

Simulation of a surrogate head model subjected to blast



Scott T. Miller - Sandia National Laboratories

Candice F. Cooper - Sandia National Laboratories

Adam M. Willis - San Antonio Military Medical Center

Ricardo Mejia - Michigan State University

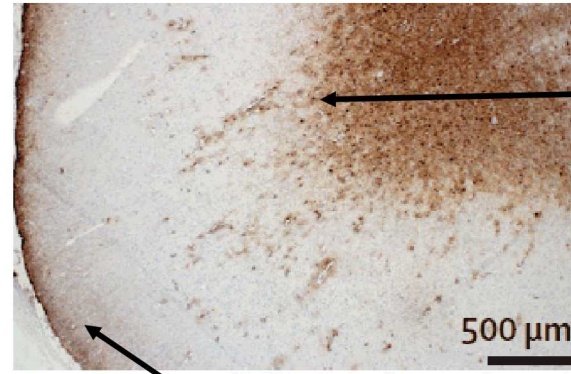
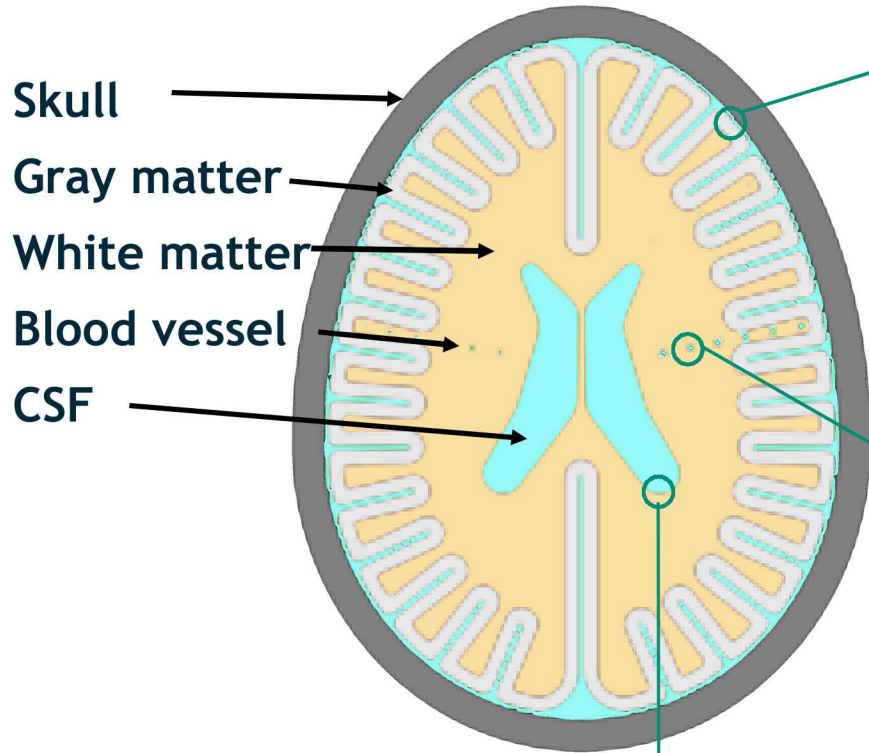


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Blast TBI is a signature wound of modern warfare.

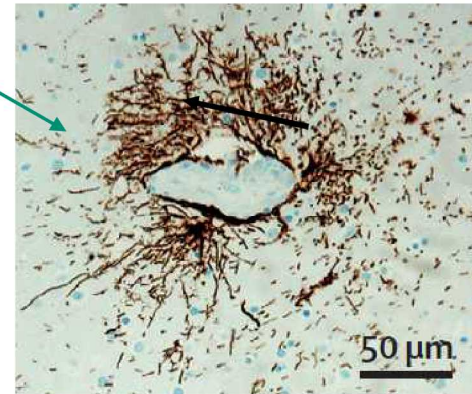
- RAND Corporation Estimate 320,000 US military personnel have traumatic brain injury (TBI)
 - 52% from improvised explosive devices
- 20% of all combat trauma
- Up to 100,000 with mild blast TBI injury
- In combat head injury accounts for
 - 38% of immediate fatalities
 - 53% of those who die prior to admission to medical treatment facilities
- Can we build better helmets to protect service members?
- Do we understand causal mechanisms/indicators to derive design metrics?

Interfacial injuries are the unique neuropathological injury of bTBI

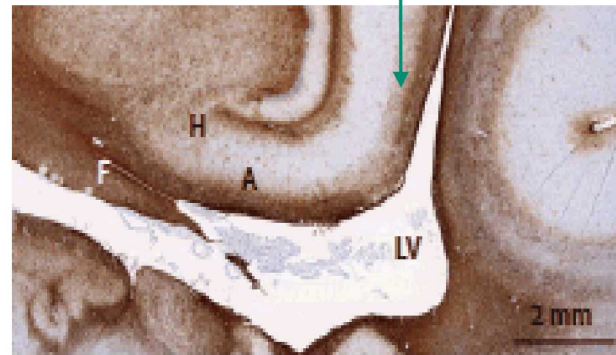


Gray-white

CSF - brain (sub-pial)



Peri-vascular



CSF-brain
(Peri-ventricular)



Characterisation of interface astroglial scarring in the human brain after blast exposure: a post-mortem case series

Sharon Baughman Shively*, Iren Horvayne-Szakaly*, Robert V Jones, James P Kelly, Regina C Armstrong, Daniel P Perl

Lancet Neurol 2016; 15: 944-53

What mechanisms cause bTBI injuries?

