Lower Extremity: Treatment of Open Fractures and Complex Wounds

Wong Moon, MD, FACS
Roswell Park Comprehensive Institute

ROSWELL PARK COMPREHENSIVE CANCER CENTER

Med-IQ®

Activity Overview

This presentation is to educate physicians, nurses and support staff that there are many options to reconstruct a lower extremity wound before considering amputation.

Target Audience

This activity is intended for primary care, trauma surgeons, orthopedic surgeons, podiatrist, and wound care physicians.

Instructions to Receive Credit

To receive credit, read the introductory CME material, watch the webcast, and complete the evaluation, attestation, and post-test, answering at least 70% of the post-test questions correctly.

Accreditation / Designation Statements

This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of Med-IQ and Roswell Park. Med-IQ is accredited by the ACCME to provide continuing medical education for physicians.

Med-IQ designates this enduring material for a maximum of 1.25 *AMA PRA Category 1 Credit*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Faculty

Wong Moon, MD, FACS

Associate Professor of Oncology

Department of Head and Neck/Plastic and Reconstructive Surgery

Roswell Park Comprehensive Cancer Center

Buffalo, NY

Activity Planners

Ashley Snowden

Director, Physician and Corporate Relations

Roswell Park Comprehensive Cancer Center

Elm & Carlton Streets

Buffalo, NY

Danielle M. Fleischmann, CPC

Physician Relations Liaison

Roswell Park Cancer Institute

Elm & Carlton Streets

Buffalo, NY

Samantha Gordon

CME Specialist

Med-IQ

Baltimore, MD

Kathryn Schaefer, MSN, RN, CPHRM

Senior Manager, Accreditation and Compliance

Med-IQ

East Lansing, MI

Disclosure Policy

Med-IQ requires any person in a position to control the content of an educational activity to disclose all relevant financial relationships with any commercial interest. The ACCME defines “relevant financial relationships” as those in any amount occurring within the past 12 months, including those of a spouse/life partner, that could create a conflict of interest (COI). Individuals who refuse to disclose will not be permitted to contribute to this CME activity in any way. Med-IQ has policies in place that will identify and resolve COIs prior to this educational activity. Med-IQ also requires faculty to disclose discussions of investigational products or unlabeled/unapproved uses of drugs or devices regulated by the US Food and Drug Administration.

Disclosure Statement

The content of this activity has been peer reviewed and has been approved for compliance. The faculty and contributors have indicated the following financial relationships, which have been resolved through an established COI resolution process, and have stated that these reported relationships will not have any impact on their ability to give an unbiased presentation.

Wong Moon, MD, FACS, has indicated no real or apparent conflicts.

The peer reviewers and activity planners have no financial relationships to disclose.

Learning Objectives

Upon completion, participants should be able to:

- Describe methods for assessing and managing extremity wounds
- Understand when to refer patients with more complex extremity wounds to specialists

Lower Extremity

- Open tibia fractures represent ~15 percent of all fractures in adults, with an incidence of 11.5/100,000 persons per year.
- Major complications requiring hospital treatment after attempted limb salvage range from 30 – 50% according to the Lower Extremity Assessment Project
- Incidence of infection 16% - 66%

Gustilo Classification

I	Open fracture, clean wound, wound <1 cm	Simple transverse or short oblique fractures
II	Open fracture, wound > 1 cm in length without extensive soft-tissue damage, flaps, avulsions	Simple transverse or short oblique fractures
III	Open fracture with extensive soft-tissue laceration, damage, or loss or an open segmental fracture. Fractures that have been open for 8hrs prior to treatment	High energy fracture pattern with significant involvement of surrounding tissues
IIIA	Type III fracture with adequate periosteal coverage	Gunshot injuries or segmental fractures
IIIB	Type III fracture with extensive soft-tissue loss and periosteal stripping and bone damage. Usually associated with massive contamination.	Above patterns but usually very contaminated
IIIC	Type III fracture associated with an arterial injury requiring repair, irrespective of degree of soft-tissue injury.	

