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Microvascular Dysfunction in PAD Patients

WICHITA STATE UNIVERSITY

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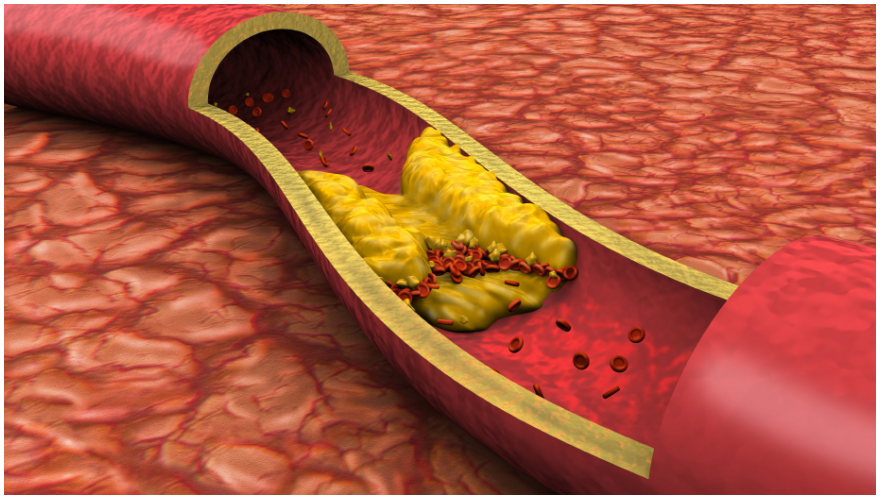
Introduction

- Peripheral arterial disease (PAD)
- Standard revascularization surgical procedures restore blood flow in the main arteries via bypass surgical grafting.
- Continued decline in limb function and walking parameters.



Introduction

- Microvascular dysfunction may impair tissue oxygenation as well as nutrient transport and may therefore be a contributor to the continued decline in limb function and walking parameters.
- In this study we assess the effectiveness of the standard lower limb revascularization strategies in PAD patients who may have microvascular dysfunction.

Risk Factor

- Over age of 50
- Elevated blood cholesterol
- Diabetes
- Smoking
- Hypertension
- Obesity

Significance

After Bypass Surgery

• Healing and recovery time	15-20 weeks
• **Wound complications**	**15-25%**
• **Major amputation**	**5-10%**
• Lymphedema	10-20%
• Graft stenosis	20%
• Graft thrombosis	10-20%
• Graft infection	1-3%

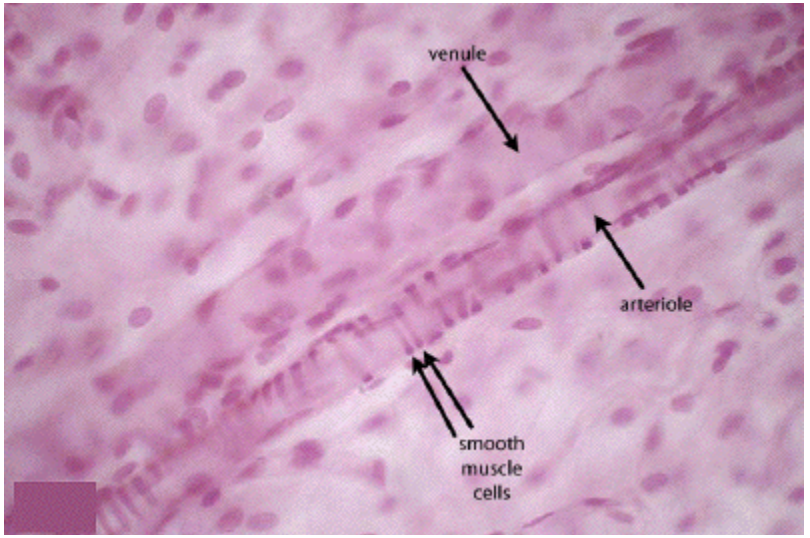
Source:James H Quillen College of Medicine

Microcirculation

- The microcirculation refers to the smallest blood vessels in the body:
  - The smallest arterioles
  - The metarterioles
  - The precapillary sphincters
  - The capillaries
  - The small venules

Microcirculation

- The principal function of the microcirculation is to permit the transfer of substances between the tissues and the circulation. This transfer occurs predominantly across the walls of the capillaries but some exchange occurs in the small venules also. Substances involved include water, electrolytes, gases (O2, CO2), nitrogenous wastes, glucose, lipids and drugs.