Investigate metrics for clinical relevance:

- Stress
- Strain
- Strain Rate
- Energy
- Cavitation

Do dilatational or shear response identify bTBI markers?

Combined experimental/computational approach will allow clear investigation of metrics with respect to clinical observations.

To study which mechanical metrics may correlate with blast injury we must build a model:

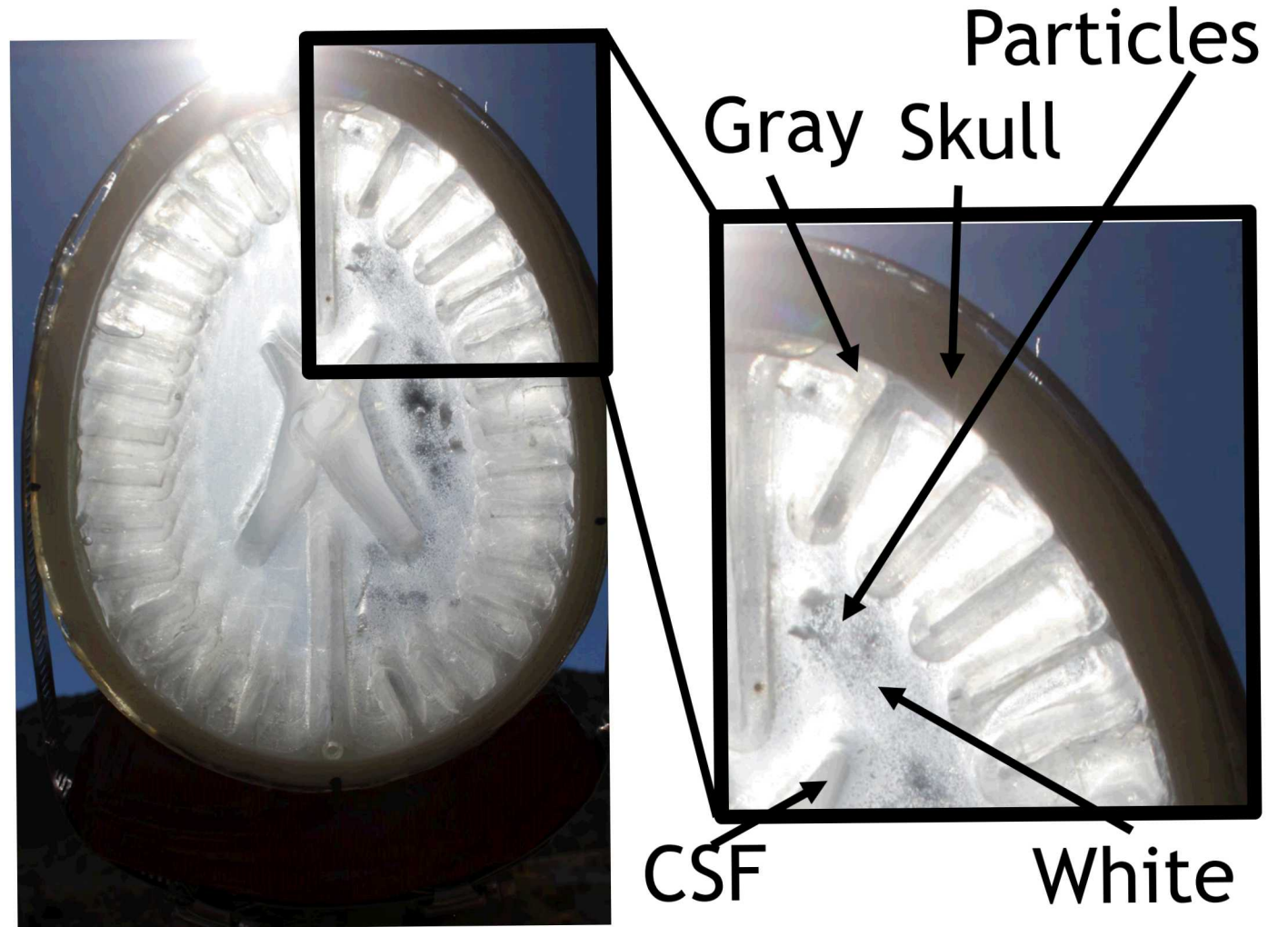
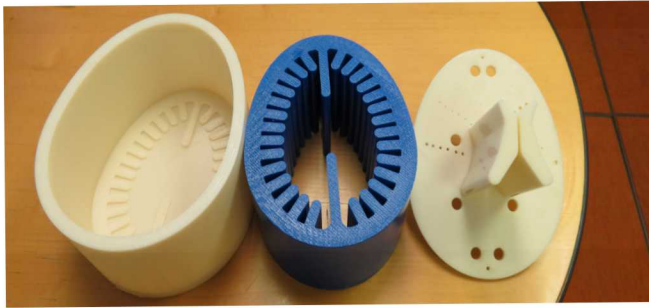
Experimental model must...

- Model gross material properties of brain material
- Visually accessible

Computational model must resolve...