Lower Extremity

- Infection
  - Soft tissue
  - osteomyelitis
- Nonunion
- Amputation
- Flap failure

Evaluation: History

- Accurate history
  - Mechanism of injury
    - Trauma (blunt, sharp, crush)
    - Infection
    - Tumor
  - Duration of injury
    - Acute (<1wk)
    - Subacute (1-6wk)
    - Chronic (>6wk)
  - Patients functional status
    - Ambulatory
    - nonambulatory

Evaluation: History

- Medications
  - steroids
  - Immunosuppression
    - Chemotherapy
    - Antirejection medication
    - Inflammatory disorders (RA)

Evaluation: History

- Past medical history
  - (Comorbidities=delayed healing)
    - Nicotine Use
    - Diabetes
    - Vascular disease (PVD, DVT)
    - Malnutrition (albumin <3)
    - Renal failure
    - Hepatic failure
    - Obesity
    - Hypothyroidism
    - Hereditary (Ehlers-Danlos Syndrome)
    - Ionizing radiation treatment
  - Cardiac, cerebral, or pulmonary issues that prohibit surgery

Evaluation: History

- Surgical history
  - Flaps or skin grafts
  - Vascular surgery
- Social history
  - Smoking
  - Drugs
  - Alcohol

Evaluation: Physical Examination

- Cardiac and pulmonary exam
- Vascular exam
- Neurologic exam
- Define the extent of tissue loss
  - Skin
  - Muscle and tendon
  - Neurovascular
  - Bone

Evaluation: Radiographic

- Plain films
- CT scan with 3-D reconstruction
- MRI
- Bone Scan
- WBC Scan
- Vascular Evaluation
  - Ankle brachial index
  - Arterial Doppler
  - Angiography
  - MRA

Lower Extremity

- Antibiotics
- Irrigation & debridement soft tissue
- Bone stabilization
- Serial irrigation & debridement soft tissue
- Soft tissue coverage

Principles of Treatment

- Early stabilization of the bone if needed
- Aggressive serial debridement of non viable tissue especially bone and muscle
- Early soft tissue coverage (within 2wks)
  - Acute phase: < 1 week
  - Subacute phase: 1 to 6 weeks
  - Chronic phase : > 6 weeks

Negative Pressure Wound Therapy After Severe Open Fractures: A Prospective Randomized Study

	Control (n=23 pt) (n=25 extremities)	Negative Pressure Wound Therapy (n=35 pt) (n=37 extremities)
Acute infections	8% (n=2)	0% (n=0)
Delayed infections	20% (n=5)	5.4% (n=2)
Deep infections	28% (n=7)*	5.4% (n=2)*
Wound bacterial colonization	20% (n=5)	8% (n=3)

Stannard, *et al J* Ortho Trauma 2009; 23:552-557

Negative Pressure Wound Therapy After Severe Open Fractures: A Prospective Randomized Study

- “The authors do not believe that NPWT should be used instead of appropriate flap or skin graft coverage”
- “The use of NPWT in conjunction with serial debridements has yielded encouraging early results in our series”

Effect of NPWT vs Standard Wound Management on 12

Month Disability Among Adults with Severe Open Fracture of the Lower Limb: The WOLLF Randomized Clinical Trial

	Control (n=234 pt)	Negative Pressure Wound Therapy (n=226 pt)
Deep infections	8.1% (19/234)	7.1% (16/226)
Wounds healed (6wks)	51.7% (93/180)	52% (91/175)
Bone union (12 mon)	71.9% (110/158)	69.6% (112/161)
Disability Rating Index (DRI)	42.4	45.5

Costa, *et al JAMA* 2018; 319(22):2280-2288

Principles of Treatment

- Consideration before closure:
  - Extent of soft tissue deficit
    - Zone of injury in high velocity injuries
  - Limited vascularity of the extremity
  - Exposure of nerve, tendon, bone and cartilage

Lower Extremity

- Early skin coverage 3-7(10)days
  - ↓ infection
  - ↓ pain
  - ↓ amputation
  - ↑ bone union
  - ↑ wound healing/flap success
  - ↑ walking
- Amputation

