

CFD analysis of cerebrospinal fluid flow in the cranio-cervical region

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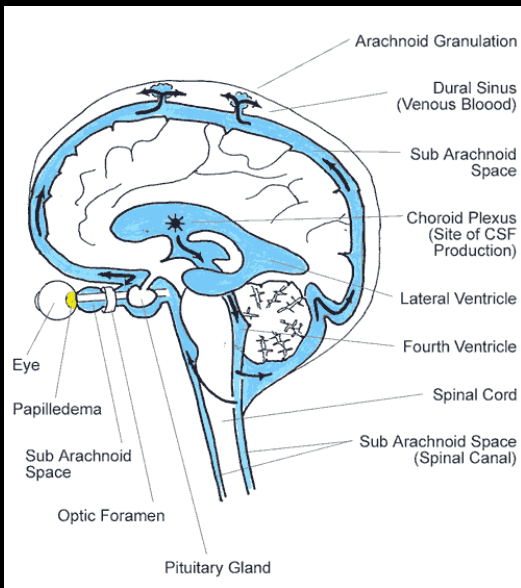
NSCM-21 17.10.08



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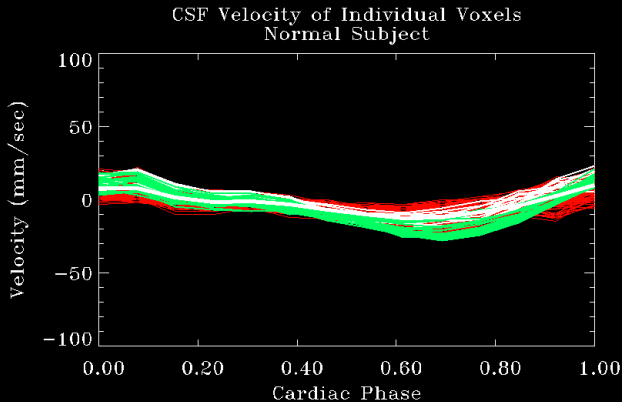


The cerebrospinal fluid (CSF)



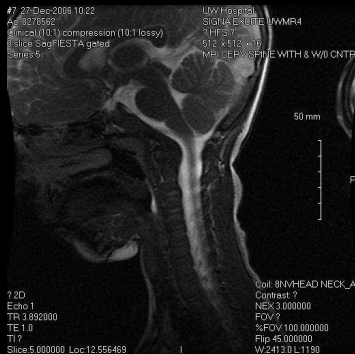
- ▶ Volume: 150ml
- ▶ Production: 0.3ml/min
- ▶ Viscosity: $0.7 \cdot 10^{-6} \text{ m}^2/\text{s}$

CSF flow dynamics



- ▶ Pulsatile/bidirectional flow
- ▶ Compensates brain expansion
- ▶ Peak velocity at Foramen Magnum: 2 – 3cm/s
- ▶ Turbulence?

Chiari I malformation



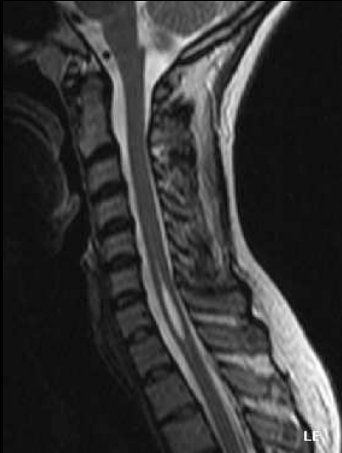
(a) Normal subject.



(b) Chiari I patient.

