Effect of Craniovertebral Decompression on CSF flow

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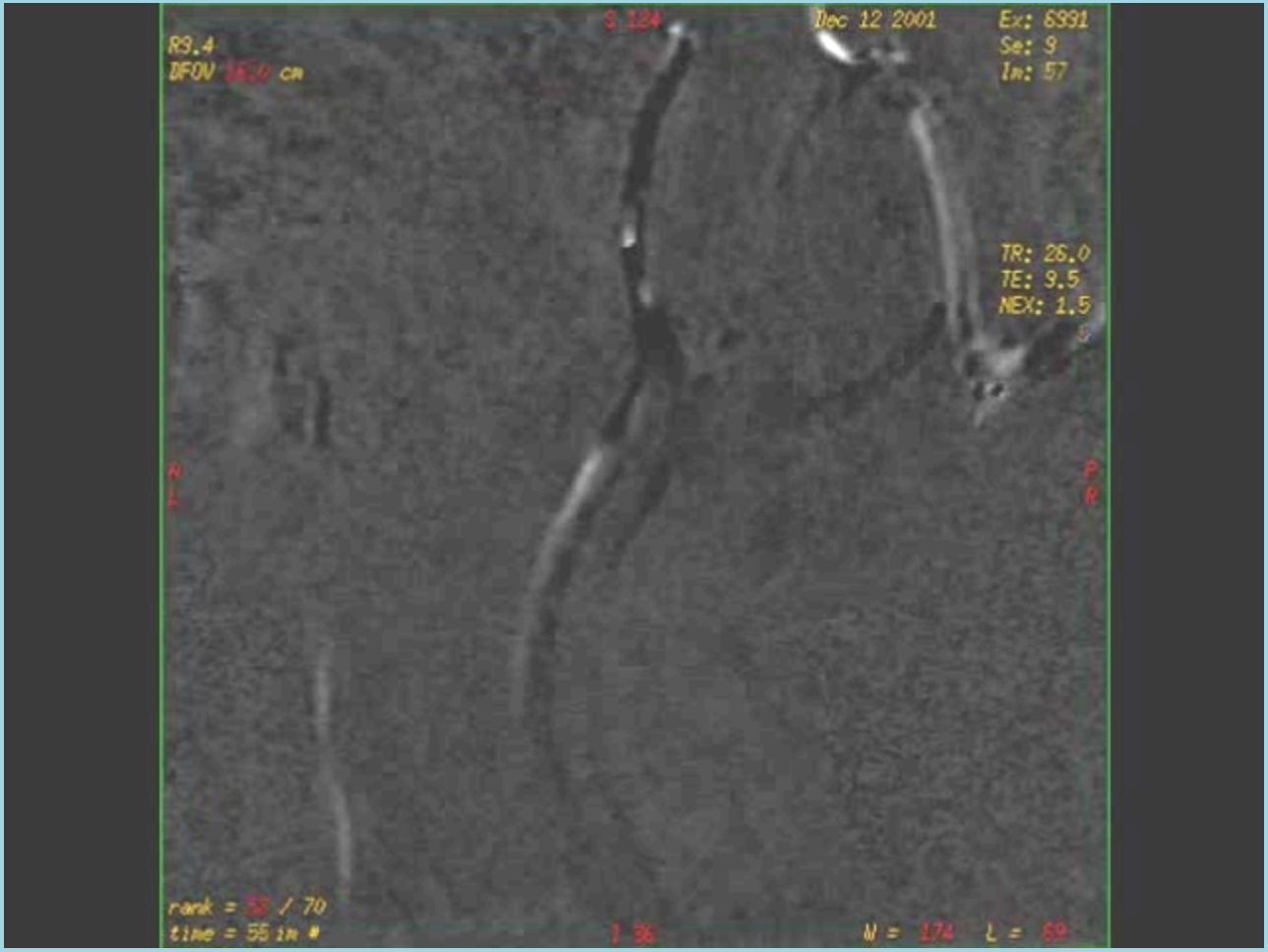
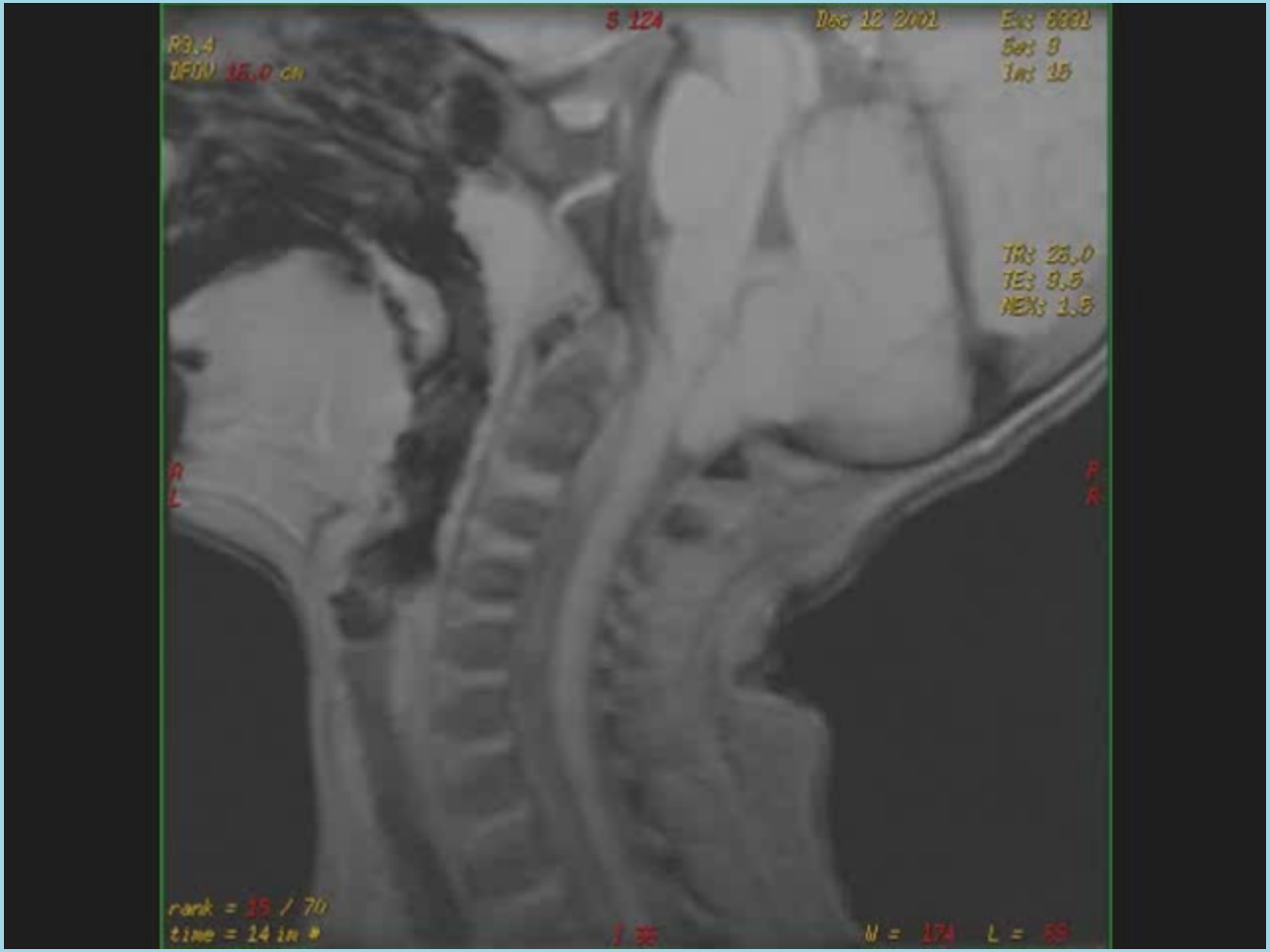
Current current knowledge of CSF flow

- Oscillatory CSF flow results from the cardiac cycle.
- Chiari I disturbs oscillatory CSF flow
- Abnormal CSF flow in theory has role in syringomyelia.
- Pathogenesis of syrinx still not known.