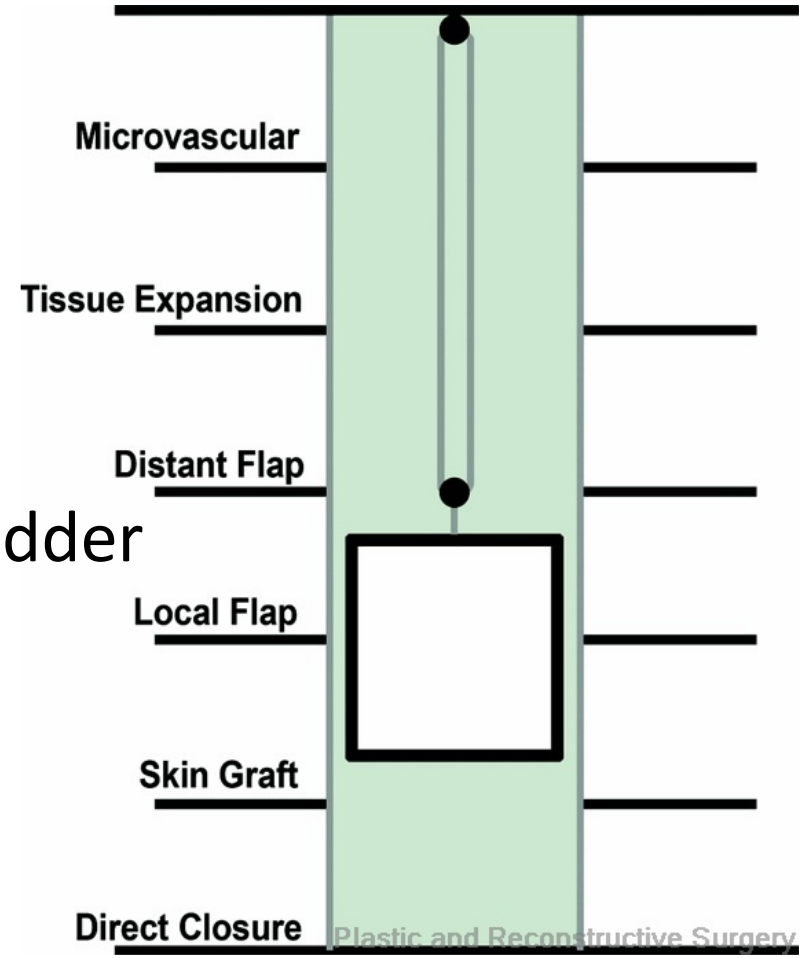
Byrd, *et al PRS* 1985; 76:719-730--191

Godina, *et al PRS* 1986; 78:285-292--532

Lee, *et al PRS 2019*; 144(3):759-767--358

Techniques of Wound Coverage

Reconstructive Ladder



Biologic Scaffolds:

- Allografts
  - Dermal substitutes
  - Other collagen matrixes
  - Cultures cells
- Xenografts
  - Dermal substitutes
  - Other collagen matrixes
  - Cultured cells

