

The Birth and Evolution of Topical Negative Pressure

Atlanta Trauma Course
April, 2017

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Orthopaedic Trauma
Navicent Medical Center
Macon, Georgia

Lawrence X Webb MD Disclosures (last 10 yrs)

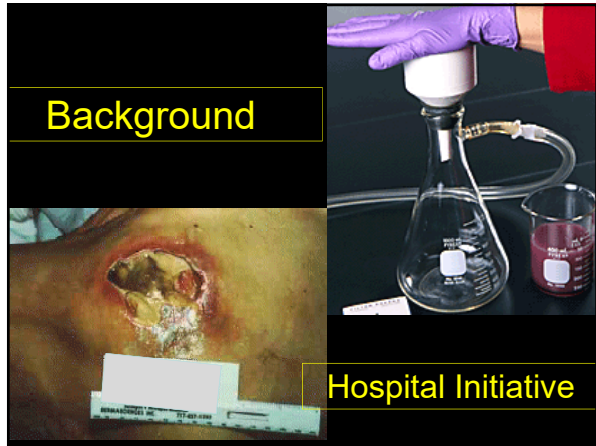
Research and Educational Support: Synthes, Zimmer, OREF,
NIH, US Dept of Defense

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

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Foundation (MTF), NFL Charities, Orthopaedic Research & Education Foundation
(OREF), Orthopaedic Trauma Association (OTA), Scoliosis Research Society (SRS),
Smith & Nephew, Synthes, Synthes Spine, Wiesler, Mordecai, Wright Medical
Technology, Zimmer

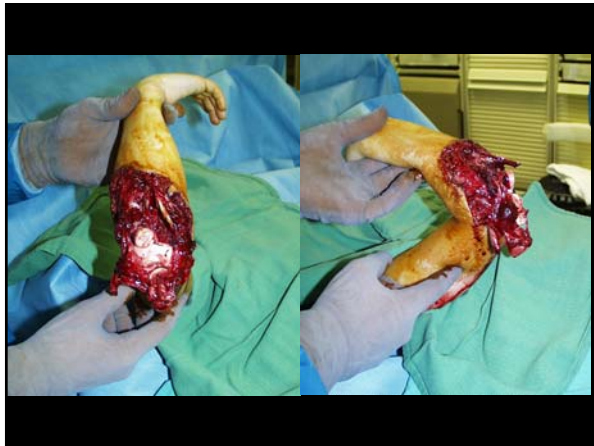
Colleagues/Collaborators

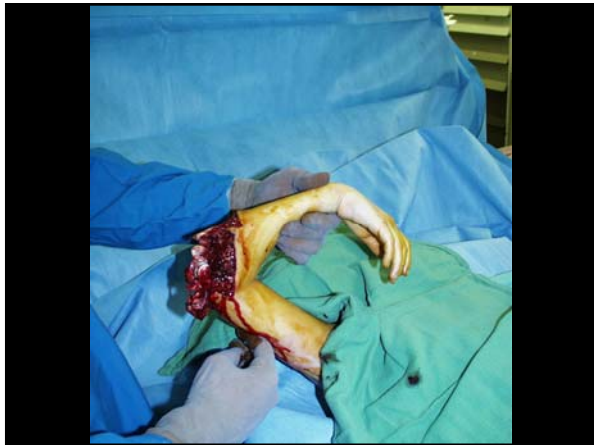
- Lou Argenta MD, Michael Morykwas PhD,
Tony DeFranzo, MD, Joe Molnar, MD, PhD,
Steve Tatter, MD, PhD, Maria McGee MD,
Zhen Zeng MD, PhD, Tom Smith, PhD,
David Carroll, PhD
- Plastic Surgery, Orthopaedic Surgery,
Neurosurgery, Cardiovascular Surgery,
Basic Sciences, Nanotechnology