CSF Flow in sagittal PC MR



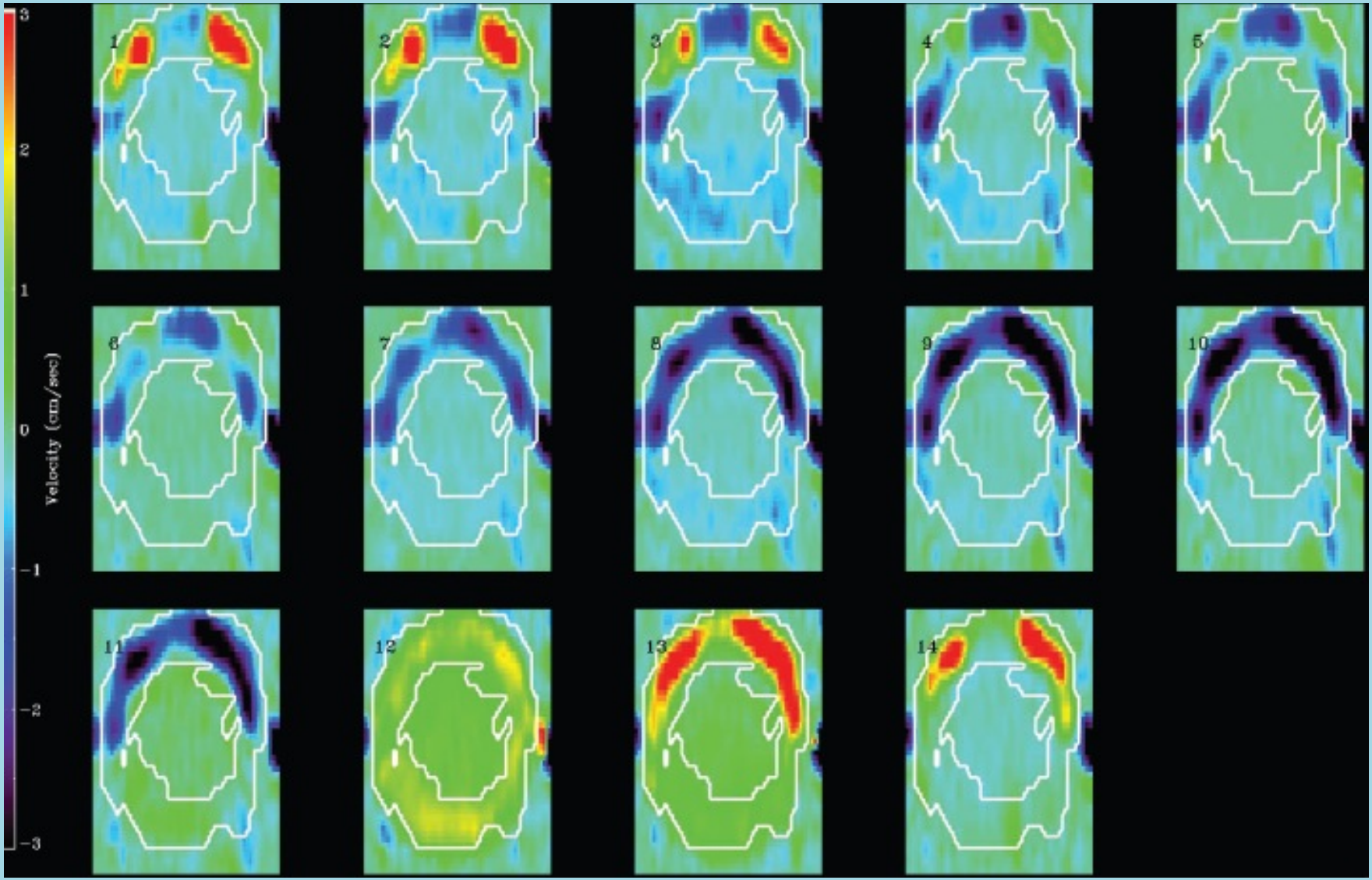
CINE: Tonsil movement



PC MR Cine CSF flow in Chiari I

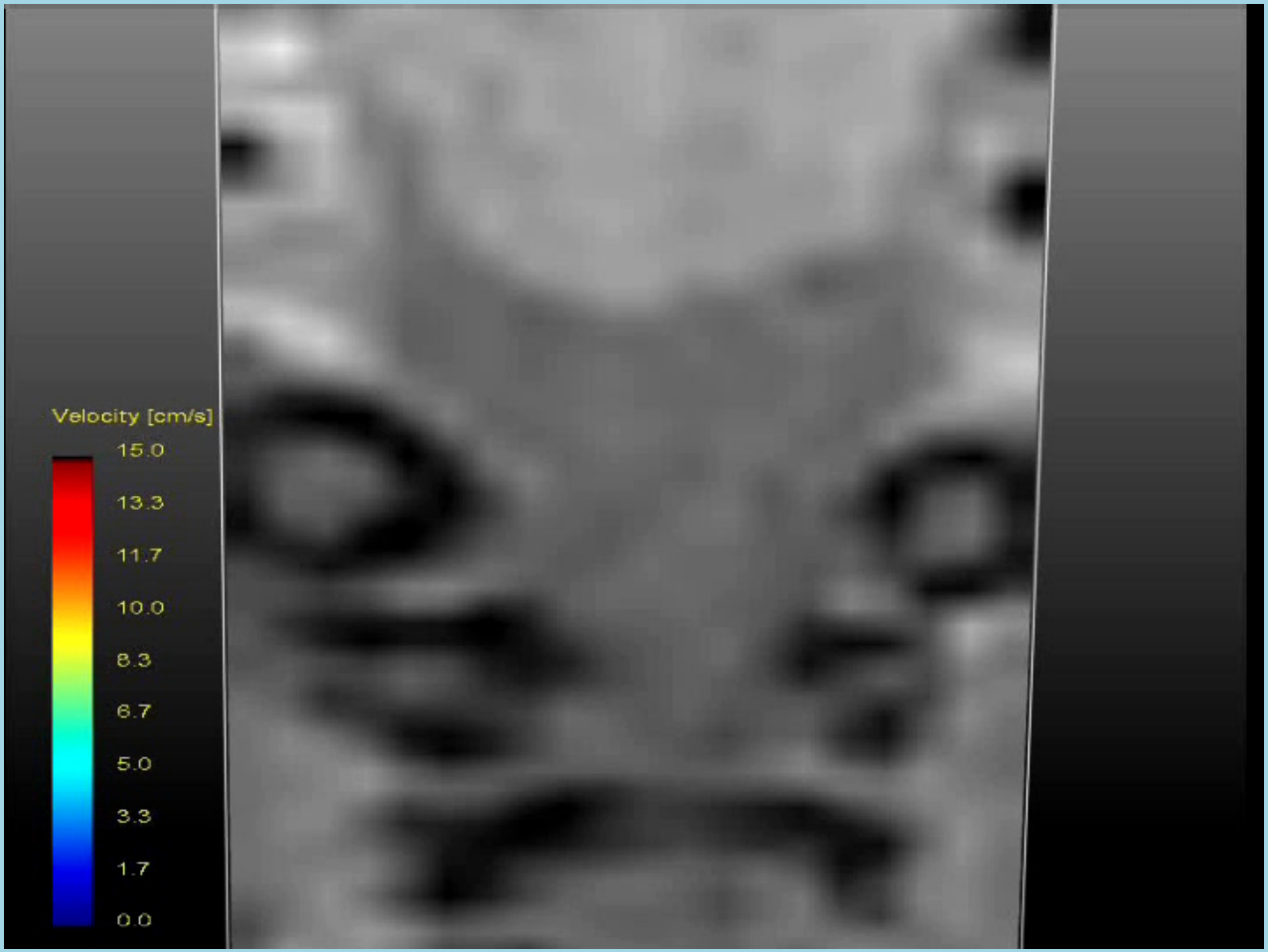
Synchronous bidirectional flow

MRI measurements, foramen magnum, Chiari patient



(Quigley et al., 2004)

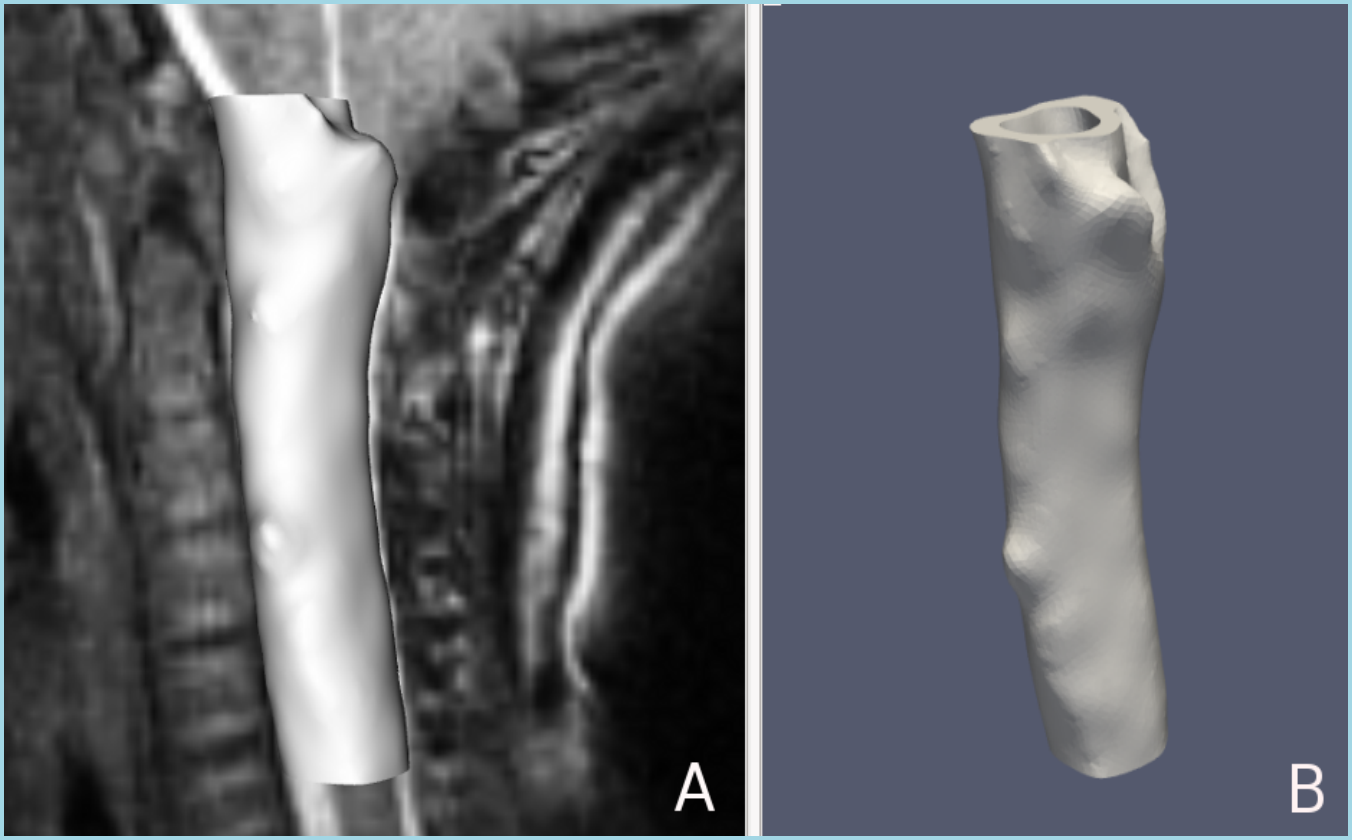
Complex CSF Flow: 3D PC MR



Computational Fluid Dynamics

