

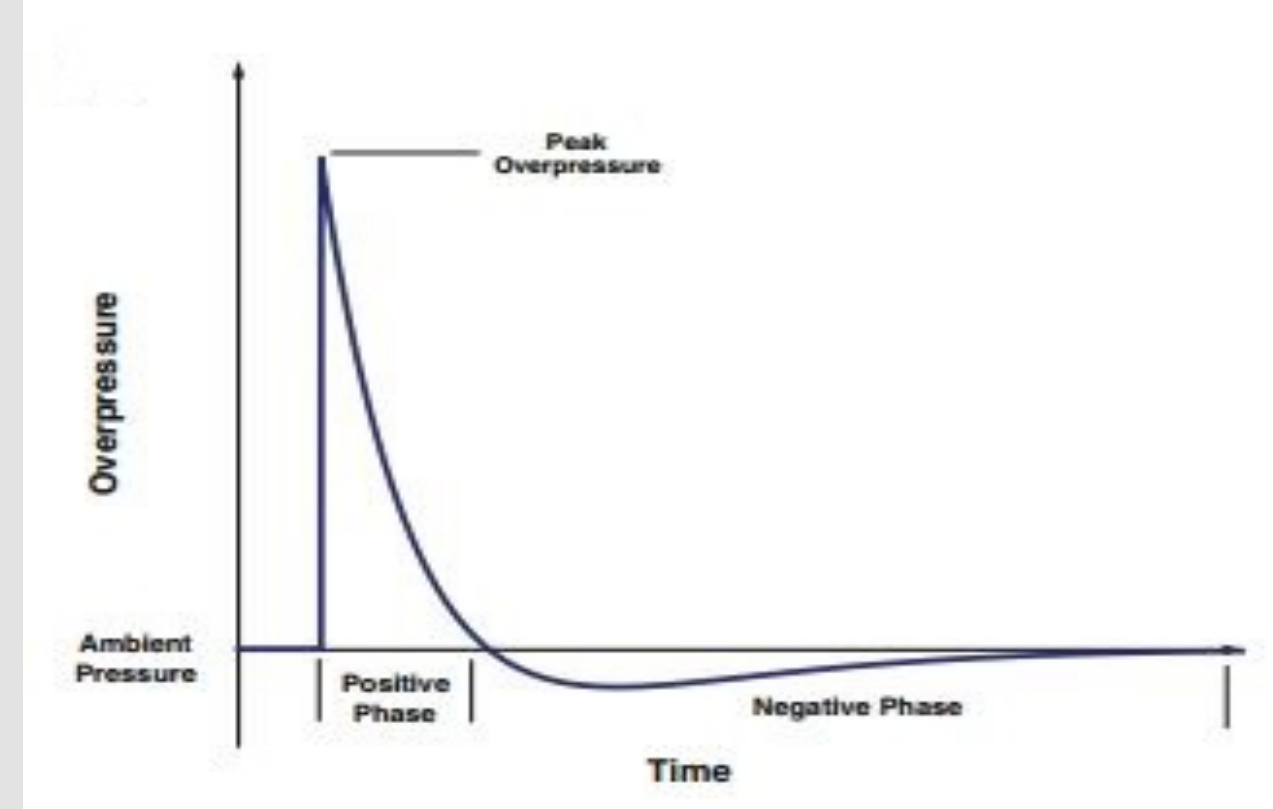
DEVELOPMENT OF FINITE ELEMENT MOUSE MODEL FOR PRIMARY BLAST SIMULATIONS



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Introduction

- Incidence of exposure to explosive threats has increased in recent military conflicts [1].
- With increased usage of thoracic body armor, shown to provide pulmonary protection, observation of blast related traumatic brain injury has increased [2].
- Primary blast can be characterized in a 1D air-blast by peak overpressure, overpressure duration, and pressure impulse [3].