Microcirculation

- Electrolytes and other small molecules cross the membrane through pores. Lipid soluble substances (including oxygen and carbon dioxide) can also easily cross the thin (1 mm) capillary walls. Proteins are large and do not cross easily via pores but some transfer does occur via pinocytosis (endocytosis/exocytosis).

Microcirculation

- Water molecules are smaller than the size of the pores in the capillary and can cross the capillary wall very easily. The capillary endothelial cells in some tissues (eg glomerulus, intestinal mucosa) have gaps (called fenestrations) in their cytoplasm which are quite large. The water conductivity across these capillaries is much higher then in non-fenestrated capillaries in other tissues of the body.
- The transfer of water across the capillary membrane occurs by two processes: diffusion and filtration.

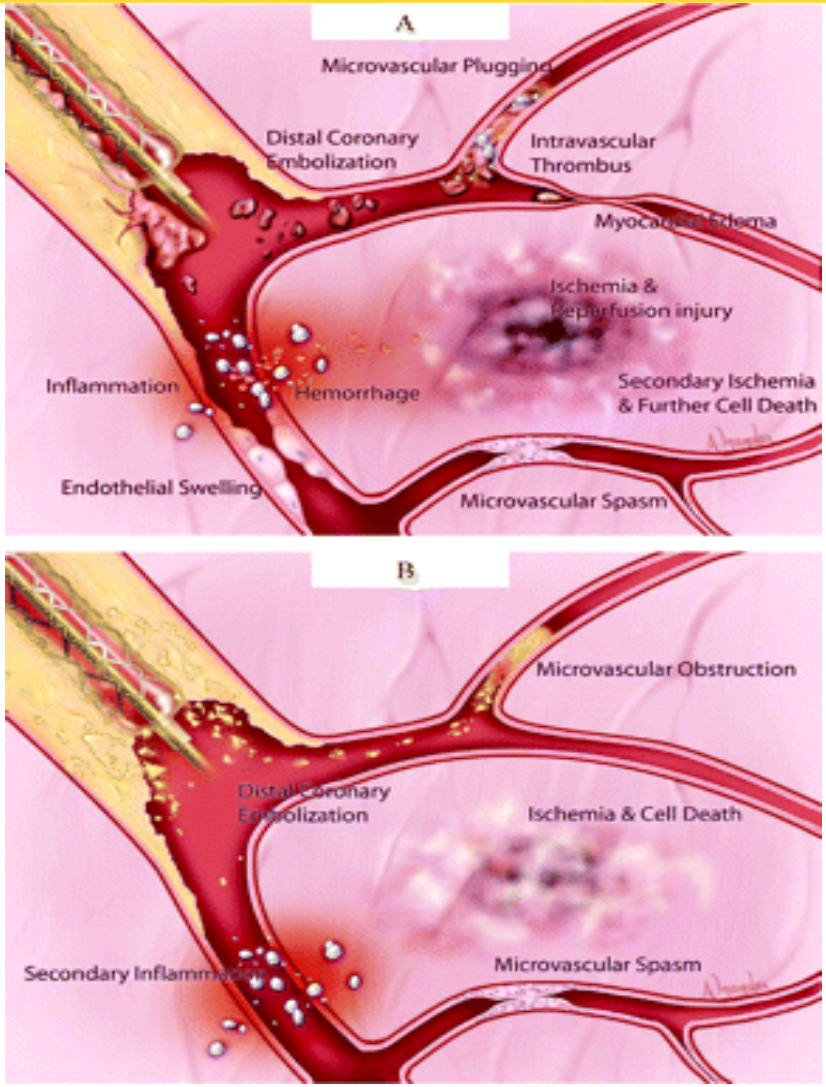
Diffusion

- The total daily diffusional turnover of water across all the capillaries in the body is huge
- Diffusion occurs in both directions and does not result in net water movement across the capillary wall.

