McCraw and Arnold's Atlas of Muscle and Musculocutaneous Flaps

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BASIC PRINCIPLES OF MUSCLE FLAP SURGERY

This "back to the basics" chapter may be of little help to the active practitioner of muscle flap surgery, but even the most experienced of us has faced the disappointed patient or the problem caused by our own faulty logic. Nine years of Flap Dissection Workshops has instructed the faculty as much as the participants. Each year, more time has progressively been devoted to discussions of basic principles and complications. The presentation by Luis Vasconez on Complications is the perennial favorite. Luis calls his talk "That's Not Plastic Surgery," and his first sentence is always: "I didn't borrow these cases." He follows with the *Four Laws of Vasconez* pertaining to flap survival:

1. Some do, some don't.
2. All of the flap survived, except for the part needed to cover the defect.
3. If plan A is a complete failure, do not make plan B exactly the same as plan A.
4. It always happens to me.

If an expert in muscle flap surgery can do this so self-effacingly, so must we all. Let's consider several important factors, beginning with the central figure — the patient.

PATIENT EDUCATION

The questions: "Did you have to use plastic surgery?" or "Did you have to use plastic?" occur all too often and reflect a lack of understanding of the fundamental role of the reconstructive surgeon. Once instructed that the basis for the specialty is tissue transfer, it is easier for the patient to understand our place in his care. First we must clarify our role as a consultant in wound healing, tissue transfer, form and function. It is still the perception of many patients that the reconstructive surgeon is simply one who is technically meticulous and who deals in surgery that relates as much to appearance as to function. It is also not unusual for the patient to be surprised to learn that his trusted internist or personal surgeon is not as thoroughly versed as the reconstruction surgeon in the complicated problems of wound healing and wound repair.

The intended goals of a reconstructive surgical procedure are better accepted if the patient understands the *reasons for considering various options*, e.g. a flap, a skin graft or secondary healing. For instance, a painful skin graft becomes more palatable once the patient recognizes that it will shorten the time of healing and provide a more durable surface than an epithelialized scar. When a flap is needed, the reasons for choosing from among muscle, musculocutaneous and cutaneous flaps should also be carefully delineated. The donor site deformity, the expected quality of the reconstruction, as well as the overall morbidity all need to be thoroughly understood by the patient. When the "built-in" risk of failure is high, e.g. the recurrence of a long-standing osteomyelitis or the potential loss of an extremity with the failed coverage of a vascular prosthesis, the patient must recognize and accept these risks in advance of any surgical efforts.

Patients should understand that *no restorative surgery can return them to complete normality* and that imperfections of contour or function may require later revisions. On the other hand, the patient must recognize that the current methods of reconstruction offer reasonable solutions to some difficult problems and that these methods escaped our comprehension and exceeded our surgical capabilities a mere ten years past. The present methods of breast reconstruction offer a good example of the vastly improved quality of our reconstructive capabilities. Even so, the surgeon should help the patient understand that these imperfect reconstructions must be contrasted with the mastectomy deformity or with older types of reconstructions, rather than with the normal breast. The distinct benefits of our current surgical methods can easily outweigh the inherent imperfections, the attendant morbidity, the expected risks; and the reconstructive burden can be diminished for both the patient and the surgeon. As a final note on communication with patients, we must all remember our personal dread of surgery upon ourselves. Imagining the "great surgeon" in their place is a real source of empathy for patients undergoing these major procedures. We must be sure that this empathy transcends that trite quip: "Of course every operation is a major operation, if you're having it." We can do better than that.

PATIENT SELECTION

The most significant factor in patient selection is an understanding by the surgeon of the *patient's perceptions of the anticipated surgery*, after the patient has been thoroughly informed and apprised of the various options. This transfer of information is difficult because

it requires us to blend a technical education with a humanistic approach. What is legally called "informed consent" is practically impossible to obtain literally because patients remember very little of what they have been told and also because they optimistically place themselves in the uncomplicated, "good result" category of patients. It is very clear that the patient should not be considered as a candidate for any surgery, regardless of the legal niceties, unless he is able to "intelligently concur" with the known risks, benefits, and alternatives. He must also accept the expected length of hospital stay, the need for prolonged follow-up, and the reasonable possibility of unusual complications and secondary revisions.

Medicine has now evolved from a system of condescending physician "paternalism" to one of active patient "consumerism" in an effort to restore some personal control for the patient. In today's litigious environment surgeons are reluctant to persuade and even more loathe to coerce the decision of any patient. We presume that the patient, after receiving a monochromatic factual litany of the various options, is fully capable of making an intelligent choice between profoundly different procedures without the benefit of any prior knowledge or surgical experience. This is patently unfair to the patient because it deprives him of any basis for a reasonable judgment. We also presume that, once the choice is made by the patient, we are absolved of any responsibility as to the appropriateness of the choice. Hence, when things go awry, it has to be the patient's fault. Nothing could be more reminiscent of the Cultural Revolution in China. We don't need peasants acting as surgeons, no matter what the legal or governmental stresses might dictate. We need actively to direct patients away from any and all bad choices which are influenced by the rush of the moment, expediency, or by their inexperience in making complex reconstructive surgical decisions. Likewise, patients may refuse what is considered to be the appropriate treatment for any number of psychological reasons. For example, the paraplegic's refusal of a total thigh flap, when that is the only possible option, is a way of reasserting control over his condition of dependency. Such open recalcitrance can also be a manifestation of secondary depression which arises from a feeling of helplessness and hopelessness. Similarly, the patient who insists on an immediate breast reconstruction, so that she'll have "two normal breasts" when she awakes from the anesthetic, is overtly denying the existence of either the breast cancer or the mastectomy. This patient will have no way of knowing that her goal is unrealistic unless her choices are carefully guided. The surgeon who participates in this denial "play acting" and allows himself to be manipulated away from the reality of the situation only reinforces these feelings. The surgeon thereby sets himself up to produce an impossible goal in trying to fulfill the patient's inflated expectations. When he does not achieve the anticipated goal, he is perceived as either deceitful or incompetent, to the eventual detriment of the patient-doctor relationship.

