Experimental Evaluation of the Physiologic Response of the Venous Valve

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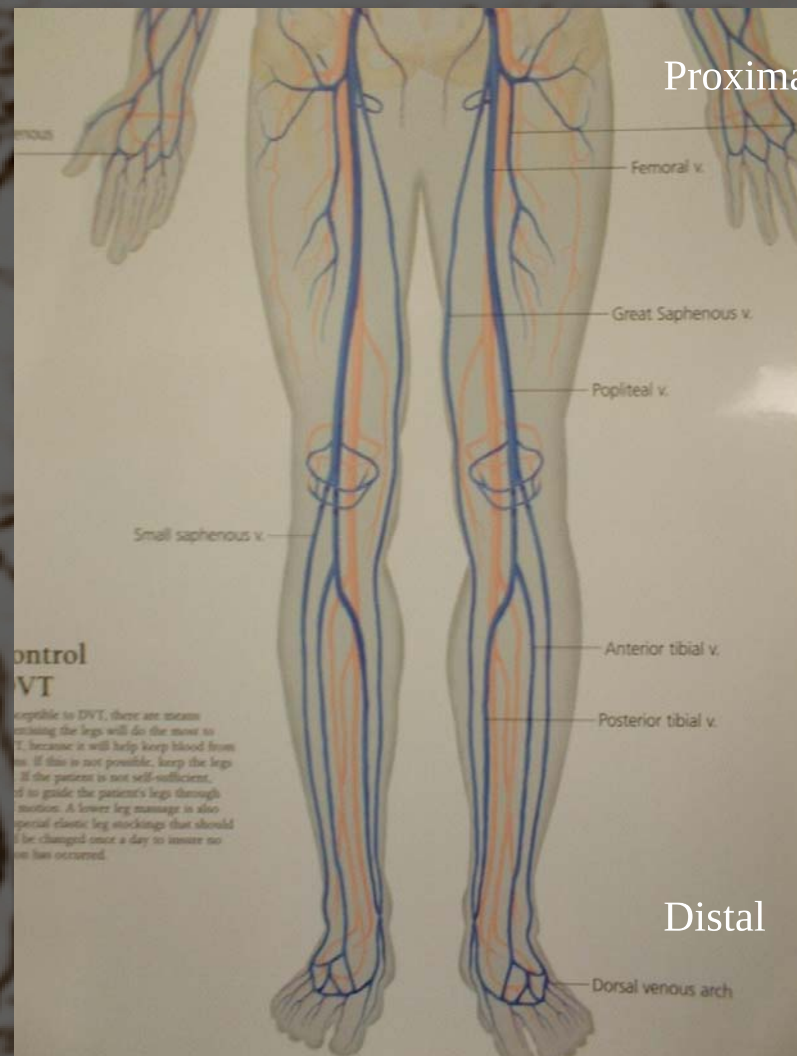
Presentation Overview

- Introduction to deep venous thrombosis (DVT)
- Venous valve anatomy
- Experiment
- Results
- Summary
- Future work

Venous anatomy of lower limbs

- Red vessels are arteries pumping blood from the heart
- Blue vessels are veins returning blood to the heart
- Focus on VEINS



Introduction to DVT

- Virchow's triad (1850) -- 3 conditions that enhance thrombogenisis
  - Slow or stagnant blood flow
    - circulatory stasis
  - Hyper-coagulability state
    - biochemical cascade
  - Loss of endothelial cell function
    - physical damage or trauma

Causes of thrombus

	Hyper-coagulability	Stasis	Trauma
• **Hereditary**			
– Protein C deficiency	Y		
– Protein S deficiency	Y		
– Leiden Factor V	Y		
• **Acquired**			
– Vitamin deficiency	Y		
– Pregnancy		Y	
– Obesity		Y	
– Prolonged immobilization		Y	
– Major surgery		Y	Y
– Previous DVT	Y	Y	Y

Medical problems associated with thrombus

- Deep Vein Thrombosis (DVT)
- Chronic Venous Insufficiency (CVI)
- Edema
- Leg Ulcers
- Pulmonary Embolism (PE)

