Lower Extremity:
Treatment of Open Fractures
and Complex Wounds
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.
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.
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.
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**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Open fracture, clean wound, wound &lt;1 cm</td>
<td>Simple transverse or short oblique fractures</td>
</tr>
<tr>
<td>II</td>
<td>Open fracture, wound &gt; 1 cm in length without extensive soft-tissue damage, flaps, avulsions</td>
<td>Simple transverse or short oblique fractures</td>
</tr>
<tr>
<td>III</td>
<td>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.</td>
<td>High energy fracture pattern with significant involvement of surrounding tissues</td>
</tr>
<tr>
<td>IIIA</td>
<td>Type III fracture with adequate periosteal coverage</td>
<td>Gunshot injuries or segmental fractures</td>
</tr>
<tr>
<td>IIIB</td>
<td>Type III fracture with extensive soft-tissue loss and periosteal stripping and bone damage. Usually associated with massive contamination.</td>
<td>Above patterns but usually very contaminated</td>
</tr>
<tr>
<td>IIIC</td>
<td>Type III fracture associated with an arterial injury requiring repair, irrespective of degree of soft-tissue injury.</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
<th>Control (n=23 pt) (n=25 extremities)</th>
<th>Negative Pressure Wound Therapy (n=35 pt) (n=37 extremities)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute infections</td>
<td>8% (n=2)</td>
<td>0% (n=0)</td>
</tr>
<tr>
<td>Delayed infections</td>
<td>20% (n=5)</td>
<td>5.4% (n=2)</td>
</tr>
<tr>
<td>Deep infections</td>
<td>28% (n=7)*</td>
<td>5.4% (n=2)*</td>
</tr>
<tr>
<td>Wound bacterial colonization</td>
<td>20% (n=5)</td>
<td>8% (n=3)</td>
</tr>
</tbody>
</table>

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

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

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

Techniques of Wound Coverage

Reconstructive Ladder

- Microvascular
- Tissue Expansion
- Distant Flap
- Local Flap
- Skin Graft
- Direct Closure
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
- Inosculuation (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

- Infection
- Ischemia
- Foreign Bodies
- Edema/Elevated Tissue Pressure
- Impaired 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
Pedicle Flap: Reverse Sural
Pedicle Flap: Reverse Sural
Pedicle Flap: Reverse Sural
## Fasciocutaneous and Muscle Flaps

<table>
<thead>
<tr>
<th>Fasciocutaneous</th>
<th>Muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Higher vascular density</td>
<td>– Less vascular density</td>
</tr>
<tr>
<td>• ↑ wound healing</td>
<td>– ↑ wound healing</td>
</tr>
<tr>
<td>• ↑ fracture healing</td>
<td>– ↑ fracture healing</td>
</tr>
<tr>
<td>• ↑ antimicrobial properties</td>
<td>• ↑ osteogenic mesenchymal stem cells</td>
</tr>
<tr>
<td></td>
<td>• ↑ bone anabolics such as interleukin-6 and fibroblast growth factor-2</td>
</tr>
<tr>
<td></td>
<td>– ↑ antimicrobial properties.</td>
</tr>
</tbody>
</table>
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
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.

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


References


• 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


References

- Hui-Chou, Helen G.; Sulek, Jay; Bluebond-Langner, Rachel; More
References

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®.

Unless otherwise indicated, photographed subjects who appear within the content of this activity or on artwork associated with this activity are models; they are not actual patients or doctors.