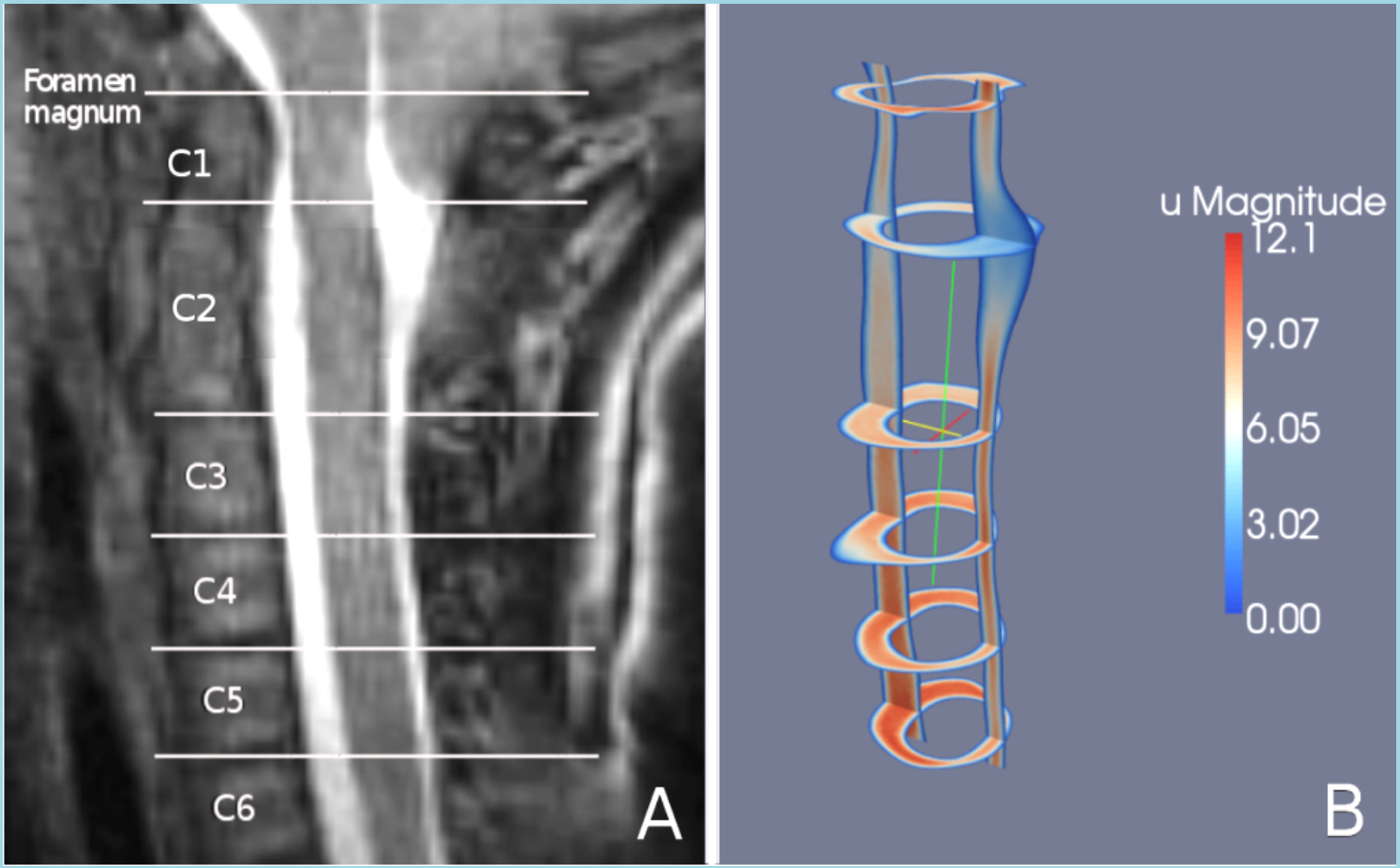
- Engineering tool for measuring velocities and pressures in fluids
- Better spatial and temporal resolution than PC MR
- Demonstrates complexity of CSF flow.
  - synchronous bidirectional flow
  - Vortices
- Assumes is that flow laminar
- Near threshold for unstable and turbulent flow.
- Suggests new theories on the pathogenesis of syringomyelia.