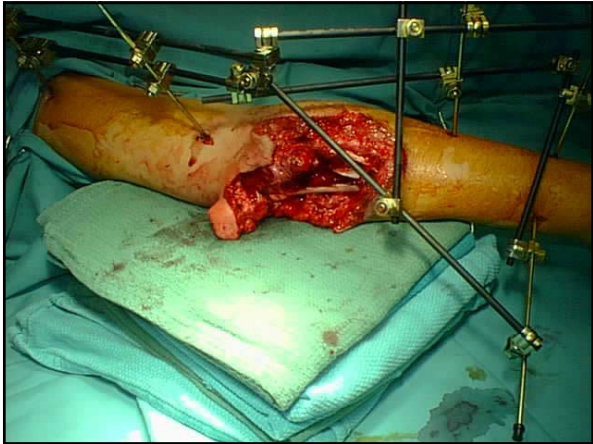


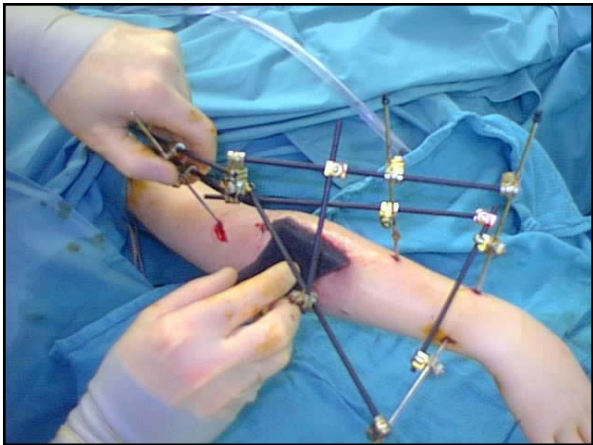








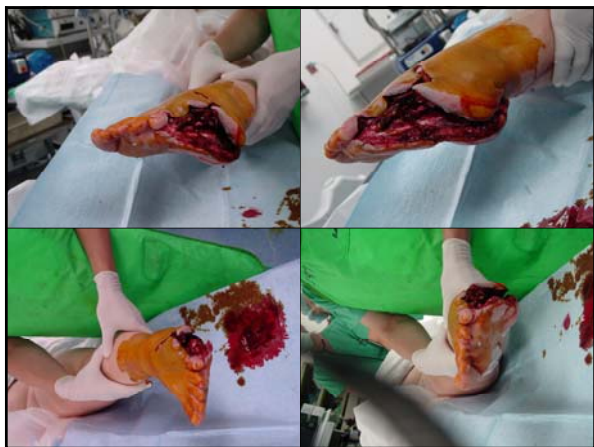






















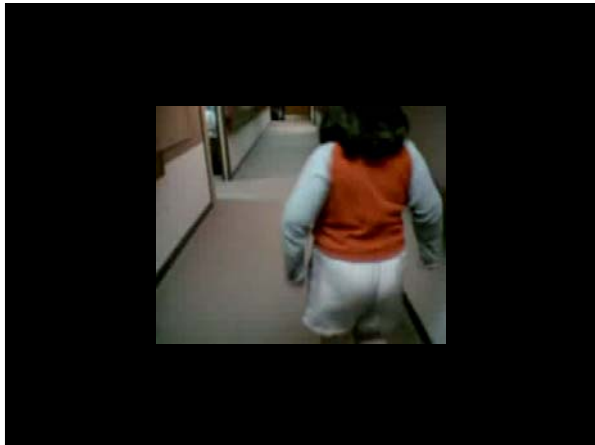


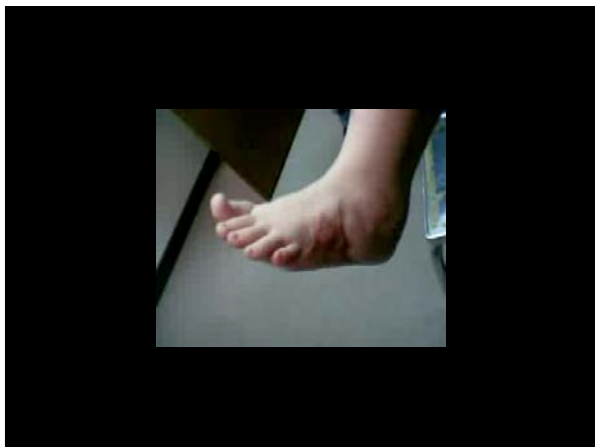






