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A 2D AXISYMMETRIC COMPUTATIONAL MODEL FOR THE STUDY OF MASS TRANSPORT INTO LYMPHATIC CAPILLARIES AND PRE-COLLECTOR VESSELS

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Introduction to lymphatic system

Lymphatic system

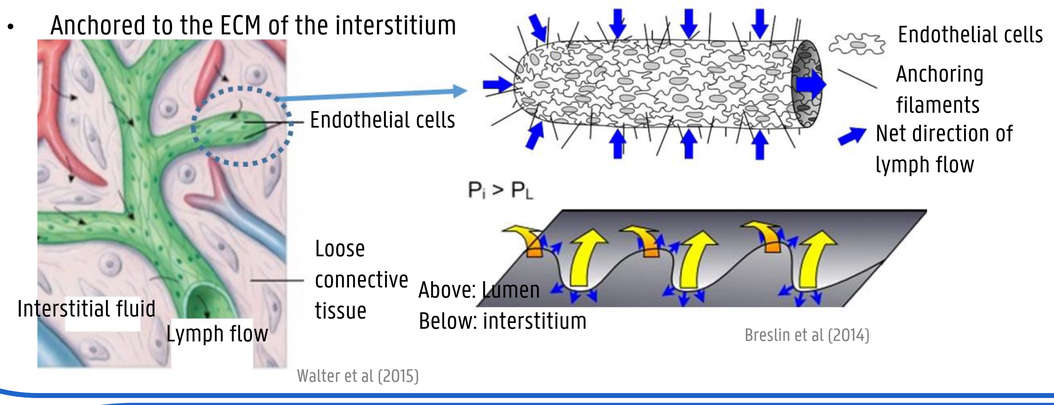
- Unidirectional vessel network
- Evacuate the interstitial fluid back into the venous circulation

Interstitium

- Porous medium which provides structural support to cells (Extra-Cellular Matrix)
- Clearance of catabolic products
- Provide physical stimuli to modulate lymph formation

Lymphatic capillaries

- Single endothelial layer forming one-way valves
- Anchored to the ECM of the interstitium



Walter et al (2015)

Breslin et al (2014)

Lymphedema

- Secondary lymphedema is acquired as a result of cancer surgery, such as axillary lymph-node excision
- Lymphedema affect patient's life in a long-term condition
- So far no permanent treatment available

Michelini et al (2018)

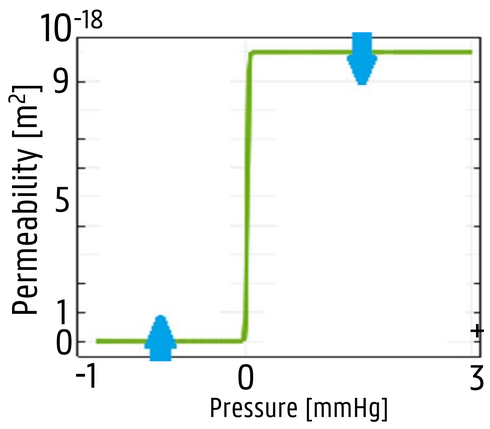
Objective

- The aim of this study was to develop a computer model focusing on lymphatic clearance during lymphedema
- Our goal is to develop a model of primary valves that can mimic their function in different lymphedema stages and in normal physiological conditions

Methods & Results

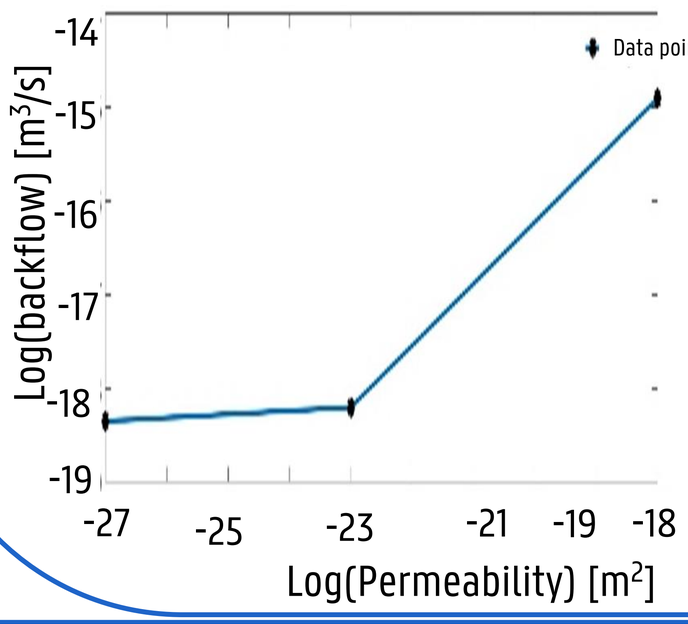
Permeability of the valves → Pressure dependent permeability ranging from 10^{-18} to 10^{-27} m^2:

- **Lymphatic leakage** → Valves remain open with a permeability ranging from 10^{-18} to 10^{-27} m^2
- **Lymphatic obstruction** → Valves reduce their opening by increasing permeability ranging from 10^{-18} to 10^{-20} m^2