CSF: Computational Fluid Dynamics

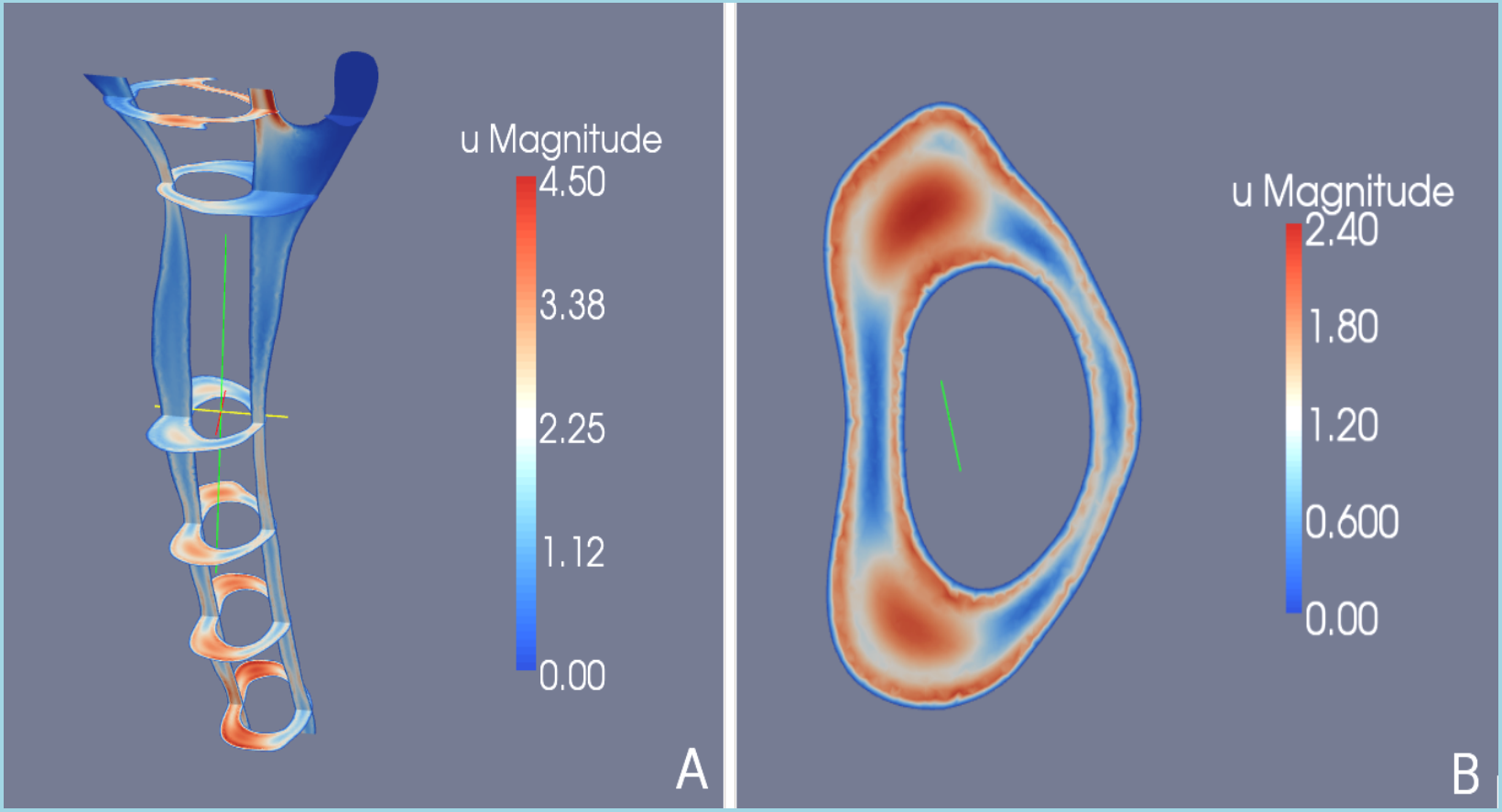


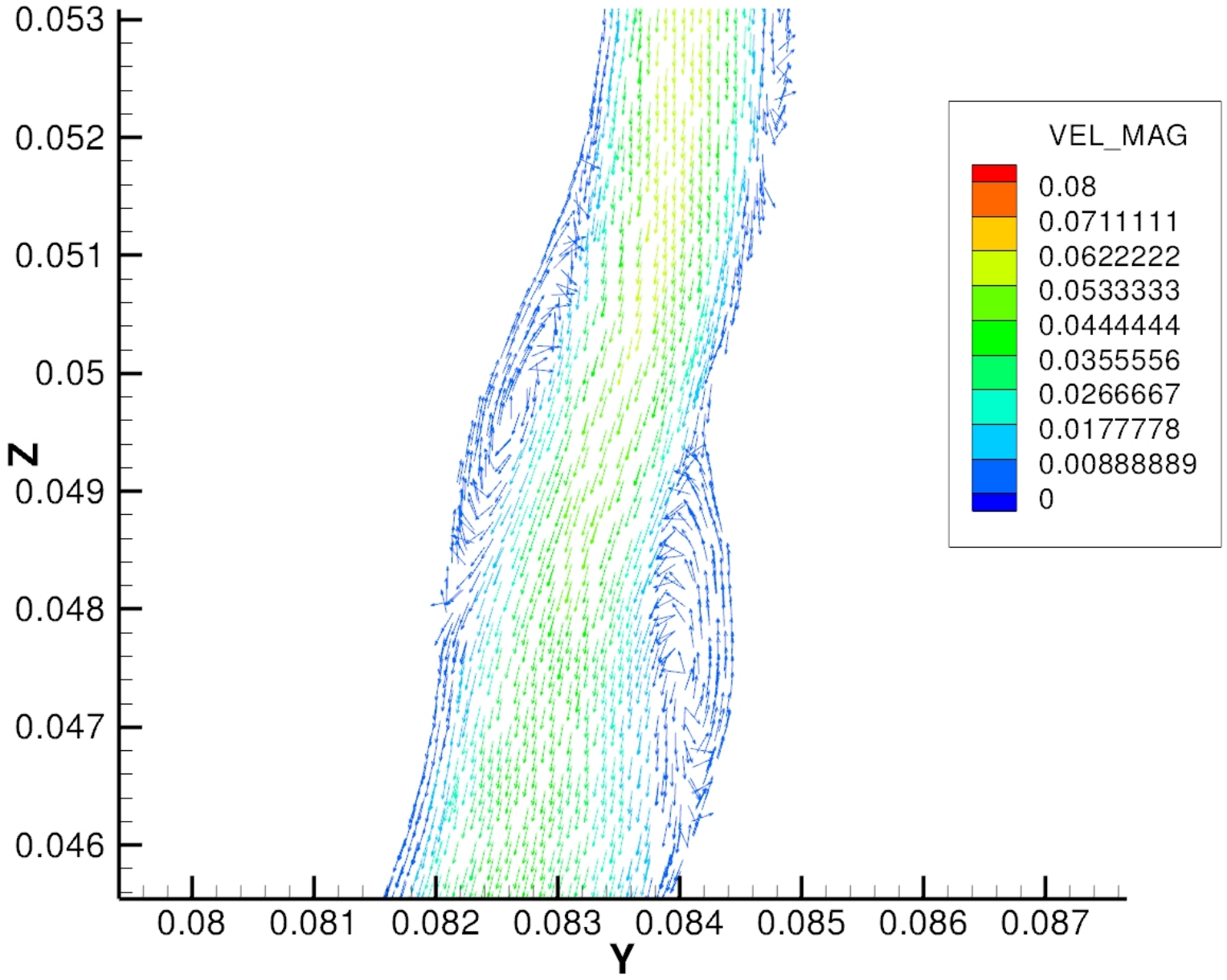
Computational Fluid Dynamics, Center for Biomedical Computing, Oslo

CSF Flow patterns Upper cervical spinal canal of Chiari I patient