Patients frequently become angry about their disease, because of bitterness about their fate, guilt that they somehow caused the disease or fear for the well-being of loved ones in the case of their absence. This anger is easily "displaced" toward the physician, who may be blamed for the entire chain of events. The doctor must recognize and resolve this anger prior to any reconstruction intervention or it will evolve into patient dissatisfaction and even more anger — the common denominator of malpractice claims. Two recent lawsuits can be cited to illustrate the full spectrum of this "displaced" anger toward the reconstructive surgeon.

Case #1

A thirty-two-year-old nurse consulted her general surgeon for a very large neglected adenocarcinoma of the breast. The tumor was intentionally neglected by the patient because she was afraid that a biopsy would be malignant and would result in the loss of her breast. The general surgeon recommended a massive resection of breast skin in order to obtain an adequate extirpation as well as a soft tissue reconstruction with a latissimus dorsi myocutaneous flap rather than a skin graft. The operation was a technical success, but the patient failed psychologically. She sued both surgeons because of her anger about the disease, the deforming operation, and the general surgeon's fee. Even though she remained friendly with the plastic surgeon, *he was sued because his ability to correct a massive defect with a flap caused the general surgeon to perform a larger and more deforming mastectomy* than he would have performed in the absence of a plastic surgeon. Faulty logic, yes, but reasonable enough to the plaintiff lawyer who was in search of "deep pockets." The uninsured general surgeon precipitated the legal action because of his abrasive, uncaring personality and his relentless pursuit of his surgical fee. Since the general surgeon was "bare" and had no tangible assets, he was released from the suit. After days of tiring courtroom proceedings and seemingly unfair press coverage, the suit was decided in favor of the defendant plastic surgeon. Was this suit avoidable? Definitely. The young plastic surgeon was pleased with the fine surgical result, and his patient appeared to be happy and appreciative. What went wrong? The plastic surgeon thought of himself as only a consultant in the case, presuming that the patient was well prepared for both the extirpative and reconstructive operations, and that the judgment of the general surgeon

was correct. During the trial, evidence was introduced to the effect that the extensive mastectomy was not indicated, that a large flap was no better than a skin graft and that the additive reconstructive procedure unnecessarily scarred the back. Naturally, these opinions were refuted by the defense. The general surgeon was portrayed as incompetent, negligent, abrasive, greedy and slothful. The naive young plastic surgeon was painted with the same brush of vicarious liability. Instead of recognizing the patient's preexisting anger and ill-preparation, the plastic surgeon participated in the case as a "flap technician" rather than as a physician. In his eyes, she was the general surgeon's patient, and he was just "helping out." He paid for this judgmental error dearly even though the case was "won." In fact, both sides lost.

Case #2

A sixty-eight-year-old florist was healthy and working until the day he was admitted to the hospital for a femoral artery thrombectomy. Four months later he was still in the hospital, having undergone numerous unsuccessful vascular reconstructive procedures by highly competent vascular surgeons. The foot was adequately revascularized by a femoral-popliteal and a popliteal-posterior tibial Gortex® graft. The Gortex® graft became exposed in the mid-calf, and the skin on the dorsum of the foot was lost because of an occluded anterior tibial artery. The exposed Gortex® graft in the calf was successfully covered with a soleus muscle flap. Multiple attempts to skin graft the dorsum of the foot were unsuccessful, and since no local or distant flaps were reasonable considerations, it became necessary to amputate the foot. *The plastic surgeon was sued for the loss of the foot.* The patient was embittered by the prolonged hospitalization and the loss of his foot, but he couldn't bring himself to be angry with his good friend, the vascular surgeon. He then directed his anger toward the plastic surgeon. His deteriorating psychological condition was compounded by the fact that he had lost his floral business and that the hospital expenses had drained him of his life savings. The plastic surgeon ignored the psychodynamics of the existing situation and didn't emphasize the gravity and complexity of his proposed reconstructive salvage attempts. It was shown in court, to the satisfaction of the jury, that the reconstructive surgeon was responsible for saving the leg, not for losing the foot. How much easier it would have been to have settled these matters prior to the successful muscle flap operation in the calf. The plaintiff left the courtroom still feeling angry and injured, and further in debt. The plastic surgeon left feeling innocent and falsely accused — a victim of the "unfair" legal system. The plastic surgeon also was left with a permanent legal blemish on a previously untarnished record — a fact which could subsequently hurt his ability to maintain his hospital credentials.

Declining or deferring participation in the care of a patient is something which is difficult for any surgeon because we view ourselves as simply trying to "help" the patient. The surgeon should strongly consider not undertaking any surgical reconstruction when the negative factors of psychological instability, unrealistic goals, disagreement with treatment modalities, or expected future non-compliance with instructions are suspected. In this situation, it is fair to explain to the patient that you are not capable of achieving a result which is acceptable to yourself and expected by him. Once this important caveat is established, the discussion should be rationally and amicably ended. Another simple and helpful method of pre-operative evaluation is an analysis of the rapport which is established at three minutes and maintained at thirty minutes after initiation of the patient interview. If one is comfortable with the patient quickly, and if this mutual understanding remains established at thirty minutes, one can rely on this as an extremely valuable prognosticator of future understanding and cooperation. If any of these non-surgical details is left unresolved before surgery, it will be hard for the patient to accept the traumatic experience involved with some of these difficult reconstruction endeavors.

WOUND PREPARATION

Although muscle flaps are known to facilitate the decontamination of minimally infected wounds, their capabilities are certainly limited and must be assisted by appropriate *wound preparation*. Quantitative wound cultures are frequently used to monitor problem wounds because they are both accurate and quantitative. A reasonable effort should be made to obtain a pre-operative quantitative bacteriological count of less than 10^5 bacteria per gram of tissue, but the test can be over-used and should not replace clinical judgment. Burn wounds may provide the exception to this rule, but as experience provides improved clinical judgment, quantitative cultures tend to be employed in an inverse proportion to the worth of this clinical judgment. One experienced surgeon has said: "The main time that I get quantitative cultures is when I forget to tell the resident not to get them." Quantitative cultures have little or no place in frank osteomyelitis or in infected ulcers because a satisfactory culture cannot be obtained without a vigorous operative debridement. Furthermore, the test results can be spurious as a result of a poorly selected biopsy site.

