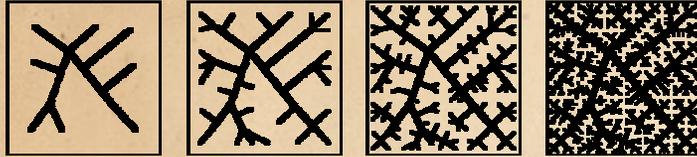


Marc E. Gottlieb, MD, FACS

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Closing the Foot - Repair, Reconstruction, and Plastic Surgery of the Lower Extremity

Supplemental questions and cases

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Question # 1

This 78 year old woman has a recent leg ulcer, painful, and progressing in spite of non-specific topical care. She has chronic recurring migratory dermatitis and panniculitis of the legs, currently active on the left. She also has long standing malaise, arthralgias, dry eyes, dry mouth, oral ulcers, and intermittent neurolepsy. Pulses are normal. Assuming that basic competent wound care, edema control, and workup are initiated, the most important initial treatment is:



- Complete excisional debridement.
- A skin graft or flaps.
- Systemic and intralesional steroids.
- Topical pharmaceuticals to stimulate wound healing.

Answer:

Previously undiagnosed, she has an obvious connective tissue disease, Sjögren's being the "best fit" diagnosis. Untreated and out of control, it is the obvious cause of progressive lytic leg ulceration. Marginal skin necrosis, dissolution of adipose, loss of the sural fascia, and pain are characteristic of immunopathic ulcers. This ulcer is actively pathological, and wound healing is suppressed.

Grafts and flaps, which depend on healthy competent wound healing, are guaranteed to fail. Wound stimulating drugs (e.g. PDGF), will also fail and be wasted until pathology and inflammation are arrested. Debridement will be required at some point, but these wounds are subject to pathergy, and indiscriminate excision is another injury which will promote more necrosis. Controlling disease and pathological inflammation are of paramount importance. Once these are controlled, further options can be considered. The ulcer eventually healed with patient systematic care.

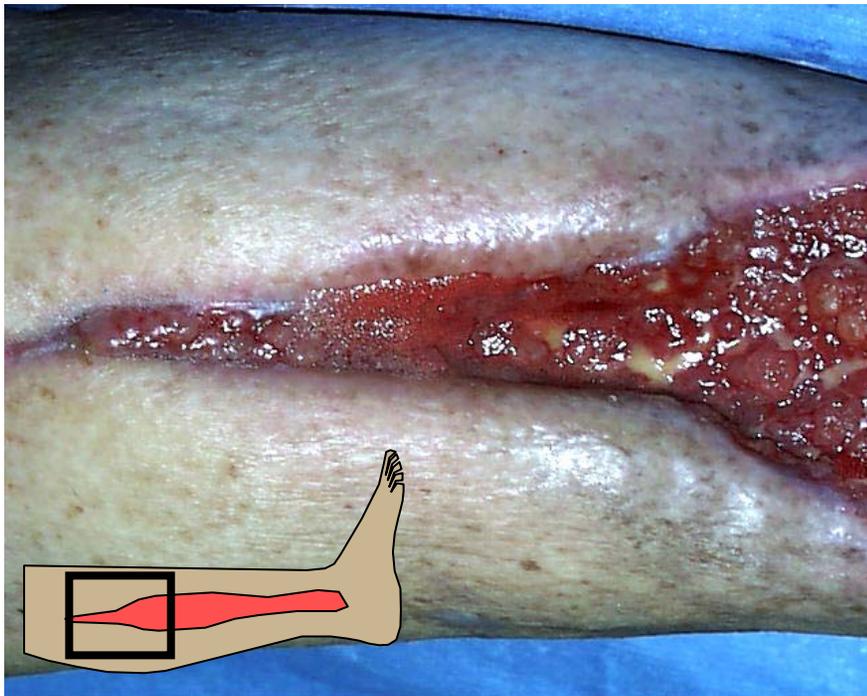
Correct answer: c



Question # 2

This elderly man had acute arterial thrombo-occlusion and compartment syndrome. After revascularization and a period of topical wound care, the fasciotomy wound looks as shown. Suitable options for further management include all of the following except:

- a. Topical hygienic wound care.
- b. A skin graft.
- c. Topical pharmaceuticals to stimulate wound healing.
- d. A flap.