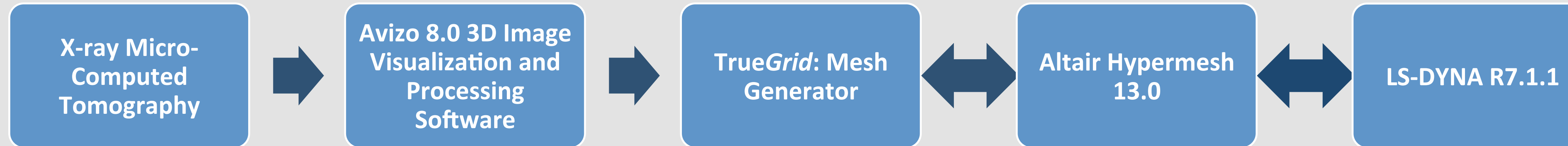
- Animal models are often used to assess physiological outcomes from blast exposure without considering interspecies scaling to human equivalent exposures
- Using interspecies scaling laws such as those developed by Bowen [4], the dose-response of the experimental models can be used to estimate a human equivalent using relative body mass:

$$\Delta t_{\text{scaled}} = \lambda \Delta t \quad \lambda = \left(\frac{m_{\text{reference}}}{m} \right)^{\alpha} \quad (4)$$
 where Δt is the duration and $\alpha = 0.33$
- Coupling the experimental models with numerical tools such as finite element (FE) modeling allows for tight control of boundary conditions and observation of transient response during the blast event, as well as stress propagation that would be difficult to obtain empirically.

Objectives

- Develop an *in silico* finite element model of a mouse head and neck comprised of linear hexahedral elements
- Maintain geometry of underlying anatomy and structures
- Optimize for the Jacobian, length and aspect ratio of each element to minimize model error

Methods



Avizo 8.0

- Imported micro-CT scan of complete mouse, downsampled, segmented voxels based on linear attenuation thresholds into five tissue layers: brain, bone, soft tissue, airway, and lungs
- Removed all anatomical regions behind the mid cervical spine and filled in gaps to ensure continuity
- Isolated individual tissue layers, extracted surface, remeshed and smoothed the surface shell elements

TrueGrid

- Imported mesh boundary from Avizo brain surface file
- Created a multi-block mesh and utilized projection methods to conform mesh to surface geometry
- Applied Laplacian smoothing

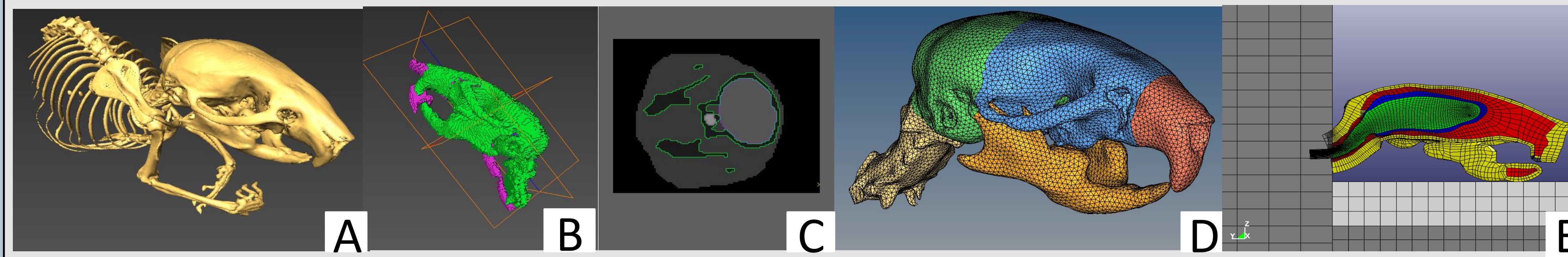
Hypermesh

- Quantitatively assessed the quality of elements using Jacobian, length, and aspect ratio.
- Created interpolations to remove micro-CT surface artifacts and refine layer boundaries, created new elements offset from brain mesh, projected onto surface definition to match geometry
- Manually and automatically smoothed elements
- Equivalence nodes to create continuous, deformable mesh for proper wave propagation

LS-DYNA

- Material properties assigned, nodal constraints defined, all iterations of blast simulations will be run in LS-DYNA.