Diagram of Valve in Vein

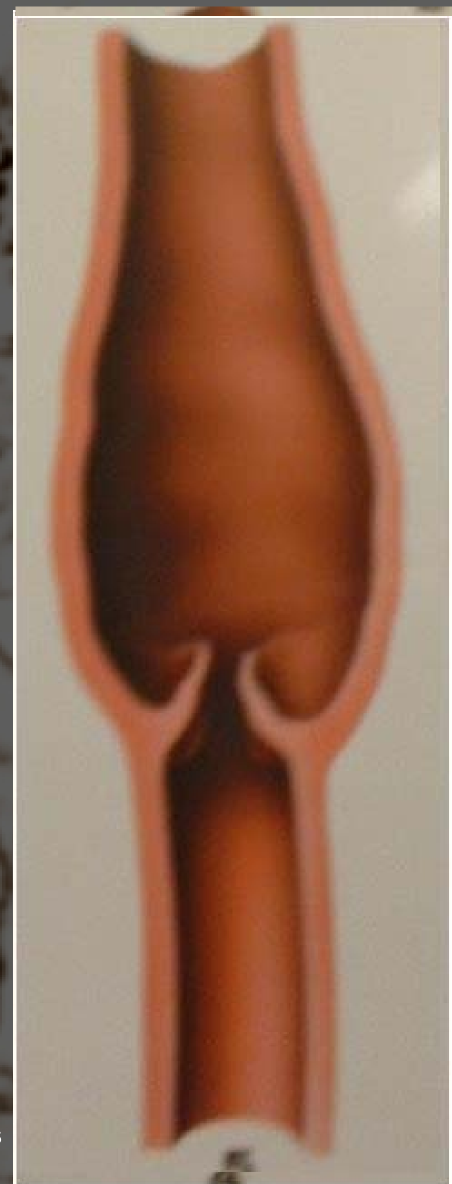
The vein is totally occluded by thrombus (PE could occur at any time after this)

Initiation of DVT behind the

Thrombus grows into the vein

Vein walls are damaged (1/3 of Virchow's triad)

A normal, healthy valve

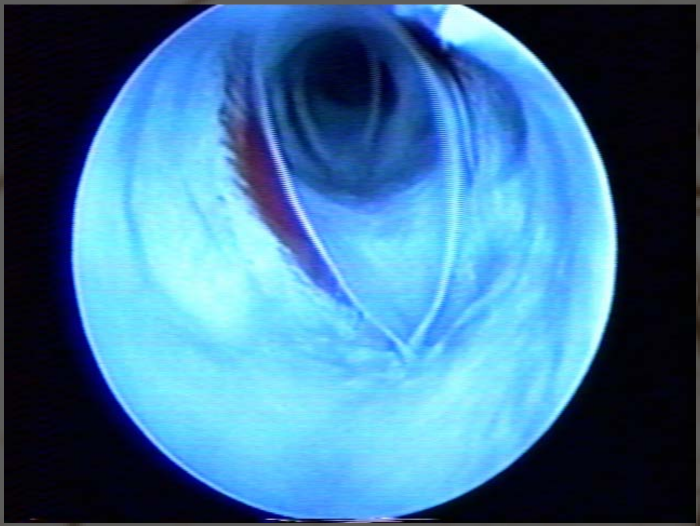


Hypothesis

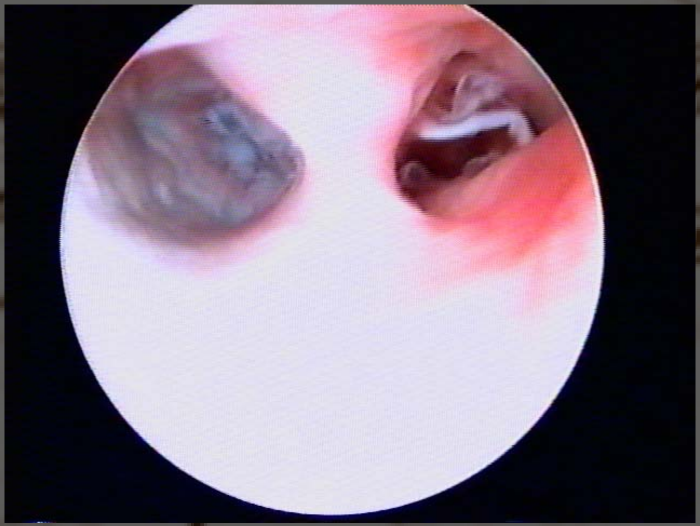
- Flow behavior and ultimately valvular competency are dependent on variations in the geometry of the venous valve

