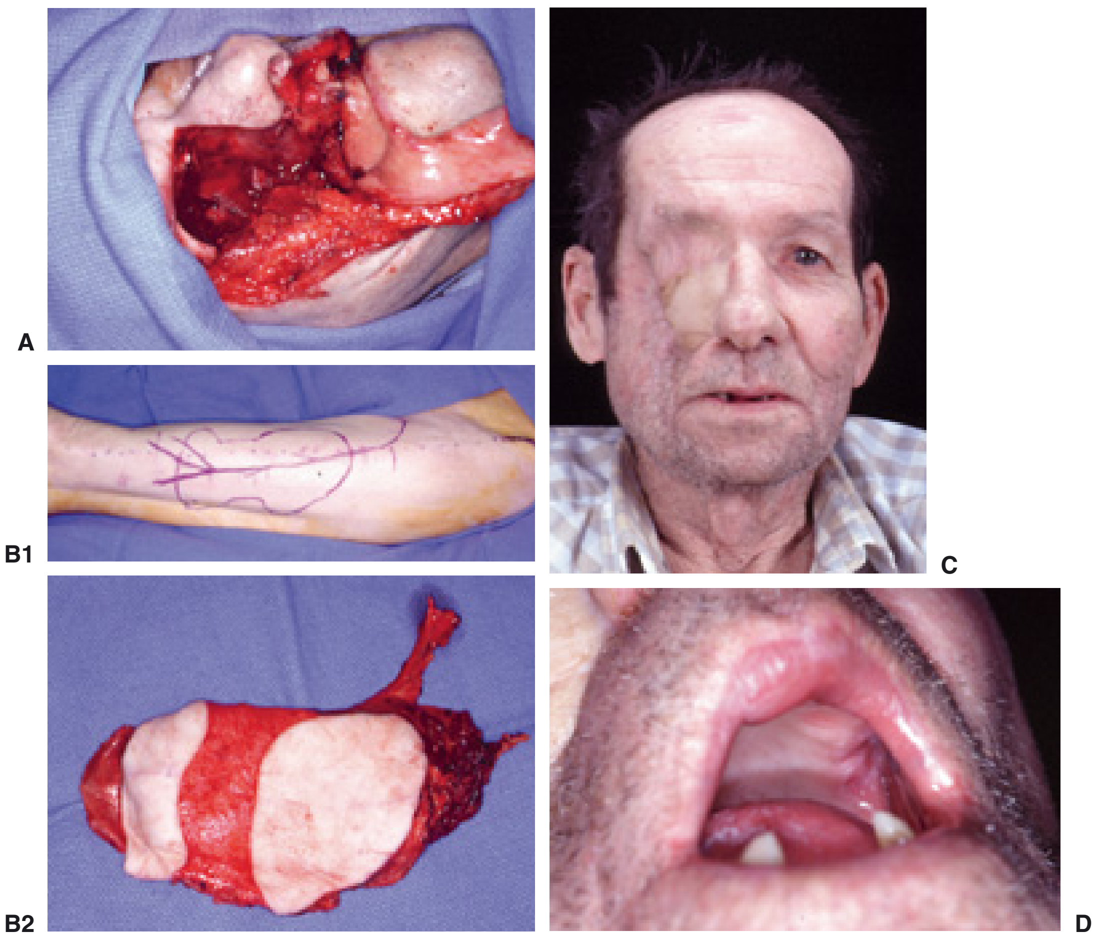


Figure 2.3. (**A**) A complex defect of the face involving the orbit, nose, palate and external skin. (**B1, B2**) Intralateral thigh flap is utilized to provide adequate coverage. The skin paddles are designed to support the palate, nose and external lining. (**C, D**) Final result with obliteration of the defect and adequate coverage of the skin and palate.