Answer:

Arterial disease does not cause any intrinsic impairment of wound healing. The machinery of repair is inherently healthy, and it functions properly as soon as ischemia is relieved. In this patient, the wound shows all of the features of an active proliferative wound module, i.e. it is healing, including significant contraction and epithelialization. Given sufficient time and continued hygienic care, it will close completely.

Surgery and wound healing pharmaceuticals are not required, but they may be a worthwhile option in some such patients, in order to expedite the final result, saving time, cost, and inconvenience.

If surgery is done, there are no special requirements for closure other than to replace missing skin. The wound is independently wound healing competent, there are no exposed essential structures, and there are no special requirements for the quality of the final scar. A split thickness skin graft satisfies these requirements, with only nominal risk to the patient and reasonable cost. Flaps serve no special purpose here, and they would be unnecessarily intrusive and risky.

Correct answer: d

Question # 3

This 29 year old man has had many years of intermittent leg ulceration. But unlike previous episodes, where the ulcers healed slowly, this current set of bilateral leg ulcers has not healed in two years. He is otherwise healthy. There is no special personal history, but there is a family history of miscarriages. The most important therapy in healing these wounds will be:

- a. Establish and treat the underlying diagnosis.
- b. Topical pharmaceuticals to stimulate wound healing.
- c. Excision and suture repair of the lesions.
- d. A skin graft.



Answer:

Size-wise, these are trivial wounds which would heal “in the blink of an eye” if the system was healthy. These are pathological ulcers, with some underlying devil of a disease at work. Pathological ulcers cannot be cured until the cause of the ongoing injury or the cause of wound healing failure can be established and corrected. In this case, patient profile and family history are very suggestive of a hypercoagulable disorder. Workup confirmed high anticardiolipins, and the ulcers healed in just 10 weeks with warfarin, accompanied by basic non-specific topical wound hygiene and edema control.

High-end technology products to stimulate wound repair are of marginal value when the cause of injury remains active. They are also expensive. In a case like this, they have a possible role when other basic care and correction of disease have been tried but have failed by themselves to heal the wounds.

Excision and repair, like any conventional surgery, depends on a competent healing process. Tried here, without correcting the disease, simple repair would result in necrosis at the wound margins, dehiscence, and enlarged ulceration. A skin graft would not be injurious or detrimental, but local wound conditions would prevent it from healing, and the underlying disease would put the skin graft donor sites at risk.

Correct answer: a

Question # 4

This 60 year old woman has ignored her health and doctors for many years. Her rheumatoid arthritis is severely out of control. This immunopathic leg lesion, which is severely inflamed and undergoing rapid progressive lysis and ulceration, is further complicated by atherosclerotic arterial insufficiency.



Best initial wound care is:

- Good hygiene, silver sulfadiazine, debride.
- Hydrocolloid or other absorbent dressings.
- Porcine skin xenograft or cadaveric allograft.
- Wound stimulus drugs.

If and when the wound is eligible for closure, the conventional rules of plastic surgery dictate which option:

- Skin grafts.
- Soleus muscle flap.
- Rectus abdominis free flap.
- Omentum free flap.

Answer:

This wound has multiple causes and risks, creating the ulcer and preventing healing. Primary obligations are to control disease (steroids), alleviate risks (revascularize), and provide good wound care (hygiene, debridement, edema control, and topical care). Various non-specific dressings and topicals are not disallowed, but wounds of this biological severity need best possible control, i.e. silver or sulfa preparations. Non-autograft skin can protect a wound already treated and controlled, but they will quickly lyse in this wound, for the same reasons the ulcer is actively enlarging. Wound healing drugs are an expensive waste in this inflamed active ulcer.