4D CSF Flow: Sagittal and axial view of flow at peak of systolic flow

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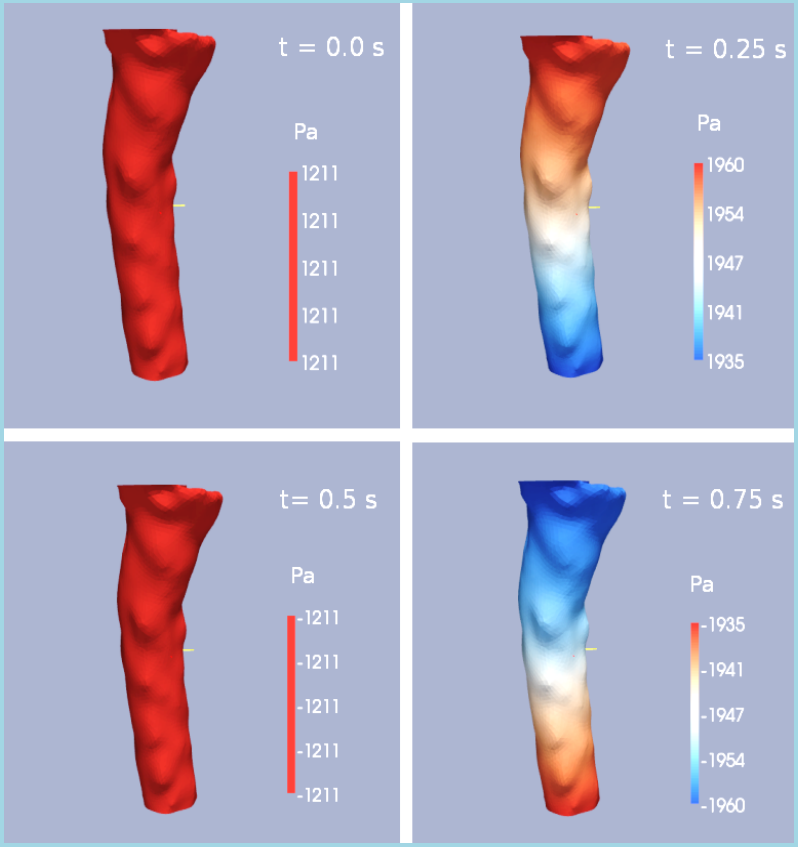
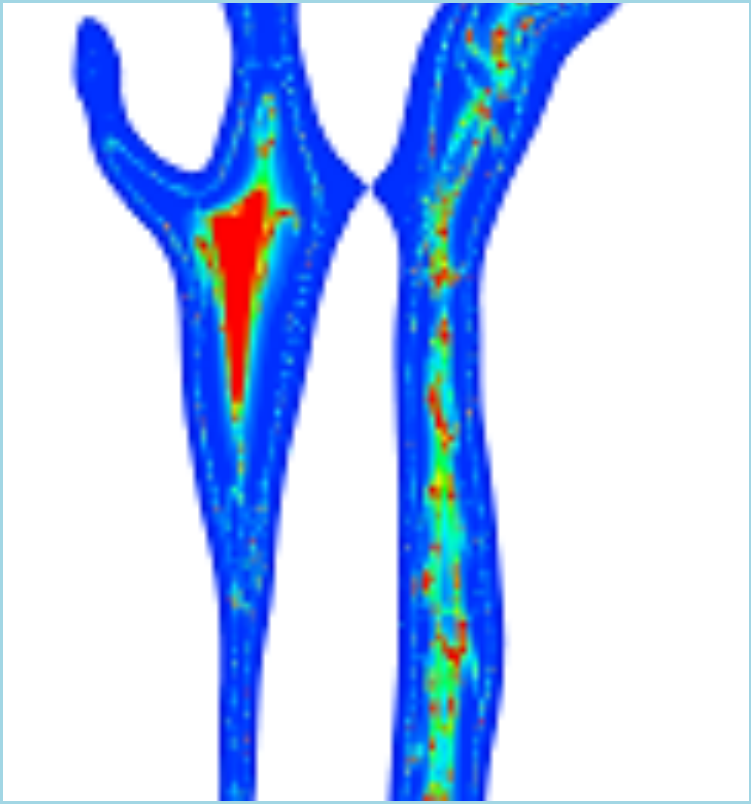
CSF Pressure Gradients; Oscillatory Flow