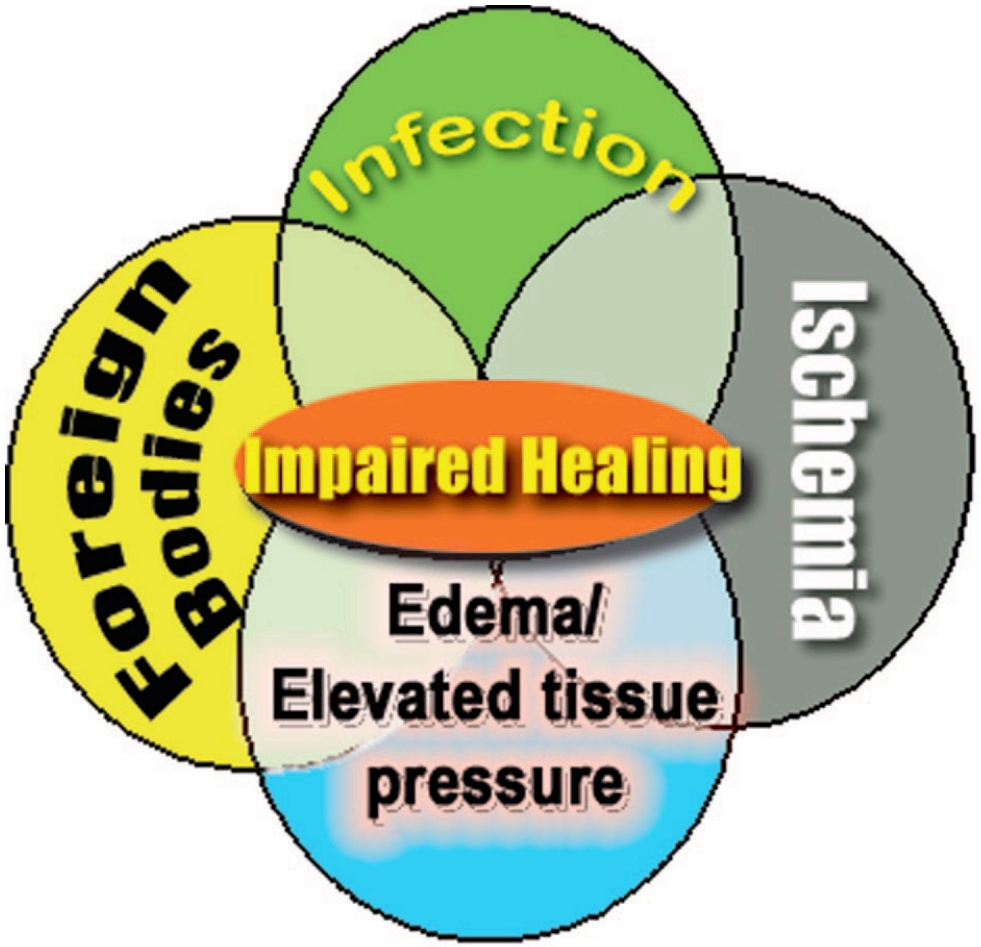
Phases of skin graft healing

- Imibibition (1-2d)
  - Cells survive by diffusion of plasma
- Inosculation (2d -1wk)
  - Vascular buds to vessels in skin graft
  - Revascularization of base and periphery
- Remodeling (1wk-1mon)

Phases of wound healing

- Inflammatory Phase (0-6d)
  - Hemostasis (vasoconstriction, platelet aggregation, thromboplastin)
  - Inflammation (vasodilation, macrophages)
- Proliferative Phase (4d to 2wks)
  - Granulation (fibroblasts, collagen, capillaries)
  - Contraction
  - Epithelialization (3cm)
- Remodeling Phase (2wks-1yr)
  - New collagen type I
  - 3mon 80% wound strength

Local factors impairing wound healing



Grafting:

Indications

- Clean wound
- Flat surface
- “Good” vascular bed
  - No dead tissue
  - peripheral vascular disease
- No foreign body
  - Hardware exposure
  - Cement
- Small wounds
- No other additional surgery is necessary or temporary coverage (shear force unstable)

Contraindications

- Infection
- Dead space
- Poor vascular bed
  - Dead tissue
  - Severe peripheral vascular disease
- Foreign body
  - Hardware
  - Cement
- Larger wounds
- Additional surgery is necessary

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

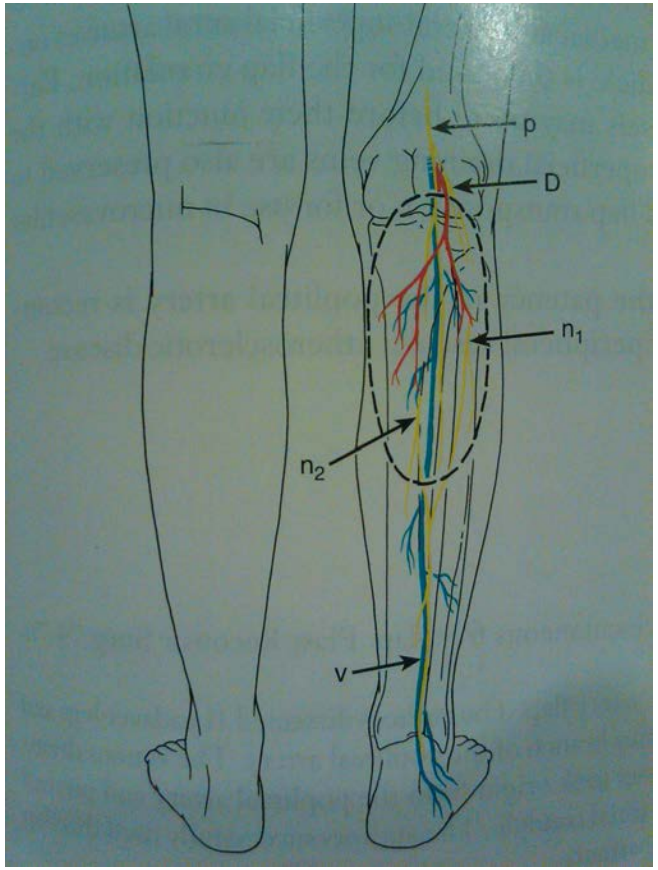
Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Biologic Scaffold