Filtration

- This is actually ultrafiltration as the plasma proteins do not cross the capillary membrane in most tissues.
- For the whole body, there is an ultrafiltration outward of 20 liters per day and inwards of 18 liters per day. The difference (about 2 liters/day) is returned to the circulation as lymph.
- Filtration results in net movement of water because there is an imbalance between the forces promoting outward flow and the forces promoting inward flow.

Microvascular dysfunction



Hypothesis

- Our central hypothesis is to justify that the poor wound healing and end organ failure cases in patients with PAD even after revascularization is due to microvascular dysfunction in limbs similar to the myocardial ischemia that results from abnormal coronary microcirculation.

Methods

- Comsol was used as our method to validate our hypothesis.

Equation

- Governing Equation
  - **Fick's Law of Diffusion**
  - **Navier-Stokes**

$$\nabla C = \hat{i}\frac{\partial C}{\partial x} + \hat{j}\frac{\partial C}{\partial y} + \hat{k}\frac{\partial C}{\partial z}$$

$$\rho\frac{\partial \mathbf{u}}{\partial t}_{fluid} + \rho\left(\mathbf{u}_{fluid}\cdot\nabla\right)\mathbf{u}_{fluid} =$$

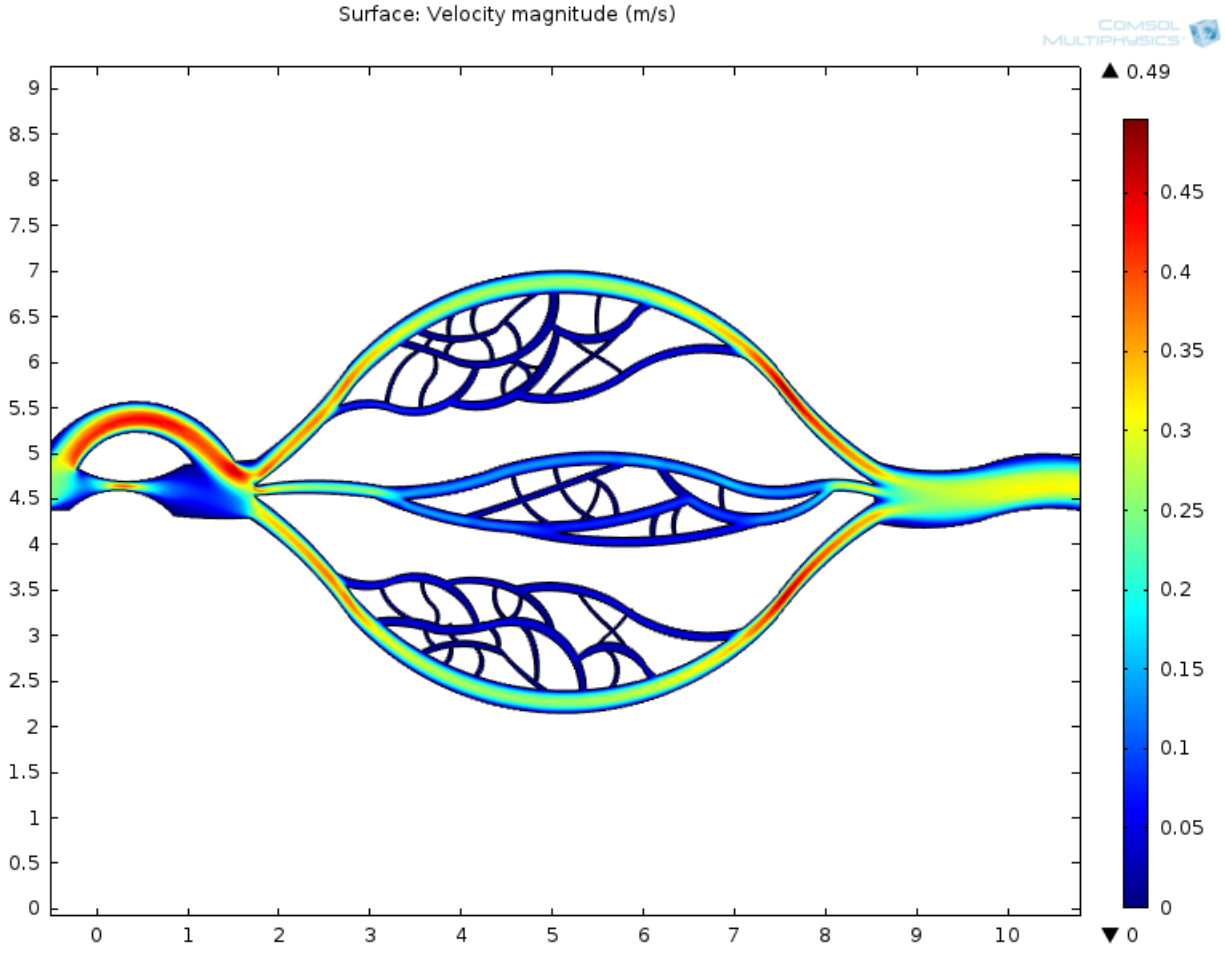
$$\nabla.[-pI + \mu\left(\nabla\mathbf{u}_{fluid} + (\nabla\mathbf{u}_{fluid})^{T}\right)] + \mathrm{F}$$