split-thickness skin grafts over exposed muscle in the forearm following cancer resection are acceptable because function is not compromised, and the residual contour is minimal. A split-thickness skin graft on the lower eyelid, however, may result in a cicatricial ectropion and contour deformities *(10–12)*. Improved functional and aesthetic results for these defects are often achieved with local flaps from adjacent tissues. Such flaps would include V-Y, transposition, rhomboid, rotation, or advancement flaps *(13)*. Regional flaps, such as the forehead flap, are extremely valuable staged reconstructions of nasal defects because of the relative abundance of forehead tissue and because of the similar color and texture of these two anatomical structures (Figure 2.4) *(14)*. Almost all skin above the clavicle has similar color and is generally darker than skin from other areas in the body. Reconstruction of defects above the clavicle offers a better final appearance if the donor site can be harvested within this region as well. Even full-thickness skin grafts taken from the supraclavicular, pre-auricular, or post-auricular areas will blend in to greater extent when applied to facial defects compared to full-thickness

A,B C D E

Figure 2.4. (**A, B**) Nasal defect with exposed cartilage. (**C**) A forehead flap is designed on the right supratrochlear vessels. (**D**) The flap is transposed to cover the defect while the donor site is closed primarily. (**E**) Final result after division and inset and maturation of the flap on the nose.

Figure 2.5. (**A, B, C**) A long standing defect of the forehead with exposed mesh draining sinus from a previous orbital exoneration is noted. (**D**) A chimeric flap involving the latissimus and scapular flap has been elevated on one pedicle. (**E**) The mesh is removed, the muscle portion of the flap is used to provide vascularized coverage underneath the forehead skin while the scapular flap provides adequate obliteration of the orbit.

graft harvested from other donor sites. Split-thickness skin grafts have the advantage of more reliable engraftment and ample donor sites. Full-thickness skin grafts, on the other hand, offer of the advantage of limited secondary contraction and the potential for partial sensory re-innervation. Unfortunately, both full- and split-thickness grafts may result in pigmentation changes, unpredictable contraction, or loss of the graft secondary to infection, hematoma, seroma, or shearing *(10–12)*. To prevent secondary joint contracture in the extremities, reconstruction of resection defects over flexion creases are better served with a flap from local, regional, or distant areas.

Despite a variety of donor sites now available in the armamentarium for reconstruction, plastic surgeons should capitalize on the inherent characteristics of each site. For instance, the scapular flap provides an abundant skin paddle that is easily pliable and able to conform to the three-dimensional defects. This flap can also be harvested as an osteocutaneous flap or as a chimeric flap incorporating the serratus anterior muscle and/or the LD muscle on a single pedicle (Figure 2.5) *(15–16)*.

The vascular pedicle itself is rather long and the vessel diameters are relatively large. Although these characteristics make the scapular flap rather appealing, the donor site often lends itself to inconvenient positioning of the patient, a prominent scar on the back, a high incidence of seroma formation, and a limit on the width and length of the flap *(17)*. The anterolateral thigh flap, on the other hand, can provide an enormous skin paddle incorporating muscle and/or fascia, and has a very long pedicle with large caliber vessels (Figure 2.6). The flap does not typically have an osseous component, however. The lateral leg can be closed primarily if a small flap is harvested. Larger flaps can leave a significant donor defect where a split-thickness skin graft is necessary for closure. The contour of the defect is matched to donor site characteristics to minimize secondary procedures yet maximize the goals of the reconstruction (Figure 2.7) *(18)*. The reconstructive surgeon, then, must weigh the pros and cons of each donor site and match them to the recipient site's specific requirements.

