Effect of geometry on collagen flow in constricted channels for cell delivery

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Cell therapy has been recently proposed as an effective strategy for the treatment of several neurodegenerative disorders, including Parkinson's disease. Natural biomaterials, such as collagen, have been used as scaffolds to facilitate cell deposition, through needle-based delivery. However, despite the protective environment of the scaffold, fluid forces acting on the cells during injection may impact or disrupt their viability [1]. This study aims at developing a novel delivery device for a cell-embedded *in situ* forming collagen hydrogel. Here, preliminary computational results on constricted channels representing the syringe-needle connection are discussed, providing insight into the effects of the syringe geometry and the needle diameter on collagen flow.

A combination of three different syringe geometries and four needle diameters, connected co-axially, were assumed computationally in two dimensions. A low dead-space syringe design (Geometry 1), a sudden contraction (Geometry 2), and a tapered contraction design (Geometry 3) were modelled. The viscous flow of an incompressible, non-Newtonian collagen solution was approximated in these geometries with a finite volume numerical scheme, assuming a constant inlet velocity that corresponds to a maximum delivery volume.

Velocity and wall shear stress values were examined at the syringe-needle connection for the various syringe geometries and needle diameters. The simulation results exhibited a 10% reduction in the maximum velocity magnitude at the entrance to the needle in Geometry 2, compared to Geometries 1 and 3. Wall shear stress values were found 40% higher in Geometries 1 and 3, than in Geometry 2, at the same location. The effects of needle diameter on velocity and shear stresses were also examined. Simulation results demonstrated 48% higher values in the maximum velocity magnitude for the 26 Gauge needle, compared to those for the 22 Gauge, and the accelerated fluid entered the needle from regions further away from the wall. Shear stresses indicated a greater influence of the higher Gauge needle on collagen flow.

This study demonstrates the significance of syringe geometry and needle diameter on the design of new cell delivery devices. As therapeutic cells pass from the syringe barrel to the needle, the pressure drop and the increased velocity could damage them. Further analysis is required including the simulation of cells during injection and analysis of their deformation.

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References

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