$$\rho\nabla\cdot\mathbf{u}_{fluid} = 0$$

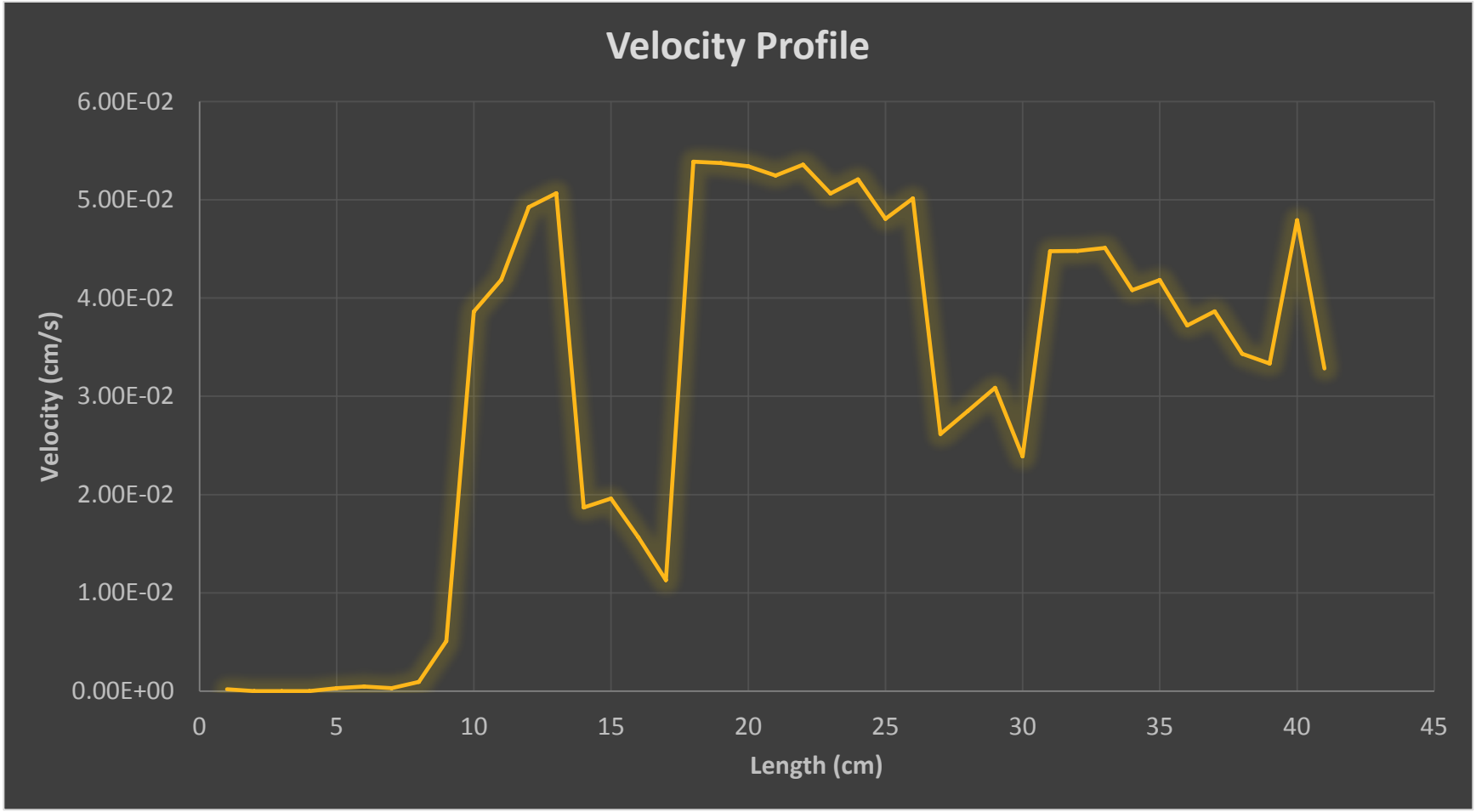
Results

- Velocity