Pedicle Flap: Reverse Sural



Pedicle Flap: Reverse Sural

Pedicle Flap: Reverse Sural

Pedicle Flap: Reverse Sural

Fasciocutaneous and Muscle Flaps

Fasciocutaneous

- Higher vascular density
- ↑ wound healing
- ↑ fracture healing
- ↑ antimicrobial properties

Muscle

- Less vascular density
- ↑ wound healing
- ↑ fracture healing
  - ↑ osteogenic mesenchymal stem cells
  - ↑ bone anabolics such as interleukin-6 and fibroblast grow factor-2
- ↑ antimicrobial properties.

Choice of Free Flaps

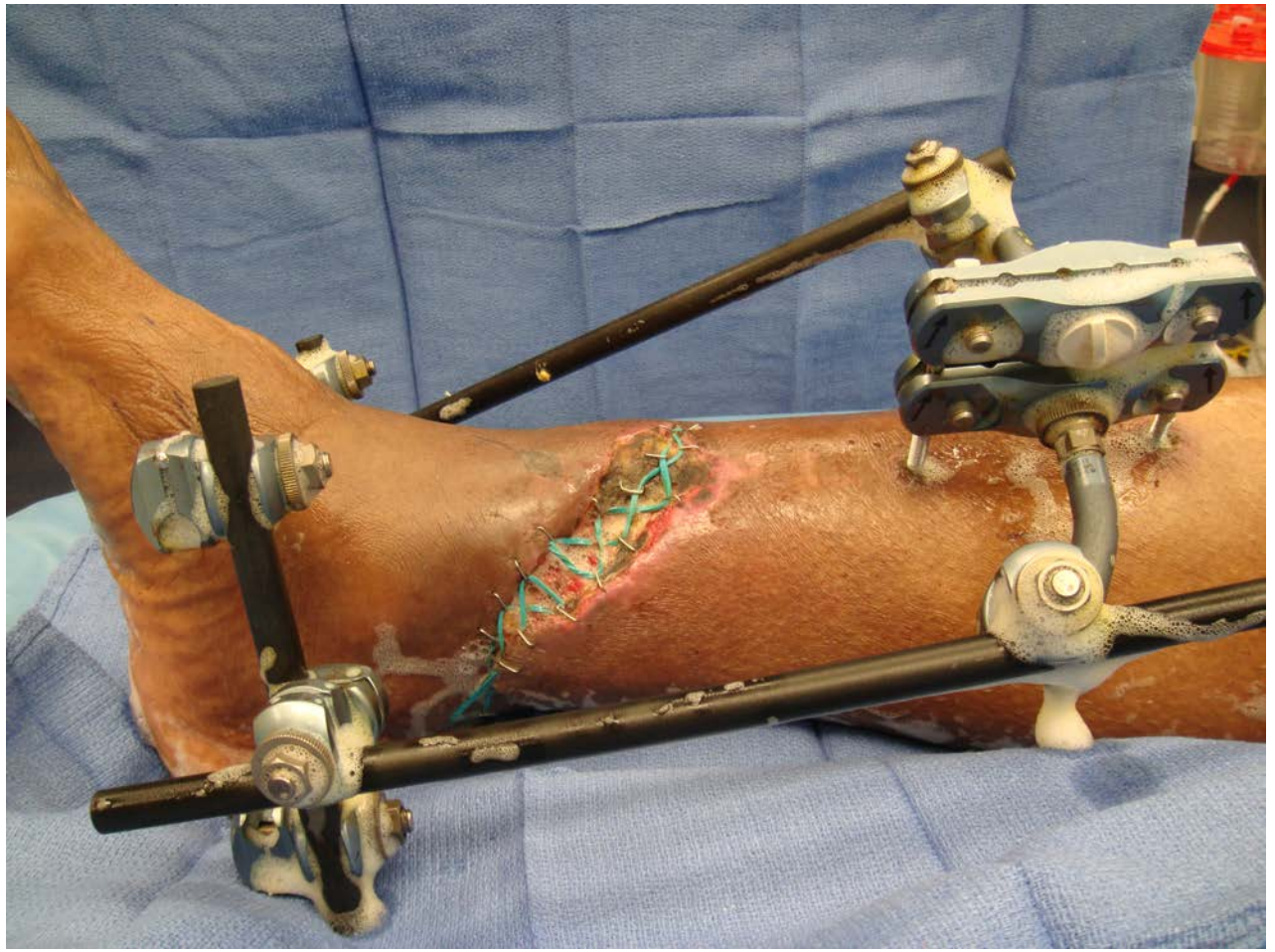
- Large diameter vessels
  - Flow is related to the radius of the vessel to the 4th power
- Consistent anatomy
- Long pedicle
- Minimal atherosclerosis

