Physiological Considerations for Compression Bandaging

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At the completion of this presentation participants will be able to:

1. State the difference between edema and lymphedema
2. State at least one process that can cause edema
3. Describe the basic processes involved in lymphatic transport
4. Describe long-stretch and short-stretch bandages and their use
5. Contrast the effects of resting vs. working pressures
6. Describe Laplace’s law as it applies to bandaging

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Relationship to Wound Healing

**Impediments to Healing**
- Blood Flow
- Oxygenation
- Infection
- Tissue Environment

**Deficit Origins**
- Arterial
- Venous
- Microvascular
- Lymphatic

**Localized Edema/Lymphedema**

**Compression Therapy**

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Normal Fluid Balance

Resorption

15

Blood Capillary

~27 liters/day

| Protein |

Filtration

PA

35 mmHg

\( \Pi = 25 \text{ mmHg} \)

\( \Pi = 25 \text{ mmHg} \)

~30 liters/day

\( \Pi = 25 \text{ mmHg} \)

Lymphatic Capillary

~3 liters/day

(10% of filtered)
Increased Venous Pressure or Capillary Permeability

- Less Resorption
- More Filtration

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If Net Filtration Exceeds Lymphatic Transport Capacity

Overload = Edema

+ [Protein]

= Lymphedema

Therapy Options

• Reduce Filtration
• Increase Transport

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Normal Lymph Transport

• Lymphangion Contraction
• Skeletal Muscle Pump
• Arterial Pulsations
• Body Movements
• Respiration

All are Dynamic Processes

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Lymphatic Capillaries

**Lymphatic Capillary**

Lumen: $P_L > P_T$

EC

Anchoring Filaments

**Blood Capillary**

Lumen: $P_L < P_T$

EC

+$P_T$

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Lymphatic ‘Hearts’

Peristaltic-like contractions propel lymph to next segment

Lymphangion (lymph micro heart)

Lymph Capillary

Walls have a muscular media

Valve

Contraction force is preload and afterload dependent - analogous to heart

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Calf Muscle Pump and Normal Valves

Superficial

Deep

Relaxed

Contracted

Skin

Fascia

Skin

Fascia

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Relaxed Calf Muscle Pump and Valve Dysfunction

Resting Venous Pressure INCREASED

Veins Distended

Contracted

• High pressure transmitted to Superficial Veins
• Pump Efficiency Reduced
Venous Valve Dysfunction

Chronic venous hypertension due to Chronic venous insufficiency (CVI) predisposes to developing venous ulcers

Increased Ambulatory Venous Pressure

Venous Pressure

Resting

Normal

CVI

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Types of Compression

- Bandage → { Short-Stretch
- Bandage-like → Long-Stretch
- Bandage-like → Short-Stretch
- Pumps → Dynamic
- Stockings → { Prevention
                      Maintenance
Arrangement

Superficial
- Drains Skin and Subcutis

Deep
- Vascular Sheath
- Muscle
- Bone

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Vascular Sheath

Arterial Pulsations Can Mechanically Augment Lymph Transport

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Arterial Flow Pulses

Below Knee Blood Flow via Nuclear Magnetic Resonance

Control Leg

ml/min

52

Treated Leg

ml/min

47

Before Bandage

Increased pulses likely augment Lymph/venous transport

With Bandage

52

49

74

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Compartments

Tibia

Greater Saphenous

Anterior Tibial

Anterior

Lateral

Deep Posterior

Superficial Posterior

Fibula

Peroneal

Lesser Saphenous

Skin

Want Therapy to Affect Superficial and Deep

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Skin

Pressures of Interest

• Sub-bandage
• Surface
• Contact

Compression Bandage or Device

Tibia

Tissue

Interstitial

Fibula

Soleus m.

Gastroc m.

Popliteus m.

Tibialis m.

Peroneus

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Edema and Tissue Pressure

Normal

Loose Fibrous Trabeculae

$P_T$
Resting (Static) Pressure

Muscles Relaxed

Pressure due to bandage tension (T) projecting an inward radial pressure (P).

Superficial vessels affected the most

Laplace’s Law

$$P \sim \frac{T}{R}$$

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Pressure Gradient Concept

Compression Applied at Constant Tension

\[ P \sim \frac{T}{R} \]

Increasing \( R \)
Decreasing \( P \)

Mimics Normal Intravascular Pressure Gradient

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Working (Dynamic) Pressure

Contracted Muscles

Bandage acts as a restraint to muscle expansion

Positive affect on deeper vessels

Pressure is developed from ‘within’

\[ P \sim \text{Contraction Force} \times \text{‘Rigidity’} \]

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Dynamic Pressure Depends on Bandage Material Features

Dynamic Pressure ($\Delta P$)

- Form fitted steel pipe
- ‘short stretch’
- ‘long stretch’
- No external compression

Bandage ‘Stretchibility’

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Working vs. Resting Pressures
Role of Compression Material

Tissue Pressure ($P_T$)

Emptying
Filling
Filling

Short Stretch
Long Stretch

Resting

Time

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Overall Impact of Compression

*Depends on both working and resting pressures*

- **Filling**: Inflow $\sim P_U - P_T$
- **Emptying**: Outflow $\sim \Delta V \sim \Delta P_T$
- **Best**: Adequate resting $P_T$ and High $\Delta P_T$

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Compression set at various static levels to compare dynamic sub-bandage pressures achieved with different bandages during calf muscle contraction and relaxation

*Pneumatic sensor: Talley Oxford Pressure Monitor
*Electronic Sensor: http://bioscience-research.net
Dynamic (Working) Pressures

Static Pressures Set by Compression

Dynamic pressures via calf muscle contraction

Comparison of Different Bandage Types

Efficient Dynamic Pressure

Inefficient Low Dynamic Pressure

Cohesive Elastic Multilayer

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Multiple Choice Questions

1. According to Laplace’s law, if a limb is bandaged with constant tension, then the contact pressure experienced by the limb will be:
   a) greater where the limb is widest
   b) greater where the limb is narrowest*
   c) equal at all sites since the tension is constant
   d) least over areas of bony prominence such as the malleolus

2. A short-stretch bandage, as compared to a long-stretch:
   a) results in a greater resting pressure
   b) affects the deep vessels more than the superficial vessels
   c) results in a greater working pressure*
   d) has a greater effect on underlying blood vessels at rest

3. A short-stretch bandage provides more efficient venous and lymphatic filling and emptying because it produces:
   a) greater working pressure and greater resting pressure
   b) reduced working pressure and reduced resting pressure
   c) greater working pressure and reduced resting pressure*
   d) reduced working pressure and greater resting pressure

References