The Birth and Evolution of Topical Negative Pressure

Atlanta Trauma Course
April, 2017

Lawrence X Webb MD
Orthopaedic Trauma
Navicent Medical Center
Macon, Georgia

Lawrence X Webb MD
Disclosures (last 10 yrs)

Research and Educational Support: Synthes, Zimmer, OREF,
NIH, US Dept of Defense
Musculoskeletal Transplant Foundation – Speaker
Zimmer consultant, serves in education and on surgical panels
Biocomposites Inc Consultant
Board, Southeastern Fracture Consortium,
Board, Central Georgia Health Network
Chair OTA Bylaws Committee

Colleagues/Collaborators

• Lou Argenta MD, Michael Morykwas PhD,
  Tony DeFranzo, MD, Joe Molnar, MD, PhD,
  Steve Tatter, MD, PhD, Maria Mcgee MD,
  Zhen Zeng MD, PhD, Tom Smith, PhD,
  David Carroll, PhD

• Plastic Surgery, Orthopaedic Surgery,
  Neurosurgery, Cardiovascular Surgery,
  Basic Sciences, Nanotechnology
"IMSICS"

- "A novel protocol for managing the high-energy open fracture involves two techniques. First, Bernoulli's principle is used to facilitate a systematic excision of contaminants, as well as the wound surface to which they are adsorbed. Second, topical negative pressure is established to resuscitate the remaining edema laden wound tissue to help avoid embarrassment to the microcirculatory blood flow."

Joe Molnar MD, PhD and Tony DeFranzo MD

• Burn conference, presentations on burn dressings and the mediocre results to date with artificial skin - difficulties with % “take” and quality of the “take”
• At coffee break…
Early '70s through 2006 (over 30 years!)

Acceleration of Integra incorporation in complex tissue defects with subatmospheric pressure

- N=8 with complex wounds
- Exposed bone in 62.5%, joint in 50%, tendon in 37.5% and bowel in 25%
- Complications: 0
- Integra take was 96%
- STSG @ 4-11 days (mean of 7.25) with a 93% take rate.
- Conclusion: Application of subatmospheric pressure improved the take rate and time to vascularization of Integra, compared to previous published results, even with complicated wounds.


Peel Strength (dynes x 10^3)

- p<0.01
Histological Analysis

3 Days

Capillary

3 Days
High energy open wound

Debridement, stabilization, appropriate dressings
Return for a "second look" debridement at 24-48 hrs

"Demarcates"

B Brumback’s “Debridement” in Lower Extremity Salvage and Reconstruction
Trauma- tissue damage, foreign debris, bacteria

Inflammatory Mediators, Free Radicals, Vasoactive Substances

Leaky Capillaries

Extravascular tissue space edema and elevated interstitial pressure

Venular embarrassment, Increased capillary afterload

Compromised exchange of O₂ and CO₂, glucose and urea

Cell, Tissue Death

Surgical Debridement

Antibiotic

Skeletal Stabilization

TNP

Cell, Tissue Death

The contaminated high-energy open fracture: a protocol to prevent and treat inflammatory mediator storm-induced soft-tissue compartment syndrome (IMSICS).

Webb LX1, Dedmond B, Schlatterer D, Laverty D.

Abstract

The treatment modalities currently used in surgical débridement leave the traumatic wound with viable but tenuous tissue and a variable level of microcontaminants potentially laden with bacteria. In high-energy contaminated wounds, retention of these contaminants within the tenuous tissue of the so-called zone of stasis can result in further tissue necrosis and the development of infection. A novel protocol for managing the high-energy contaminated open fractures involves two new techniques. First, Bernoulli’s principle is used to facilitate a systematic excision of contaminants, as well as the wound surface to which they are adsorbed, by means of a high-velocity fluid stream. Second, topical negative pressure is established as a means to resuscitate the remaining edema-laden wound tissue to help avoid embarrassment to microcirculatory blood flow.
Jackson’s 3 zones of a burn wound (1947)

- Zone of coagulation
- Zone of stasis
- Zone of hyperemia
Evacuation of an Engorged Interstitium
(diminution of capillary afterload)

Microvascular Effects of Subatmospheric Pressure in Striated Muscle

- Rat cremaster model
- Increased blood flow (significant arteriolar dilatation)
- Decreased albumin in the interstitium (washout of fluorescein isothiocyanate (FITC)-labeled albumin and topical leukotriene B4 (LTB4) delivered to the cremaster

N=211, 56 (26.5%)
Wound Description | % INFECTED
---|---
GSW (n/N) | 21.7
SCHRAPNEL (n/N) | 32.7


