Medical Compression: Affects on Leg Blood Flow

Dr. Harvey N. Mayrovitz

NSU/CMS Seminar September 5, 2008
Medical Compression Bandaging

Major treatment component for venous ulcers and limb lymphedema

Dr. HN Mayrovitz
Medical Compression Pressures

Pressures need to be adequate but not so high as to negatively impact blood flow.

A special concern is use in patients with co-present diabetes and/or lower extremity arterial disease.

Standard is about 40 mmHg at ankle

DP = Dynamic Pressure = (max – min)
MRF Principle

Permanent Magnet 0.1 T

Transmitter
Vertical Gradient

Horizontal Gradient

Receiver

Modulator

Dr. HN Mayrovitz

Scanner Magnet and Coil System
FLOW = (Area under flow-time curve) x Heart Rate

PERFUSION = FLOW / (Limb volume distal to measured site)

ASI = PERFUSION / Width
Flow Signals at multiple limb sites with paired limbs simultaneously determined.
Left Leg (ml/min/100g) vs. Right Leg (ml/min/100g)

- **Equation:** Left = 0.957 Right + 0.043
- **Correlation:** R = 0.882, N= 30 leg pairs
- **Standard Deviation:** $|\Delta| = 0.19 \pm 0.14 \text{sd} \text{ ml/min/100g}$

Dr. HN Mayrovitz
Protocol

BILATERAL PULSATILE BLOOD FLOW

1) First in 14 healthy subjects
2) 5 Venous Ulcer patients and 5 healthy subjects

MAGNETIC RESONANCE FLOWMETRY

FOUR-LAYER COMPRESSION BANDAGE ONE LEG (Profore)

MONITOR SUB-BANDAGE PRESSURE 40.7 ± 4.0 mmHg

REPEAT BILATERAL FLOW MEASUREMENTS

Dr. HN Mayrovitz
Pressure Sensors

1 2

Pre-Compression Setup

Profore layer 1 (no compression)

3

Baseline Flow with Layer 1

Dr. HN Mayrovitz

Compression

4

Unilateral Compression Flow
Before Compression                              During Compression
Both panels are left leg
Dr. HN Mayrovitz
Leg Pulsatile Blood Flow

Low Flow Leg

Normal
Flow Increases with Compression

Flow is greater at all leg sites except ankle

Dr. HN Mayrovitz

N=14
What are the Flow Augmenting Mechanisms of Compression?
Myogenic Response

Limb under Compression

Artery with myogenic response properties

Tissue pressure increases

Artery transmural pressure decreases

Reduction due to initial transmural pressure decrease may occur (mechanical)

Artery Diameter

Before compression

With Compression

Myogenic Response via smooth muscle relaxation due to reduced wall stretch (Active Response)

Reduced Arteriolar Resistance

Dr. HN Mayrovitz
**Veno-Arterial (V-A) Coupling**

- **Limb under Compression**
- **Compressed Vein**
- **Arteriolar Vasodilation**
- **Increased wall shear stress**
- **V-A reflex**
- **Dr. HN Mayrovitz**

**Altered Arteriolar Compliance**

**Reduced Arteriolar Resistance**
Compliance Related Affects

Femoral Artery

Pressure gradient (space derivative)

Flow \sim \frac{dp}{dz} \sim \frac{dp}{dt} \frac{1}{C}

Flow pulse peak and pattern depend on pulse-wave speed and \( \frac{dp}{dt} \) both of which are affected by artery compliance
Flow Augmenting Mechanisms of Compression?

Arteriolar transmural pressure decreases

- Myogenic response
- Vascular smooth muscle relaxation
- Vasodilation
- Decreased resistance
- + Forward Flow-Wave
- - Backward Flow-Wave

Venous compression

- + venous velocity
- + wall shear rate
- + Nitric oxide V-A reflex

Artery compliance

- Pulse Pressure
  - Wave Speed (C)
  - \( \frac{dp}{dt} \)
- Pressure Gradient \( \frac{dp}{dz} \)
- Flow \( \sim \frac{dp}{dz} \sim \frac{dp}{dt} \cdot C \)

+ Peak and + Width of measured composite Flow Pulse
Thanks for your Attention
Medical Compression Bandaging

Major treatment component for venous ulcers and limb lymphedema

SAVE

Dr. HN Mayrovitz
Medical Compression Pressures

Pressures need to be adequate but not so high as to negatively impact blood flow.

A special concern is use in patients with co-present diabetes and/or lower extremity arterial disease.

Standard is about 40 mmHg at ankle.
Arterial Flow Pulses
Below Knee Blood Flow via Nuclear Magnetic Resonance

Control Leg
Before Bandage
52 ml/min
Increased pulses
likely augment Lymph/venous transport

Treated Leg
Before Bandage
47 ml/min

With Bandage
49 ml/min

With Bandage
74 ml/min
Doppler Ultrasound – Posterior Tibia

44 cm/s  
72 cm/s  
50 cm/s

DUS also demonstrates the compression effect

Dr. HN Mayrovitz
Paired Leg Flow Ratio Increases
Paired-ratio normal range
N=60
This group before bandage
This group with bandage
Paired-Leg flow ratio
Greater with bandaging
Dr. HN Mayrovitz

BLOOD FLOW RATIO
(Bandaged Leg / Control Leg)

LEG SITE (%)

Paired-Leg flow ratio
Greater with bandaging
This group with bandage
Paired-ratio normal range
N=60
This group before bandage

Malleolus
Knee
Decreased perfusion in control leg with target leg bandaged.

Before bandaging target leg
With bandage on target leg

Control
Target

N=14

P<0.05

P<0.01

Dr. HN Mayrovitz
Protocol

BILATERAL PULSATILE BLOOD FLOW

1) First in 14 healthy subjects

2) 5 Venous Ulcer patients and 5 healthy subjects

MAGNETIC RESONANCE FLOWMETRY

FOUR-LAYER COMPRESSION BANDAGE ONE LEG (Profore)

MONITOR SUB-BANDAGE PRESSURE 40.1 ± 3.7 mmHg

REPEAT BILATERAL FLOW MEASUREMENTS

Dr. HN Mayrovitz
Flow pulse peak and width are both increased

Occurs in healthy legs and those with long-standing V. Ulcers

Pulse flow increase may aid in reducing wbc-capillary effects postulated to be involved in V. ulcer etiology and maintenance

Pulse flow increase may augment lymph/venous transport

Mechanism of the flow increase being investigated include:

- Arteriolar vasodilation via
  Transmural pressure affects
  Veno-arterial coupling and NO
- Compression related increase in arterial compliance
- Altered arterial pulse-wave reflection features