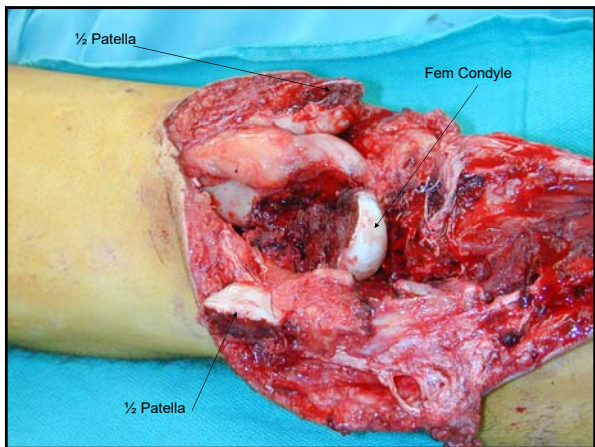


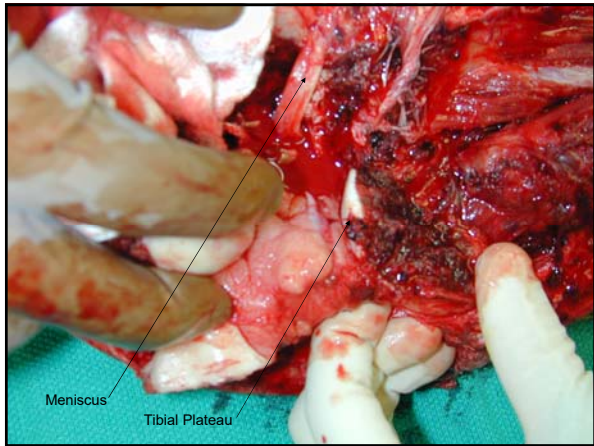


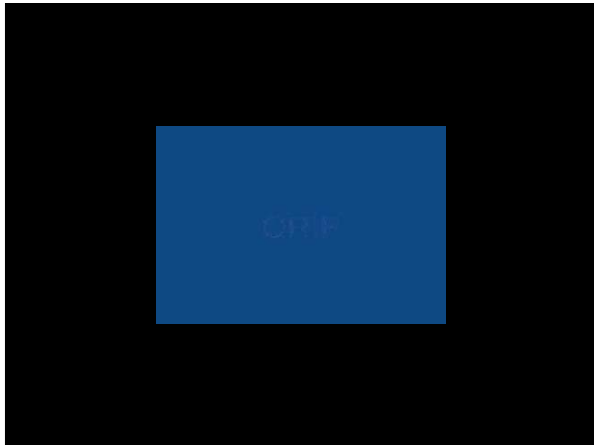


15-25 yo WM
involved in
MVA
Painful knee
inability to
bend knee
inability to
straighten knee



