

**Atlanta Trauma Symposium**



**Post-Traumatic Swelling**

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- Owner of LymphEd, LLC
  - A educational company providing courses on lymphedema to medical professionals.
- Casley-Smith International Certified Lymphedema Instructor

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**Objectives**

- To learn the revised Starling's Equilibrium
- To be able to understand how the revised Starling's can impact orthopedic trauma
- To recognize when edema may need assistance to clear
- To know what treatment options are available for prolonged edema

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# STARLING'S EQUILIBRIUM

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## Starling Forces

- **Hydrostatic Pressures:**
  - Pressure exerted by the fluid
  - Is considered a “pushing” force
  - Blood (BHP); Tissue (THP); Lymphatic (LHP)
- **Colloidal Osmotic Pressure:**
  - Pressure exerted by the proteins
  - Is considered a “pulling” force
  - Blood (BCOP); Tissue (TCOP); Lymphatic (LCOP)
- *Note: Blood can impact tissue pressures; yet, tissue can not impact blood*

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## Other Important Terms

- **Ultrafiltration**
  - fluid coming out of the capillaries into the tissues
- **Reabsorption**
  - fluid going back into the capillaries from the tissues - Transient
- **Proteolysis**
  - Proteins broken down by Macrophages in the tissues

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## Starling's Equation

Net fluid flow =  $K_f (BHP - THP) - \sigma(BCOP - TCOP)$

*Fluid in the tissues* = ultrafiltration - reabsorption

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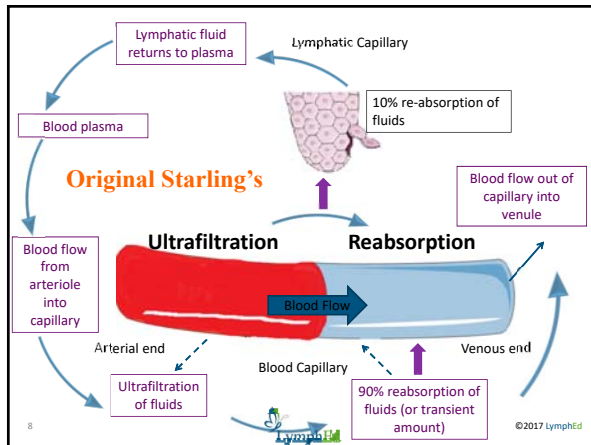
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## Levick's Work on Starling's

- Why reabsorption is transient
  - Previous theory: reabsorption was not transient. 90% of excess fluid was reabsorbed at venous end of capillaries because of BCOP pulling fluid in.
  - New understanding: the normal TCOP is much higher than previously known. (~16 mm Hg) It acts as a stronger counterforce to BCOP and does not allow much fluid to be reabsorbed by capillaries. Instead the majority of the fluid is absorbed by the lymphatics.
- Revised Starling's
  - Instead of the lymphatic system being a backup to the venous system in cases of increased fluid in the tissues, the **lymphatic system is the main remover of tissue fluid.**
  - The venous end of the capillaries reabsorbs a small amount of the excess. It is the backup for the lymphatic system instead of vice versa. This is very rare and only a very small amount.

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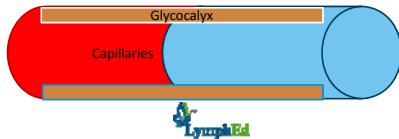
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## Endothelial Glycocalyx

- A fiber matrix that is hydrophobic
- It binds to plasma proteins, resulting in a high intravascular oncotic pressure
- Opposes the ultrafiltration rate and helps limit the amount of fluid going into the tissues
- Prevents fluid from being reabsorbed from the tissues on the venous side of the capillaries