- Oxygen Consumption

Velocity Profile



Velocity Profile



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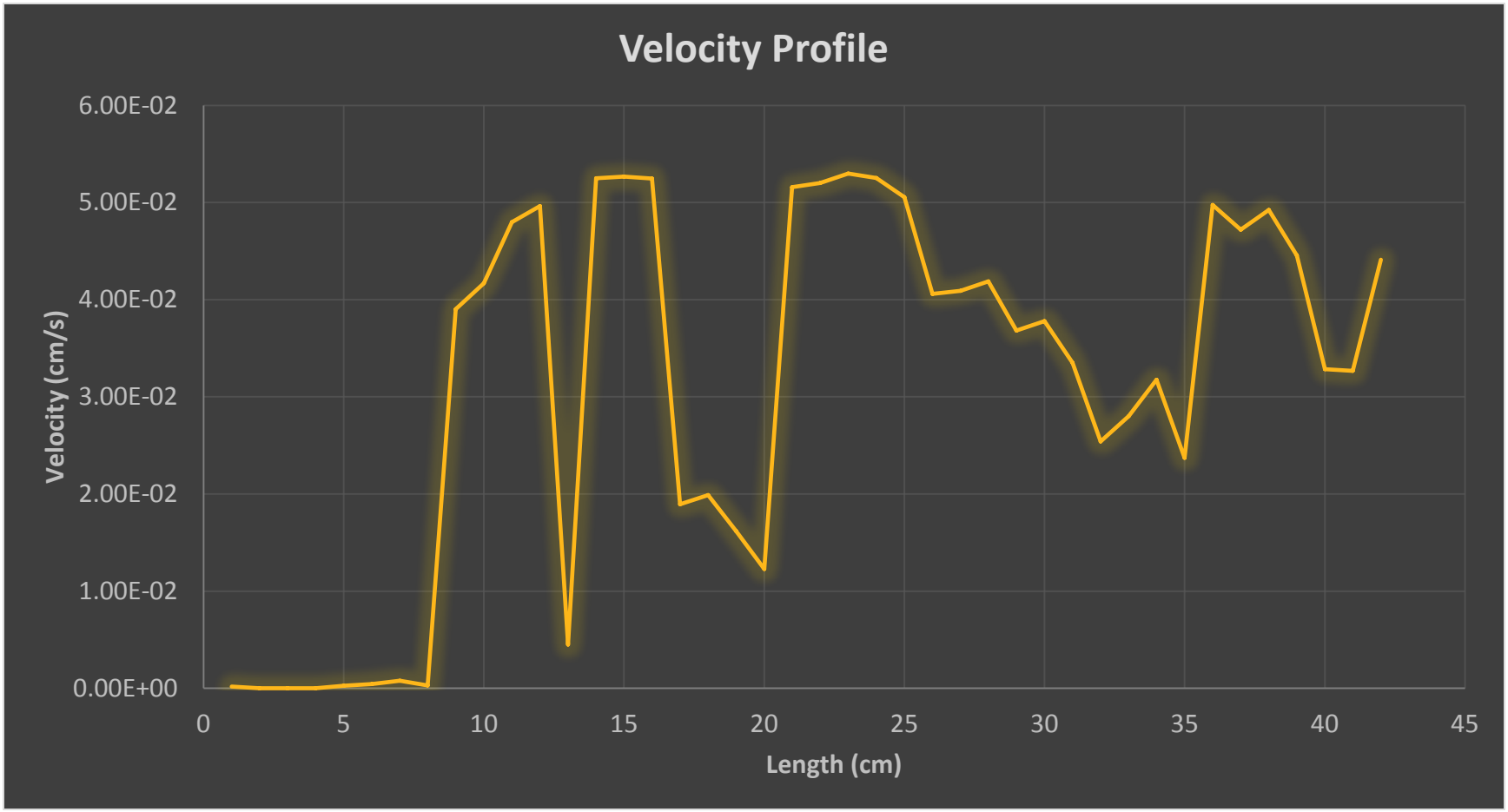
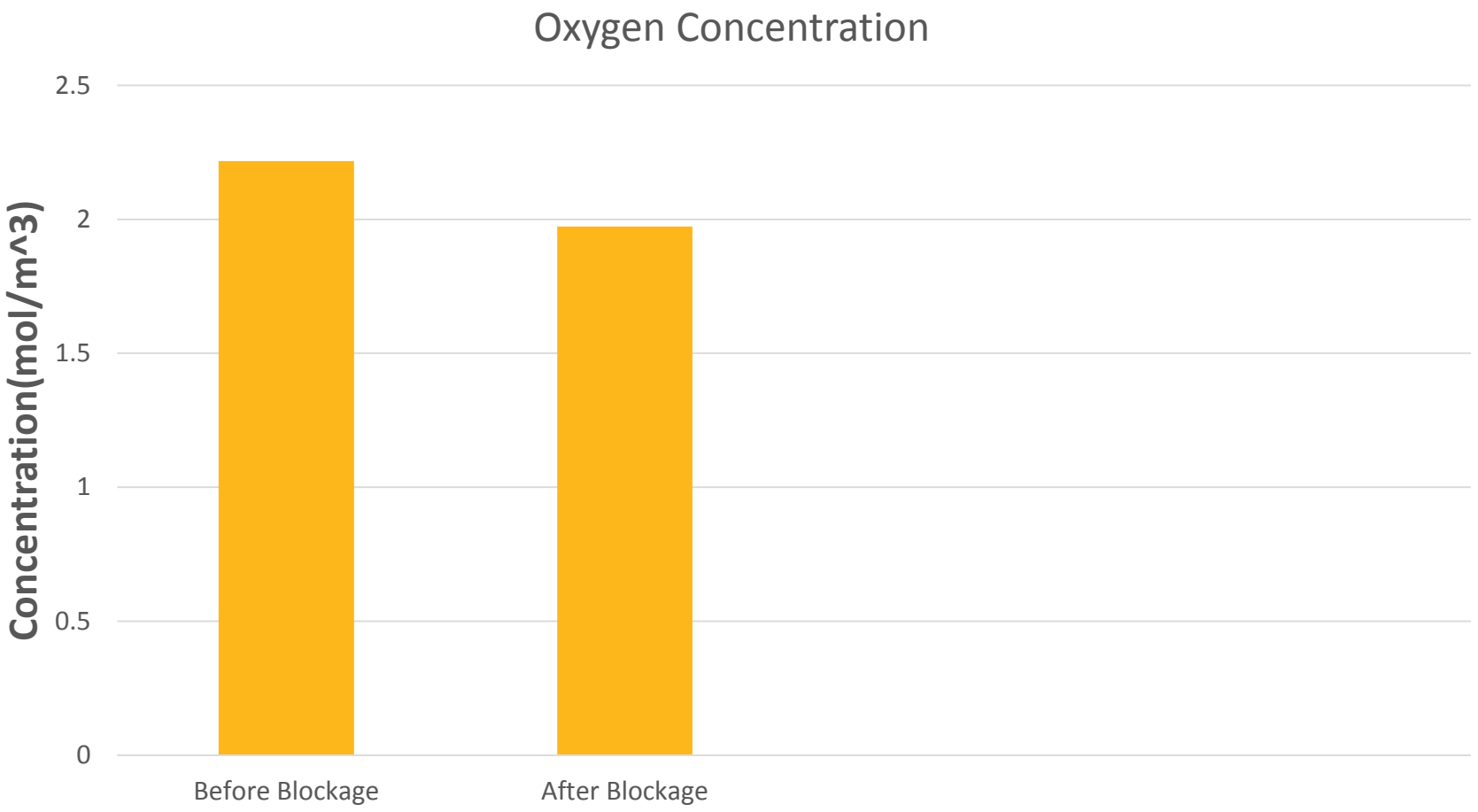