Free Flap: Muscle

- Advantages
  - Obliterate dead space
  - Larger vessel
  - Shorter operating time

- Disadvantages
  - Tolerate shorter ischemia time (1hr)
  - Loss of muscle function
  - Irregular contour
  - Large composite 3-D defects
  - Harder to elevate
  - No sensation

Muscle Flap: Gracilis



Muscle Flap: Gracilis

Muscle Flap: Gracilis

Muscle Flap: Gracilis

Free Flap: Fasciocutaneous

- Advantages
  - No functional muscle deficit
  - Replaces like tissue
  - Similar contour
  - Easier to elevate flap
  - Easier to contour/thin flap
  - Tolerate longer ischemia time (4hrs)
  - Innervate for sensation
- Disadvantage
  - Smaller to moderate size defects
  - Superficial defects
    - Does not obliterate dead space
  - Smaller vessels
  - Donor site defect?
  - Longer operative time

Fasciocutaneous Flap:ALT

Fasciocutaneous Flap:ALT

Fasciocutaneous Flap:ALT

Fasciocutaneous Flap:ALT

Fasciocutaneous Flap:ALT

Fasciocutaneous Flap:ALT

Mortality

- Large studies of general surgery patients show a mortality rate of 5 percent for 80-90 y.o.
- 13 to 25 percent for > 90 y.o.

Djokovic, *et al JAMA* 242: 2301, 1979

Conclusion

- Accurate history and physical exam
- Early treatment aggressive debridement
- Reverse sural artery perforator flap
  - Venous stasis
  - PVD
- Advances in last 15 years
  - Tissue matrixes
  - Fasciocutaneous flaps
- Treat patients how you or your family members would be treated
- Get advice from colleagues

References

- Byrd HS, Spicer TE, Cierney G III. Management of open tibial fractures. *Plast Reconstr Surg.* 1985;76:719–730.
- Godina M. Early microsurgical reconstruction of com- plex trauma of the extremities. *Plast Reconstr Surg*. 1986;78:285–292.
- StannardJP,VolgasDA,StewartR,McGwinGJr, Alonso JE. Negative pressure wound therapy after severe open fractures:a prospective randomized study. *J Orthop Trauma*. 2009;23(8):552-557.
- Aslan A, Uysal E, Ozmeriç A. A staged surgical treatment outcome of type 3 open tibial fractures. ISRN Orthop. 2014;2014:721041.
- Arnez ZM, Papa G, Ramella V, et al. Limb and flap salvage in Gustilo IIIC injuries treated by vascular repair and emer- gency free flap transfer. J Reconstr Microsurg. 2017;33:S03–S07.
- Soni A, Tzafetta K, Knight S, Giannoudis PV. Gustilo IIIC fractures in the lower limb: Our 15-year experience. J Bone Joint Surg Br. 2012;94:698–703.
- Medina, Nilton D.; Kovach, Stephen J. III; Levin, L. Scott. An Evidence-Based Approach to Lower Extremity Acute Trauma. Plastic and Reconstructive Surgery. 127(2):926-931, February 2011.

