A multiphase tracking of perfusion through *in silico* dense tumor domain

Mohammad Mehedi Hasan Akash[1], Nilotpal Chakraborty[2], and Saikat Basu[1]

[1] Department of Mechanical Engineering, South Dakota State University, Brookings, SD

[2] Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, India

APS DFD / 2021, Phoenix, AZ

basu Lab
Biomedical and Bio-Inspired Fluid Dynamics Lab

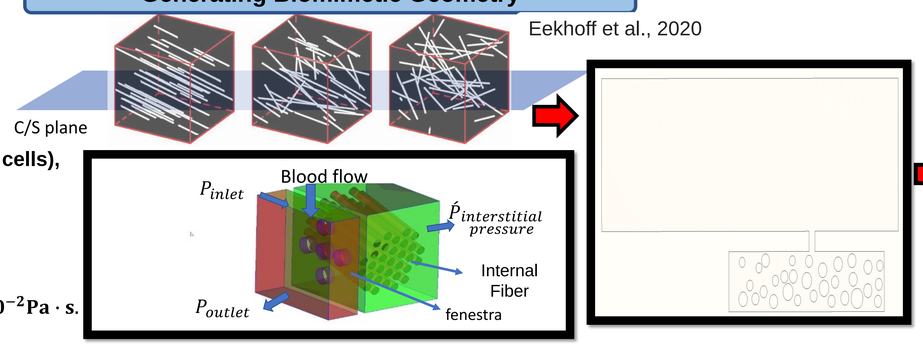
Approach

- We have developed a reduced order biomimetic geometry for solid tumor vasculature, with focus on tracking perfusion inside dense pancreatic tumors.
- Computational Fluid Dynamics (CFD) tools are being used to quantify and compare the leakiness for plasma entry into the tumor, through varying the sizes of the fenestra openings.
- ***Extension to realistic cases***: We will apply this *in silico* modeling platform to track plasma percolation in geometries derived from imaging data of solid pancreatic tumors in mouse xenograft models.

Methods

- Fenestra cross-sectional sizes for Geometry 1, Geometry 2, Geometry 3 are respectively 0.1 μm, 0.3 μm, 0.5 μm.
- ***Tracking plasma perfusion***: via a 2-step simulation
- 3-phase viscous-laminar transient simulation with Plasma, RBCs (red blood cells), and WBCs (white blood cells)
- Diameters of RBCs and WBCs are respectively 7 μm and 14 μm.
- Densities of Plasma and WBCs are respectively 1030 kg/m^3 and 1080 kg/m^3.
- Viscosities of Plasma and WBCs are respectively 1.2$\times 10^{-3}$Pa $\cdot$ s and 1.1$\times 10^{-2}$Pa $\cdot$ s.

Generating Biomimetic Geometry



Biomimetic Geometry (Blood vessel and Tumor region)

Figure 1 (a): Blood vessel

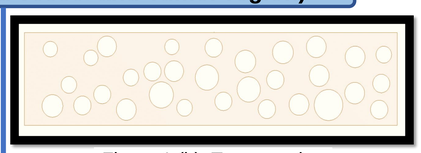


Figure 1 (b): Tumor region

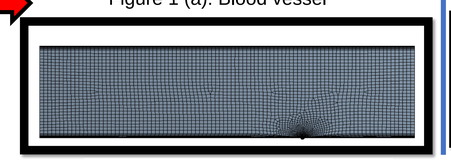


Figure 1 (c): Mesh of blood vessel

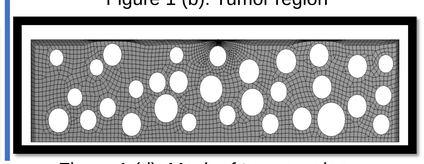
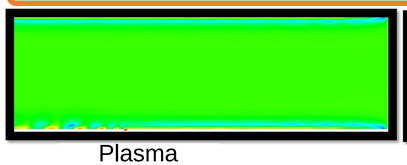