Oxygen Concentration



Oxygen

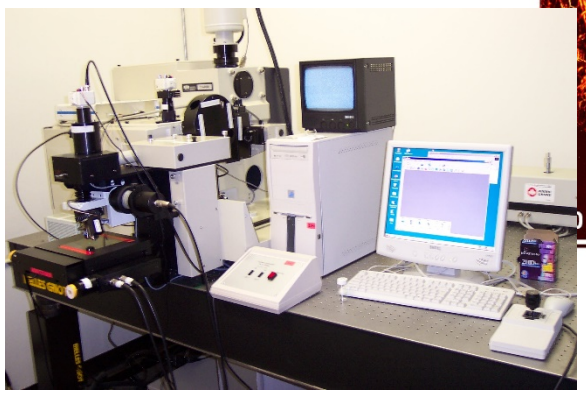
- We have noticed there is a change in oxygen saturation even after the graft, therefore we expect patients to get less oxygen demand to the muscle as a result of that in some cases the tissue will be dead and the patient will have more complication.

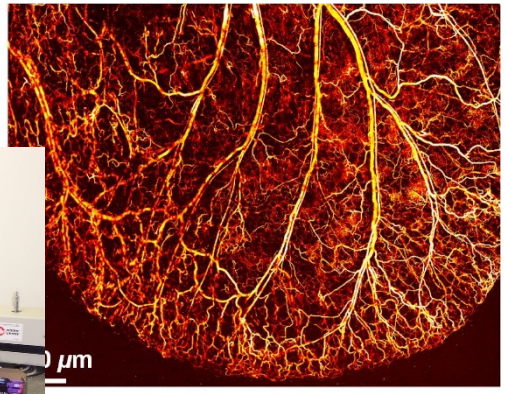
Conclusion

- Microvascular dysfunction can be a significant factor in PAD patients which should be addressed by physician.
- Bypass surgery without addressing this problem is less effective

Future Works

- Blood analysis using Raman spectroscopy.
- Blood nutrient transport.





Q&A

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