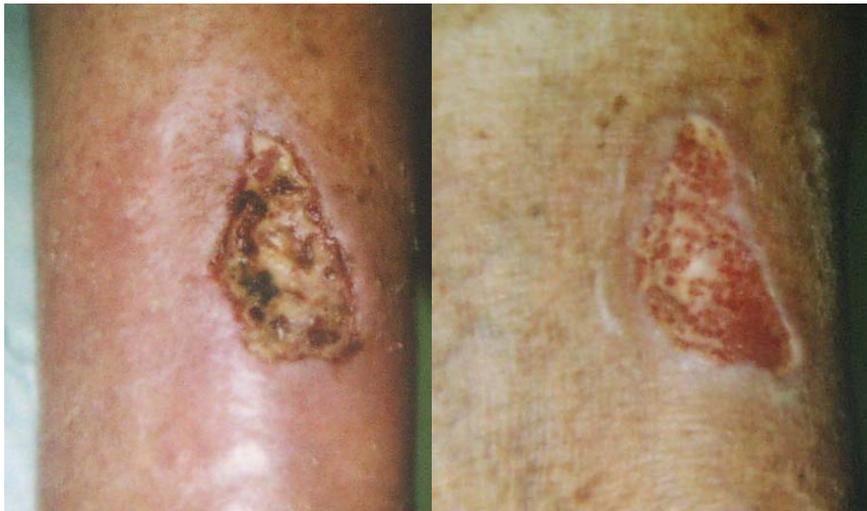
Correct answer: a

Assume that the wound eventually gets to the point where healing is active and operative closure can be contemplated. Skin grafts have limited success over tendons, moving structures, and ischemic tissues, so conventional rules require a flap. The soleus is good for closing distal leg defects, but only for small areas, not this large wound. With no local flaps available, a free flap is needed. Rectus abdominis is a usual choice for a large long defect (latissimus dorsi is also common). However, if local atherosclerosis prevents flap revascularization at the popliteal, omentum could be used, anastomosed to the femoral artery in the groin.

Correct answer: g or h

Question # 5

This 70 year old patient has a leg ulcer of recent onset (image 1). There is no evidence of any disorder other than ordinary venous hypertension and venous vasculitis, with stasis, dermatitis, and ulceration over a saphenous perforator. Initial care consisted of hygiene and topical care, and elastic compression and elevation. The wound improved quickly, but it failed to contract or epithelialize. Three months later, it looks like it should be healing, but it is stalled (image 2). Options for further care include all but:



- a. A skin graft.
- b. Apligraf (cultured living skin, Organogenesis, Inc.).
- c. PDGF (platelet derived growth factor, Regranex®, Ethicon, Inc).
- d. A flap.

Answer:

Some ulcers are wound healing competent to a degree, easily improved, but still failing physiological closure. Topical care and compression can be done indefinitely, but if the plan is to advance to more costly modalities to force the wound to close, there are several choices. This wound is eligible for skin grafts, but it is a “50-50” choice, because whatever is hindering the wound also threatens the graft. Cost inefficient if done in an OR, a graft is worth a try if done in office or clinic. However, this is precisely the situation where wound stimulatory therapies work well, including Apligraf and PDGF. Three weeks after Apligraf was applied, this wound is substantially improved (image 3), and healed at 10 weeks (image 4). This wound has no criteria which warrant a flap, and if a flap was done, it would leave a donor site which might become its own chronic ulcer.

Correct answer: d



Question # 6

A 67 year old woman has infarction and ulceration of foot and ankle due to complications of atherosclerosis (image 1). With revascularization, good wound care, and ultimate skin reconstruction, this remains an inherently good foot which can be salvaged (image 2).

When it comes time to consider closure, which of these criteria mandates a flap:

- Improved skin quality to resist shear from footwear.
- Exposed bone, joints, and major tendons.
- Atherosclerotic arterial disease.
- Large wound area.

All but one of these conditions in this specific wound disqualifies a flap or makes it risky:

- Unstable post-debridement osteotomies.
- Atherosclerotic arterial disease.
- Large wound area.
- General patient risk and comorbidities.



Answer:

Improved skin mechanics is a good discretionary reason to use a flap, but for the acute goal of wound closure, exposed structures and unstable moving parts, which do not support grafts, are the mandatory reasons for a flap. Arterial disease does not preclude flaps, but it is not an indication for flaps, as they make flaps riskier, killing them by ischemia, and preventing free flap anastomosis. Size does not disqualify a flap, but in this case, donors are limited, risky from vascular disease, and technically tricky, especially in a geometrically complex area where contours and adherence can be a challenge. “Bigger” compounds these inherent risks, and either way, there are no local flaps big enough to cover this wound. Free flaps, the textbook choice for this wound, can be long, physiologically taxing procedures best avoided in many sick patients. When conventional criteria warrant a flap, but circumstances preclude a flap, Integra® collagen-gag matrix solves the problem (images 3, 4).

