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 -> Filtration

Blood Capillary:
- Filtration: ~30 liters/day
- Resorption: ~27 liters/day
- Lymphatic Capillary: ~3 liters/day (10% of filtered)

Pressure:
- P_A = 35 mmHg
- \( \Pi = 25 \text{ mmHg} \)

protein

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Increased Venous Pressure or Capillary Permeability

- Resorption
  - Less Resorption

- Filtration
  - More Filtration

Blood Capillary

\[ P_A = 35 \text{ mmHg} \]

\[ P_V = 20 \]

Lymphatic Capillary

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If Net Filtration Exceeds Lymphatic Transport Capacity

Overload = Edema

+ [Protein]

= Lymphedema

Therapy Options

• Reduce Filtration
• Increase Transport
Normal Lymph Transport

• Lymphangion Contraction

• Skeletal Muscle Pump

• Arterial Pulsations

• Body Movements

• Respiration

All are Dynamic Processes
Lymphatic Capillaries

Lymphatic Capillary

Lumen

EC

P_L

P_L > P_T

Anchoring Filaments

Blood Capillary

P_T

Lumen

EC

P_L

P_L < P_T

+P_T

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Lymphatic ‘Hearts’

Peristaltic-like contractions propel lymph to next segment

Walls have a muscular media

Contraction force is preload and afterload dependent - analogous to heart

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Calf Muscle Pump and Normal Valves

Superficial
Skin
Fascia

Deep

Relaxed

Superficial
Skin
Fascia

Deep

Contracted

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Calf Muscle Pump and Valve Dysfunction

- Relaxed Veins Distended
- Resting Venous Pressure INCREASED

- 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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External Compression

Arteriolar Vasodilation

Nitric Oxide

Normalize Permeability

Tissue Pressure

Vein Diameter

Velocity

Shear Stress

WBC Adherence

Trans-locate Volume

Venous Pressure

Promote Fluid Absorption

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Types of Compression

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

Superficial
- Skin
- Drains Skin and Subcutis

Facia
- Vascular Sheath
- Muscle
- Bone

Deep

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Arterial Pulsations Can Mechanically Augment Lymph Transport

Vascular Sheath

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Arterial Flow Pulses

Below Knee Blood Flow via Nuclear Magnetic Resonance

Control Leg  |  Treated Leg

Before Bandage:
- Control Leg: 52 ml/min
- Treated Leg: 47 ml/min

With Bandage:
- Control Leg: 49 ml/min
- Treated Leg: 74 ml/min

Increased pulses likely augment lymph/venous transport

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Compartments

Tibia

Greater Saphenous

Posterior Tibial

Tibial Anterior

Fibula

Anterior Tibial

Lateral

Superficial Posterior

Deep Posterior

Peroneal

Lesser Saphenous

Skin

Want Therapy to Affect Superficial and Deep

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Pressures of Interest

- Sub-bandage
- Surface
- Contact

1. Compression Bandage or Device
2. Tissue
   - Tibialis m.
   - Soleus m.
   - Gastroc m.

3. Intramuscular
   - Tibialis m.
   - Peroneus
   - Popliteus m.

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Edema and Tissue Pressure

Normal

Loose Fibrous Trabeculae

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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

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

Compression Bandage or Device

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Pressure Gradient Concept

Compression Applied at Constant Tension

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

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’

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

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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**