The *type of topical care* is less important than the interest of the doctors and nurses in preparing the wound.

Professor Robert Chase once said: "The best way to get a wound to granulate is to get a third year medical student interested in it" — succinct, but sage advice. Wet-to-dry dressings are the most commonly used form of dressing, but they are difficult to properly perform. The modern nurse is no longer well versed in this type of wound care unless he or she has had a special experience or a particular interest in wound care. The wet-to-dry dressing frequently fails because it is allowed to completely dry out. When this happens, the dressing serves little more purpose than a simple dry dressing. Iodoform gauze packing is an even more pernicious form of dressing. The chemical agent effectively "pickles" or "fixes" the margins of the wound so that capillary ingrowth and secondary healing are thwarted. Only its medicinal smell belies its usefulness.

Enzymes have been used for many years, but they are not necessarily any more effective than diligent saline dressings. Most of the enzyme preparations have been singularly disappointing, with the exception of Travase.® Travase® can be helpful in removing the final adherent slough if it is less than one mm in thickness. The ointment must be applied in a very thick coat and covered with a moist dressing which is neither totally wet nor allowed to dry. In every case it is imperative to change the dressing frequently. If this agent has not had a significant effect in three to four days, it probably will not contribute much more with time. Debrisan® is another agent which can be helpful in reducing the bacterial count in weeping wounds, but it is not helpful in the usual dry venous or arterial ulcer. It is simple to use, but it can trap surface bacteria if it is not completely removed at each dressing change. The *Waterpik®* is the best method to remove this material, and it usually does not cause any significant discomfort. One wonders whether the debridement accomplished by the Waterpik® itself is not the more significant agent in allowing the humoral defenses to gain the upper hand over the existing surface bacteria. *Systemic antibiotics* have not been particularly helpful unless the wounds are frankly infected. Even then, antibiotics may not achieve a sufficient tissue concentration at the wound surface. Osteomyelitis is more appropriately treated by operative debridement since it is never cured by antibiotics alone. Short term administration of systemic antibiotics is probably completely superfluous in the surgical process of eradicating osteomyelitis, but long term I.V. antibiotics have been helpful in conjunction with surgical debridement and closure.

Deep wounds are more difficult to deal with because they are not amenable to the usual topical agents. Whenever they can be used, in-and-out irrigation systems have offered some impressive results. Diluted Betadine® is commonly used in lieu of saline, but it is difficult to tell whether or not it is any more effective than saline. Even diluted Betadine® instillation may cause harm by "drying out" the wound. Saline flushing of the wound surface certainly seems to be just as effective in diluting the bacterial population. In either case, the volume of the fluid is the critical factor in the process.

Whirlpool treatments are relatively ineffective and slow in debriding deep wounds unless the Waterpik® is used simultaneously. The major advantage of the whirlpool is related to the diligent dressing changes offered by the physical therapist. It also provides a convenient bath. The major disadvantage is that the surgeon is allowed to remove himself from these seemingly mundane chores, and when the patient is "out of sight and out of mind," everything moves more slowly. A progress notation of "still going to whirlpool," when translated, equates with "still spending somebody's money." One of the most effective methods of cleaning a dirty wound, whether it is a sternotomy wound or an osteomyelitic cavity, is the bathroom shower. A Waterpik® can also be used at the same time as the shower. The high pressure pulsations probably speed along the process, but the large volumes of fluid in the irrigation seem to make the critical difference. It doesn't matter whether tap water or saline is the agent or whether the irrigation is performed by the patient himself or by a highly trained professional. The point is to get the patient actively involved.

TIMING

The *timing of the muscle flap coverage* is preferably deferred until the wound is clean. If the dressings are green and the wound is slick, shiny and stinks, you don't need quantitative cultures to guide you. Xenograft and allograft "take" can be used as predictive factors in burn wounds, but they are seldom used in muscle flap closures. Multiple debridements may be necessary, prior to definitive wound closure, but it is not always essential to remove a foreign body such as a metallic implant to prepare the wound adequately. Some deep ulcers and osteomyelitic defects can only be prepared by repeated vigorous operating room debridements. The decision as to whether or not a muscle flap should be immediately elevated and inset is a matter of practiced surgical judgment. There are no "rules," and there should be no recriminations involved with the expense of one or more operative debridements to successfully prepare a difficult wound.

In the case of complex, open tibial fractures, the recent trend is to provide early and complete muscle coverage in the *"golden period"* of the first five days. After this brief interlude, the incidence of chronic os-

teomyelitis increases dramatically. The fear of closing these wounds and creating a "closed space" infection is based on the faulty surgical logic of the 1930's. Empirical observation finally has dispelled this myth even though it prevails at times in current practice. A reasonable extension of the concept of early local muscle coverage of these wounds is the use of immediate "free" muscle flaps. Godina and Bajec have demonstrated that "free" muscle flaps can be effective in the prevention of osteomyelitis in over four hundred cases of complex tibial fractures. Their reasons for choosing "free" flaps over "potentially" injured local muscle flaps is thought provoking. First, the survivability of "free" flaps, in their hands, is comparable to local muscle flaps — both 95%. Second, the size of the defect is a matter of little concern when the problem is approached with large "free" flaps such as the latissimus dorsi or rectus abdominis muscles. Third, the "zone of injury" is not further disturbed by additional dissection, which should preserve the remaining integrity of the "muscle-periosteal unit." Their final and weakest argument is that a successful "free" muscle flap never becomes ischemic while, in their opinion, a local muscle flap must always become ischemic. This line of reasoning is predicated on the differences in the terminal, end-artery vasculature of calf muscle flaps compared to the robust intramuscular vascular connections of freely transferred flat muscles — a factor which should mitigate against distal or peripheral muscle flap ischemia. This may be true, but it probably can never be proven. Whether their reasoning is correct or not, these authors have reconfirmed the fact that appropriate debridement and adequate muscle coverage can effectively prevent a vicious cycle; and the sooner this is done, the better. The ultimate nihilistic and defeatist argument against either early or late closure of infected bone with muscle flaps is that osteomyelitis will recur "if you wait long enough." We don't need dogs or pigs to refute this notion because we have already done these operations in humans.

