Fixing cerebral shunt catheter blockage

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Background

- Hydrocephalus which causes elevated intracranial pressure (ICP), affects 1 in 500 newborns [1]
- Shunting relieves ICP by removing excess cerebrospinal fluid from the brain's ventricles
- 40% of shunts fail within 2 years of implantation [2]
- Obstruction account for 50% of failures [3]

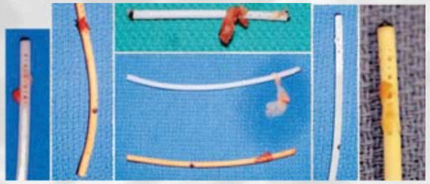

Fig 1. Explanted catheters occluded at their proximal holes[4]

Replicating blockage

- A bench-top catheter drainage unit was built to investigated the effectiveness of flushing for unblocking catheters
- Catheter dimensions: 1.6mm x Ø7mm, Ø0.25mm drainage holes
- Microfibers were seeded into the drainage reservoir

Drainage setup

- Clinical cerebral shunts have dimensions of (**L** = 170mm) & (**r** = 0.38mm)
- Clinical unobstructed shunt flow of (**Q** = 2.5ml/min) was required
- Following Eq. 1, the hydrostatic pressure was adjusted to (**ΔP** = 230mmH_2O) to achieve the desired flow

$$Q = \frac{\Delta P r^4}{8 \mu L}$$, *where μ is the dynamic viscosity*

Equation 1. Hagen-Poiseuille Equation

- Peristaltic pumps were used to unblock catheters

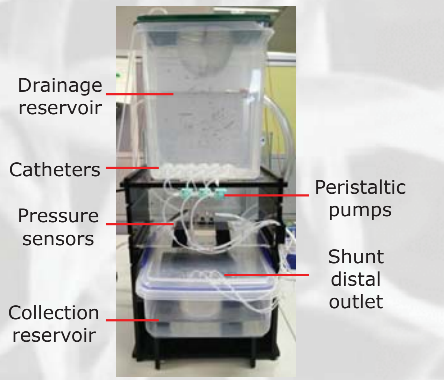

Fig 2. Bench-top catheter obstruction drainage setup

Results

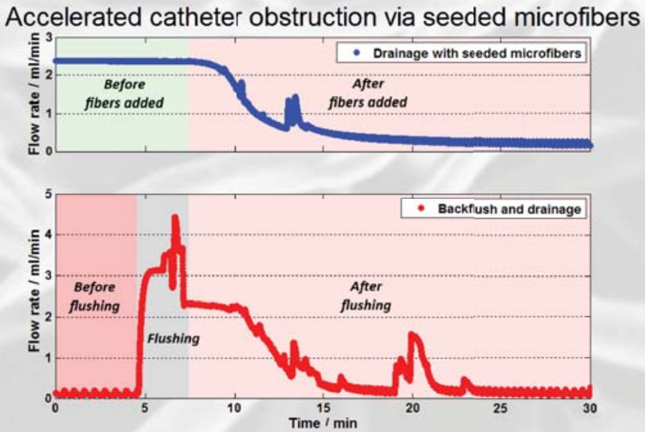

Fig 3. Accelerated catheter failure model (Flow readings during flushing is invalid)

- Flow reduced to 0.2ml/min within 20 minutes after microfibers were added *(Fig. 3, Top)*
- Patency was restored temporarily after a flushing procedure *(Fig. 3, Bottom)*
- Spikes could be explained by a sudden dislodge of fibers out of the drainage holes

The background shows a microscopic view of microfibers (≈20μm x 500μm) at a magnification of x150. Above is a scale of 100μm

Flow measurement setup

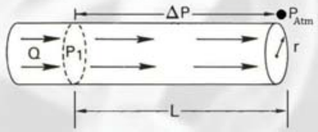

Fig 4. A graphical representation of the Hagen-Poiseuille equation

- Gage pressure sensors tapped pressure along the shunt-line
- NI USB-6009 DAQ card sampled pressure signals at 10Hz
- Flow rate calculated using Eq. 1

Future work

- Investigate the effect of microfiber length on time-course of obstruction
- Experiment with filler materials capable of coagulating microfibers
- Tune microfiber parameters to fit blockage flow profile patterns of clinical external ventricular drains

References

[1] National Institute of Neurological Disorders and Stroke. Hydrocephalus Fact Sheet. Retrieved February 11 2015, from http://www.ninds.nih.gov/disorders/hydrocephalus/detail_hydrocephalus.htm

[2] Lutz, B.R. *et al., New and improved ways to treat hydrocephalus: Pursuit of a smart shunt.* Surgical Neurology International , 2013. **4**(1) p. S38-S50

[3] Kestle, J. *et al., Long-term follow-up data from the shunt design trial.* Pediatric Neurosurgery, 2000. **33**(5): p. 230-236.

[4] Lin, J et al., Computational and experimental study of proximal flow in ventricular catheters: Technical note. Journal of Neurosurgery, 2003. **99**(2): p.426-431.