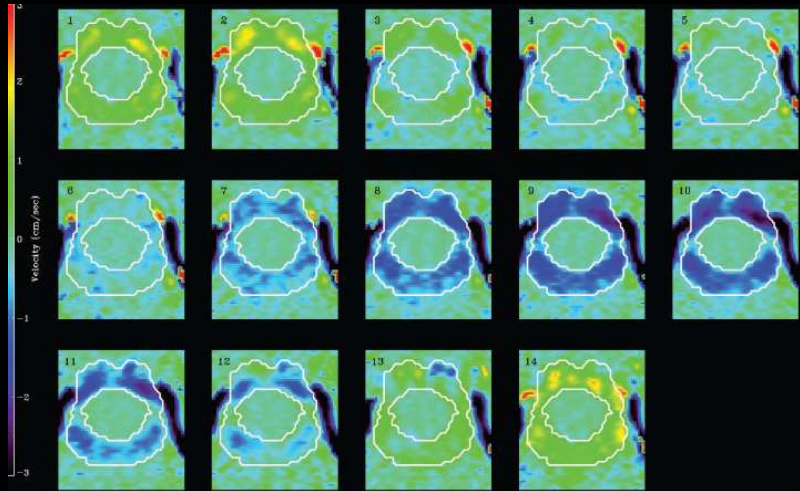
- ▶ Partial blocking of the Foramen Magnum.
- ▶ Peak velocity at Foramen Magnum: 10 – 12cm/s
- ▶ The surgical treatment is craniocervical decompression.

Syringomyelia



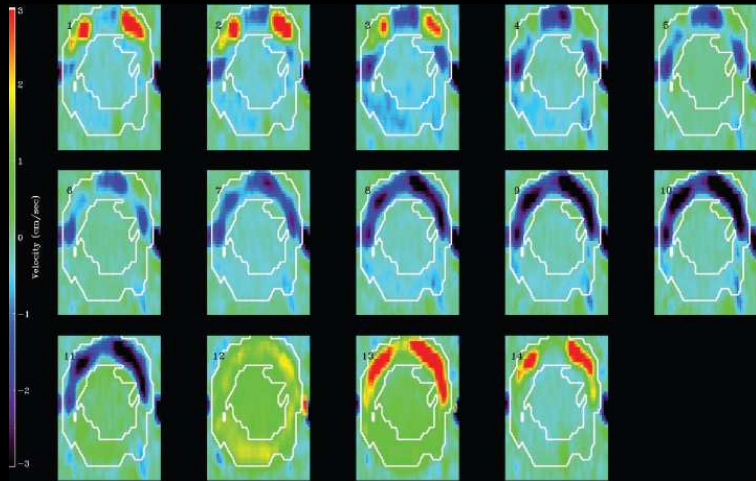
- ▶ A fluid-filled cavity within the spinal chord.
- ▶ Always a consequence of something else.
- ▶ Shrink after cranio-occipital decompression.

MRI measurements, healthy individual



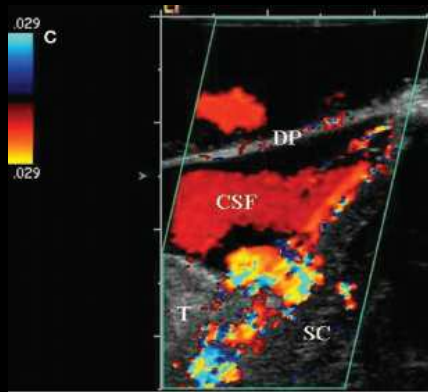
Quigley et al. 2004. Diagnostic tool, basis for surgical decisions. Limited information about volumetric behaviour.

MRI measurements, Chiari I patient



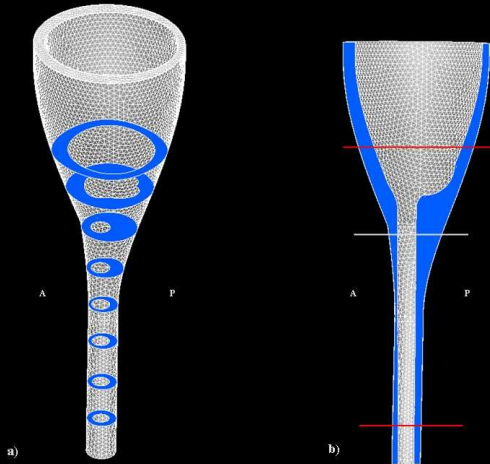
Quigley et al. 2004. Diagnostic tool, basis for surgical decisions. Limited information about volumetric behaviour.

