The Swollen Limb: “What Lies Beneath”

Healing Leg Ulcers with Compression Therapy

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Learning Objectives

• Learn the vital role compression plays in healing lower extremity wounds
• Understand the physiology of the venous and lymphatic system
• Learn the difference between edema & lymphedema
• Explain the physics of compression bandaging
PEARLS

1. Edema/lymphedema is a major impediment to wound healing
2. Smart compression removes edema and lymphedema (lymph stasis)
3. Smart compression is not like squeezing a tube of toothpaste
4. Smart compression demands short stretch bandages
Paul Gerson Unna
1850-1929
Compression:

the application of external compression initiates a variety of complex physiological and biochemical effects involving the venous, arterial and lymphatic systems
the lymphatic system
Physiology of Lymphatic System

• Every 24 hrs., 80-200 grams of protein must be carried away by lymphatic system

• Recent data suggests that lymphatics may carry 20+ % of the fluid returning to the heart

• 2-6 liters per 24 hrs. (?more)

Peter Mortimer, MRCP
LYMPH

“Tissue Waste Material”

- Fat
- Cells
- Bacteria, Virus
- Cell Residue
- Matrix Metalloprotease (MMP)
- Mediator Proteins—Cytokines
- Polysaccharides, Glycoproteins
- Fibronectin, Vitronectin
- Water
INITIAL LYMPHATICS
NORMAL LEG LYMPHATICS
Lymphatic Capillaries

Lymphatic Capillary

Lumen

EC

PL

PL > PT

PT

Anchoring Filaments

Blood Capillary

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Lymphatic Capillaries

Lymphatic Capillary

Lumen

EC

PL

PL > PT

Anchoring Filaments

Blood Capillary

PT

Lumen

EC

PL

PL < PT

+PT

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Lymphatic ‘Hearts’

Peristaltic-like contractions propel lymph to next segment

- **Lymph Capillary**
- **Lymphangion** (lymph micro heart)
- **Valve**

Walls have a muscular media

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Vascular Sheath

Arterial Pulsations Can Mechanically Augment Lymph Transport

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Normal Lymph Transport

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

All are Dynamic Processes
the venous system
Normal Fluid Balance

**Resorption**

Blood Capillary

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

\[ 15 \]

\[ ~27 \text{ liters/day} \]

Filtration

Lymphatic Capillary

\[ \Pi = 25 \text{ mmHg} \]

\[ ~30 \text{ liters/day} \]

\[ \sim 3 \text{ liters/day} \]

(10% of filtered)

protein

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Increased Venous Pressure or Capillary Permeability

Resorption

Blood Capillary

Filtration

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

\[ P_V = 20 \]

- Less Resorption
- More Filtration

Lymphatic Capillary

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EDEMA

- Natural secondary response
- Often temporary
- Normal lymphatic system
- Primarily water
Etiology of Edema

- Passive Hyperemia
  - Venous insufficiency
  - Cardiac
  - Pulmonary
  - Pregnancy
  - Inactivity/dependency
  - Airline travel
- Active Hyperemia
  - Inflammation
  - Allergy

- Hypoproteinemia
  - Malabsorption
  - Malnutrition
- Renal disease
- Cyclic idiopathic edema syndromes
- Drugs
LYMPHEDEMA

- High protein edema (lymph and water)

- The result of either damage to or absence of the normal lymphatic anatomy
Etiology of Lymphedema

- Primary
  - Birth
  - Prae Cox (adolescent)
  - Tardum (age 35+)

- Secondary
  - Surgery
  - Infection
  - Tumor
  - Radiation
  - Wounds
  - Venous
  - Trauma
  - Neurological
  - Filiariasis
Stage III Filarial Lymphedema
If Net Filtration Exceeds Lymphatic Transport Capacity

Overload = Edema

Lymphatic Transport Malfunction + Edema + Protein = Lymphedema

Therapy Options
- Reduce Filtration
- Increase Transport Capacity
How do we reduce filtration and increase transport capacity?

Physiologic Compression
LYMPHEDEMA
COMPRESSION BANDAGING

Inelastic (short stretch) bandages
Complex Decongestive Physiotherapy
Complex Decongestive Physiotherapy
Complex Decongestive Physiotherapy

5-11-06

8-17-06
Compression Therapy Considerations
Bandage Effects

- Skin
  - Lymphatic
  - Muscle
    - Initial State: NO FLOW
    - Elastic bandage or no bandage: NO FLOW
    - Low-stretch bandage: FLOW

- Bandage & tissues
  - Bandage & tissues do not move L. compressed
Compartments

Want Therapy to Affect Superficial and Deep

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Pressures of Interest

- Sub-bandage
- Surface
- Contact

- Tissue
- Interstitial

- Intramuscular

Tibia

Fibula

Soleus m.

Gastroc m.

Popliteus m.

Tibialis m.