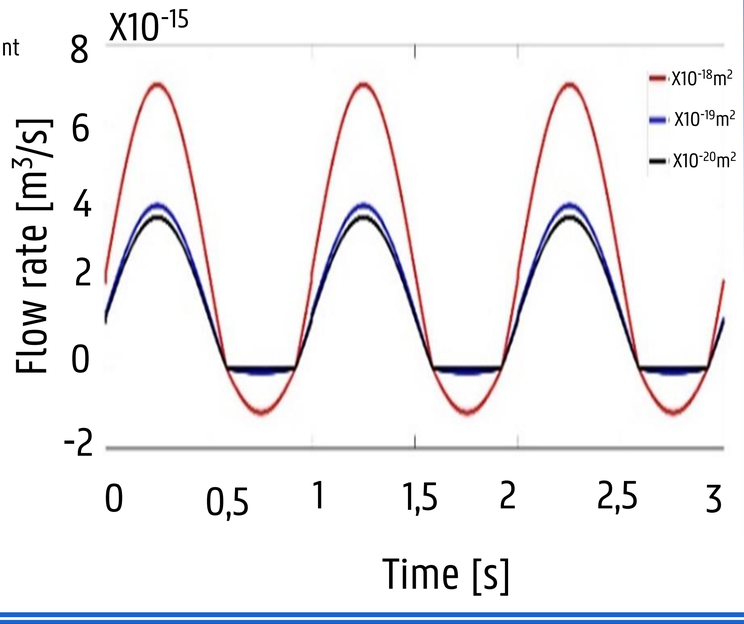
Leakage

Lymphatic leakage (increased permeability) provokes that fluid is being cleared from the tissue less efficiently than under normal physiological conditions.

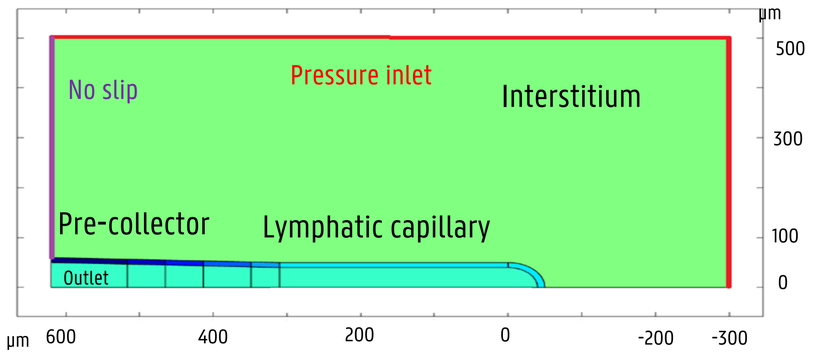


Obstruction

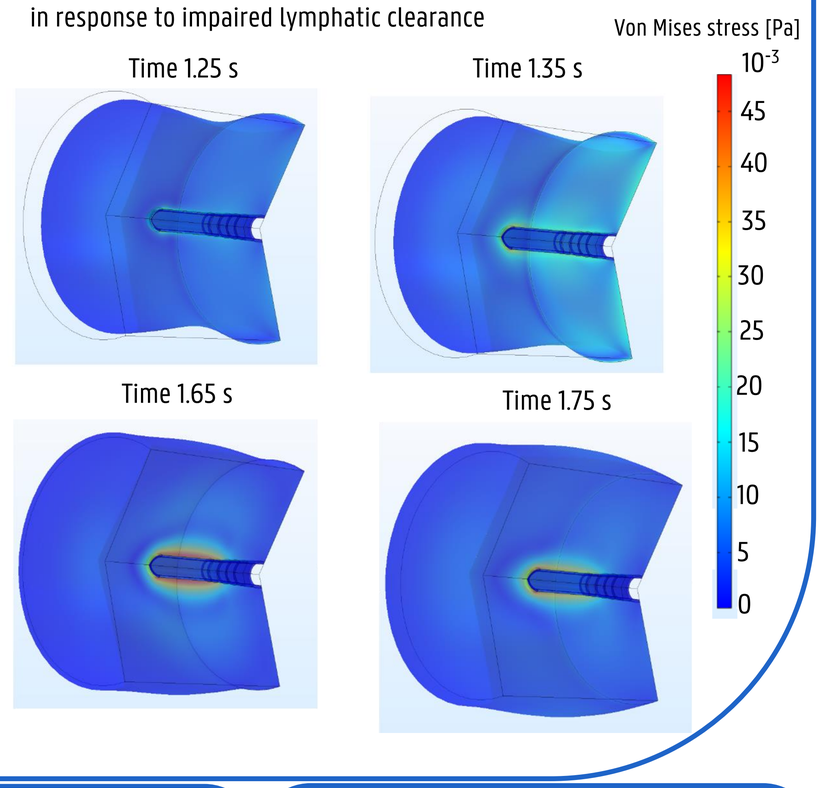
the flow rate of the capillary is critically dependent on the permeability, since a decrease of it reduce inflow.



- 2D axisymmetric model in COMSOL Multiphysics
- Inlet → A sinusoidal pressure (peak-to-peak from 3 to -1 mmHg; 1Hz)
- Outlet → zero pressure
- One way valves → modelled as a porous material
- Interstitium → Poroelastic material
- Capillary and Pre-collector channel → Single phase fluid



Increase of interstitial fluid volume and swelling of the tissue in response to impaired lymphatic clearance



CONCLUSION

- This 3D computational model of the poroelastic interstitial space and initial and secondary lymphatics allowed us **to replicate lymphedema**.
- Primary valve malfunctioning at the level of the individual valves has been replicated **by modelling valve function via a pressure (and space) dependent wall permeability.**
- Our model **represent different levels of impairment of the pre-collectors and the lymphatic capillaries**, from a total obstructed capillary (zero wall permeability at all times) to a leaking one (high permeability at all tiles) and any intermediate situation.
- **Further research will focus on further extension of the model,** coupling it to pumping lymphangions, and extensive validation.

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