Natural Anatomical Anomalies That Occur in the Human Venous System

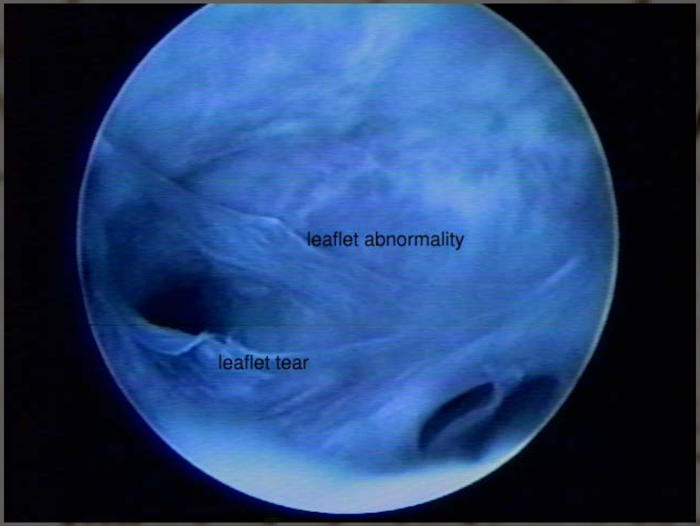
(images taken by Dr. H.F. Janssen at TTUHSC)