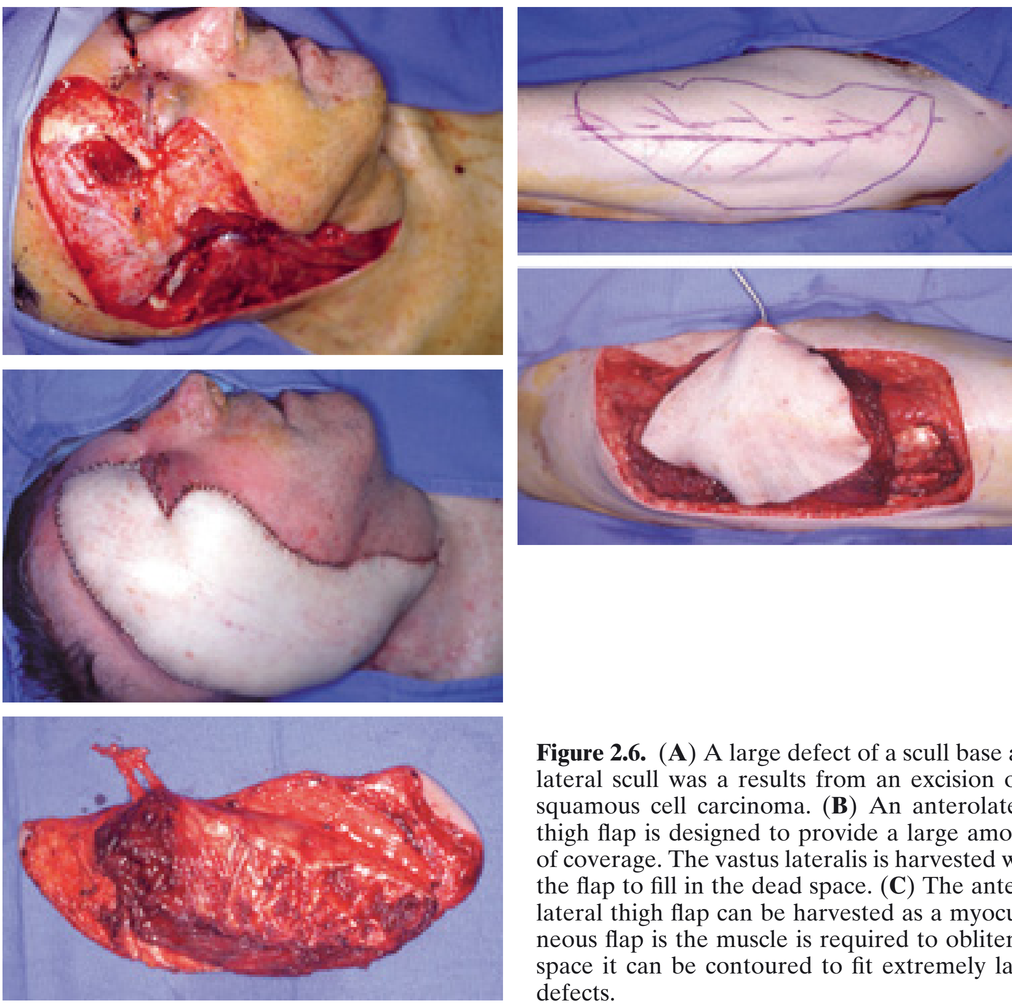


Figure 2.6. (**A**) A large defect of a scull base and lateral scull was a results from an excision of a squamous cell carcinoma. (**B**) An anterolateral thigh flap is designed to provide a large amount of coverage. The vastus lateralis is harvested with the flap to fill in the dead space. (**C**) The anterolateral thigh flap can be harvested as a myocutaneous flap is the muscle is required to obliterate space it can be contoured to fit extremely large defects.

A B C D,E F,G

Figure 2.7. (**A**) A malignant melanoma over the superficial parotid requires wide excision and superficial parotidectomy. (**B**) A large defect with exposed facial nerve and contour irregularity is a result of the cancer resection. (**C**) A lateral arm flap which would provide appropriate bulk is fashioned based on the posterior radial collateral artery. (**D, E**) The flap is inset on the face following anastomosis in the neck. Good contour is noted. (**F**) Lateral view illustrating the contour of a well designed flap in sensitive areas. (**G**) The donor site is acceptable.