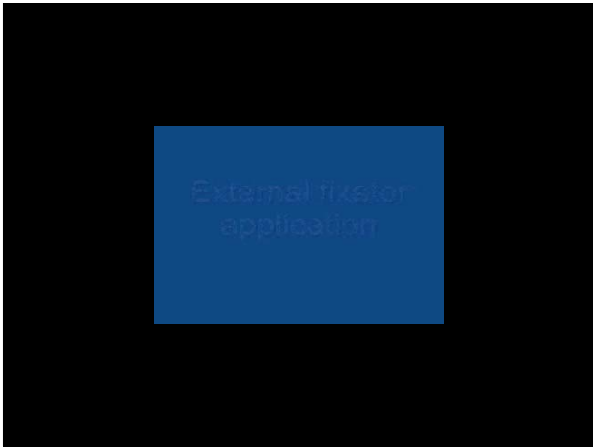






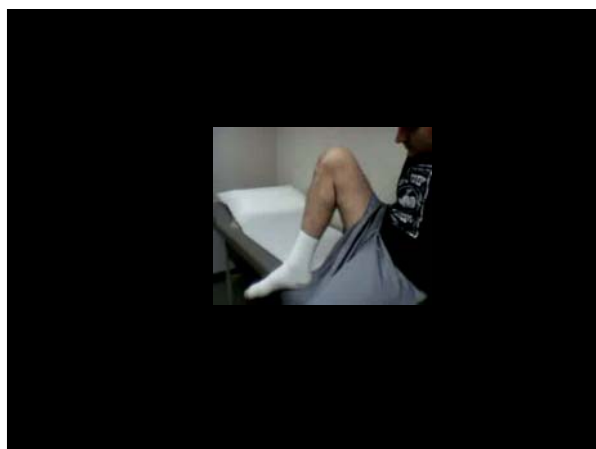












"IMSICS"

- "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."

Webb LX, Dedmond B, Schlatterer D, Lavery D. The contaminated high-energy open fracture: A protocol to prevent and treat inflammatory mediator storm-induced soft-tissue compartment syndrome (IMSICS). J Am Acad Orthop Surg, 2006 Oct 14(10 Suppl): S82-6.



**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...

Moisture

Epithelial cells

Endothelial cells
Fibroblasts

John F. Burke MD

and

Ioannas Yannas PhD

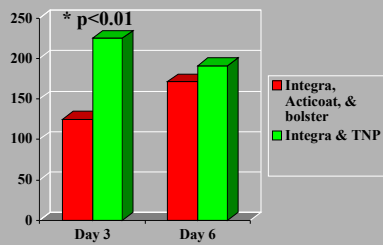
Early '70s through 2006 (over 30 years!)

Acceleration of Integra incorporation in complex tissue defects with subatmospheric pressure

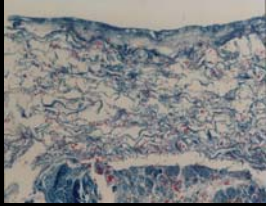
- N=8 with complex wounds
- Exposed bone in 62.5%, joint in 50%, tendon in 37.5% and bowel in 25%
- Complications: 0
- Integra take was 96%
- STSG @ 4-11 days (mean of 7.25) with a 93% take rate.
- Conclusion: Application of subatmospheric pressure improved the take rate and time to vascularization of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

Molnar, J., DeFranzo, A et al. *Plast Reconstr Surg.* 2004 Apr 15;113(5):1339-46.

Peel Strength (dynes x 10³)