- Gray-white interface
- Skull dynamics
- CSF cavitation

6 Making the surrogate head model (test object)

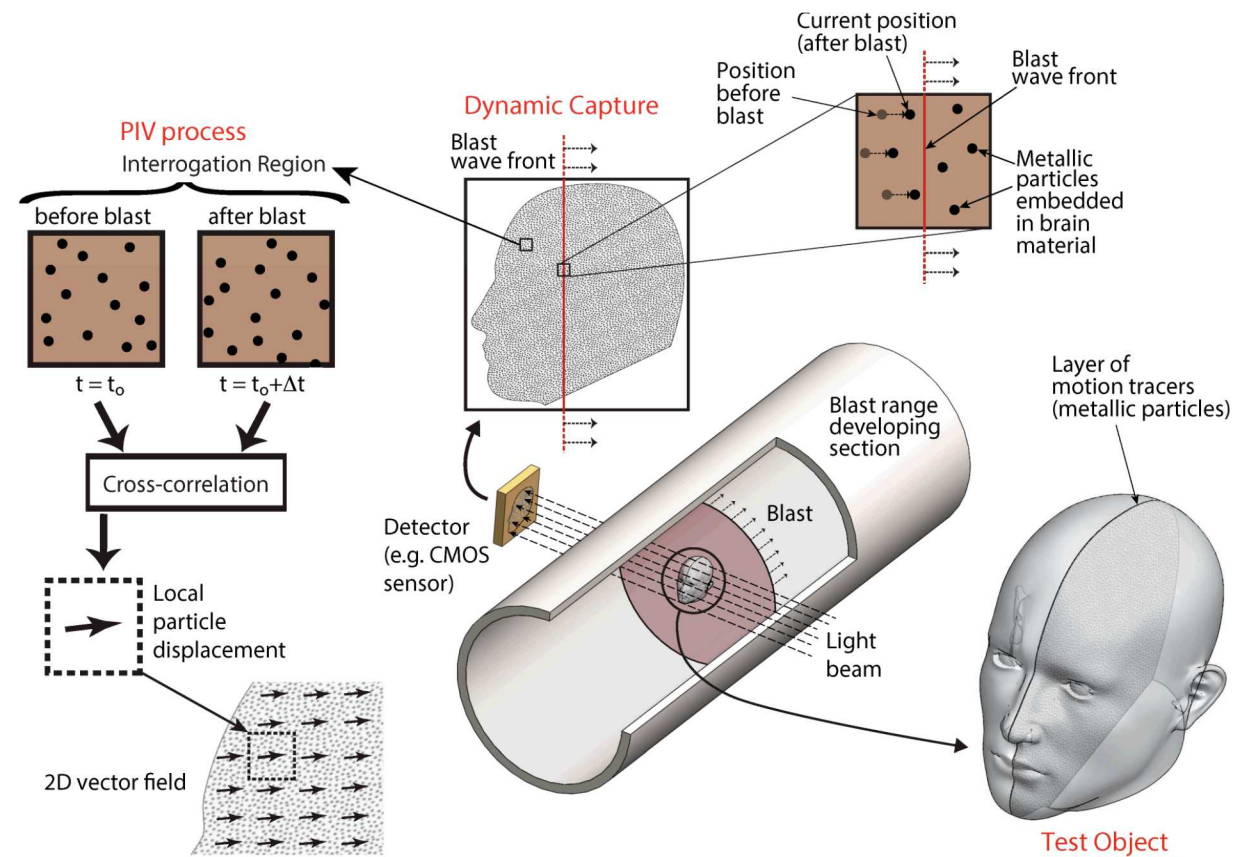


PIV is used to quantify motion.

Making the surrogate head model (test object)

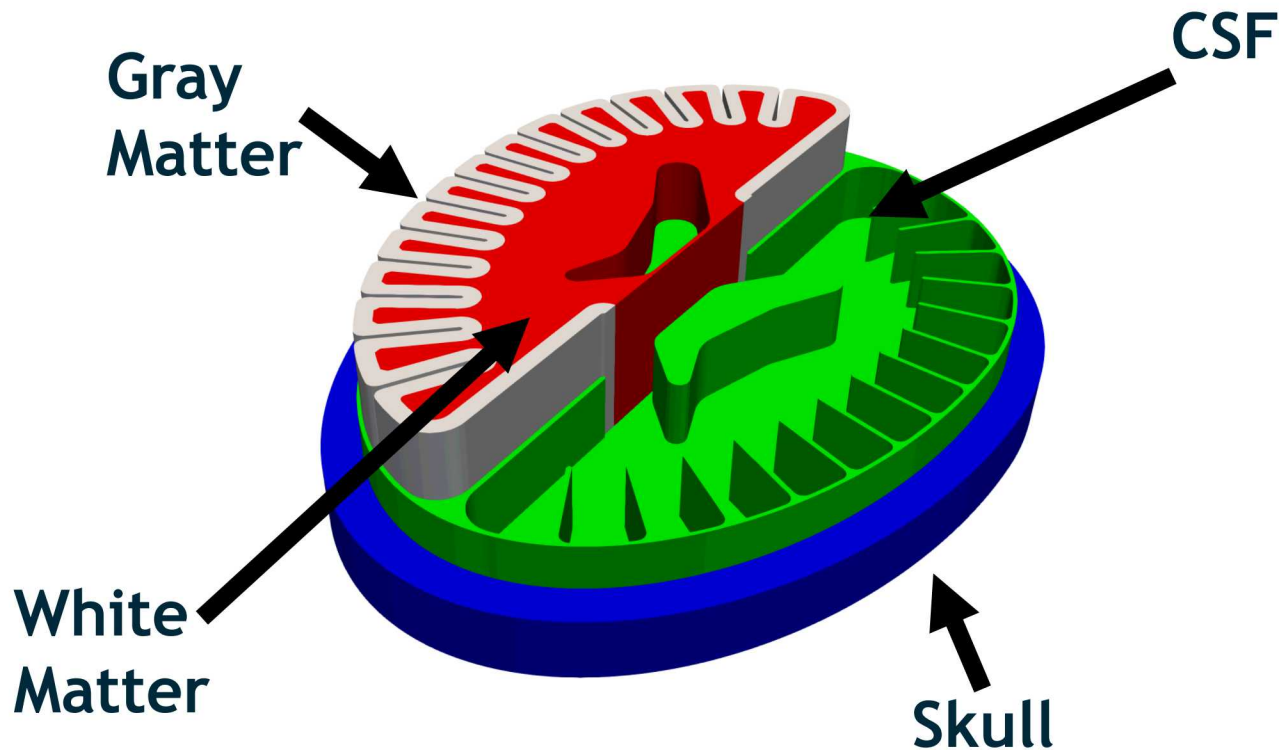
Experimental limitations:

- High strain rate properties of brain and gelatin difficult to obtain
- Strain only measurements
- Swelling of gyri reduced CSF space
- Measurements in-plane
- Test object remains simplified
- Skull flexure not currently measured



High resolution computational model

Domain: 14.4374cm x 18.7166cm x 10.4cm



Number of nodes: 2,419,095

Number of elements = 2,368,704

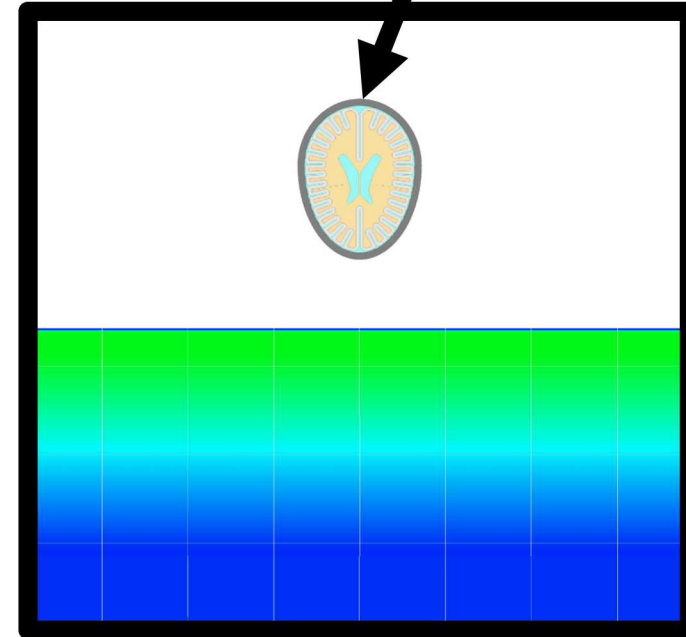
Skull: 820,432 elements

CSF: 351,152

White: 531,824

Gray: 665,296

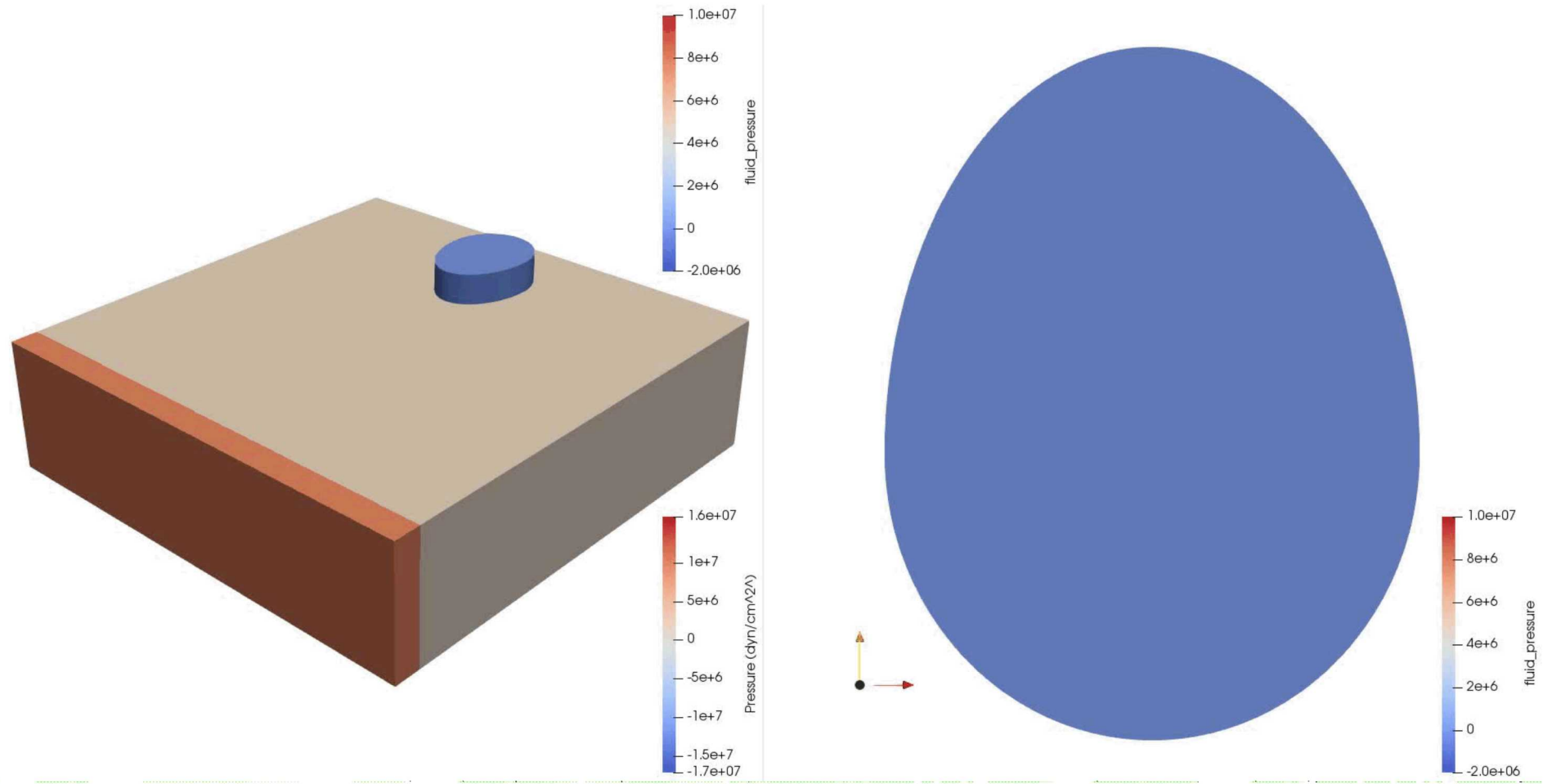
Finite Element Solver
(Sierra Mechanics)