Two specific detrimental extrinsic factors, patient's tobacco use and pre- or post-operative radiation therapy, have significant ramifications on the choice of reconstruction, as well as the ultimate outcome following reconstruction. There are many detrimental effects of smoking on the vascularity and viability of tissue (Table 2.3). Patients who use tobacco are not only at risk for the development of the cancer requiring reconstruction, but also for partial flap loss owing to necrosis. Wound healing complications at the donor site as well as the recipient site are much more prevalent in smokers than non-smokers *(3–4,19–20)*. Similarly, radiation has an extremely profound influence on the ability of tissues to heal following surgery. Radiation ultimately results in endarterits obliterans, relative ischemia, and tissue fibrosis (Table 2.4) *(3–4,21)*. As a general principle, the chronic skin changes that result from the radiation should alert the surgeon to excise this tissue and replace it with new

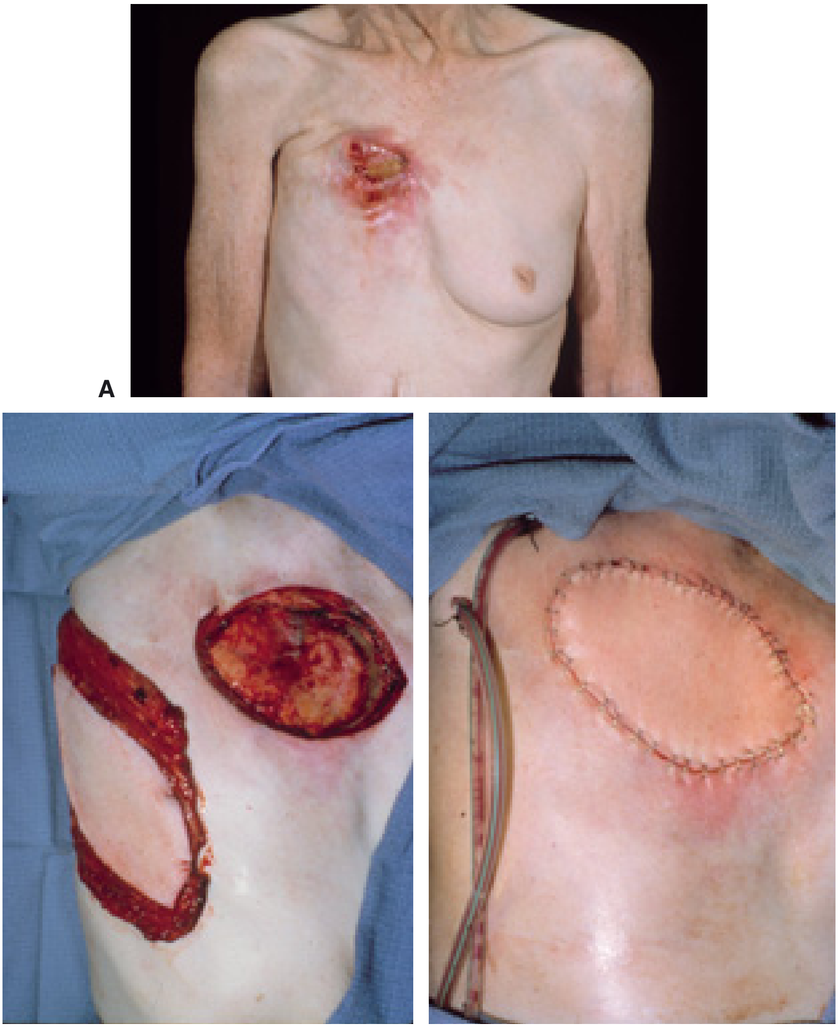
Table 2.3. Effects of Smoking on Flaps ***(19–20)***

Vasoconstriction
Increased platelet adhesions
Decreased proliferation of red blood cells, fibroblasts, and macrophages
Decreased oxygen transport and metabolism
Increased nicotine, hydrogen cyanides, and carbon monoxide levels
Fat necrosis
Delayed wound healing
Wound infections
Poor scaring
Wound dehiscence
Flap necrosis
Skin sloughing

vascularized tissue either as a pedicled flap or a free flap (Figure 2.8). Skin grafts in these areas are not as reliable because they necessitate procuring a blood supply from the recipient bed; a bed that is already compromised. The skin graft is prone to poor engraftment and subsequent break down, leading to prolonged wound healing complications. *(3–4,22)*. Post-operative radiation also has detrimental effects on the flap reconstruction. Radiation results in fibrosis and shrinkage of the flap, leading to a negative impact on the contour, position, and function of the flap. With the effects of post-operative radiation in mind, the surgeon has a few choices. If possible in this circumstance, the flap reconstruction should be delayed. This is exemplified in breast reconstruction, where reconstructive surgery following mastectomy should be delayed until after the radiation treatments have finished. This decreases radiation's potential compromising effects on the final aesthetic outcome *(23–25)*.