CHOICE OF FLAPS

There are numerous factors which affect our decisions to use either a muscle, a musculocutaneous, or an axial flap. These considerations must be weighed in aggregate because no single factor is usually overriding in its importance. In the past we have been guided by the so-called *"reconstructive ladder"* as the primary determinate in choosing a logical surgical approach. In this scheme, simplicity of the procedure is emphasized, in that one is advised always to choose the simplest type of procedure first. For example, one progresses from a skin graft to a local flap and finally, to a distant flap. Unfortunately, this prefatory approach ignores all of the other attributes of a specific reconstruction which can contribute to its overall success. These important contributory factors obviously include durability, morbidity, and esthetic considerations. A skin graft may be simpler than a muscle flap, but it may be vastly inferior in other respects. There are also many times when a myocutaneous flap provides faster healing than a skin graft. The skin-grafted radical mastectomy defect is a good example of this. Although the latissimus dorsi myocutaneous flap is a more complex procedure, it provides an esthetic color match, a reconstitution of the contour deformity, and a durable and comfortable soft tissue surface. A "free" flap to the low-pretibial area may be more complex than a local muscle flap; but it may also prevent multiple re-operations, lessen the morbidity, and shorten the time of healing. In this instance, the criticism of prolonged operative time is an empty one.

Conversely, we can't be *extravagant in our choices*. A recto-vaginal fistula can be elegantly closed with an inferiorly based rectus abdominis muscle using an intra-abdominal approach. This same defect can also be repaired using a gracilis muscle which has an inconsequential donor site, or when the abdomen is already opened, an omental flap can easily be used. This approach obviates the need to rely on the extra abdominal "parts department." Most head and neck cancer defects can be corrected by using the "island" pectoralis paddle, but the surgeon who always chooses this method denigrates the value of the other helpful local flaps in the head and neck area. Surgical ignorance of all of the available options is forever inexcusable. "When your only tool is a hammer, the whole world looks like a nail" best describes such practices. Occasionally, we will want to use a less desirable choice in the first instance, in an effort to save our best flap for a recurrence or a later problem. Whether or not we use our best flap choice in the first instance, we must always be ready for its failure and have a backup flap in mind which will "dig us out of a hole."

SIZE AND ARC

Our foremost consideration is whether or not the proposed *flap will cover the defect*. This is primarily decided by the axis of the dominant vasculature and the expected size of the muscle or musculocutaneous flap. It is always imperative to know the exact extent of flap excursion since this is decided by immutable anatomical constants. This knowledge can only be gained through operative experience or through cadaver dissections.

VASCULATURE

The *location and relative dominance of the muscle vasculature* are the anatomic and physiologic keystones of muscle flap surgery. The deep vasculature of the muscles has been classified according to the various "Types" of vessel arrangements. Although this information is of critical importance, we tend to take a "lumper" rather than a "splitter" approach to the matter. It is not so important that one remembers which muscles are considered to be Type I or Type II, etc., for this is an almost impossible task. It is occasionally difficult even to remember the name of the dominant vessel supplying the muscle. Nevertheless, it is important to know the location and functional significance of each major muscular vessel. Most frequently transposed muscles are supplied by a dominant proximal vascular leash with a backup system of deep perforating vessels. A physiologic modifier of the vascular anatomy is the nature of the intramuscular vascular interconnections. Broad, flat muscles tend to have excellent intramuscular vascular connections while long, thin muscles more often have "segmental" vascular arrangements. The biceps femoris and sartorius muscles are the best examples of a "segmental" vasculature in which none of these deep vessels can be safely sacrificed. The rectus femoris muscle is a prime example of a dominant, proximal vasculature without any accompanying deep perforating system. The rectus abdominis muscle best exemplifies an equally dominant proximal and distal vasculature. The vascular anatomy of the gracilis muscle lies somewhere in between. The soleus and extensor digitorum communis muscles demonstrate balanced proximal, dominant, and distal deep perforating systems. Broad, flat muscles tend to have either a totally "segmental" vascular system, as is the case of the external oblique muscle, or a duplicate system, as seen in the arrangement of the pectoralis and latissimus muscle. The physiologic nature of these intramuscular vascular connections is the reason why numerous segmental vessels can be sacrificed in the case of the external oblique muscle and not in the case of the biceps femoris muscle.

ACCESSIBILITY

The ability to expose the flap through a *single operative field* is a mundane, but important consideration. Repositioning the patient is awkward, time-consuming, and precludes elevation of the flap at the time of the recreation of the deformity. This is the obvious reason why the "island" vertical trapezius myocutaneous flap is chosen less often for head and neck defects than is the pectoralis "paddle." The same criticism applies to the latissimus dorsi and pectoralis major myocutaneous flaps in the case of two operative fields. Even though the latissimus dorsi myocutaneous flap is just as useful as the pectoralis "paddle" flap for head and neck defects, it is less often chosen because of its lack of accessibility.

DONOR SITE

The *donor site considerations* are pivotal in the choice of a flap. The known problems range from the bothersome seroma of the latissimus dorsi flap donor site to the life-threatening carotid "blowout" potential of the sternomastoid flap donor site. Functional loss should always be considered, but it is usually a less important consideration than the donor site. These problems must be weighed in aggregate when choosing any muscle flap procedure.