Blast loading
(CTH)

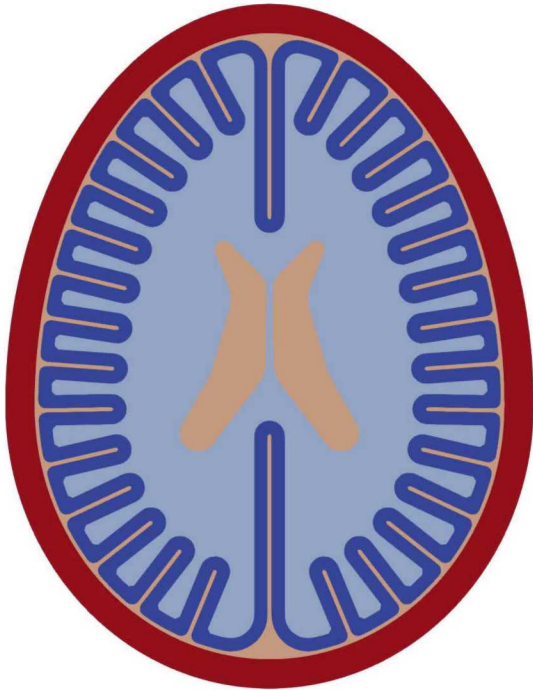
Fully coupled with
Zapotec

9 Animation: frontal blast

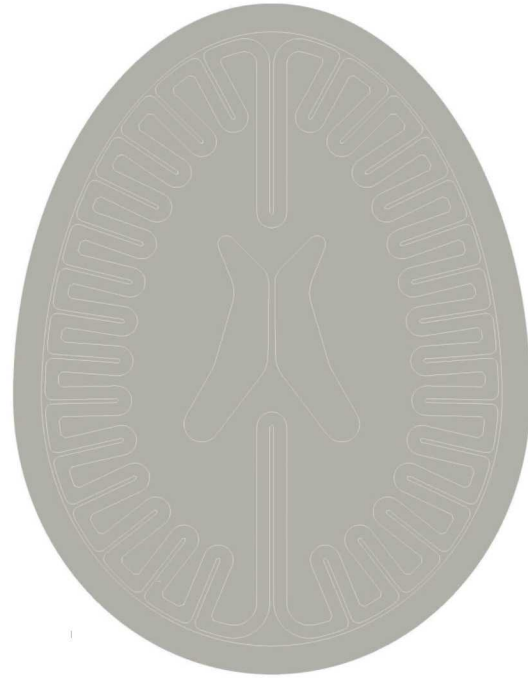


Computational modeling: strain response

Displacement



Dilatation



Shear

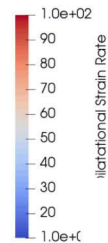
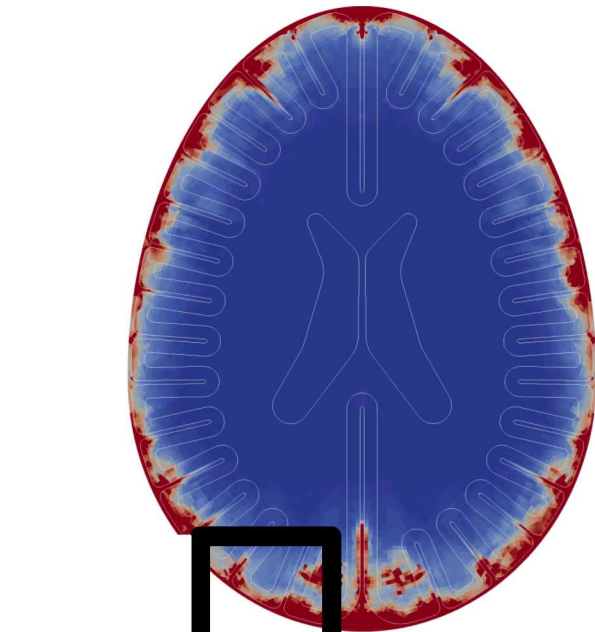