Results: Model Development



Results: Model Simulation

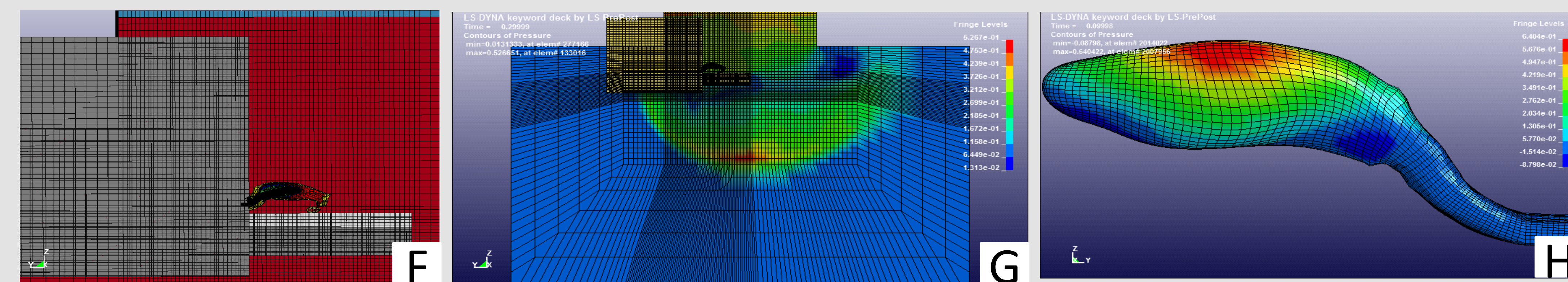


Figure 1 A) Original micro-CT data visualized using Avizo. Only bone structures are displayed before any truncations or segmenting B) 3-D reconstruction comprised of many 2-D slices post-material segmentation C) A single 2-D coronal slice post-segmentation D) Full skull surface shell element mesh imported to Hypermesh from Avizo E) Current mouse hexahedral FE model including the brain, spinal cord, CSF, vertebral bodies, skull and skin F) Simulation testing conditions with air, source of pressure differential, physical anchoring structure, and support plank G) Primary blast wave pressure field propagation through mesh H) Pressure field on brain from trial primary blast simulation

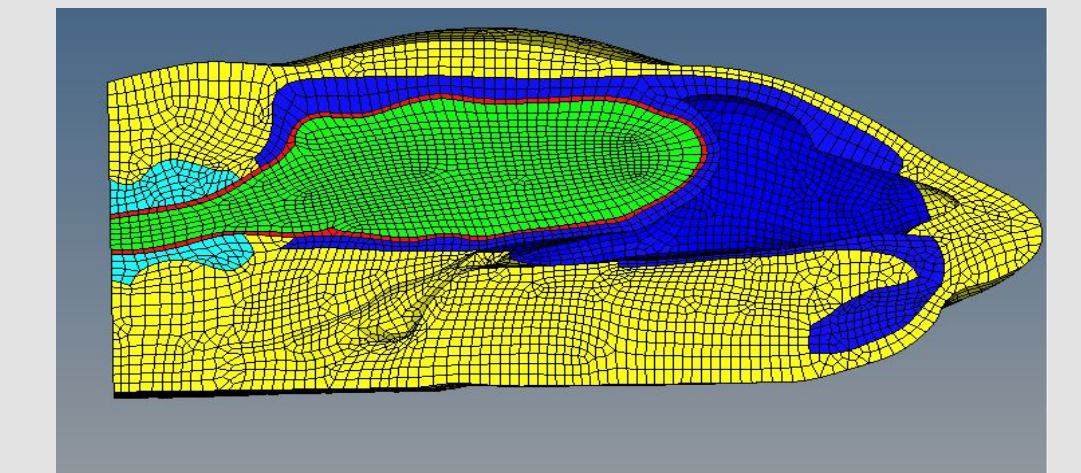
Model Parameters

Part	Total # Elements	Jacobian Below 0.5	Aspect Ratio Above 5	Average Element Length
Brain	18535	13 (0%)	614 (3%)	0.27 mm
CSF	3908	36 (1%)	298 (8%)	0.36 mm
Bone	8239	200 (2%)	436 (5%)	0.41 mm
Skin	5583	343 (6%)	1484 (27%)	0.77 mm

Total Number of Elements	Length (mm)	Width (mm)	Height (mm)
36265	31	6.5	13.5

Future Work

- Complete mesh refinement and introduce geometric complexities to ensure accurate structural response
- Complete inverse FEA using stress-strain data from mouse brain *in vitro* indentation tests to provide the mechanical properties of the FE mouse brain
- Validate the FE simulation results with existing *in vivo* mouse blast experimental data
- Perform a convergence study to ensure accurate blast dose response and minimize computation time
- Comparison of FE mouse model to existing FE ferret model for development and validation of mechanically-based interspecies scaling models



[5]

- Identify susceptible brain regions during the transient blast response and correlation with deficits during post-blast functional and behavioral testing

References

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