Histological Analysis



3 Days

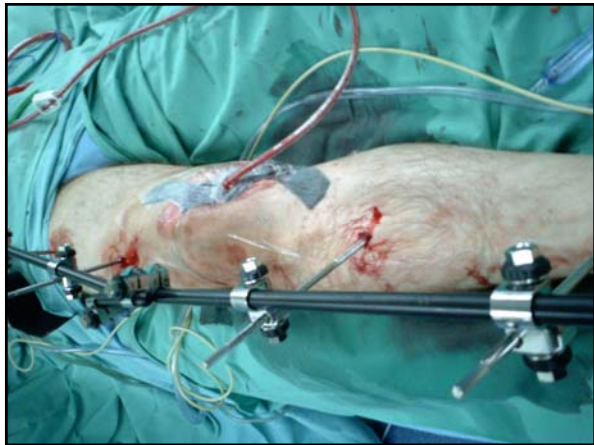


3 Days















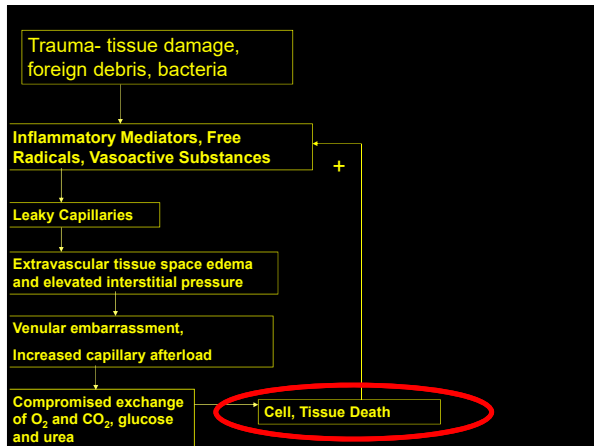
High energy open wound

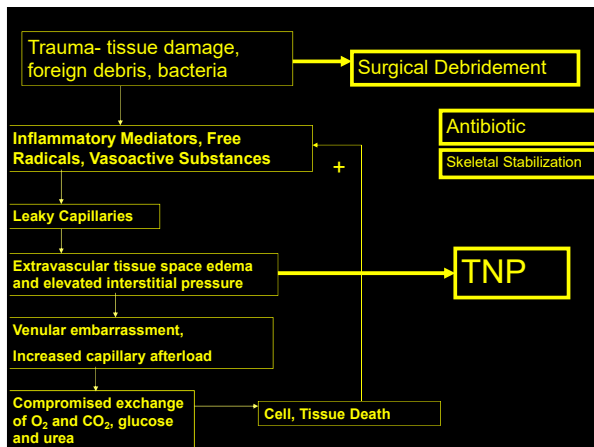
Debridement, stabilization, appropriate dressings

Return for a "second look" debridement at 24-48 hrs

"Demarcates"

B Brumback "Debridement" in *Lower Extremity Salvage and Reconstruction*
Yaremchuk, M, Burgess, AR and Brumback, RJ Lippincott Baltimore 1989





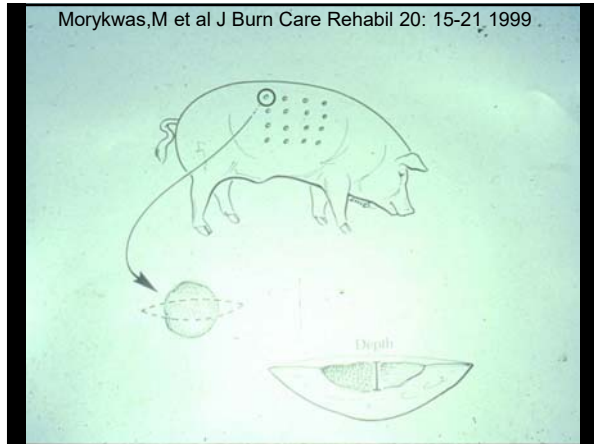
J Am Acad Orthop Surg, 2006;14(10 Spec No.):S82-6.

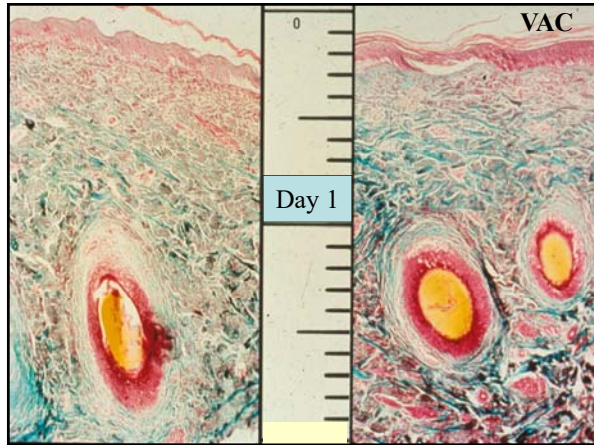
The contaminated high-energy open fracture: a protocol to prevent and treat inflammatory mediator storm-induced soft-tissue compartment syndrome (IMSICS).