Figure 1 (d): Mesh of tumor region

Results

Plasma perfusion during three different flow times for 3 Geometries

Representative blood vessel during the flow time 0.15 sec



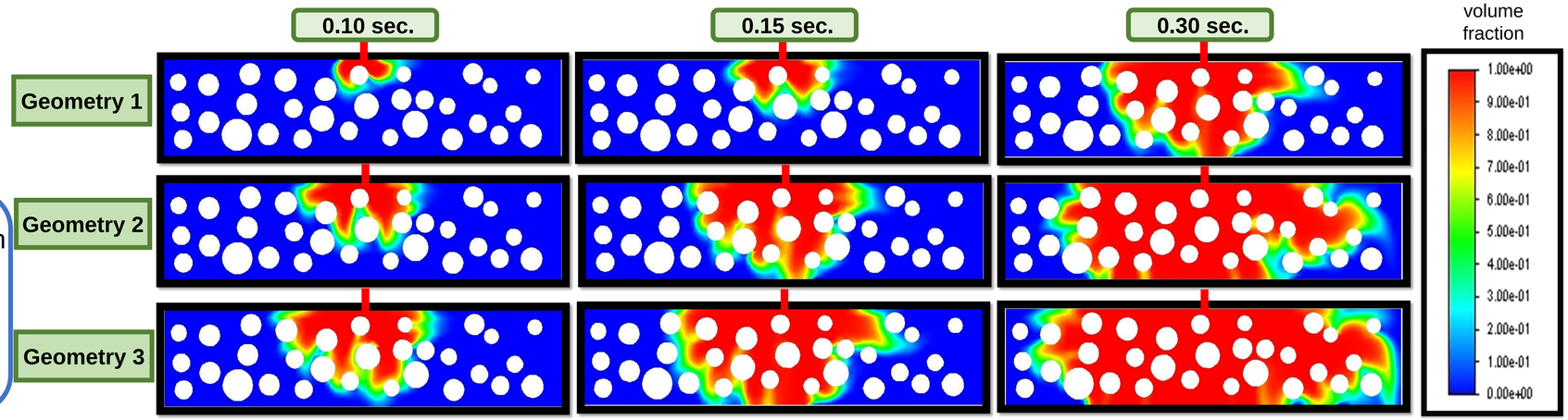
Plasma

WBCs

RBCs

Plasma, RBCs, and WBCs are being tracked inside the blood vessel. Volume fractions of Plasma, RBCs, and WBCs are respectively 54%, 45%, and 1%.

Plasma perfusion is gradually increasing with flow time inside tumor region.



Discussion

	Flow time=0.10 sec	Flow time=0.15 sec	Flow time=0.30 sec
Geometry 1	(R+G):B=0.021:1	(R+G):B=0.024:1	(R+G):B=0.42:1
Geometry 2	(R+G):B=0.087:1	(R+G):B=0.167:1	(R+G):B=4.1:1
Geometry 3	(R+G):B=0.141:1	(R+G):B=0.82:1	(R+G):B=4.65:1

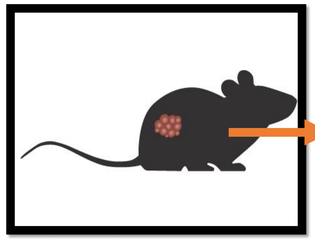


Figure 2(a) : Cartoon tumor schematic

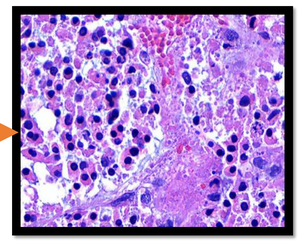


Figure 2(b): Mice CT scan

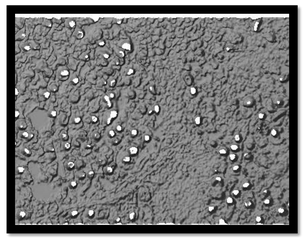


Figure 2(c): STL of mice Scan

Selected References

1. Eekhoff, J. D. and Lake, S.P. *Three-Dimensional Computation of Fiber Orientation, Diameter and Branching in Segmented Image Stacks of Fibrous Networks*. *J. R. Soc. Interface* **2020**, *17*, 20200371
2. Akash, M.M.H., Chakraborty, N., and Basu, S. *Computational modeling of perfusion in dense solid tumors. arXiv preprint:* 2012.04095v2, **2021**
3. Nithiarasu, P. *Biofluid Dynamics* (p. 20). **2021**
4. MacBride M. M. *Studying T Cell Distribution in Syngeneic Tumor Models*. *TACONIC* **2019**

Acknowledgments

- Figure 2(b) is courtesy of the NDSU Animal Core Team (Dr. Jiyan Mohammad, Animal Core Facility Manager, North Dakota State University).
- This work is supported as a pilot project under the NIH COBRE Pilot Grant Project Number 5P20GM109024.

Email: Saikat.Basu@sdstate.edu