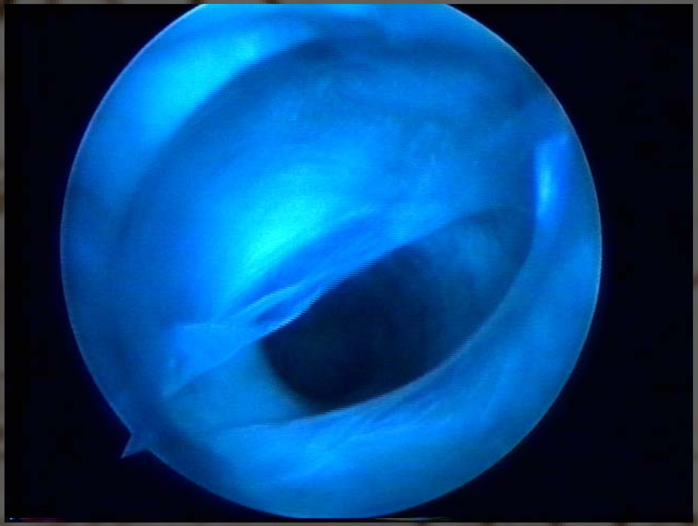
Two valves in a line



Two valves next to each other



Torn leaflet



Abnormal attachment

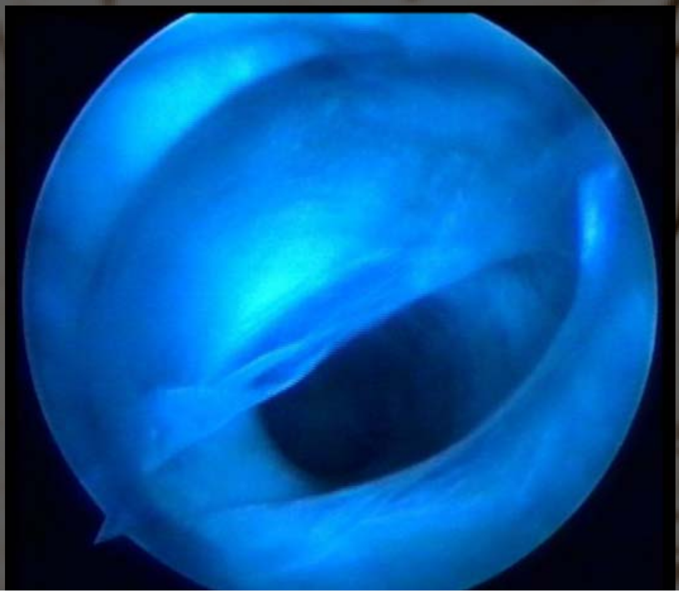
Variations in venous valve geometry

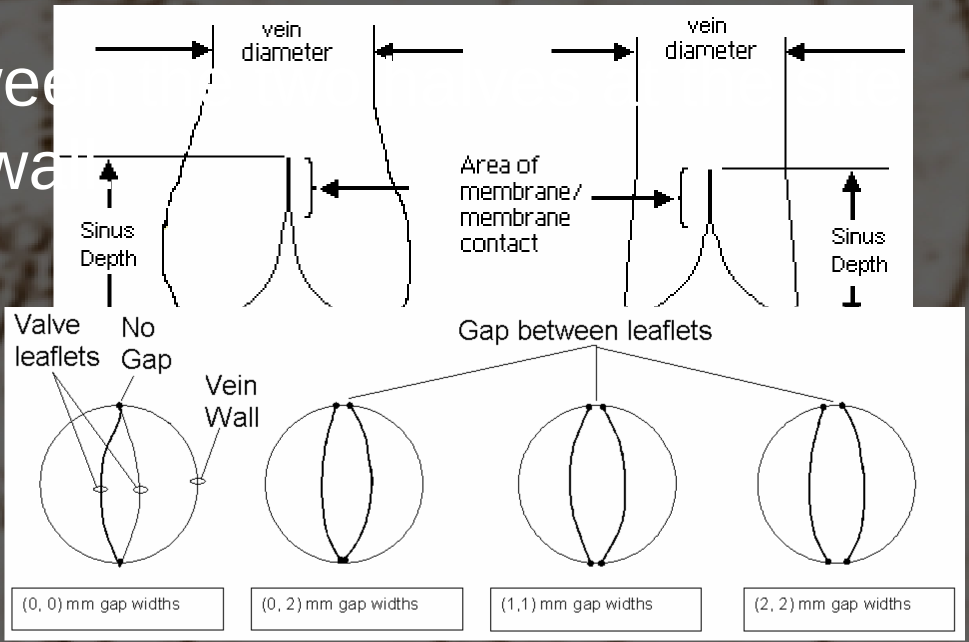
- the surface area of contact between the two leaflets

