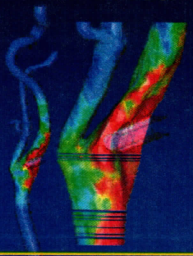
Preliminary Data and Technical Plan for Modeling Methodology

Joel Stitzel, Eric Kennedy,
Stefan Duma
October 24, 2004
Far Side Meeting



Virginia Tech CIB Wake Forest
Center for Injury Biomechanics

Carotid Artery Injuries in Far Side Impacts

Concern about differing loads resulting in carotid injury
For new restraint systems

With Dr. Stefan Duma, Center for Injury Biomechanics, VT

Introduction

The purpose of this report is to serve as a draft technical plan for the Virginia Tech – Wake Forest Center for Injury Biomechanics' work in carotid artery injury modeling.

Carotid Anatomy

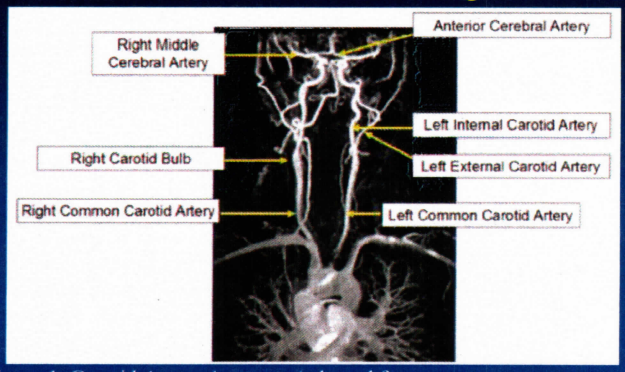
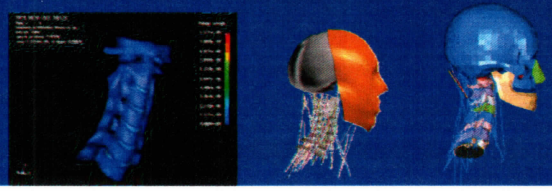


Figure 1. Carotid Artery Anatomy (adapted from http://www.cme.wisc.edu/online/radiology/carotid/anatomy.htm)

Component Neck Models

- Detailed design of local neck geometry and interactions
- Computationally more efficient then full body models
- Boundary condition concerns for response due to restraint systems



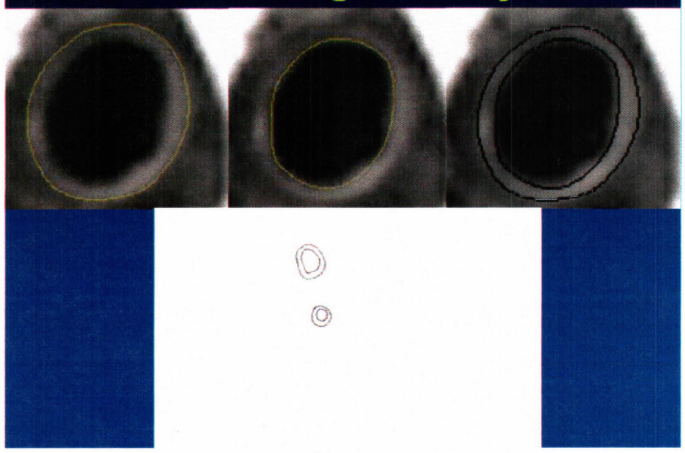
MADYMO Detailed Neck

- Published by De Jager, Van der Horst, and Meijer
- Refined geometry of vertebral bodies
- Active and passive muscle effects
- Widely validated, including some side impact with good correlation
- No FE techniques
- Integrated into 50th percentile full body model

Approach (in progress) for creating FE model of carotid

- Visible human data was not used (CT data is better, and we have scans specific to carotid and neck with contrast)
  - Exceeds accuracy and detail of MRI
  - May be scaled as needed
- Scans from 57 year old, male, with normally assessed carotid artery
- 270 slices (aorta to condyles)
  - 0.625 mm slice thickness
  - 0.3125 mm/ pixel resolution