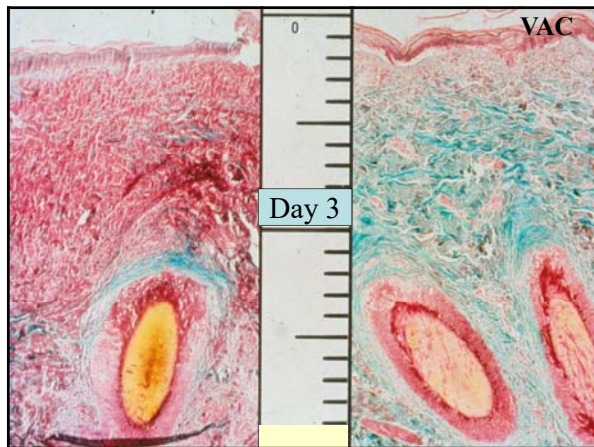
Webb LK1, Desmond B, Schlatterer D, Lavery D.
 Author information

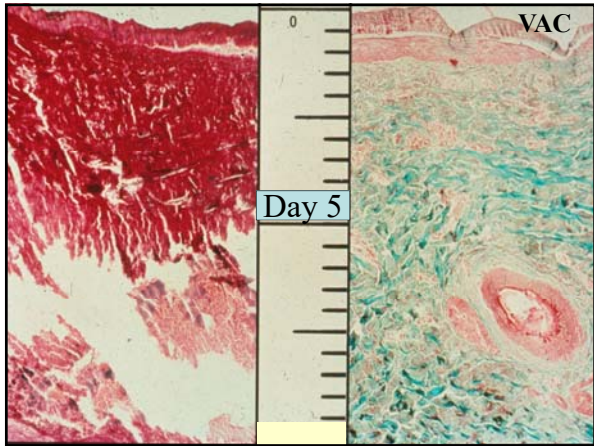
Abstract
 The treatment modalities currently used in surgical débridement leave the traumatic wound with viable but tenuous tissue and a variable level of microcontaminants potentially laden with bacteria. In high-energy contaminated wounds, retention of these contaminants within the tenuous tissue of 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 fracture 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.**

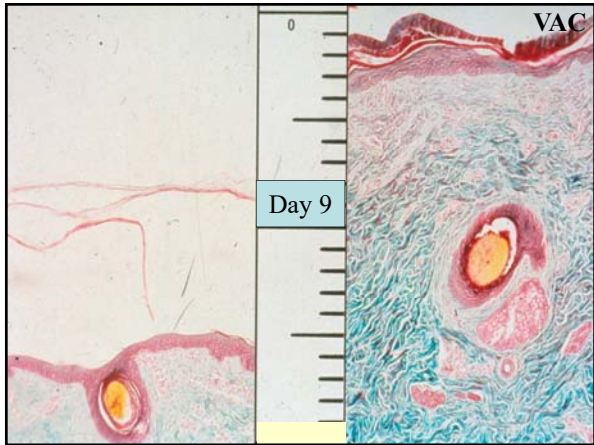
Morykwas, M et al J Burn Care Rehabil 20: 15-21, 1999