Ultrasound, Doppler measurements



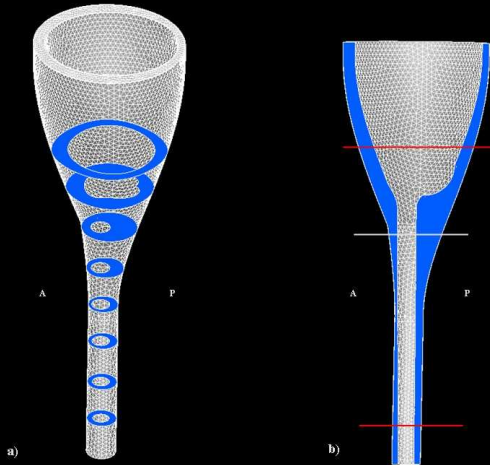
Milhorat et al. 2003. Measures CSF-velocity during surgery.

3D computational model



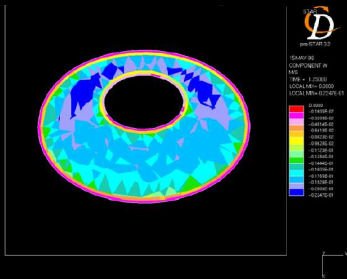
- ▶ Dimensions in the model approximate an anatomic model (Visible Human project).
- ▶ Idealized geometry, not patient specific.

3D computational model

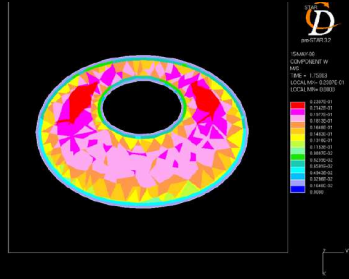


- ▶ Rigid walls with no-slip boundary conditions.
- ▶ Prescribed sinusoidal velocity at both ends.

Validation of the computational model



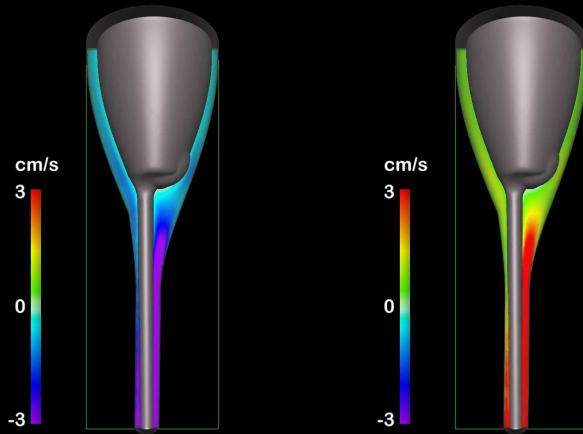
Caudad flow.



Cephalad flow.

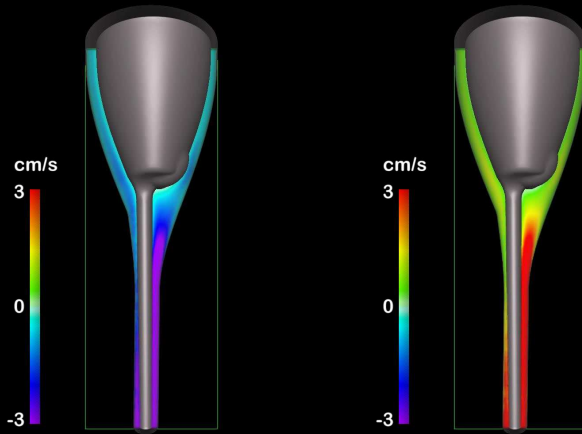
- ▶ Visual inspection of the flow at the Foramen Magnum by Victor Haughton.
- ▶ Comparison of qualitative and quantitative properties with MRI measurements.

Spatio-temporal detail



- ▶ CFD demonstrates both the overall flow pattern, and local phenomena.
- ▶ Easy to zoom in on specific areas and velocities.

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- ▶ Animation by Anders Helgeland at FFI using VoluViz.

Future work

- ▶ Include Chiari I malformation in the geometric model.

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- ▶ Patient specific geometry.

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- ▶ Include movement of the spinal chord in the computational model.
- ▶ Include elasticity in the computational model.

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Thank you!