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Hydrodynamic effects of interfacial tension on microtubes

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Abstract

Purpose : Glaucoma drainage devices (GDD) have reduced in size over time, following the trend towards minimally invasive surgery (MIGS). However, the impact of the interfacial tension of the complex ocular biofluids with different polymer microtubes used in glaucoma drainage devices has not been well described and could impact the device outflow resistance.

Methods : Biofluid flow and interfacial tension were assessed using bevelled and unbevelled microtubes with internal lumen diameters ranging from 25 to 300 μm. Microtubes fabricated from hydrophilic and hydrophobic polymers (PEEK, Polyimide, Silicone, PTFE) were included, characterised by water contact angles ranging from 71 to 115°. Dynamic interfacial tensions of Millipore filtered water and Bovine serum albumin solutions (BSA) (Sigma, Germany) with concentrations ranging from 0.4 to 80 mg/ml (equivalent viscosity 1.01 to 1.47 mPa.s) were measured using a microfluidic system (Fluigent, France). Interfacial tension measurements were obtained at 0.1 second intervals throughout the entire drop formation and detachment period, using a controlled flow rate ranging from 0.3 to 4 μl/min, to allow for drop growth profile assessment and pressure change. An average of 88 drops were analysed from each experiment.

Results : Pressure change due to interfacial tension ranged from 1.75± 0.02 to 15.5±0.23 mmHg independent of flow rates ranging 0.3 to 4 µl/min. Hydrophobic microtubes (PTFE) showed the greatest pressure change compared to hydrophilic microtubes with a mean difference (MD) of 13.4mmHg (95% CI, 13.3 to 13.5; p< 0.0001; 2-tailed student t-test). Bevelling 45° of PTFE microtubes reduced the pressure by 40.1% compared to unbevelled PTFE (MD 6.23 mmHg; 95% CI, 6.2 to 6.25; p<0.0001). High BSA concentrations (80 mg/ml) reduced pressure by a further 64% in bevelled PFTE microtubes (MD 5.78mmHg; 95% CI, 5.76 to 5.79 p<0.0001). The drop growth profile of hydrophobic microtubes showed a higher frequency drop cycle (Figure).

Conclusions : Interfacial hydrodynamic effects from hydrophobic materials, bevelling and surface rheology of biofluids should be considered when flow testing GDD/MIGS *in vitro;* these effects are more prominent with smaller microtubes. Further characterisation of the impact of interfacial tensions of aqueous on the outflow resistance of GDD *in vivo* is warranted.

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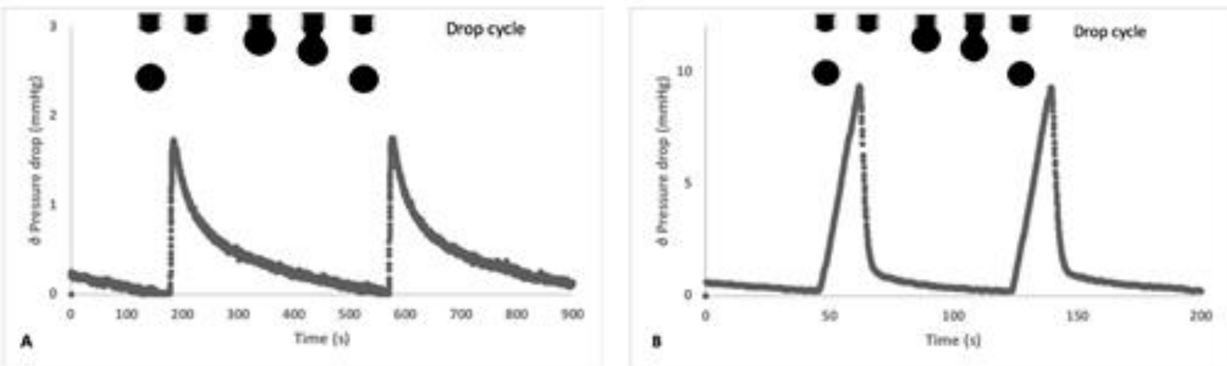

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Drop profiles of hydrophilic bevelled microtube (A) and hydrophobic bevelled microtube (B) at a flow rate of 2µl/min.