References

- Kumar, Anand R.; Grewal, Navanjun S.; Chung, Thomas L.; More. Lessons from Operation Iraqi Freedom: Successful Subacute Reconstruction of Complex Lower Extremity Battle Injuries. Plastic and Reconstructive Surgery. 123(1):218-229, January 2009.
- Ricci, Joseph A.; Stranix, John T.; Lee, Z-Hye; More. Comparing Reconstructive Outcomes in Patients with Gustilo Type IIIB Fractures and Concomitant Arterial Injuries. Plastic and Reconstructive Surgery. 143(5):1522-1529, May 2019.
- Feng, Shaoqing; Min, Peiru; Grassetti, Luca; et al. A Prospective Head-to-Head Comparison of Color Doppler Ultrasound and Computed Tomographic Angiography in the Preoperative Planning of Lower Extremity Perforator Flaps. Plastic and Reconstructive Surgery. 137(1):335-347, January 2016.
- Heller, Lior; Levin, L. Scott. Lower Extremity Microsurgical Reconstruction. Plastic and Reconstructive Surgery. 108(4):1029-1041, September 15, 2001.
- Momoh, Adeyiza O.; Kumaran, Senthil; Lyons, Daniel; More. An Argument for Salvage in Severe Lower Extremity Trauma with Posterior Tibial Nerve Injury: The Ganga Hospital Experience. Plastic and Reconstructive Surgery. 136(6):1337-1352, December 2015.

References

- Ricci, Joseph A.; Abdou, Salma A.; Stranix, John T.; More. Reconstruction of Gustilo Type IIIC Injuries of the Lower Extremity. Plastic and Reconstructive Surgery. 144(4):982-987, October 2019.
- Lee, Z-Hye; Stranix, John T.; Rifkin, William J.; More. Timing of Microsurgical Reconstruction in Lower Extremity Trauma: An Update of the Godina Paradigm. Plastic and Reconstructive Surgery. 144(3):759-767, September 2019.
- Abdelfattah, Usama; Power, Hollie A.; Song, Sinyoung; More. Algorithm for free perforator flap selection in lower extremity reconstruction based on 563 cases. Plastic and Reconstructive Surgery. ., Post Acceptance: August 05, 2019
- Stranix, John T; Azoury, Said; Lee, Z-Hye; More. “Matched Comparison of Microsurgical Anastomoses Performed with Loupes Magnification Versus Operating Microscope in Traumatic Lower Extremity Reconstruction”. Plastic and Reconstructive Surgery. ., Post Acceptance: October 08, 2019
- Egeler, Sabine A.; de Jong, Tim; Luijsterburg, Antonius J. M.; More. Long-Term Patient-Reported Outcomes following Free Flap Lower Extremity Reconstruction for Traumatic Injuries. Plastic and Reconstructive Surgery. 141(3):773-783, March 2018.

References

- Soltanian, Hooman; Garcia, Ryan M.; Hollenbeck, Scott T. Current Concepts in Lower Extremity Reconstruction. Plastic and Reconstructive Surgery. 136(6):815e-829e, December 2015.
- Sheckter, Clifford C.; Pridgen, Brian; Li, Alexander; More. Regional Variation and Trends in the Timing of Lower Extremity Reconstruction: A 10-Year Review of the Nationwide Inpatient Sample. Plastic and Reconstructive Surgery. 142(5):1337-1347, November 2018.
- Cho, Eugenia H.; Shammas, Ronnie L.; Carney, Martin J.; More. Muscle versus Fasciocutaneous Free Flaps in Lower Extremity Traumatic Reconstruction: A Multicenter Outcomes Analysis. Plastic and Reconstructive Surgery. 141(1):191-199, January 2018.
- Momeni, Arash; Lanni, Michael; Levin, L. Scott; More.Microsurgical Reconstruction of Traumatic Lower Extremity Defects in the Pediatric Population. Plastic and Reconstructive Surgery. 139(4):998-1004, April 2017.
- Shammas, Ronnie L.; Mundy, Lily R.; Truong, Tracy; More. Identifying Predictors of Time to Soft-Tissue Reconstruction following Open Tibia Fractures. Plastic and Reconstructive Surgery. 142(6):1620-1628, December 2018.
- Hollenbeck, Scott T.; Toranto, Jason D.; Taylor, Bruce J.; More. Perineal and Lower Extremity Reconstruction. Plastic and Reconstructive Surgery. 128(5):551e-563e, November 2011.
- Weichman, Katie E.; Dec, Wojciech; Morris, Carol D; More. Lower Extremity Osseous Oncologic Reconstruction with Composite Microsurgical Free Fibula Inside Massive Bony Allograft. Plastic and Reconstructive Surgery. 136(2):396-403, August 2015.