Correct answers: b and e



Question # 7

A 69 year old woman had a small medial leg ulcer, situated over varicose veins (image 1). Unimproved with basic care (topical hygiene and compression), surgery was done, excising the varicose cluster and closing the lesion. The sutured wound dehiscd and further ulcerated (image 2). Workup revealed protein C deficiency, and warfarin was started. There are good options for both surgical and non-operative care, but if surgery is opted, valid choices include all except:



- a. Split thickness skin graft.
- b. Full thickness skin graft.
- c. Integra® collagen-gag matrix.
- d. Small local flap.
- e. Free flap.

Answer:

Any choice would work for a comparable wound in a healthy patient, but so would have the simple option of direct repair. Normal rules of surgery are suspended for risky pathological wounds. In this case, anticoagulation and topical care should suffice. But in these disorders, warfarin is difficult to regulate, and hypercoagulability may persist. If topical care and anticoagulants fail, then biological coverage gives the wound a favorable edge. Both types of skin grafts and small adjacent flaps can be opted, based on usual criteria, recognizing that thicker grafts and random flaps are averse to residual ischemia, and donor sites will be at risk for similar failure. A free flap has no role. This wound has no needs for such, and hypercoagulability jeopardizes the flap by thrombosis of the micro anastomoses. Integra is high grade biological coverage which controls micro-thrombosis by abolition of further injury and inflammation, with zero risk to the host, as was the case with this patient.

Correct answer: e



Question # 8

This man has severe femoral atherosclerosis. While recuperating from a right below knee amputation, a heating pad burned the left foot (image 1). All but two of these have a potential role in his management:

- Split thickness skin graft.
- PDGF (platelet derived growth factor, Regranex®).
- Integra® collagen-gag matrix.
- Small local flap.
- Free flap.
- BKA (below knee amputation).



Answer:

This injury was a foolish error. With severe arterial vasculopathy and ischemia, there is insufficient flow of blood to convect away extrinsically applied heat, allowing heat to accumulate until the tissues are cooked.

Initial mandatory treatment includes debridement, good topical care, and revascularization if possible. Once the wound is stable, closure methods can be elected, based on exposed structures and residual risks. If the wound is anatomically simple (muscles and fascias exposed), then topical care, including PDGF, and skin grafts will work. If bones, joints, and tendons are open, preferred options are Integra or small flaps of residual skin from the excised toes. In this case, plantar toe flaps and split thickness skin grafts were both used, for a healed foot.

Atherosclerosis can nullify a free flap or make it very risky for failure. Transmetatarsal amputation with primary closure would be a safer, more efficient, more reliable bet than a free flap. Amputation is a reality for some vascular patients, but pre-emptive BKA for a foot like this one, which can be cured with standard diligent care, is a reprehensible anachronism that will cripple this patient who already has the other leg amputated.

Integra would have been opted if there were no flaps to cover the osteotomies, but in this case, available tissues allowed for a simplified one stage reconstruction.

Correct answers: e and f

Question # 9

A 75 year old diabetic man developed forefoot abscess and necrosis from a malperforans ulcer. Acute disease was eliminated by simple transtarsal transection (image 1). This is a “good” amputation, because all major ankle motors (tendons) are attached. However, there is not enough skin to close the wound, and recessing bone to get “enough” skin will destabilize the ankle, making a leg amputation preferable. Conventional rules of plastic surgery mandate a flap to close the open joints and osteotomies. In spite of that, all but one of these conditions contraindicates a flap:

- Insufficient amount of skin on the remaining foot.
- Even if sufficient quantity, nearby skin is inelastic.
- Neuropathy risks accidental injury to the flap.
- Vascular ischemia makes flaps risky for necrosis.
- Sclerotic vessels prevent free flap anastomosis.



Answer:

Unless one is specifically doing a motor or sensory reconstruction, flap innervation is entirely irrelevant. On the contrary, dissection and elevation of almost any flap denervates it. Flap success is highly dependent on design and technique, as governed mostly by the biomechanics of soft tissues, the biophysics of blood flow, and the anatomical availability of donor tissues.