SENSATION

Most muscle flaps maintain some pressure *sensibility*, but with rare exception, no surface sensibility. Most "island" myocutaneous flaps maintain neither deep nor superficial sensibility because the segmental nerves are distant from the "island" vessels and are sacrificed in the process of the flap elevation. Still, the deep pressure sensibility which persists in a muscle flap may be adequate to provide a durable surface for walking or for the protection of a skin graft. In the case of the gastrocnemius and soleus muscle flaps, surface tactile sensibility is somehow preserved. Restoration of the sensation to the major myocutaneous flaps is an awaiting horizon. This event could transform the highly desirable esthetic result of the rectus abdominis breast reconstruction into a sensate breast. The tensor fascia lata and external oblique myocutaneous flaps are unusual examples of flaps which sometimes maintain the integrity of their nerve supply following flap elevation.

FUNCTION

Because of the redundancy of muscle strength and actions, the *functional importance* of any given muscle is difficult to establish. It comes as a surprise that muscles which are as large as the latissimus, gastrocnemius, soleus, and rectus femoris can be sacrificed with little or no functional loss. One would think that the tensor fascia lata flap would be functionally less important than the rectus femoris myocutaneous flap, but this may not be the case. Conversely, hand and forearm muscle flaps are not included in this discussion because the use of any single muscle as a local flap in the hand or forearm may be difficult to justify. The gluteus maximus muscle is a functionally important muscle, and it is used judi-

ciously in the walking patient. The tibialis anterior muscle is so important and unduplicated in foot dorsiflexion, as the peroneus longus and brevis muscles are in foot eversion, that these muscles are rarely considered as useful muscle flaps.

THE DEFECT

The size, location, depth, and *nature of the defect* ultimately determine which muscle flap will be applicable. Muscle is always chosen over other types of flaps when it is necessary to revascularize ischemic, irradiated, and infected wounds. A muscle flap alone is the standard choice for obliterating cavities. Fasciocutaneous flaps have virtually no place in either the eradication of an infection or in the obliteration of a contaminated cavity. The size and depth of the wound may also be the major factor in flap choices. For instance, the removal of a total hip prosthesis may give such a sizable wound that the TFL flap would have no effect in obliterating the defect. Further, the rectus femoris muscle flap may be too small to correct the resulting hip defect so that it may be necessary to use the larger vastus lateralis muscle flap to totally correct the problem. In the case of pretibial defects, failure to cover even one centimeter of the bone is tantamount to total failure. For this reason, one must always be prepared to use both the soleus and gastrocnemius muscle flaps to correct certain unanticipated pretibial problems. Most intrathoracic cavities are too sizable to completely obliterate even if all of the chest wall muscles were used in combination. Intrathoracic muscle transpositions are almost always employed as a "seal" and seldom as a sole means of cavitary obliteration.

The *types of exposed structures* must be dealt with individually. Exposed and dried bone is usually not infected nor a contributor to wound infections, and it can be safely debrided at the time of the definitive flap closure. Exposed or dried arteries are more perilous because such vessels can rupture at any time. This problem requires urgent coverage and total debridement of the surrounding ischemic wound with immediate and complete muscular coverage of the involved artery. The exposed or infected prosthetic arterial graft is even more difficult because a wider resection of the surrounding "pseudosheath" and ischemic marginal wound must be carried out, and the entire graft must be totally surrounded by muscle. Dried nerves may lose their epineural blood supply, which can lead to a significant functional nerve deficit. Drying of nerves should be avoided at all costs; but if it cannot, nerves may be partially revascularized with appropriate muscle flap coverage. Dried tendon is a less difficult situation to deal with because tendon can be covered with a vascularized flap and will completely reconstitute its substance even though the tendon is, in fact, dead and tanned. Conversely, the "soupy" tendon is autolyzed and must be excised. Metallic prostheses cannot always be removed, and removal is not always necessary. It may be necessary to remove metallic plates or intramedullary rods from long bones and replace them with an external fixation device when the infection extends into the screw hole sites or remains inaccessible to the muscle flap coverage. Exposed total knee and ankle joints have been successfully covered with muscle flaps even though the wound-healing logic of this event evades our explanation.

In the case of a bronchopleural fistula, the purpose of the flap is to seal the bronchopleural fistula. The transposed muscle is not intended to obliterate the remaining chest cavity which will obliterate itself. Neither will a muscle flap obliterate deeply imbedded infection in bone. This must always be surgically removed. One cannot expect even the most powerful antibiotics to have any curative effect on "undebrided" osteomyelitis. This is best exemplified by attempting to treat a tubular sequestrum of the tibia by removing the anterior cortex of the bone and covering it with a gastrocnemius and/or soleus muscle flap. Unless the entire sequestrum is removed, the muscle flaps will have no effect on the remaining infected bone, and neither will prolonged intravenous antibiotics. The nature of the defect requires us to consider factors other than which flaps will "reach" the defect. In the leg a skin-grafted soleus muscle flap is esthetically superior to the medical gastrocnemius myocutaneous flap because of the less attractive myocutaneous flap donor site skin graft. Although one can cite numerous disadvantages for the "island" vertical trapezius myocutaneous flap, it is the only local flap which will comfortably reach the occiput. The excellent color match achieved by the horizontal trapezius myocutaneous flap when it is used to replace anterior neck skin is also an important factor. This esthetic consideration alone would temper the usefulness of a skin grafted pectoralis muscle or a pectoralis "paddle" for the same problem. The nature of the defect is frequently the sole determinant for the choice of a flap. It is axiomatic that flaps transposed into irradiated wounds should carry their own blood supply. It must also be recognized that inadequate debridement of the surrounding irradiated tissue may lead to further necrosis of this tissue even though the muscle flap survives in the middle of a sea of dying irradiated skin. The volume of muscle bulk is probably a poor reason to choose a muscle to cover a pressure sore since this may or may not be protective against future ulcers. Contrary to the conventional wisdom, muscle flaps can be used in ischemic legs even when their primary vessels are not visualized on an arteriogram. If the muscle is not tender, has a

good appearance, and is functioning well in situ, it may survive transposition. This would obviously not be our first choice, but it may be an option. A latissimus muscle flap may be desirable for a chest wall skeletal defect even when there is adequate overlying skin cover because it serves the purposes of both covering an artificial mesh and adding a second well vascularized layer to a potentially life-threatening wound. Primary skin closure of such a thoracic defect would be a simpler method in the "reconstructive ladder," but it would not afford the safety of a latissimus dorsi muscle flap closure, which is further up the "reconstructive ladder."