Peroneus

Compression Bandage or Device

Skin

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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

Compression Bandage or Device

Laplace’s Law

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

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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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TYPES OF COMPRESSION

- Bandages
  - Inelastic (short stretch)
  - Elastic
  - Combination 4 layer

- Bandage like
  - Inelastic (short stretch)
    (Unnaboot, CircAid®)

- Stockings
  - Prevention

- Pumps
  - Dynamic
Dynamic Pressure Depends on Bandage Material Features

Form fitted steel pipe

Inelastic (short stretch)

Elastic (long stretch)

No external compression

Dynamic Pressure ($\Delta P$)

Bandage ‘Stretchability’

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resting pressure ± 40 mmHg
Standing pressure $\pm 70$ mmHg
static stiffness index ± 30

Examination date: 13/05/2009
exercises:
maximum plantar and dorsiflexion of the ankle joint
amplitude ± 50

Right Leg

Examination date: 13/05/2009
Resting pressure and amplitude measurement on both legs (probe at B1)

modified from:
Classification of compression bandages: practical aspects.
the higher stiffness of the short stretch bandage is characterized by the higher pressure amplitudes during movement, but also by the higher increase of the pressure by standing up from the supine position.

Amplitudes of a Patient with Larger Muscles

Figure 2: This illustration represents the SSI and amplitudes of a patient with well-developed muscle strength. Peak amplitudes are approximately 45 mmHg.

Amplitudes of a Patient with Smaller Muscles

Figure 3: This illustration represents the SSI and amplitudes of a patient with less muscle tone. At about 25 mmHg, the amplitudes are lower than the original, but still reflect effective compression with an SSI well above 10.
Short Stretch  vs. Multi-layer

• Multi-layer systems can function as short stretch due to the friction of overlapping layers and, if they contain a short stretch component.

• Both systems can produce effective, dynamic working and resting pressures.

• Short stretch systems are effective at a lower resting and working pressure than multi-stretch systems.

• A lower resting and working pressure offers safer compression in the compromised limb.
the arterial system
Values in ml/min

Before compression:
- 48
- 45
- 47
- 36
- 20

Volunteer X

During compression:
- 85
- 77
- 58
- 44
- 35

Modified from:

Nuclear magnetic resonance flowmetry
Compression improves microcirculation

- Reducing the distance between capillaries, facilitating transport of nutrients
- Normalizing veno-arterial reflex?
- Release of mediators from endothelial cells

Increase of capillary density

Oedema

Compression

Bollinger A, Fagrell B. Clinical capillaroscopy, Hofgreve & Huber 1990
Compression improves venous and lymphatic return

- Reduction of venous reflux
- Improvement of venous pumping function
- Reduction of ambulatory venous hypertension
- Increase of arterio-venous pressure gradient
- Improvement of lymphatic drainage

Compression effects on arterial circulation

- **Sustained compression**
  - light pressure enhances arterial flow
  - strong pressure reduces arterial flow

- **Intermittent compression**
  - enhances arterial flow

Mayrovitz HN et al. Ostomy Wound Management 1998;44:56-60

Mayrovitz HN et al. Adv Skin Wound Care 2003;16198
Dai G et al. AJP-Heart and Circ Physiol2002;282:2066
Increase of blood flow under light compression

- Myogenic relaxation in arterial wall
- Release of vasodilating mediators
- Reduction of arterio-venous pressure gradient by improvement of venous return

- This was shown in normals –
- But what about mixed ulcers?
  - Which compression pressure is safe and effective?
Fig. 1. Mechanical effects of pneumatic compression on a vein or artery. The pneumatic compression increases intravascular flow, shear and compressive strain on endothelial cells with the resulting release of biochemical mediators. tPA: tissue plasminogen activator; NO: nitric oxide; TFPI: tissue factor pathway inhibitor.
1416 leg ulcers with venous reflux

Humphreys ML et al. Br J Surg. 2007 Sep;94(9):1104-7
Main targets of compression in mixed ulceration

1. Prevention and reduction of oedema
2. Improvement of microcirculation and stimulation of endothelial cells
3. Promotion of venous and lymphatic return
4. Increase of arterial inflow
25 patients with mixed ulcers

1. Flat Laser Doppler under the bandage
2. Standard Laser Doppler on first toe (plantar)
3. TcPO2 dorsum of the foot
4. Toe pressure
   - without bandage
   - Inelastic bandages
     - 20-30  31-40  41-50 mm Hg
     (measured by Picopress)
UNDER the bandage: increase of flow
DISTAL to the bandage

Laser Doppler flux distal to the bandages (toe)

- baseline
- 20-30
- 31-40
- 41-50

PU
- +3%
- -4%
- -20%

TcPO2
- baseline
- 31-40

No impairment of arterial flow up to a pressure of 40 mmHg
Inelastic compression improves venous pump
Conclusions

Compression with inelastic bandages up to a pressure of 40 mm Hg
• does not lead to a measurable reduction of arterial inflow,
• improves venous pumping function significantly.
• (Increase of arterial inflow due to a reduction of arterio-venous pressure gradient?)
Sustained bandage pressure should never exceed the arterial perfusion pressure (= ankle pressure)!

Persisting or increasing pain: Remove the bandage!

Consider neuropathy!
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Merci Beaucoup