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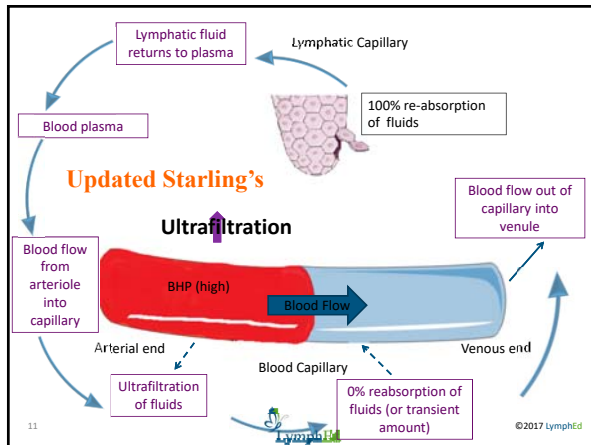
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## Venous Reabsorption

- Main conditions when reabsorption happens
  - BCOP *must* be higher than BHP
  - THP is very high and/or lymph uptake is low
  - TCOP is low compared to THP
- When does this occur:
  - Temporarily will occur with hypovolemia-trauma
  - With Pre-capillary vasoconstriction
  - With post-capillary vasodilation
  - With all- will only last a few minutes and then ultrafiltration resumes at the new lower BHP, usually no change to BCOP.



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12

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# PATHOLOGY WITH STARLING'S EQUATION

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## Functional Lymphatic System

- The TC is the amount of fluid the lymphatics can carry.
- The LTV, the Lymph Time Volume, is the total amount that can be carried to reach equilibrium
- FR, Functional Reserve, is the amount of remaining space in the lymphatics to reach LTV

14

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## Dynamic Insufficiency

- There is an increased lymphatic load – on a healthy lymphatic system
- The fluid level is now greater than the TC and LTV loads
- Examples of dynamic insufficiency
  - Venous hypertension
  - Congestive heart failure
  - Injury from fall
  - Post Operative
  - Trauma

15

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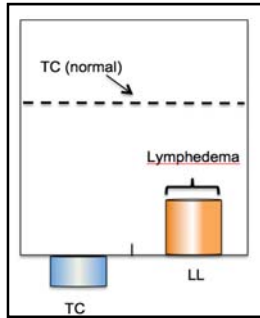
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### Mechanical Insufficiency

- Normal lymphatic load on a damaged lymphatic system.
- The TC has reduced
- There is more fluid, or LL than the TC can accommodate.
- Examples of mechanical insufficiency:
  - Primary lymphedema
  - Lymphadenectomy



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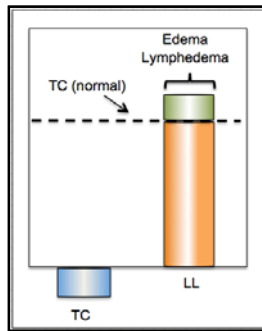
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### Combined Insufficiency

- Increased lymphatic load – on a damaged lymphatic system
- Combined insufficiency, or a composite of the two
- Examples:
  - cellulitis after a lymph node dissection (mechanical first)
  - Prolonged post-op or post trauma edema (dynamic first)
  - Infection post-op or post trauma



17



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### Effects of Edema: Clinical

- Clinical presentation of patients:
  - Swelling
  - Pain/Discomfort
  - Loss of function
  - Reduced healing

18



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### Effects of Prolonged Edemas, Especially High Protein Edemas

- Lymphatics
  - ↑ numbers
  - ↑ uptake of fluid and proteins
  - Eventually initial vessels will collapse and larger vessels will have fibrosis and stop functioning.
  - This will lead increase in proteins and other debris to be left behind in the tissues.
- Blood Vessels
  - Initial collapse
  - ↑ growth of blood vessels
  - Arterio-venous anastomoses used
- Tissue Cells
  - ↓ elastin
  - ↑ fibroblasts → excess fibrosis
  - Fibrocytes turn to adipocytes
  - ↑ macrophages, but many are lipid-filled
  - ↓ oxygenation
- Clinical
  - Poor healing of incisions
  - Reduced gains in ROM and strength
  - Prolonged pain and numbness
  - Increased risk of infections
  - Reduced outcomes