In summary, our decisions in regard to flap choices are multifaceted and complex. They must all lead toward solving the problem at hand in a balanced fashion. The proper design of a muscle flap procedure is the critical determinant in its success.

BIBLIOGRAPHY

BASIC PRINCIPLES

Abbe, R. "A new plastic operation for the relief of deformity due to double hare lip." *Med. Rec.* 53: 477, 1898.

Abbe, R. "Case of plastic operation on the nose." *Med. Rec.* 87: 921, 1915.

Arnold, P.G. and Mixter, R.C. "Making the most of the gastrocnemius muscles." *Plast. and Reconstr. Surg.* 72(1): 38, 1983.

Arnold, P.G. and Pairolero, P.C. "Chest wall reconstruction: Experience with 100 consecutive patients." *Ann. Surg.* 199(6): 725, 1984.

Arnold, P.G. and Pairolero, P.C. "Use of pectoralis major muscle flaps to repair defects of the anterior chest wall." *Plast. Reconstr. Surg.* 63: 205, 1979.

Arnold, P.G., Pairolero, P.C. and Waldorf, J.C. "The serratus anterior muscle: intrathoracic and extrathoracic utilization." *Plast. and Reconstr. Surg.* 73(2): 240, 1984.

Bakamjian, V.Y. "A technique for primary reconstruction of the palate after radical maxillectomy for cancer." *Plast. Reconstr. Surg.* 31: 103, 1963.

Bakamjian, V.Y. "A two-stage method for pharyngoesophageal reconstruction with a primary pectoral skin flap." *Plast. Reconstr. Surg.* 36: 173, 1965.

Campbell, J. and Pennefather, C. "An investigation into the blood supply of muscle with special reference to war surgery." *Lancet*, 1: 294, 1919.

Cole, H.P. "Ununited fractures of the mandible: their incidence, causation, and treatment." *Br. J. Surg.* 6: 57, 1918-19.

Clark, W.E. and Blomfield, L.B. "The efficiency of intramuscular anastomoses with observations on the regeneration of devascularized muscle." *J. Anat.* 79: 15, 1945.

Cormack, G.C. and Lamberty, B.G.H. "A classification of fasciocutaneous flaps according to their patterns of vascularization." *Br. J. Plast. Surg.* 37: 80, 1984.

Cormack, G.C. and Lamberty, B.G.H. "Fasciocutaneous vessels in the upper arm: Application to the design of new fasciocutaneous flaps." *Plast. Reconstr. Surg.* 74: 244, 1984.

Cormack, G.C. and Lamberty, B.G.H. "The blood supply of the thigh skin." *Plast. Reconstr. Surg.* 75: 342, 1985.

Davis, J.S. "The story of plastic surgery." *Ann. Surg.* 113: 641, 1941.

Davis, J.S. *Plastic Surgery, Its Principles and Practice.* Philadelphia: P. Blakiston's Son and Co., 1919.

Davis, W.M., McCraw, J.B., and Carraway, J.H. "Use of a direct transverse thoracoabdominal flap to close difficult wounds of the thorax and upper extremity." *Plast. Reconstr. Surg.* 60(4): 526, 1977.

Dibbell, D.G. "Use of a long island flap to bring sensation to the sacral area in young paraplegics." *Plast Reconstr. Surg.* 54: 221, 1974.

Dibbell, D.G., McCraw, J.B. and Edstrom, L.E. "Providing useful and protective sensibility in patients with meningocele." *Plast. and Reconstr. Surg.* 64: 796. 1979.

Dowden, R.V., and McCraw, J.B. "The vastus lateralis muscle flap: technique and applications." *Annals of Plastic Surgery* 4: 396, 1980.

Erk, Y., Rhodes, F.A., and Spira, M. "Vascular augmentation of skin and musculocutaneous flaps." *Ann. Plast. Surg.* 10: 341, 1983.

Estlander, J.A. "Methode de autoplastic de la joul on d'une le'vre." *Rev. Mens. de Med. Ed. Chir.* 1: 344, 1877.

Gallie, W.E. and LeMesurier, A.B. "The use of living sutures in operative surgery." *Can. Med. Assoc. J.* 11: 504, 1921.

Ger, R. and Levine, S.R. "The management of decubitus ulcers by muscle transposition." *Plast. Reconstr. Surg.* 58: 419, 1976.

Hester, T.R., McConnel, F.M.S., Nahai, F., Jurkiewicz, M.J., and Brown, R.G. "Reconstruction of the cervical esophagus, hypopharynx, and oral cavity using free jejunal transfer." *Amer. J. Surg.* 140: 487, 1980.

Hester, T.R., Nahai, F., Beegle, P.E., and Bostwick, J., III. "Blood supply of the abdomen revisited with emphasis on the superficial inferior epigastric artery." *Plast. Reconstr. Surg.* 74: 657, 1984.

Hudlicka, O. *Muscle blood flow (its relation to muscle metabolism and function).* Amsterdam: Swets en Zeitlinger, B.V., 1973.

Hueston, J.T. and McConchie, I.H. "A compound pectoral flap." *Aust. N.Z. J. Surg.* 38(1): 61, 1968.

Kanavel, A.B. "Plastic procedures for the obliteration of cavities with non-collapsible walls." *Surg. Gynecol. Obstet.* 32: 453, 1921.

Kaplan, I. "Neurovascular island flap in the treatment of trophic ulceration of the heel." *Br. J. Plast. Surg.* 22: 143, 1969.

