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**Estimating Fluid Local Velocity within a Novel 3D Collagen Matrix Perfusion
System**

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ABSTRACT

Traditional cell culture, performed on flat surfaces under static conditions, does not accurately represent physiologic conditions. As an alternative, groups have applied interstitial fluid flow (0.1-2.0 $\mu\text{m/s}$) through a 3D cell-embedded extracellular matrix (ECM). Cells sense the flow via mechanotransduction, a process by which cells sense mechanical forces and resultantly respond with biochemical signaling. Previous work demonstrates enhanced cell morphogenesis under interstitial flow conditions. However, fluid flow is poorly described within these systems, stressing the need for a well-characterized 3D interstitial flow system. Understanding fluid mechanics within a perfusion system will help elucidate cellular response to flow-induced mechanical forces.

The objective of this study was to quantify the fluid flow velocity through a controlled ECM. The changes in the collagen concentration are directly related to the fibril density of the collagen (stiffness).

A fluorescent Rhodamine solution was pumped at a constant flow rate through a collagen matrix-containing chamber. The resulting flow front was visualized at the center of the chamber using a fluorescent microscope. A Matlab program was developed to track the light intensity between time points to provide measures of flow velocity.

The results suggest that collagen concentration affects the estimated velocity measurements. As collagen fibril density increases, the resistance to flow increases, leading to a decrease in estimated velocity. These results validate the device's ability to consistently distribute flow over a range of ECM stiffness. Control and quantification of local fluid velocity is essential for future experiments in which cells will be embedded in the collagen matrix to observe cell response to fluid flow.

KEYWORDS

Macrofluidic-controlled flow rate- controlled matrix-surface tension-fibril density

REFERENCES

Ng, C. P., Helm, C. L. E., & Swartz, M. A. (2004). Interstitial flow differentially stimulates blood and lymphatic endothelial cell morphogenesis in vitro. *Microvascular research*, 68(3), 258-264.

Swartz, M. A., & Fleury, M. E. (2007). Interstitial flow and its effects in soft tissues. *Annu. Rev. Biomed. Eng.*, 9, 229-256.

Shi, Z. D., Ji, X. Y., Qazi, H., & Tarbell, J. M. (2009). Interstitial flow promotes vascular fibroblast, myofibroblast, and smooth muscle cell motility in 3-D collagen I via upregulation of MMP-1. *American Journal of Physiology-Cell Physiology*, 66(4), H1225.

Pedersen, J. A., Lichter, S., & Swartz, M. A. (2010). Cells in 3D matrices under interstitial flow: effects of extracellular matrix alignment on cell shear stress and drag forces. *Journal of biomechanics*, 43(5), 900-905.

Polacheck, W. J., Charest, J. L., & Kamm, R. D. (2011). Interstitial flow influences direction of tumor cell migration through competing mechanisms. *Proceedings of the National Academy of Sciences*, 108(27), 11115-11120.