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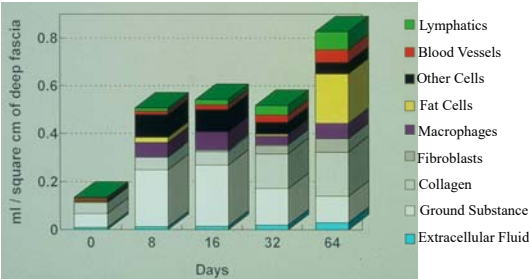
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### Tissue Elements in Chronic High Protein Edema



(Rats injected with own plasma, Casley-Smith & Gaffney, 1981)


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## HOW TO ADDRESS EDEMA


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## Complex Lymphatic Therapy (CLT)

1. Manual Lymphatic Drainage
2. Compression Bandaging or Garments
3. Exercises
4. Education
5. Home Program

• *For orthopedics this is often shortened.*

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## Complex Lymphatic Therapy (CLT)

1. Manual Lymphatic Drainage
  - Moves fluid and debris from non-functioning or over-taxed area to a functioning area
  - Starts proximal and works distal
  - Light massage technique



23



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Near-Infrared Fluorescence Imaging

Image from Eva Sevicik  
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## Complex Lymphatic Therapy (CLT)

### 2. Gradient Compression: Bandages or garments

- Most pressure distal and most go ~ 2 inches above the edema
- Needs to be measured to fit the patient
- Often painful to use garments on very swollen limbs, better to use compression bandages to reduce.
- Garments DO NOT REDUCE



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## Orthopedic Benefits With CLT

- Post-Op:
  - Reduces edema
  - Helps with wound healing
  - Reduces edema's impact on ROM and strength
  - Speeds up return to function
  - Gentle scar tissue techniques may be used to break up restrictions and encourage flow
- Patient must also be doing regular post-op ortho program - can not limit general rehab. Usually see ortho therapist 2 x week and lymph therapist 1 x week.

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## ORTHO CASE STUDIES

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### Case Study #1



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### Case Study #1



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### Case Study #1



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### Case Study #1

- Presentation:
  - Volume of foot/calf:
    - L 1498.0cm<sup>3</sup>
    - R 1212.0cm<sup>3</sup>
    - A 23.6% difference
- Treatment
  - 5 visits in 3 weeks
  - MLD
  - Compression Bandaging
  - Exercises



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### Case Study #1

- Results
  - Volume:
    - L 1103.5cm<sup>3</sup>
    - 137% reduction



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### Case Study #2



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### Case Study #2



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### Case Study #2

- Presentation
  - Volume
    - L entire LE: 8834.6cm<sup>3</sup>
    - R entire LE 8368.6cm<sup>3</sup>
    - 5.6% difference
  - Treatment
    - MLD
    - Exercise
    - Compression shorts/hose with foam pack



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### Case Study #2

- Liposuction
- Current status
  - Volume
    - L 10028.2cm<sup>3</sup>
    - R 8732.5cm<sup>3</sup>
    - 14.8% difference



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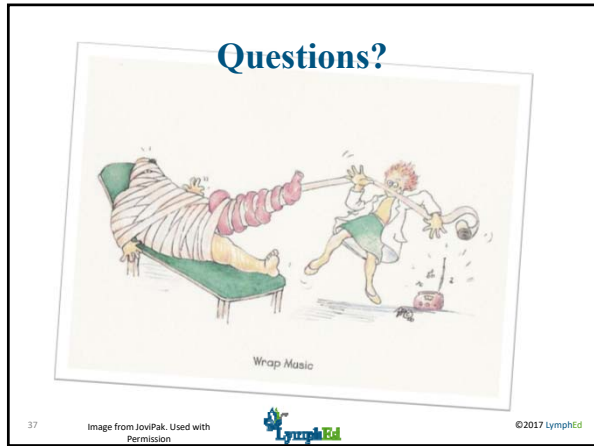
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