References

- Stranix, John T.; Lee, Z-Hye; Jacoby, Adam; More. Forty Years of Lower Extremity Take-Backs: Flap Type Influences Salvage Outcomes. Plastic and Reconstructive Surgery. 141(5):1282-1287, May 2018.
- Lachica, Roberto D. Evidence-Based Medicine: Management of Acute Lower Extremity Trauma. Plastic and Reconstructive Surgery. 139(1):287e-301e, January 2017.
- Sabino, Jennifer; Polfer, Elizabeth; Tintle, Scott; More. A Decade of Conflict: Flap Coverage Options and Outcomes in Traumatic War-Related Extremity Reconstruction. Plastic and Reconstructive Surgery. 135(3):895-902, March 2015.
- Engel, Holger; Lin, Chih-Hung; Wei, Fu-Chan. Role of Microsurgery in Lower Extremity Reconstruction. Plastic and Reconstructive Surgery. 127:228S-238S, January 2011.
- Crowe, Christopher S.; Cho, Daniel Y.; Kneib, Cameron J.; More.
  Strategies for Reconstruction of the Plantar Surface of the Foot: A Systematic Review of the Literature. Plastic and Reconstructive Surgery. 143(4):1223-1244, April 2019.
- Harrison, Bridget L.; Lakhiani, Chrisovalantis; Lee, Michael R.; More. Timing of Traumatic Upper Extremity Free Flap Reconstruction: A Systematic Review and Progress Report. Plastic and Reconstructive Surgery. 132(3):591-596, September 2013.
- Hui-Chou, Helen G.; Sulek, Jay; Bluebond-Langner, Rachel; More

References

- Hui-Chou, Helen G.; Sulek, Jay; Bluebond-Langner, Rachel; More. Secondary Refinements of Free Perforator Flaps for Lower Extremity Reconstruction. Plastic and Reconstructive Surgery. 127(1):248-257, January 2011.
- Hallock, Geoffrey G. Evidence-Based Medicine: Lower Extremity Acute Trauma. Plastic and Reconstructive Surgery. 132(6):1733-1741, December 2013.
- Casey, Kevin; Sabino, Jennifer; Jessie, Elliot; More. Flap Coverage Outcomes following Vascular Injury and Repair: Chronicling a Decade of Severe War-Related Extremity Trauma. Plastic and Reconstructive Surgery. 135(1):301-308, January 2015.
- Colen, David L.; Carney, Martin J.; Shubinets, Valeriy; More. Soft-Tissue Reconstruction of the Complicated Knee Arthroplasty: Principles and Predictors of Salvage. Plastic and Reconstructive Surgery. 141(4):1040-1048, April 2018.
- Eom, Jin Sup; Sun, Sang Hoon; Hong, Joon Pio. Use of the Upper Medial Thigh Perforator Flap (Gracilis Perforator Flap) for Lower Extremity Reconstruction. Plastic and Reconstructive Surgery. 127(2):731-737, February 2011.
- Hallock, Geoffrey G. Lower Extremity Muscle Perforator Flaps for Lower Extremity Reconstruction. Plastic and Reconstructive Surgery. 114(5):1123-1130, October 2004.
- Costa ML, Achten J, Bruce J, Tutton E, Petrou S, Lamb SE, Parsons NR; UK WOLLF Collaboration. Effect of Negative Pressure Wound Therapy vs Standard Wound Management on 12-Month Disability Among Adults With Severe Open Fracture of the Lower Limb: The WOLLF Randomized Clinical Trial. JAMA. 2018 Jun 12;319(22):2280-2288. doi: 10.1001/jama.2018.6452.

Instructions to Receive Credit

To receive credit, read the introductory CME material, watch the webcast, and complete the evaluation, attestation, and post-test, answering at least 70% of the post-test questions correctly.

Contact Information

Call (toll-free) 866 858 7434
Email info@med-iq.com

Please visit us online at www.Med-IQ.com for additional activities provided by Med-IQ®.