Pressure wave compresses followed by sulcal dilatation and gyral compression

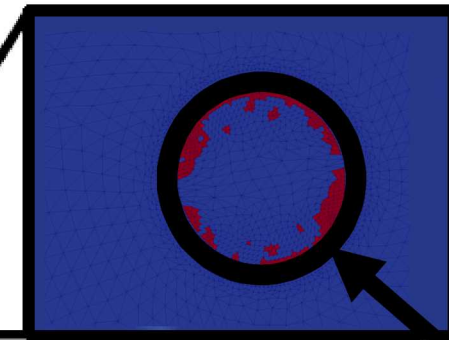
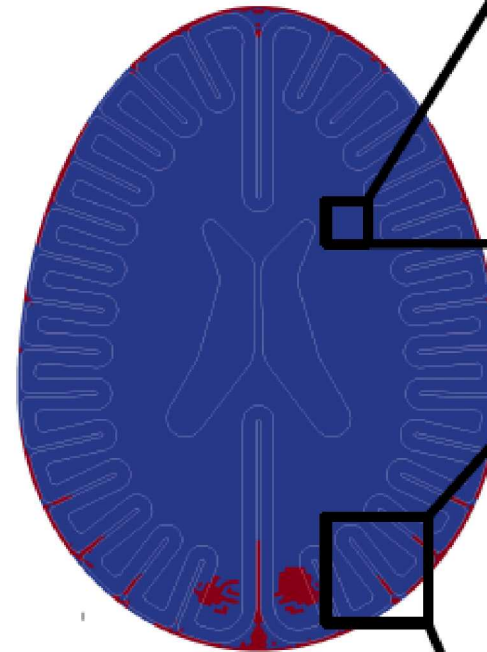
Later time development of shear correlated with sulcal dilatation

Strain response indicates maximization of strains near sub-pial glial plate and gray-white regions.