•Different gap widths betwee

of attachment to the vein wa

- Two different depth to



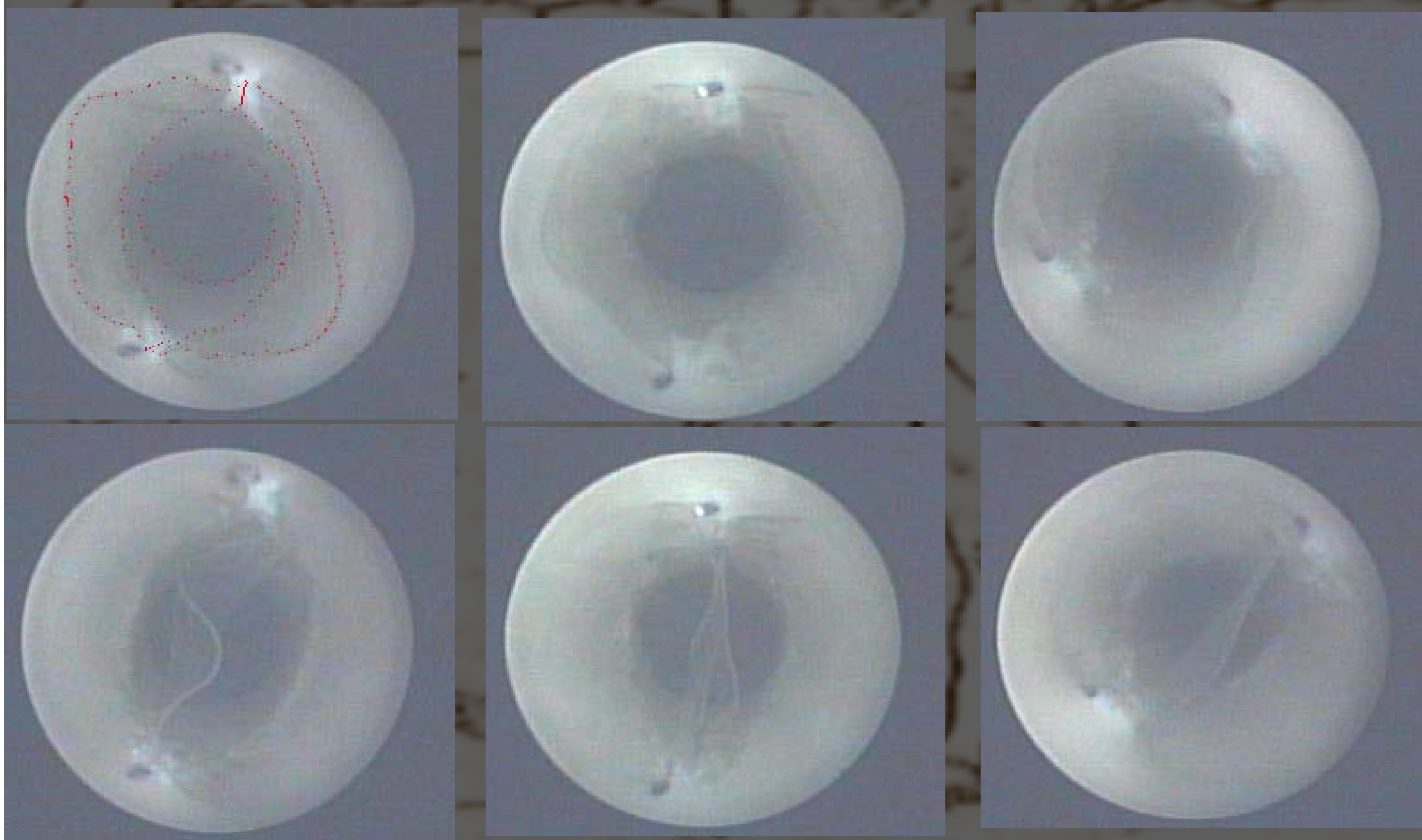


Artificial vein/valve system designed to evaluate abnormal wall attachment

0,0 mm membrane gap at wall

1,1 mm membrane gap at wall

2,2 mm membrane gap at wall



Antegrade flow (membrane is open)

Retrograde flow (membrane is closed)

