Analyzing the Science of Negative Pressure Wound Therapy

Joan Wilson, MSN, MHA, RN, Austin Price, BS, CCRC

Joseph M. Still Research Foundation, Inc., Augusta, Georgia

Introduction

In the lifespan of Negative Pressure Wound Therapy (NPWT), clinicians in nearly every care setting have perfected the use of NPWT. In fact, it is accepted as a standard of care in many settings for advanced wound care management. How to apply the dressing and maintain the therapy is understood in a broad, general sense by most clinicians. However, not many can describe the fundamentals of what makes these devices perform as they do. Having this understanding elevates practice and knowledge.

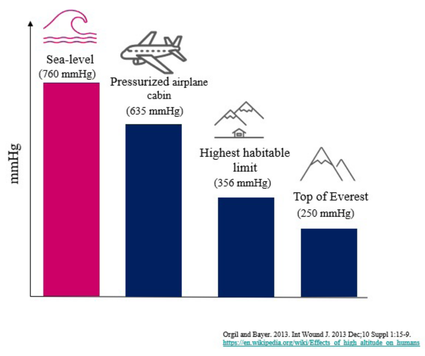
Methods

- Review of the literature
- Discussion of the physics and dynamics of fluid and pressure in relation to NPWT.

Discussion

Atmospheric Pressure

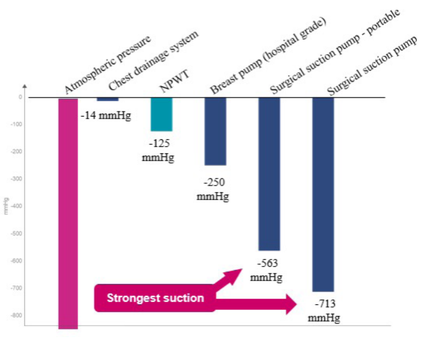
- The force exerted against and object gy the weight of the air molecules above the object.
- Humans are comfortable between 360mmHg and 760mmHg.
- As altitude decreases, atmospheric pressure decreases.



Orgil and Bayer. 2013. Int Wound J. 2013 Dec;10 Suppl 1:15-9.
https://en.wikipedia.org/wiki/Effects_of_high_altitude_on_humans

Pressure Devices in Medicine

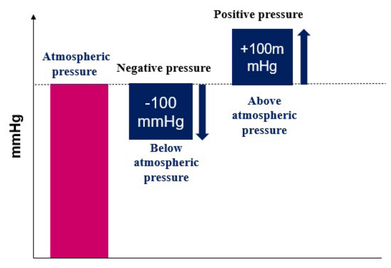
- Use of Negative Pressure in medical applications requires a great variety in the actual amount of negative pressure applied.
- Pumps that generate the highest negative pressure gradient have the strongest pulling force, pulling more fluid.
- The recommended pressure range for NPWT is between -40 to -150mmHg.
- Values correspond to a selection of Medela pumps



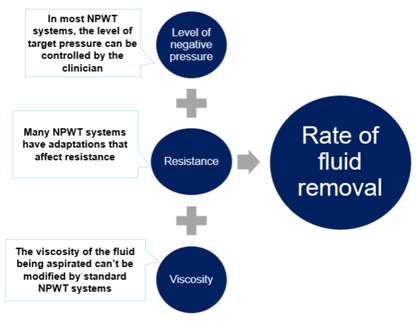
Mojallal et al. Biomed Mater Eng 2008;18(4-5):193-7

What Does Negative Pressure Mean?

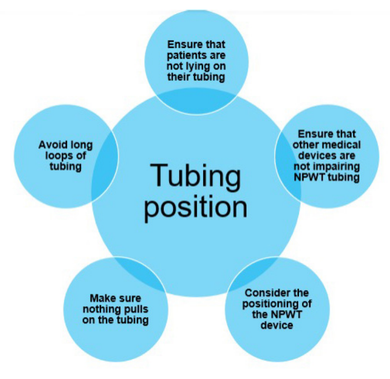
- As the pump removes some of the air molecules from the closed environment, the pressure within the chamber will be reduced, compared with its original pressure, meaning that a sub-atmospheric pressure — or negative pressure is produced within the container.



- The ability of a system to remove fluid is affected by several variables
- Some, but not all of these variables are modifiable



- The movement of fluid through NPWT tubing can also be improved through positioning of the tubing and the device.
- These factors are more important in some NPWT systems than others.



Microdeformation

- The suction forces that occur when NPWT is applied cause Microdeformation in the tissues of the wound bed.
- This causes the tissue to stretch.
- This mechanical stress has a direct effect on the behavior of the cells in the wound bed.