Pressure gradient maximal at time of flow reversal

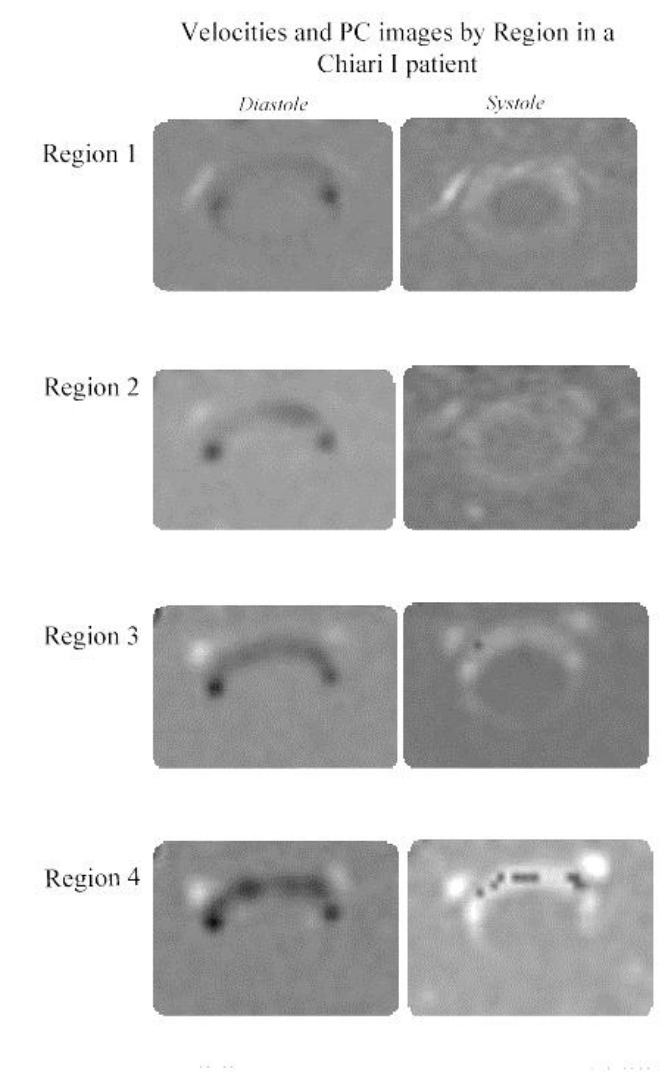
Ratio of inertial to viscous force

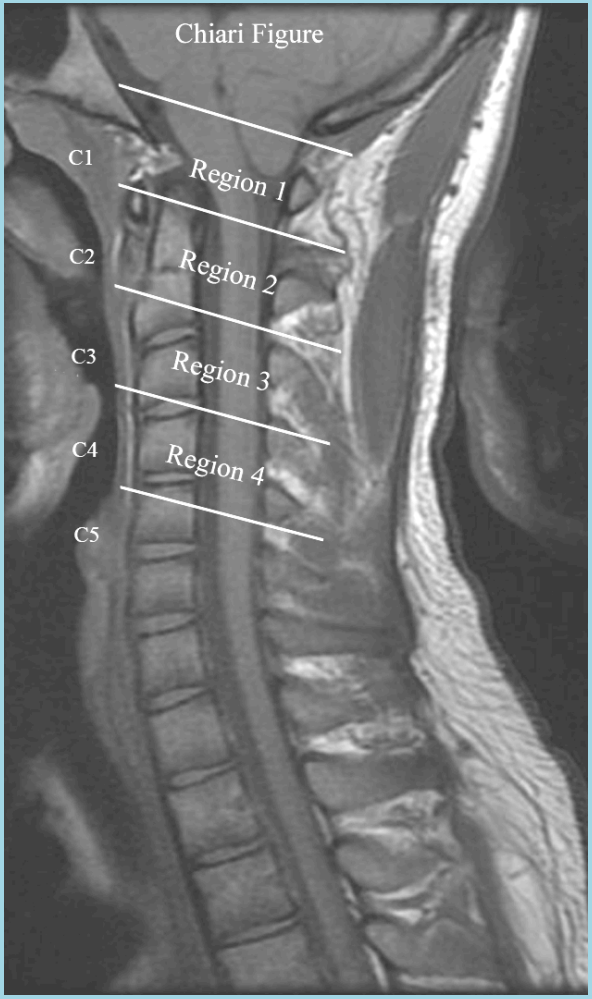


Cause for increasing velocity from C1 to C4

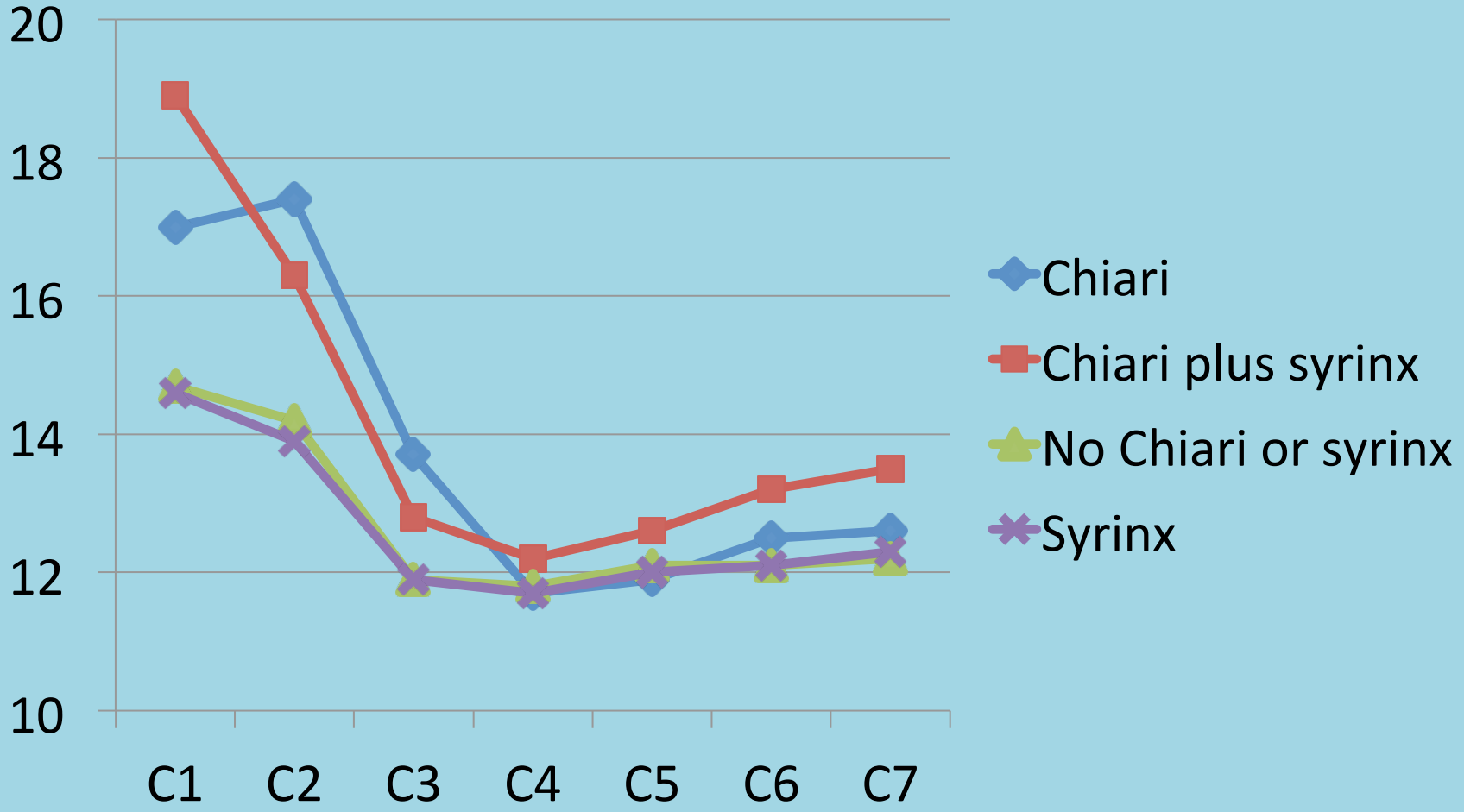
- Measure diameter of spinal canal at each cervical spinal level
- Plot diameters by spinal level
- Fit linear trendline by least squares
- Calculate slope of trendline
- Calculate goodness of fit (R^2)
- Stratify by presence or absence of Chiari I