Table 2.4. Early/Late Effects of Radiation ***(21–25)***

Early	Late
nuclear chronatin dumping	endarteritis obliterans
nuclear swelling	tissue fibrosis
mitochondrial and endoplasmic reticular degeneration	tissue ischemia
cellular necrosis	hyperpigmentation
mitotic inhibition	flap contracture
generation of free radicals	fat necrosis
erythema	
skin desquamation	
ulceration	
hemorrhage	
necrosis	
infection	
dehiscence	



A

B

C

Figure 2.8. (**A**) Radiation osteonecrosis on a non-healing ulcer following a mastectomy and radiation therapy for breast cancer. (**B**) A latissimus dorsi myocutaneous flap is elevated following resection of the damaged irradiated tissue on the chest wall. (**C**) The latissimus flap is inset providing good stable vascularized coverage to the defect. The flap was harvested as a pedicle.

There are times when cancer reconstruction does not require the transfer of other tissue. Tissue expansion of local or adjacent tissues may meet the needs of adequate soft tissue coverage in certain circumstances. Nowhere is this more evident than in breast reconstruction, where tissue expansion beneath the pectoralis major muscle can provide an adequate pocket suitable for implants to restore breast form and contour (Figure 2.9) *(26)*. Secondary tissue expansion can be used to correct contour deformities, areas of scarring, alopecia, contractures, and unstable skin graft sites following the primary reconstruction *(27–28)*. The principles of tissue expansion have been well described, but it is usually performed as a secondary procedure rather than as the primary tumor resection and reconstruction procedure.

Figure 2.9. Implant reconstruction following a mastectomy. The implant is placed underneath the pectoralis major muscle to provide stable coverage for the implant.

The surgical resection of cancer can have a number of physical and psychological ramifications for patients. The reconstructive surgeon has the responsibility to coordinate the care of the patient to optimize the definitive contour and functional restoration. An accurate evaluation of the patient's medical history, the patient's expectations and goals, the resection defect, and the functional reconstruction goals are all very important components involved in the principles of cancer reconstruction.

References

1. Mathes S, Hansen S. Flap classification and application. In: Mathes S, Hentz V, eds. *Mathes plastic surgery*. Philadelphia: Saunders; 2006:365–378.
2. Mathes S, Nahai F. Flap selection: analysis of function, modifications, applications. *Reconstructive surgery: principles, anatomy and technique.* New York: Churchill Livingstone; 1997:37–160.
3. Broughton G, Janis J, Attinger C. Wound healing: an overview. Plas Reconstr Surg 2006;117:1e-S–32e-S.
4. Attinger C, Janis J, Steinberg J, et al. Clinical approach to wounds: debridgement and wound bed preparation including the use of dressings and wound-healing adjuvants. Plas Reconstr Surg 2006;117:72S–109S.
5. Furuta S, Sakaguchi Y, Iwasawa M, et al. Reconstruction of the lips. Oral commisure, and full-thickness cheek with a composite radial forearm palmaris longus free flap. Ann Plas Surg 1994;33:544–547.
6. Urken ML, Buckbinder D, Costantino PD. Oromandibular reconstruction using microvascular composite flaps: report of 210 cases. Arch Otolaryngol Head Neck Surg 1998;124:46–55.
7. Cordeiro P, Disa J, Hidalgo D, et al. Reconstruction of the mandible with osseous free flaps: a 10-year experience with 150 consecutive patients. Plas Reconstr Surg 1999;104:1314–1320.
8. Sakuraba M, Kimata Y, Ota Y, et al. Simple maxillary reconstruction using free tissue transfer and prostheses. Plas Reconstr Surg 2003;111:594–598.
9. Quillen CG. Latissimus dorsi myocutaneous flaps in head and neck reconstruction. Plast Reconstr Surg 1979;63:664–670.
10. Ratner D. Skin grafting from here to there. Dermatol Clin 1998;16(1):75–90.