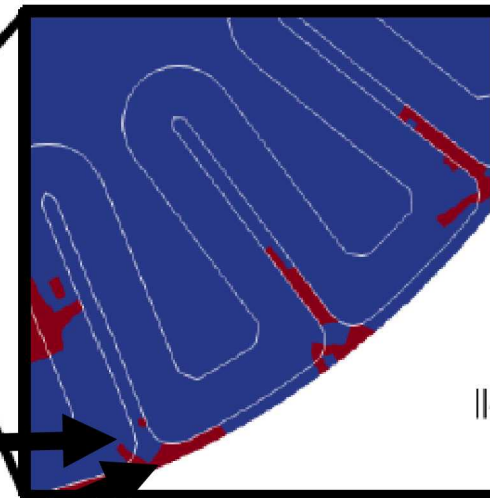
Dilatation



Cavitation



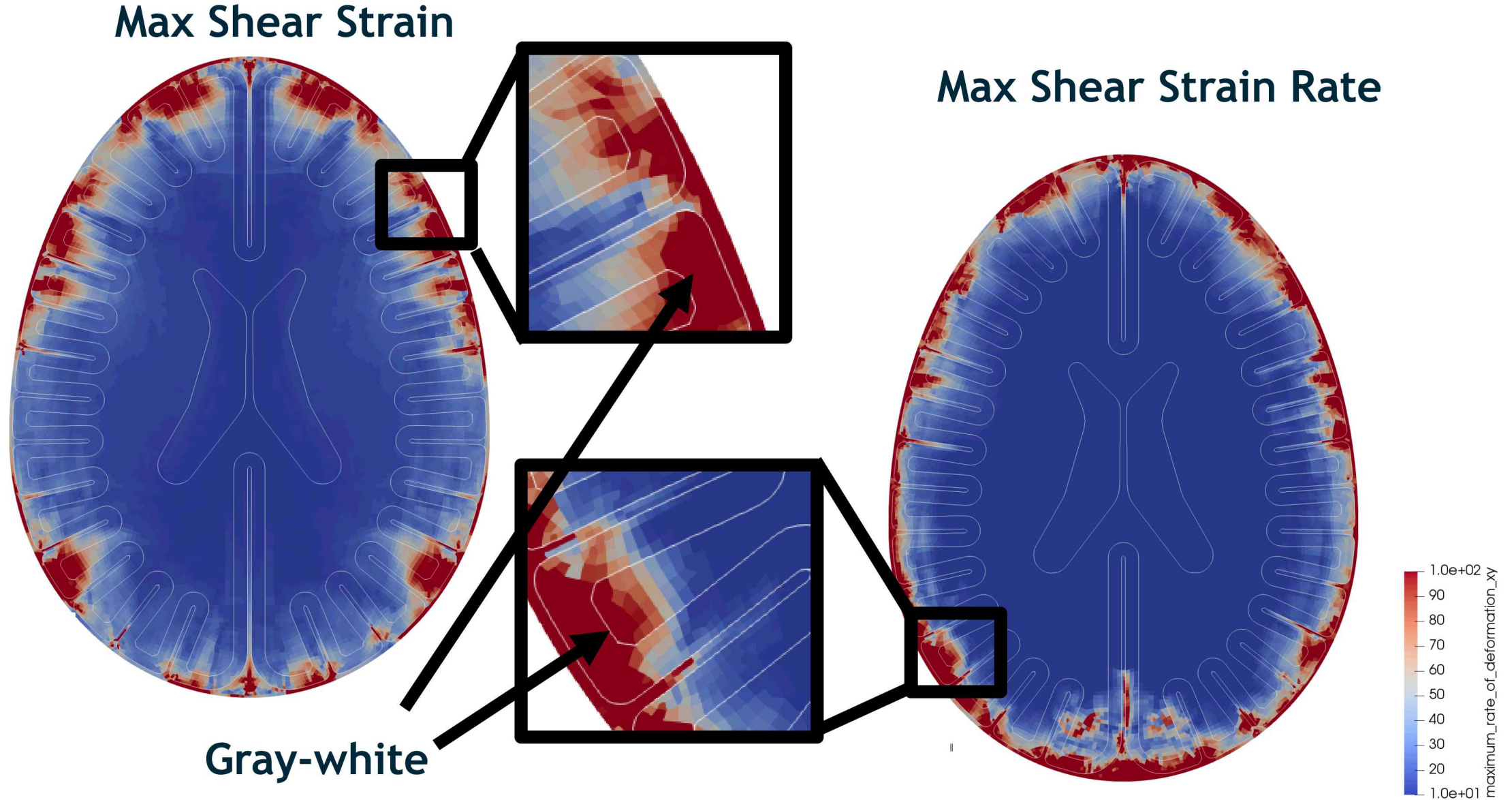
Small vasculature



Sub-pial glial plate

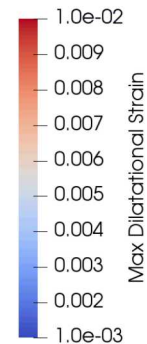
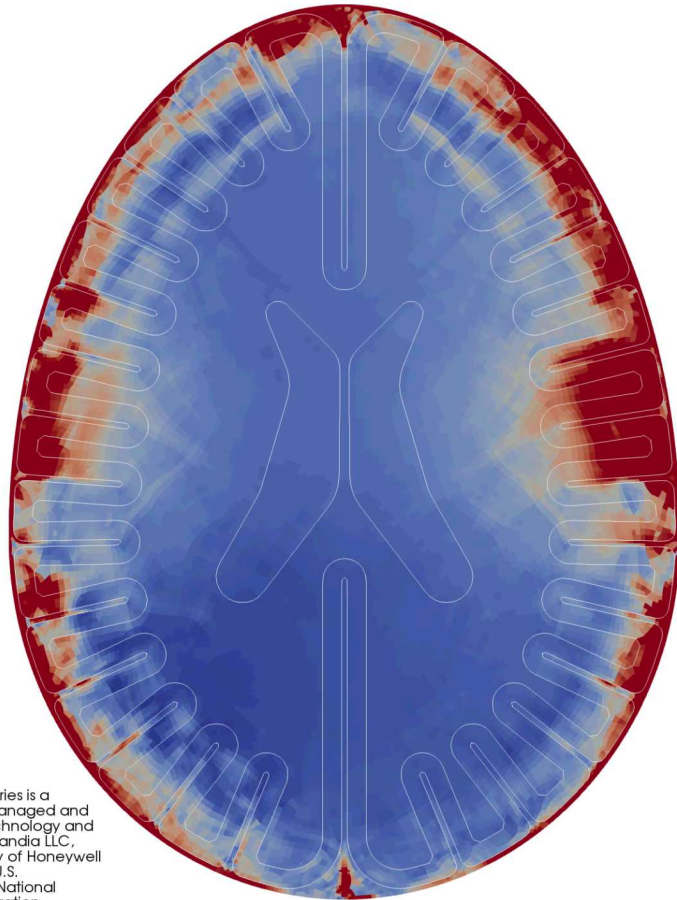
Subarachnoid space
(large vasculature)

Strain response indicates maximization of strains near sub-pial glial plate and gray-white regions.

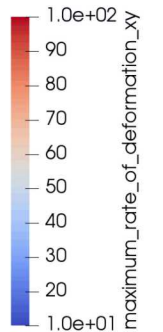
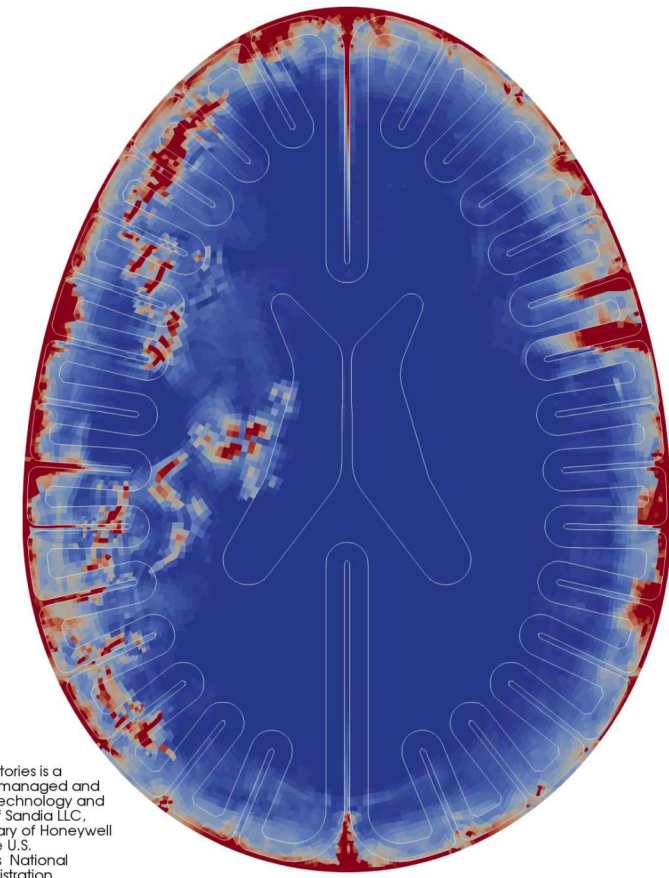


Similar pathology is seen for side blast exposures.