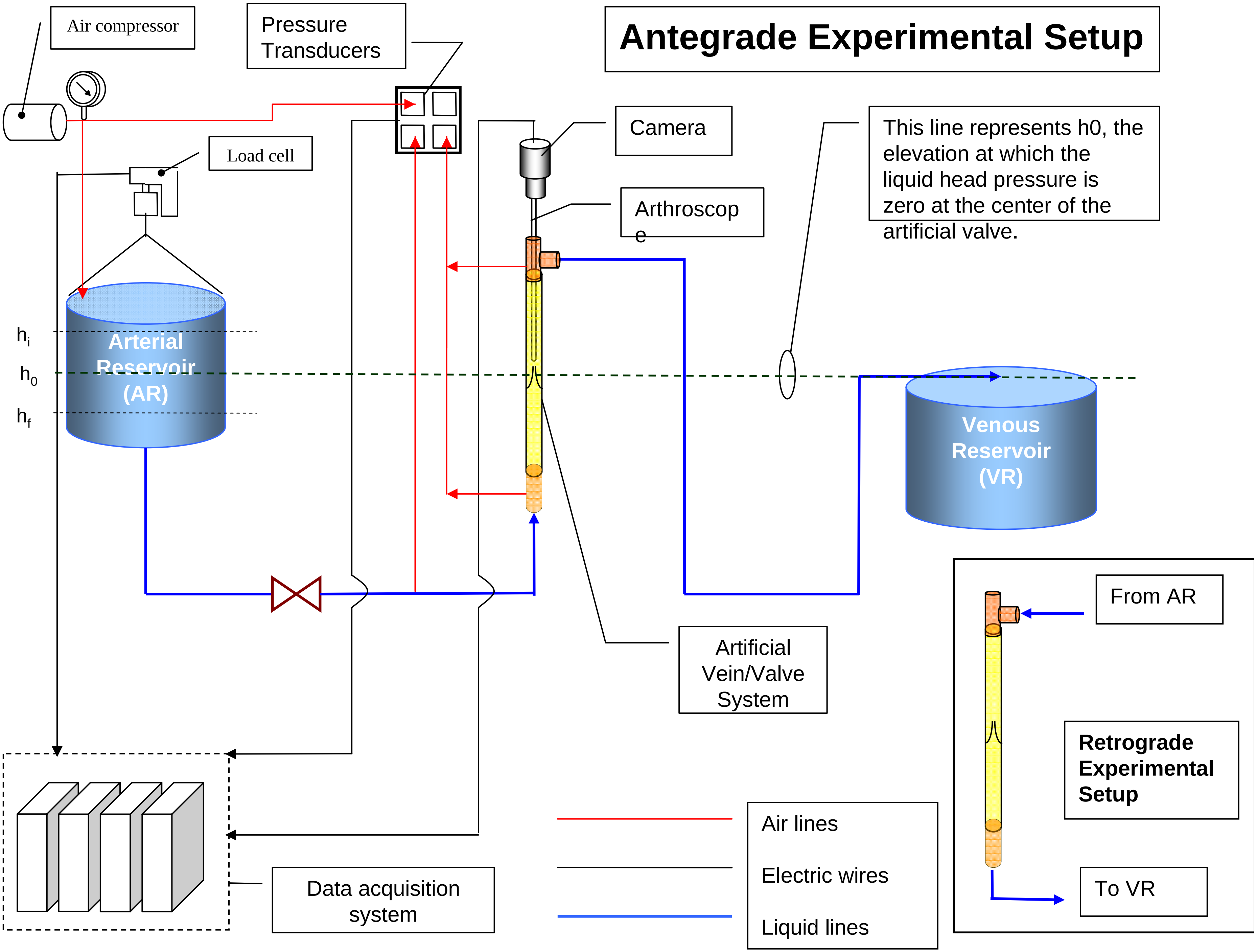
Benefits of using artificial system

- Can be made with different types of polymers
  - Material properties can be controlled
  - to simulate either “good” or “bad” veins
- Can make imperfect valves
  - Tears in cusps
  - Dog ears
  - Closure where cusps meet at vein wall
- Can put more than one valve in a vein
  - Similar to real veins
- Can make many models with identical geometry
  - Statistical repeatability

Experimental Setup

- Designed to measure parameters needed to calculate competency over a range of operating conditions:
  - Flowrate
  - Pressure
  - System geometry
- Can investigate the effect of natural anatomical anomalies on the competency of human venous valves
  - Membrane attachment at tube wall
  - Can compare artificial systems with biological systems
- Establishes a baseline for membrane performance or “competency”

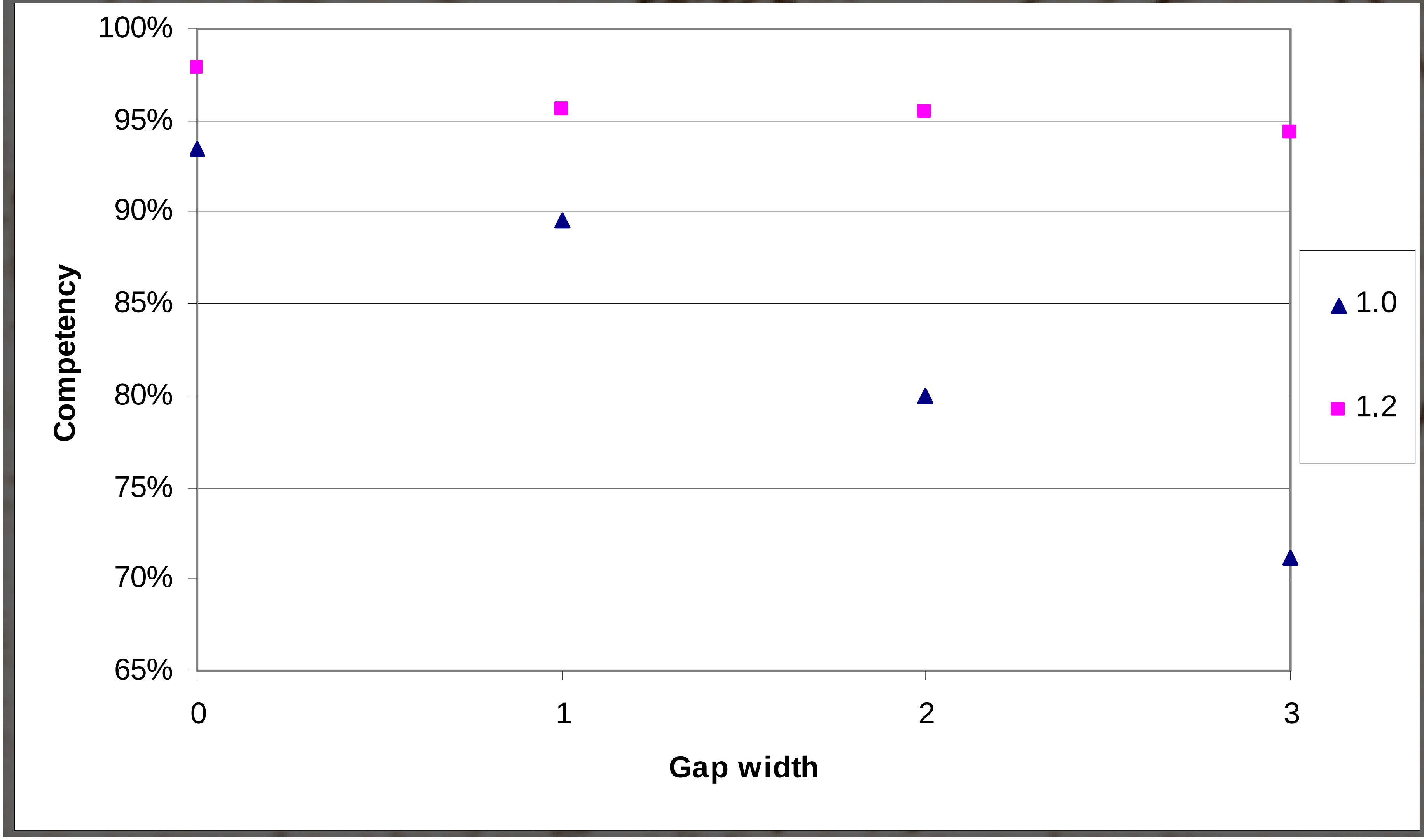
Competency = (1-(retrograde MFR/ antegrade MFR)) *100%