Experience with Wound VAC and Delayed Primary Closure of Contaminated Soft Tissue Injuries in Iraq

- Ni=88 high-energy soft tissue wounds in 77 patients.
- All were high-energy injuries, treated with rapid and aggressive debridement with pulsatile lavage, then covered with negative pressure (vacuum-assisted closure [VAC]) dressings while in the O.R.
- wound infection rate: 0%
- overall wound complication rate was: 0%
- “Experience with these patients suggests that conventional wound management doctrine may be improved with the wound VAC, resulting in earlier more reliable primary closure of wartime injuries.
- Evidence: Level IV

Leininger,B et al. J Trauma. 2006 Nov;61(5):1207-11

Goals of Operative Debridement

- Removal/Elimination of wound contaminants
- Removal/Elimination of bacteria
- Removal/Elimination of all necrotic
- Resuscitation of Tissue in peril?
Complex Traumatic Wound

- That which is dead
- That which may die
- Reactive tissue

Infarct

- That which is dead
- That which may die
- Reactive tissue

Blood Flow Changes in Normal and Ischemic Myocardium During Topically Applied Negative Pressure

- 6 pigs, Laser-Doppler Velocimetry. Analyses were performed before (LAD occlusion, normal myocardium), after 20 minutes of LAD occlusion (ischemic myocardium), and after an interval of reperfusion (reperfused myocardium).
- TNP at -50 mm Hg increased microvascular blood flow in the normal myocardium from 14.7 ± 3.9 perfusion units (PU) before to 25.8 ± 6.1 PU after TNP application (p < 0.05), in the ischemic myocardium from 7.2 ± 1.5 PU before to 13.8 ± 2.6 PU after TNP application (p < 0.05), and in the reperfused myocardium from 10.8 ± 2.0 PU before to 19.3 ± 5.6 PU after TNP application (p < 0.05) (78.7%, 92%, 93% respectively).

- Conclusion: TNP increases the microvascular blood flow significantly in normal, ischemic, and reperfused myocardium, thereby lowering the risk for re-infarction and may provide a novel therapeutic tool in the treatment of ischemic myocardium.

Reduction of Myocardial Ichemia-Reperfusion Injury by Mechanical Tissue Resuscitation Using Sub-Atmospheric Pressure

• Swine model
• Untreated control vs 75 min LAD occlusion and 3 hrs reperfusion
• Total area of cell death reduced by 65% with -50mmHg


The effect of different topical negative pressures on microvascular blood flow in reperfused myocardium during hypothermia

• 7 pigs  Doppler velocimetry recorded before and after application of -50, -75, -100, -125 and -150 mmHg
• A TNP of -50mmHg significantly increased blood flow in the epicardium from 116.7PU to 244.5PU (p<0.05) and a TNP of -50mmHg significantly increased blood flow in the myocardium from 116.7PU to 244.5PU (p<0.05)
• Conclusion: Only a TNP of -50 mmHg applied over the LAD artery region in reperfused hypothermic myocardium significantly increased the microvascular blood flow in the epicardium and in the myocardium


Incisional VAC

• Patient in ICU
• Weeping wounds in ICU or floor
• Applied on all operated obese patients, acetabular fracture patients and “iffy” wounds in the OR
• Grand Rounds to present in Birmingham March 1993…
Prospective RCT
4 centers,
• N=249 with 263 high risk fx types
• T. plateau, pilon, calcaneus
• 23 infections in control, 14 in incisional NPWT
• Difference was significant (p=0.049)
• Rel risk was 1.9x higher in controls vs NPWT
• Evidence: level 1


Impact of negative pressure wound therapy on open diaphyseal tibial fractures: A Prospective RCT
• N= 93 open tibial fractures randomized to two groups receiving NPWT and the second group undergoing periodic irrigation, cleaning and debridement respectively
• Wounds were closed/covered on shrinkage in size and sufficient granulation. Evidence of infection was sought during the course of treatment and follow up. Also, serial cultures were sent every time the wound was cleaned.
• Control: 11 infections (22%) vs 2(4.6%) in the NPWT group. Relative risk (95% confidence interval) suggests patients who received NPWT were 5.5 times less likely to develop infection.
• Only 5 patients (25%) went on to develop osteomyelitis, all being part of the control group

Take Away Points
• Wounds- resuscitation of IMSICS/ Jackson’s Zone 2/tissue reperfusion zone
• Coverage- stsg, integra
• Survival of random pattern flap
• Incisional VAC
• Thwart to Infection in Surgical Wounds
• Thwart to Infection (acute and chronic) in open tibial fractures
• Prospects for other tissues (heart and brain)