In this case, there are simply no options to design and transfer a local flap. Free flap is the textbook choice, but it is too risky in an elder vasculopathic patient. Skin grafts are permissible and safe, but almost certain to fail. If usual principles warrant a flap, but incidental conditions prevent a flap, then what? Is there any choice other than amputation or prolonged topical care?

Integra closes the wound with no risk. Understanding when a flap should but cannot be used is to understand when Integra should be used. Neither flap nor graft, it is a distinct new paradigm - in situ tissue engineering.

Correct answer: c



Question # 10

A 45 year old woman, blind in one eye from retinal artery thrombosis, ruptured her achilles tendon during exercise. Repeated operations were all complicated by necrosis and dehiscence. An eventual muscle free flap and skin grafts developed skin dystrophy and prolonged chronic ulceration (image 1). A final attempt to revise this caused more dehiscence and necrosis. The next round of her management could include all but:

- a. Workup for underlying disease.
- b. A skin graft.
- c. Biological dressing (eg, cadaver allograft, Biobrane).
- d. Skin closure with Integra® collagen-gag matrix.



Workup confirms high serum anticardiolipins. Warfarin is started. Which of these properties of Integra is suited to the reconstruction of this particular wound:

- e. No trauma or risk to host.
- f. Ability to withstand the effects of ischemia.
- g. Superlative bio-coverage and control of pathergy.
- h. The regenerated tissue is superior to flaps and scar, thin, elastic, compliant.
- i. All of these.

Answer:

If a young “healthy” patient has multiple complications or failures of soft tissue injury, underlying disease must be diagnosed. Immunopathies and hematopathologies are most suspect. In this case, a thrombosis history and the laboratory confirm a hypercoagulable disorder. In these situations, interim wound closure is advantageous, suppressing pathergy and further necrosis. Various live, dead, and pseudo-biological materials will work. This includes autogenous skin, but since host donor sites are also at risk, and since these interim grafts will likely die, non-autogenous materials are best. The value of Integra is that it serves first as the interim skin, but then it also becomes the agent of skin reconstruction.



All stated reasons, e to h, are valid properties of Integra. Its favorable biological properties and superior mechanics are all the more exceptional because they incur no risk to the patient. In this case, Integra is the best acute option because of its high grade control of inflammation and pathergy. And even if this was a healthy patient, Integra reconstruction over the achilles tendon is still preferred, because of its superior healed properties.

Correct answers: b and i

Course Overview

This course is an overview of wound surgery, the principles and methods of operative wound closure. It will focus first on the established arts of wound repair, and it will then explain new modalities of care based on contemporary technologies.

Conventional arts of wound surgery are based on three general methods: simple repairs, grafts, and flaps. Each of these three modalities of wound closure has specific indications, strategies, and techniques. They also have one thing in common: they all depend on a competent wound healing process. If the infrastructure of wound healing is working, then conventional surgery also works, as for the healthy acute wounds that arise due to trauma and surgery. If wound repair physiology is corrupt or suppressed, due to various diseases, then conventional surgery does not work. Successful closure of chronic and pathological ulcers is often impossible with these conventional methods.

There are now technology products which can stimulate repair. Most are pharmaceutical or physical modalities designed for topical use. However, one product, a collagen-aminoglycan matrix, can induce histogenesis, even under the adverse conditions of disease. This material is a distinct new paradigm of wound closure surgery – in situ tissue regeneration – and surgeons must work this new mode into their decision schemas.

Learning Objectives

1. Understand the general concepts of wound repair surgery.
2. Understand the three usual paradigms of wound closure surgery: simple repairs, grafts, and flaps. Understand the criteria by which these techniques are selected and used to close healthy acute wounds.
3. Understand the difference between acute healthy wounds in which wound healing physiology is intact, versus chronic pathological wounds due to disease, where the wound healing process per se is impaired.
4. Understand why chronic and pathological wounds defy the conventional arts of wound surgery.
5. Understand a general scheme for managing chronic wounds.
6. Become aware of new technology based products which can stimulate wound healing, and which can induce some problem wounds to heal.
7. Become familiar with Integra® collagen-aminoglycan matrix. Understand how it induces histogenesis. Understand how it withstands the adverse conditions which threaten conventional wound surgery.
8. Understand the concept of “in situ tissue engineering”, and how Integra permits this practice.
9. Understand how Integra solves the problem of closing those wounds in which flaps are ordinarily indicated but cannot be used.

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