Image: https://els-jbs-prod-cdn.jbs.elsevierhealth.com/cms/attachment/b81d0cf1-425d-4dc9-9a09-342727b06d23/gr1_lrg.jpg

Response to Microdeformation

- The stress generated in the wound bed tissue when NPWT is applied leads to a variety of cellular responses:
  - Proliferation
  - Migration
  - Inflammatory mediators and growth factors
  - ECM Synthesis

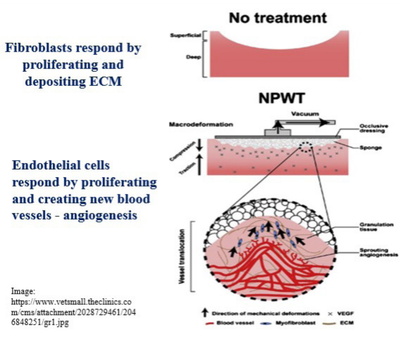


Image: https://www.vetsmall.theclinics.com/cms/attachment/2028729461/2046848251/gr1.jpg

These changes are the basis of granulation tissue formation

Daigle et al 2013. Wound Rep Reg (2013) 21 498–502

Lalezari et al 2017. Int Wound J. 2017 Aug;14(4):649-657

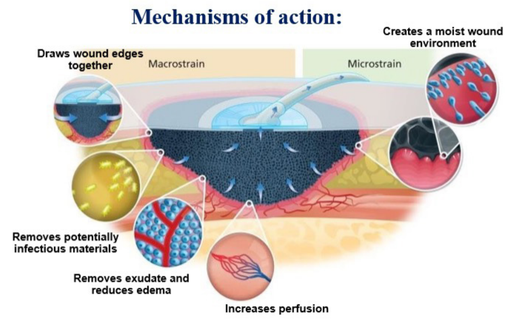
Response to Microdeformation

- Cells in all tissues of the body are finely tuned to detect and respond to physical forces.
- Ex:
  - Fibroblasts are bound to the surrounding ECM proteins.
  - When ECM is stretched, the cell is also stretched.
- "Ilizarov Effect"

WILL THERE BE AN IMAGE HERE?

Summary

- Some fundamental requirements of a NPWT system are important in driving the full mechanisms of action.
  - Target level of pressure must be delivered.
  - Pressure gradient must be created.
  - A sealed wound environment must be maintained.



Lalezari et al 2017. Int Wound J. 2017 Aug;14(4):649-657

Conclusion

- There are some fundamental requirements of a negative pressure wound therapy system that are important in driving the full mode of action. Understanding these requirements and how they relate to negative pressure ensures that the full mode of action can be delivered consistently.

REFERENCES

1. Abbadi OS. The Use of Negative Pressure in Medicine. *Int J Clin Exp Physiol*. 2020;7(3):91-5.
2. Birke-Sorenson et al 2011. Evidence-based recommendations for negative pressure wound therapy: Treatment variables (pressure levels, wound filler and contact layer) Steps towards an international consensus *J Plast Reconstr Aesthet Surg*. 2011 Sep;64 Suppl:S1-16.
3. Borgquist O, Ingemansson R, Malmsjö M. The influence of low and high pressure levels during negative-pressure wound therapy on wound contraction and fluid evacuation. *Plast Reconstr Surg 2011*; 127:551-559
4. Centers for Medicare and Medicaid Services. Negative Pressure Wound Therapy Interpretive Guidelines. Effective October 2016. https://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNMattersArticles/downloads/SE1222.pdf. Accessed Nov, 2020.
5. Daigle et al 2013. How mechanical deformations contribute to the effectiveness of negative-pressure wound therapy. *Wound Rep Reg* (2013) 21 498–502
6. Flello et al. (Eds) 2016. *Physics, the complete course for AQA*. GCP, 2016. ISBN:978 1 78294 597 0; Chapter 5.
7. Guyton and Hall. *Medical Physiology, 9th Edition*. Chapter 16, The microcirculation and the Lymphatic System. Page 187.
8. Lalezari et al 2017. Deconstructing negative pressure wound therapy: Deconstructing NPWT. *Int Wound J*. 2017 Aug;14(4):649-657
9. Mojallal et al. Influence of negative pressure when harvesting adipose tissue on cell yield of the stromal-vascular fraction. *Biomed Mater Eng* 2008;18(4-5):193-7
10. Orgil and Bayer. Negative pressure wound therapy: past, present and future. 2013. *Int Wound J*. 2013 Dec;10 Suppl 1:15-9
11. Saxena et al. Vacuum-assisted closure: microdeformations of wounds and cell proliferation. *Plastic Reconstructive Surgery* 2004;114:1086-96
12. Scherer et al. The mechanism of action of the Vacuum-Assisted Closure device. *Plast. Reconstr. Surg.* 122: 786, 2008
13. Wikipedia. Effects of high altitude on humans. Accessed Nov 2020. https://en.wikipedia.org/wiki/Effects_of_high_altitude_on_humans
14. Wikipedia. Milimetre of mercury. Accessed Nov 2020. https://en.wikipedia.org/wiki/Millimetre_of_mercury#:~:text=In%20medicine%2C%20pressure%20is%20still,mmHg%20relative%20to%20perfect%20vacuum
15. Wikipedia. Vacuum. https://en.wikipedia.org/wiki/Vacuum
16. Wong et al. Pushing Back: Wound Mechanotransduction in Repair and Regeneration. J, Invest. Dermatol 2011; 131:2186-2196.

DISCLOSURES | *There are no disclosures to make. This project received non-human research determination by Castle IRB.*

JOSEPH M. STILL RESEARCH FOUNDATION