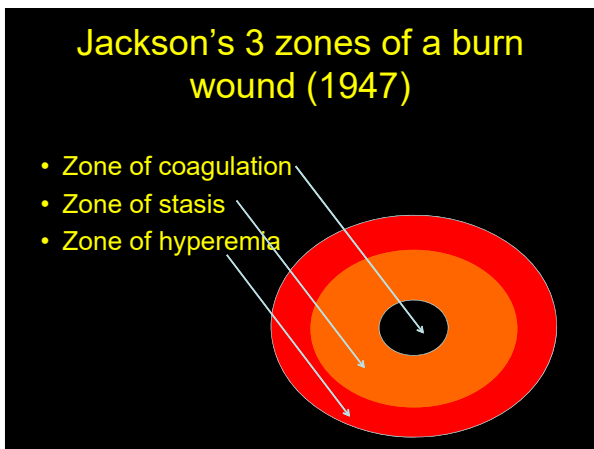




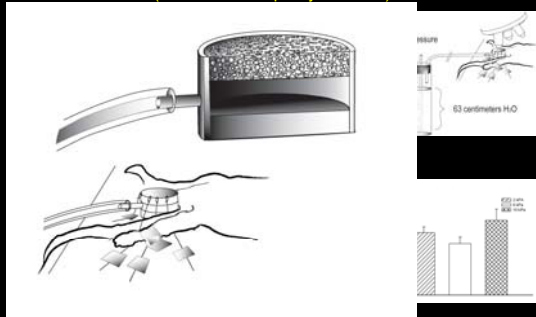








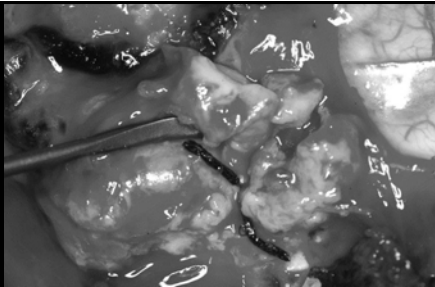
Evacuation of an Engorged Interstitium (diminution of capillary afterload)



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)

Langfitt M. et al Microvascular effects of subatmospheric pressure in striated muscle. J Reconstr Microsurg. 2013 Feb;29(2):117-23



Peterson, Kyle et al Trauma-related Infections in Battlefield Casualties from Iraq Ann Surg 2007 May; 245(5): 803-811

N=211, 56 (26.5%)

| Wound Description | % INFECTED |
|-------------------|------------|
| GSW (n/N) | 21.7 |
| SCHRAPNEL (n/N) | 32.7 |

Peterson, K et al. Ann Surg. 2007 May; 245(5): 803-811

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

- N=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

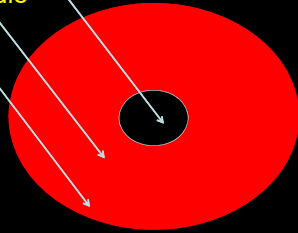
Leininger, B et al. J.Trauma. 2006 Nov;61(5):1207-11

Goals of Operative Debridement

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

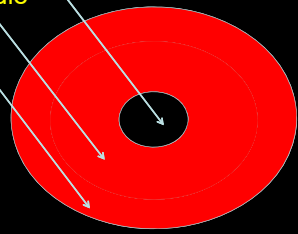
Complex Traumatic Wound

- 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 20 minutes 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, and may provide a novel therapeutic tool in the treatment of ischemic myocardium.

Lindstedt S1, Malmström M, Ingeemansson R. Blood flow changes in normal and ischemic myocardium during topically applied negative pressure. Ann Thorac Surg. 2007 Aug;84(2):568-73. Lund University, Lund Hospital

Reduction of Myocardial Ischemia-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**

Argenta, L., Morykwas, M., Mays, J., Thompson, E., Hammon, J and Jordan, J
Card Surg 2010;25:247-52

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**

Lindstedt S1, Malmström M, Ingegnansson B. The effect of different topical negative pressures on microvascular blood flow in reperfused myocardium during hypothermia *Neurosurgery*. 2014 Aug;75(2):152-62 [Lund University](#), [Lund Hospital](#)

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

Stannard,J, Volgas, DA, McGwin,G, Stewart,R, Obremsky,W , Moore,T and Andlen,J JOT 2012 Jan;26(1):37-42

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)