11. Fifer R, Pieper D, Hawtorf D. Contraction rates of meshed, nonexpanded split-thickness skin grafts versus split-thickness sheet grafts. Ann Plast Surg 1993;31:162.
12. Paletta C, Pokorny J, Rumbolo P. Skin grafts. In: Mathes S, Hentz V, eds. *Mathes plastic surgery.* Philadelphia: Saunders; 2006:293–316.
13. Place M, Herber S, Hardesty R. Basic techniques and principles in plastic surgery. In: Aston S, Beasley R, Thorne C, eds. *Grabb and Smith's plastic surgery, fifth edition.* Philadelphia: Lippincott-Raven; 1997:20–25.
14. Mazzola RF, Marcus S. History of total nasal reconstruction with particular emphasis on the folded forehead flap technique. Plast Reconstr Surg 1983;72:408–414.
15. Yamamoto Y, Nohira K, Minakawa H, et al. The combined flap based on a single vascular source: a clinical experience with 32 cases. Plast Reconstr Surg 1996;97:1385–1390.
16. Aviv J, Urken M, Vickery C, et al. The combined latissimus dorsi-scapular free flap in head and neck reconstruction. Arch Otolaryngol Head Neck Surg 1991;117:1242–1250.
17. Bidros R, Metzinger S, Guerra A. The thoracodorsal artery perforator-scapular osteocutaneous (TDAP-SOC) flap for reconstruction of palatal and maxillary defects. Ann Plast Surg 2005;54:59–65.
18. Kimata Y, Uchiyama K, Satoshi E, et al. Anteriorlateral thigh flap donor-site complications and morbidity. Plast Reconstr Surg 2000;106:584–589.
19. Krueger JK, Rohrich RJ. Clearing the smoke: the scientific rationale for tobacco abstention with plastic surgery. Plast Reconstr Surg 2001;108:1063–1073.
20. Selber J, Kurichi J, Vega S, et al. Risk factors and complications in free tram flap breast reconstruction. Ann Plast Surg 2006;56:492–497.
21. Lopez E, Guerrero R, Nunez M, et al. Early and late skin reactions to radiotherapy for breast cancer and their correlation with radiation-induced DNA damage in lymphocytes. Breast Cancer Res 2005;7:R690–R698.
22. Tadjalli H, Evans G, Gurlek A, et al. Skin graft survival after external beam irradiation. Plast Reconstr Surg 1999;103:1902–1908.
23. Bristol S, Lennox P, Clugston P. A comparison of ipsilateral pedicled TRAM flap with and without previous irradiation. Ann Plast Surg 2006;56:589–592.
24. Rogers NE, Allen RJ. Radiation effects on breast reconstruction with the deep inferior epigastric perforator flap. Plast Reconstr Surg 2002;109:1919–1924.
25. Kroll SS, Robb GL, Reece GP, et al. Does prior irradiation increase the risk of total or partial free-flap loss? J Reconstr Microsurg 1998;14:263–268.
26. Cordeiro P, McCarthy C. A single surgeon's 12-year experience with tissue expander/implant breast reconstruction: Part I. A prospective analysis of early complications. Plast Reconstr Surg 2006;118:825–831.
27. Spence R. Experience with novel uses of tissue expanders in burn reconstruction of the face and neck. Ann Plast Surg 1992;28:453–464.
28. LoGiudice J, Gosain A. Pediatric tissue expansion: indications and complications. Plast Surg Nurs 2004;24:20–26.
29. Lamberty B, Cormack G. Fasciacutaneous system. *The arterial anatomy of skin flaps.* New York: Churchill Livingstone; 1994:119–129.