Max dilatational strain

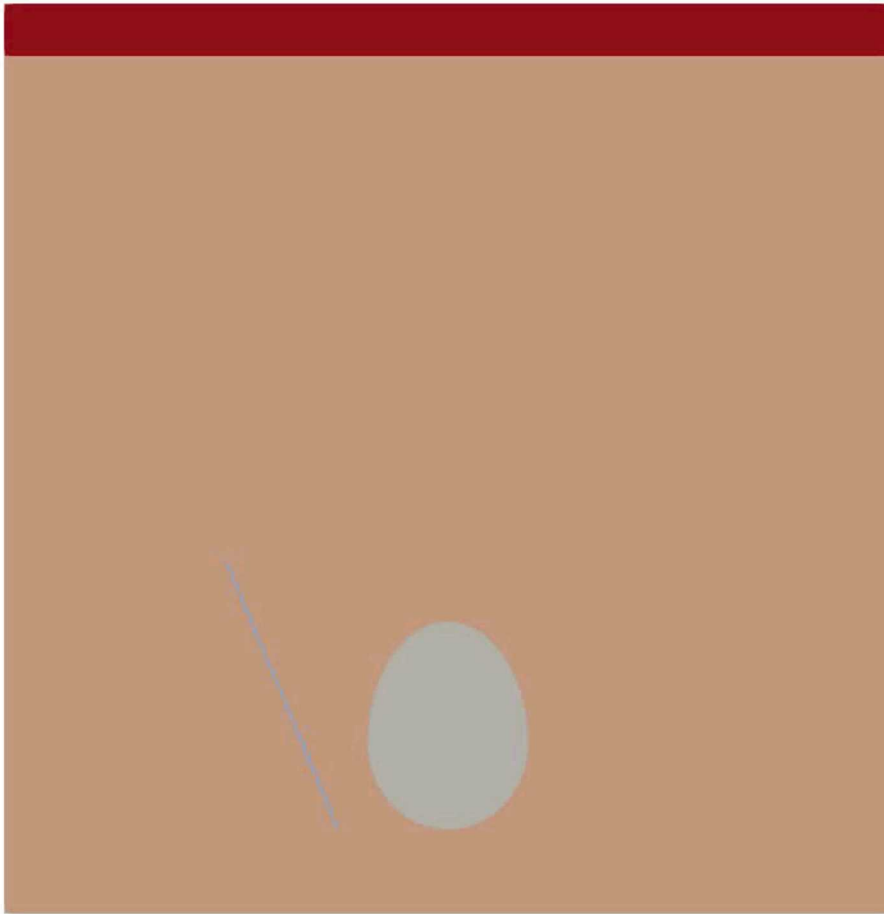



Max shear strain rate

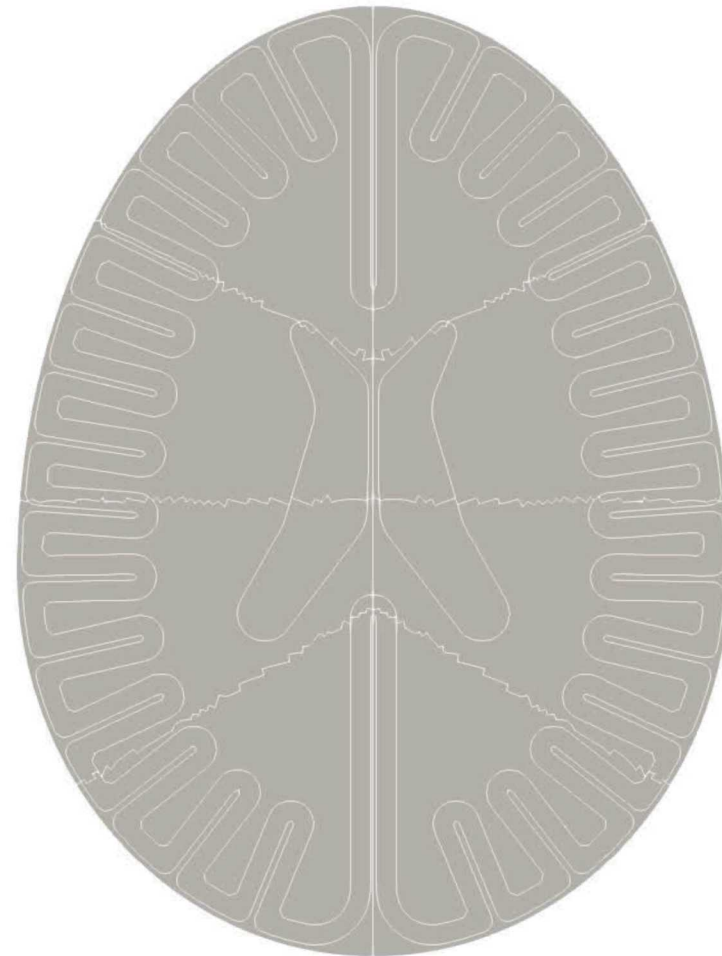



Blast impacts near obstacles (wall) generate complex loading

Pressure (dyn/cm²)



fluid_pressure



Take-away messages

Pathology seen in computational simulations links some metrics to areas of clinically observed damage.

Experimental validation is needed!

Goal: Once metrics are linked to damage, use optimization to improve helmet design

Next step: Improve geometric model, use human anatomy