Antegrade Experimental Setup
Air compressor
Pressure Transducers
Load cell
Camera
Arthroscope
This line represents h0, the elevation at which the liquid head pressure is zero at the center of the artificial valve.
h_i
h_0
h_f
Arterial Reservoir (AR)
Venous Reservoir (VR)
Artificial Vein/Valve System
Data acquisition system
Air lines
Electric wires
Liquid lines
From AR
Retrograde Experimental Setup
To VR

Results:

valves with shallow sinuses are more affected by imperfect closure more than deeper sinus

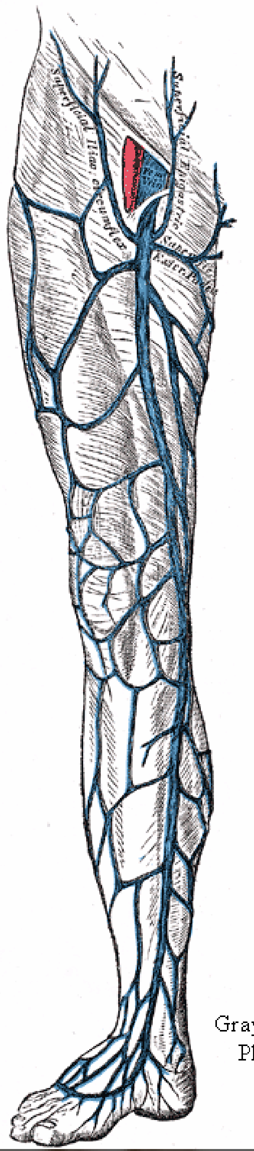


Summary

- Geometry of the venous valve is important for proper circulation

- Results from fluid flow experiments will give better understanding of hemodynamics of venous system

Future Work



Gray, Henry. *Anatomy of the Human Body.* Philadelphia: Lea & Febiger, 1918;

- Plan to use CFD to model fluid flow or hemodynamics
  - Get a better idea of overall system performance

- With a better understanding of venous anatomy we can re-design prophylactic device
  - Optimize the mechanics of the design
  - focus on patient comfort

EPC devices

- An inflatable air bag is wrapped around the leg
  - Calf
  - Thigh
  - Full length

- Periodically inflated/deflated to collapse/uncollapse veins
  - Designed to induce blood circulation

- Currently, physicians and clinicians can only guess about:
  - How fast to inflate the device
  - How much to inflate the device (i. e. optimum pressure)
  - Frequency of inflation
  - Sequence of inflation

- Patient discomfort can deter use of the device once they leave the hospital

Expected overall results of the study

- An improved understanding of the physical anatomy and physiological response of the venous valve
- A mechanical model of the vein/valve system that can be analyzed in a wide range of conditions
- Improved EPC devices

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For more information visit our website

– http://www.che.ttu.edu/Faculty/hoo2/bioResearch.htm