Kitlowski, E.A. "The preservation of tendon function by the use of skin flaps." *Amer. J. Surg.* 51: 653, 1941.

Krizek, T.J., Tani, T., Desprez, J.D. and Kiehn, C.L. "Experimental transplantation of composite grafts by microsurgical vascular anastomoses." *Plast. Reconstr. Surg.* 36: 538, 1965.

Lamberty, B.G.H. and Cormack, G.C. "The anticubital fasciocutaneous flap." *Br. J. Plast. Surg.* 36: 428, 1983.

Lang, K. and Boyd, L.J. "The use of fluorescein to determine the adequacy of circulation." *Med. Clin. N. Am.* 26: 943, 1942.

Littler, J.W. "Neurovascular pedicle method of digital transposition for reconstruction of the thumb." *Plast. Reconstr. Surg.* 12: 303, 1953.

Littler, J.W. "Neurovascular skin island transfer in reconstructive hand surgery." In *Transactions of the International Society of Plastic Surgeons*. Baltimore: Williams & Wilkins, 1960.

Littlewood, M. "Compound Flaps." In *Skin Flaps*, W.C. Grabb and M.R. Myers, Eds. Boston: Little, Brown and Co., 297-306, 1975.

Magee, W.P., McCraw, J.B., Horton, C.E., and McInnis, W.D. "Pectoralis 'paddle' myocutaneous flaps: the workhorse of head and neck reconstruction." *Amer. J. of Surg.* 140: 507, 1980.

Manchot, C. *Die Hautarteriern des Menschlichen Korpers*. Liepzig: F.C.W. Vogel, 1889.

Maruyama, Y., Ohnishi, K., and Takeuchi, S. "The lateral thigh fasciocutaneous flap in the repair of ischial and trochanteric defects." *Br. J. Plast. Surg.* 37: 103, 1984.

Mathes, S., Vasconez, L., and Jurkiewicz, M.J. "Extension and further applications of muscle flap transposition." *Plast. Reconstr. Surg.* 60: 6, 1977.

Mathes, S.J., Alpert, B., and Chang, N. "Use of the muscle flap in chronic osteomyelitis: experimental and clinical correlation." *Plast. Reconstr. Surg.* 69, 1982.

Mathes, S.J., McCraw, J.B., and Vanconez, L.O. "Muscle transposition flaps for coverage of lower extremity defects: anatomical considerations." *Surg. Clin. N. Amer.* 54: 1337, 1974.

Mathes, S.J. and Nahai, F. *Clinical Atlas of Muscle and Musculocutaneous Flaps*. St. Louis: C.V. Mosby Co. 1979.

Mathes, S.J. and Nahai, F. "Muscle flap transposition with function preservation: technical and clinical considerations." *Plast. Reconstr. Surg.* 66: 242, 1980.

Mathes, S.J. and Nahai, F. "Classification of the vascular anatomy of muscles: Experimental and clinical correlation." *Plast. Reconstr. Surg.* 67: 177, 1981.

Mathes, S.J. and Nahai, F. *Clinical Applications for Muscle and Musculocutaneous Flaps*. St. Louis: C.V. Mosby Co. 1982.

Mathes, S.J. and Nahai, F. *Clinical Applications for Muscle and Musculocutaneous Flaps*. St. Louis: The C.V. Mosby Co., 1982.

Mathes, S.J. and Nahai, F. *Clinical Atlas of Muscle and Musculocutaneous Flaps*. St. Louis: The C.V. Mosby Co., 1979.

McArthur, L.L. "Autoplastic suture in hernia and other diastases: preliminary report." *J. Amer. Med. Assoc.* 37: 1162, 1901.

McCraw, J.B., McDonald, W., McLeod, R., and Stephenson, H. Jr.: "A rapid test for intestinal perforation." *J.A.M.A.* 191: 934, 1965.

McCraw, J.B. "The recent history of myocutaneous flaps." *Clin. Plast. Surg.* 7: 3, 1980.

McCraw, J.B. "Intraoperative identification of the gracilis muscle for vaginal reconstruction." *Plast. Reconstr. Surg.* 65(3): 358, 1980.

McCraw, J.B. "You can call me Ray, you can call me Jay." (Letter): *Plast. and Reconstr. Surg.* 66: 857, 1980.

McCraw, J.B., and Dibbell, D.G. "Experimental definition of independent myocutaneous vascular territories." *Plast. Reconstr. Surg.* 60: 212, 1977.

McCraw, J.B., Dibbell, D.G., and Carraway, J.H. "Clinical definition of independent myocutaneous vascular territories." *Plast. Reconstr. Surg.* 60: 341, 1977.

McCraw, J.B., Fishman, J.H. and Sharzer, L.A. "The versatile gastrocnemius myocutaneous flap." *Plast. and Reconstr. Surg.* 62: 15, 1978.

McCraw, J.B. and Furlow, L.T., Jr. "The dorsalis pedis arterialized flap." *Plast. Reconstr. Surg.* 55: 177, 1975.

McCraw, J.B., Magee, W.P. and Kalwaic, H. "The use of the trapezius and sternomastoid myocutaneous flaps in head and neck reconstruction." *Plast. and Reconstr. Surg.* 63: 49, 1979.

McCraw, J.B., Massey, F.M., Shanklin, K.D. and Horton, C.E. Vaginal reconstruction with gracilis myocutaneous flaps." *Plast. Reconstr. Surg.* 58: 176, 1976.

McCraw, J.B., Myers, B., and Shanklin, K.D. "The value of fluorescein in predicting the viability of arterialized flaps." *Plast. Reconstr. Surg.* 60: 710, 1977.

McCraw, J.B., Penix, J.O. and Baker, J.W. "Repair of major defects of the chest wall and spine using the latissimus dorsi myocutaneous flap." *Plast. and Reconstr. Surg.* 62: 197, 1978.

McDowell, F. "Logs vs. harpsichords, blobby flaps vs. finished results (editorial)." *Plast. Reconstr. Surg.* 64: 249, 1979.