2D PC MR studies of CSF velocities in upper cervical spinal canal

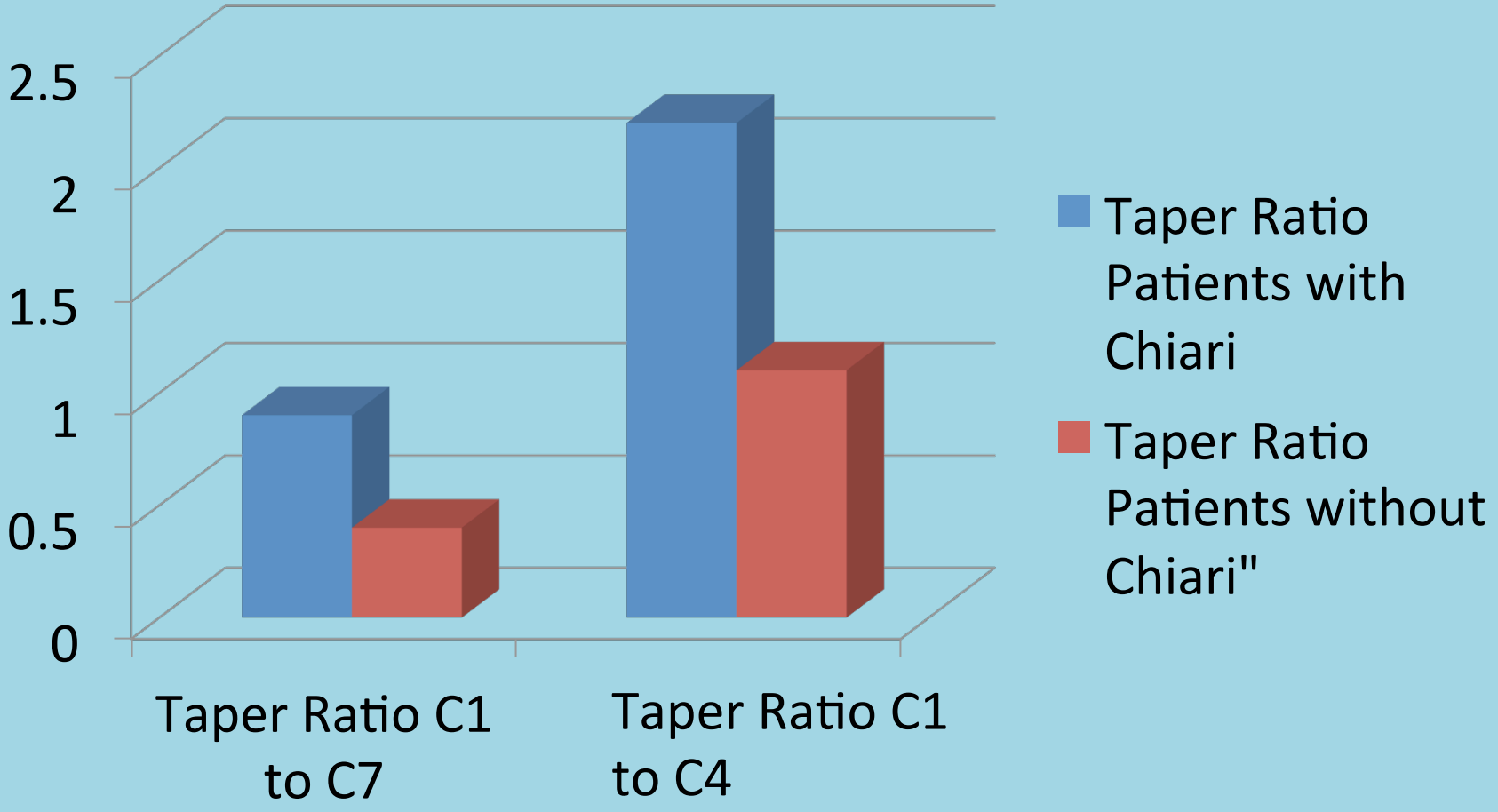




Average cervical spinal canal diameter (mm)



Taper Ratios in Patients with and without Chiari I (mm/level)



Effect of Decompressive Surgery on CSF Velocities in Chiari Patients (PC MR)

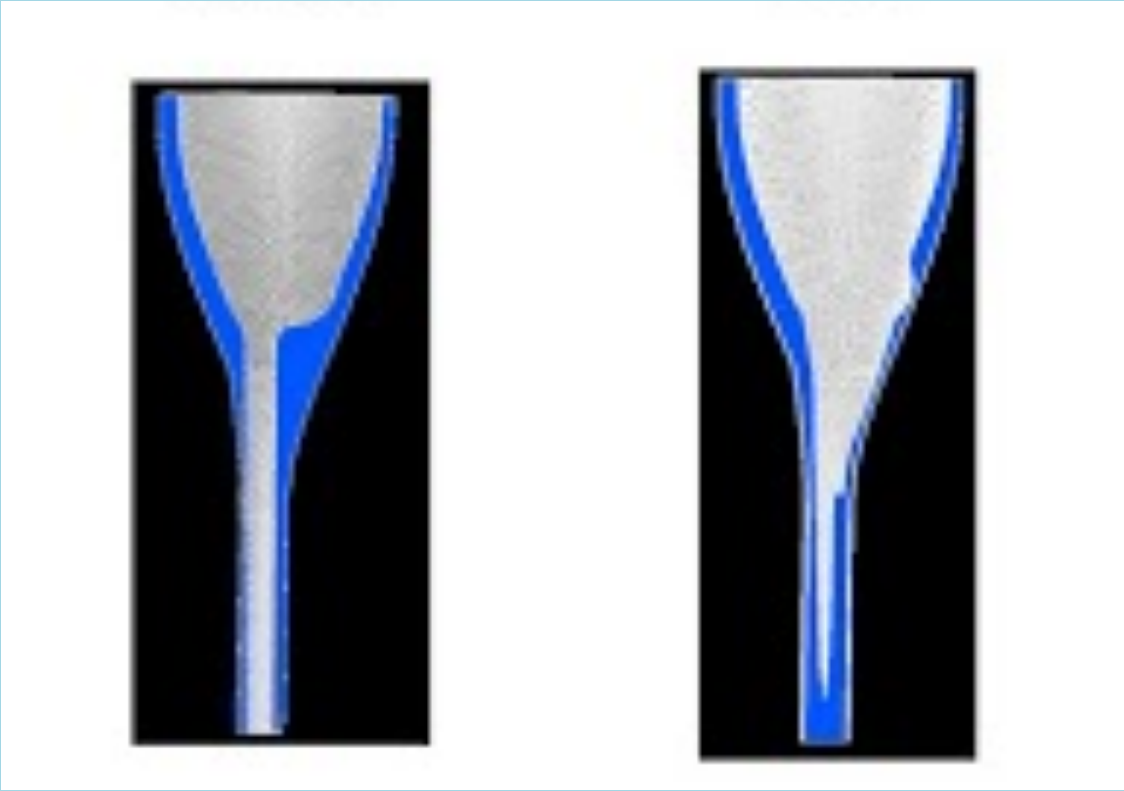
- Cephalad CSF velocity decreased
  - From 3.4 cm/s to 2.4 cm/s.
- Caudad CSF velocity decreased
  - From 6.9 cm/s to 3.9 cm/s
- Borderline statistical significance.
- In some patient velocities increased after surgery
- No correlation found between clinical outcome and reduction in CSF velocity.

