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Needle-free Jet Injection: Dispersion of Viscous Fluids

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Background

Our research group focuses on developing controllable needle-free jet injectors. These devices force a drug through an orifice forming a fine jet that can pierce through the top layer of skin [1].

After developing a bench top needle-free jet injector for viscous fluids, we were interested in analyzing how viscous fluids disperse when injected into skin. Published work [2] had not quantified the speed of the jet piercing the skin and had been limited to a small range of viscous fluids. In this work, we extend that range and provide insight into the influence of viscosity on the delivery of a drug.

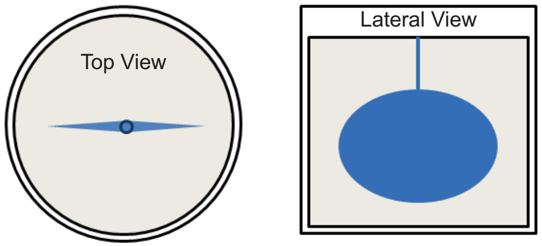

Figure 1 – Top view and lateral view of typical jet dispersion in polyacrylamide gels

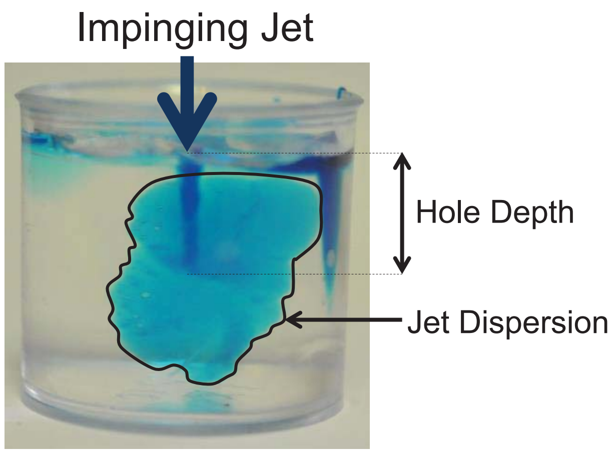

Figure 2 – Example of fluid jet dispersion in polyacrylamide gel

Method

Firstly, we performed injections into 10% polyacrylamide gels at 124 $m{\cdot}s^{-1}$ and measured the depth and area of dispersion in ImageJ (Figs. 1 and 2). We then injected contrast agent with different viscous fluids into porcine skin with a slightly slower jet speed (110 $m{\cdot}s^{-1}$). A micro-CT of the resultant skin sample (Fig. 3) allowed us to analyze the dispersion of the fluid in MATLAB.

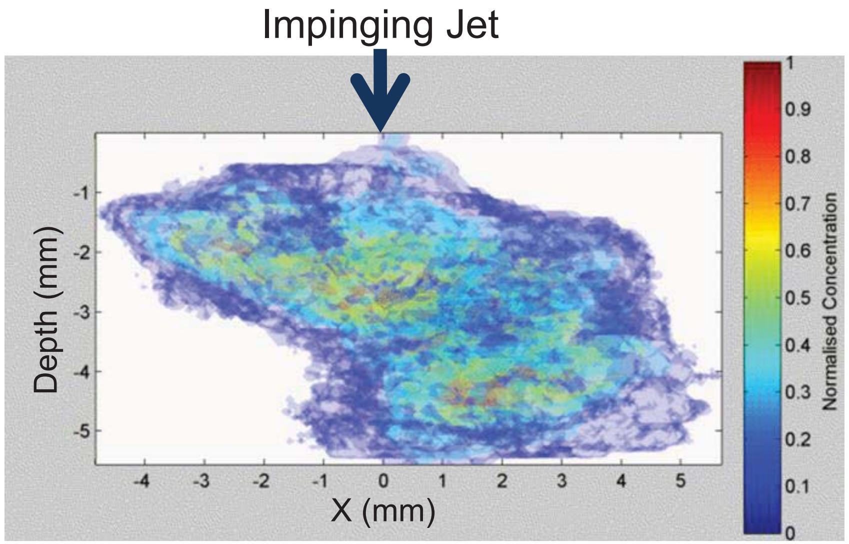

Figure 3 – Dispersion of viscous fluid underneath porcine skin surface.

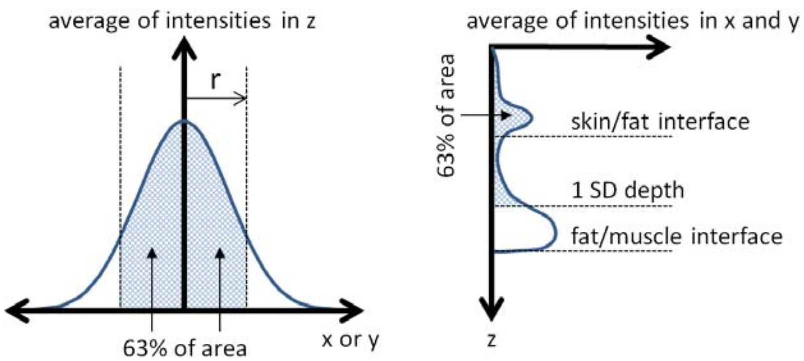

Figure 4 – Radial distribution measurement and depth measurement taken from micro-CT images.

Results

The gel tests revealed no significant difference in depth and a slight increase in the area of dispersion as viscosity was increased. The skin tests gave similar results (Table 1) with the p-values comparing each set of viscous fluid tests (n = 5) indicating no evidence of a change in dispersion due to viscosity. A p-value <0.05 indicates evidence of a difference in the dispersion measurements.

Comparison (%Glycerol)	Radial Distribution	Depth Distribution	Percentage below Surface
30%:60%	0.876	0.638	0.999
30%:75%	0.748	0.638	0.297
30%:85%	0.101	0.853	0.901
30%:95%	0.290	0.957	0.678
60%:75%	0.999	1.000	0.415
60%:85%	0.422	0.998	0.964
60%:95%	0.782	0.968	0.804
75%:85%	0.564	0.998	0.840
75%:95%	0.894	0.969	0.977
85%:95%	0.975	0.998	0.992

Table 1 – P-values for different distribution for each comparison of the viscous fluids tested in skin.

The results suggest that the variability of skin properties is a much more important determinant of dispersion than viscosity. We hypothesize that the inertia of the high-speed jet nullifies a lot of viscous fluid resistance to flow.

References

[1] Donnelly et al., "Influence of solution viscosity and injection protocol on distribution patterns of jet injectors: application to photodynamic tumour targeting.," J. Photochem. Photobiol. B., vol. 89, no. 2–3, pp. 98–109, Dec. 2007.
[2] Taberner et al., "Needle-free jet injection using real-time controlled linear Lorentz-force actuators.," Med. Eng. Phys., no. 0, Jan. 2012.

Acknowledgements

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