McGregor, I.A., and Jackson, I.T. "The Groin Flap." *Br. J. Plast. Surg.* 25: 3, 1972.

McGregor, I.A., and Morgan, G. "Axial and random pattern flaps." *Br. J. Plast. Surg.* 26: 202, 1973.

Moberg, E. "Evaluation and management of nerve injuries in the hand." *Surg. Clin. North Am.* 44: 1019, 1964.

Myers, M.B. "Prediction of skin sloughs at the time of operation with the use of fluorescein dye." *Surgery* 51: 158, 1962.

Nahai, F., Brown, R.G., and Vasconez, L.O. "Blood supply of the abdominal wall as related to planning abdominal incisions." *Am. Surg.* 42: 691, 1976.

Nahai, F., Silverton, J.S., Hill, H.L., and Vasconez, L.O. "The tensor fascia lata musculocutaneous flap." *Ann. Plast. Surg.* 1: 372, 1978.

Olivari, N. "The latissimus flap." *Br. J. Plast. Surg.* 29: 126, 1976.

Ortichocea, M. "The musculocutaneous flap method: an immediate and heroic substitute for the method of delay." *Br. J. Plast. Surg.* 25: 106, 1972.

Ortichocea, M. "A new method of total reconstruction of the penis." *Br. J. Plast. Surg.* 25: 347, 1972.

Ortichocea, M. "History of the discovery of the musculocutaneous flap method as a universal and immediate substitute for the method of delay." *Br. J. Plast. Surg.* 36: 524, 1983.

Owens, N. "Compound neck pedicle designed for repair of massive facial defects." *Plast. Reconstr. Surg.* 15: 369, 1955.

Papp, C., McCraw, J.B., and Arnold, P.G. "Experimental reconstruction of the trachea with autogeneous materials." *J. of Throracic and Cardiovascular Surg.* 90(1): 13, 1985.

Papp, C., Parker, P., Boeheim, C. and McCraw, J.B. "Experimental use of intercostal muscle flaps for repair of induced cardiac defects." *J. of Thoracic and Cardiovascular Surg.* 90(2): 261, 1985.

Pers, M., and Medgyesi, S. "Pedicle muscle flaps and their application in the surgery of repair." *Br. J. Plast. Surg.* 26: 313, 1973.

Reid, C.D. and Taylor, G.I. "The vascular territory of the acromiothoracic axis." *Br. J. Plast. Surg.* 37: 194, 1984.

Ristic, J. and Morain, W.D. Translation of *The Cutaneous Arteries of the Human Body* by Carl Manchot. New York: Springer-Verlag, 1983.

Rowsell, A.R., Davies, D.M., Eisenberg, N., and Taylor, G.I. "The anatomy of the subscapular thorcacodorsal arterial system: Study of a hundred cadaver dissections." *Br. J. Plast. Surg.* 37: 574, 1984.

Salmon, M. *Arteres de la Peam* (Arteries of the skin). Masson, 1936.

Salmon, M. *Arteres des muscles de la tete et du cou* (Arteries of the muscles of the head and neck). Masson, 1936.

Salmon, M. and Dor, J. *Les arteres des muscles des membres et du tronc* (Arteries of muscles of the trunk and extremities). Masson, 1933.

Senior, H.D. "The development of the arteries of the human lower extremity." *Am. J. Anat.* 25: 55, 1919.

Shaw, D.T. and Payne R.L. "One stage tubed abdominal flaps." *Surg. Gynecol. Obstet.* 83: 205, 1946.

Smith, P.J. "The vascular basis of axial pattern flaps." *Br. J. Plast. Surg.* 26: 150, 1973.

Smith, P.J., Foley, B., McGregor, I.A., and Jackson, I.T. "The anatomical basis of the groin flap." *Plast. Reconstr. Surg.* 49: 41, 1972.

Snyder, G.B. and Edgerton, M.T. "The principle of the island neurovascular flap in the management of ulcerated anesthetic weight bearing areas of the lower extremity." *Plast. Reconstr. Surg.* 36: 518, 1965.

Stark, R.B. "Robert Abbe and his contributions to plastic surgery." *Plast. Reconstr. Surg.* 12: 14, 1953.

Stein, S. "Laebedannelse (Cheiloplastik) Udfort paa en my methode." *Hospitals Meddelser*, 1: 212, 1848.

Tamai, S., and co-workers. "Free muscle transplants in dogs with microsurgical neurovascular anastomoses." *Plast. Reconstr. Surg.* 46: 219, 1970.

Taylor, G.I. "A discussion of blood supply of the abdomen revisited with emphasis on the superficial inferior epigastric artery." *Plast. Reconstr. Surg.* 74: 667, 1984.

Tolhurst, D.E. "Surgical indications for fasciocutaneous flaps." *Ann. Plast. Surg.* 13: 495, 1984.

Tolhurst, D.E. "Discussion of fasciocutaneous vessels in the upper arm: Application to the design of new fasciocutaneous flaps." *Plast. Reconstr. Surg.* 74: 250, 1984.

Vasconez, L., Bostwick, J., III, and McCraw, J.B. "Coverage of exposed bone by muscle transposition and skin grafting." *Plast. Reconstr. Surg.* 53: 526, 1974.

Wangensteen, O.H. "Repair of recurrent and difficult hernias and other large defects of the abdominal wall employing the iliotibial tract of fascia lata as a pedicled flap." *Surg. Gynecol. Obstet.* 59: 766, 1934.

Wangensteen, O.H. "Repair of large abdominal defects by pedicled fascial flaps." *Surg. Gynecol. Obstet.* 82: 144, 1946.

Wee, J.T.K. "Reconstruction of the lower leg and foot with the reverse-pedicled anterior tibial flap: preliminary report of a new fasciocutaneous flap." *Br. J. Plast. Surg.* 39: 327, 1986.

Wei, W.I., Lan, K.H., and Wong, J. "The true pectoralis major myocutaneous island flap: An anatomic study." *Br. J. Plast. Surg.* 37: 578, 1984.