Iskandar B. , J Neurosurgery

Linge: Effect of Cranio-vertebral Decompression on CSF dynamics

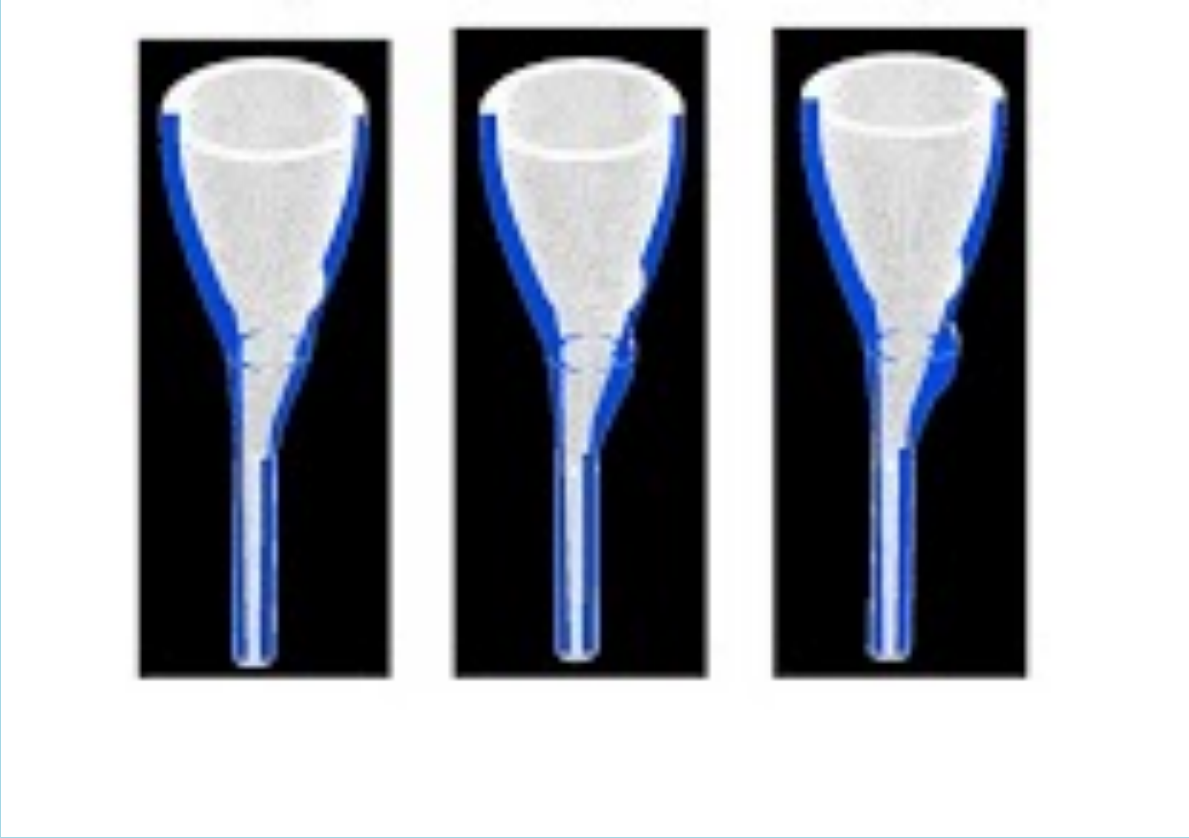
- CFD in idealized model of Chiari I and same model with virtual craniovertebral Decompression
- Pressure gradient diminishes
- Velocity in upper cervical spinal canal diminishes

Idealized models of normal and Chiari

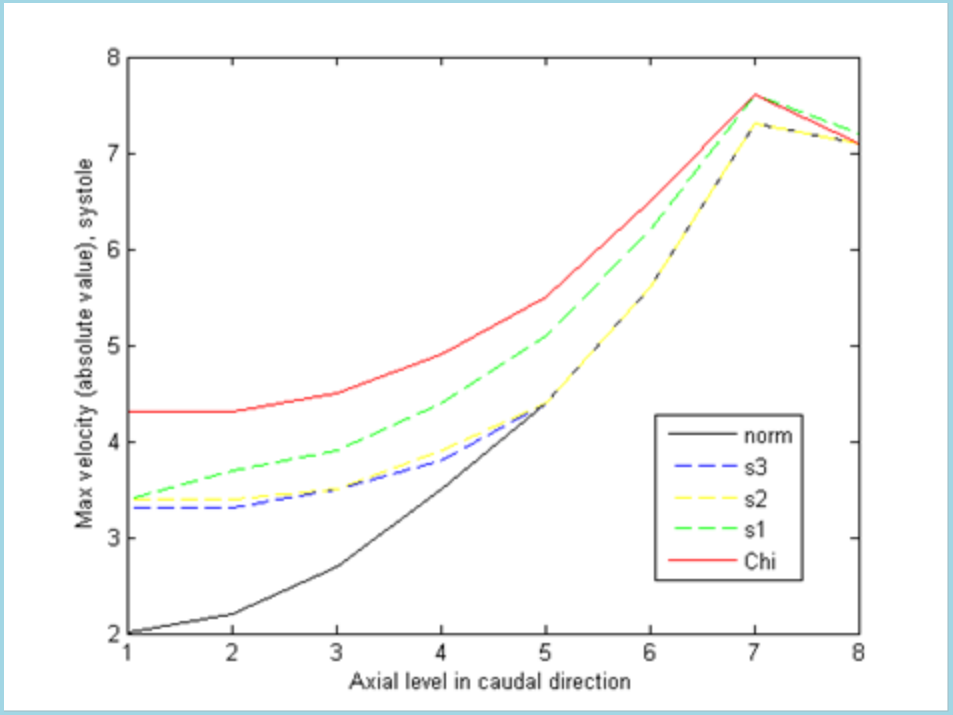


Normal Chiari

Idealized models of Decompression Surgery



Effect of “Virtual Decompression” on CSF flow



FM C1 C2 C3 C4

“Virtual Decompression”

- Idealized rather than patient-specific model
- Decompression mormalizes pressures oscillations
- Decompression reduces peak velocities
- Larger decompression yields larger change in CSF dynamics, to a point

Summary

- CSF flow patterns complex
  - Jets, synchronous bidirectional flow, vortices
- Laminar flow with some regions nearing instability
- Flow affected by tonsils and by cervical spinal anatomy
- Flow changes by surgical decompression
- Identification of critical hydrodynamic change requires additional study