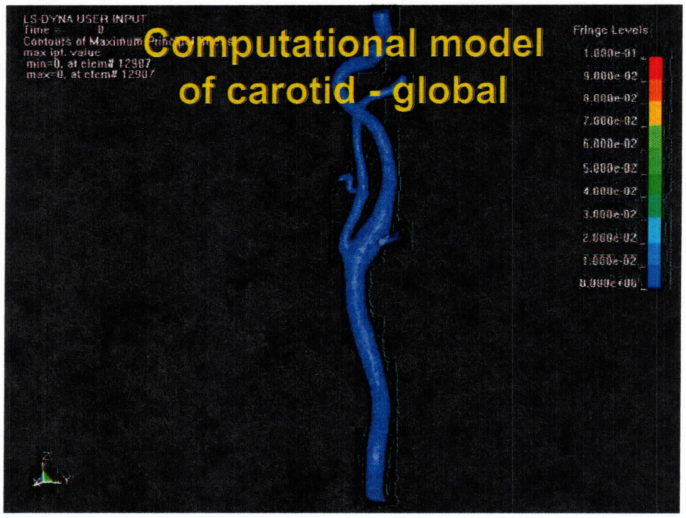
Carotid geometry



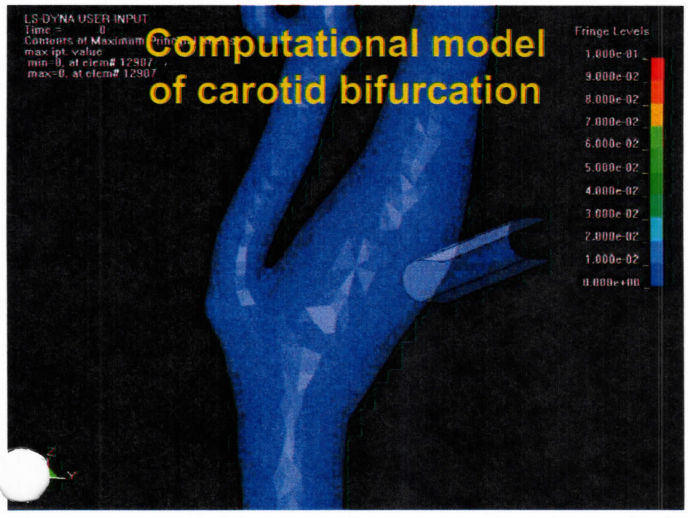
Carotid Model

- Triangular element mesh
- Single layer material
  - Intima, media, adventitia combined
- Isotropic material properties
- Contact algorithms and model stability verified
  - R1.5 mm impactor test

Computational model of carotid - global



Computational model of carotid bifurcation



Development of specimen model for validating material properties

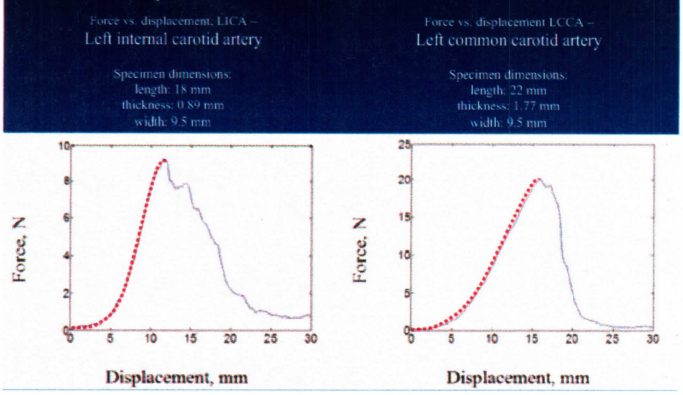
- Data and specimen dimensions obtained from Medical College of Wisconsin for
  - Left Common Carotid Artery (LCCA)
  - Left Internal Carotid Artery (LICA)
- Axial testing
- Left common carotid artery modeled – matching force-displacement response with assumed stress-strain response

Material Properties

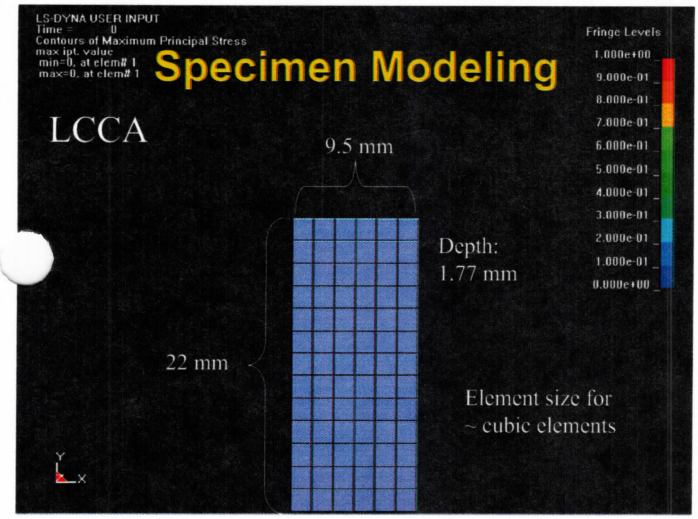
- Preliminary:
  - Mooney-Rivlin (Strain stiffening)
  - Is anisotropic behavior significant, requiring more complex meshing?
    - Experimental tests?
  - Ogden Rubber may provide better fit
    - Need data for poisson's ratio (rubber models work best when close to 0.5)

Material Properties

- Preliminary:



Specimen Modeling



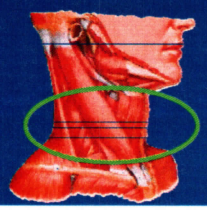
Neck Tissue Representation

Detailed bony anatomy:

- Kinematics extracted from validated global models
- Motion prescribed to local model

Soft tissues as lumped mass:

- Homogenous
- Isotropic
- Intrusion defined/ modeled



Modeling Plan

- SIMon approach for injury prediction
  - Madymo Detailed Neck model subjected to side impact simulation
    - 3 or 4 point simulations
  - Kinematics taken from vertebral bodies and imposed on LS-Dyna neck with carotid artery
  - Soft tissue deformation evaluated from Madymo output or simulated in LS-Dyna with other contacts
  - Resulting stress response of carotid observed
    - Risk assessed at prioritized modes of failure

Injury Prediction

- What type of injuries do we want to assess?
  - Separate assessment of intimal, media, and adventitial layers?
    - Independent layer for each?
    - Strain assumption for single layered model?
  - Failure of each layer will require further mechanical testing

Conclusions

- Geometry implemented in LS-Dyna
- Preliminary validation begun
- Data fit from MCW ongoing
- Require experimental test to verify adequate material representation
- SIMon approach to evaluating soft tissue interaction
- Definition of injury prediction capabilities

Acknowledgements

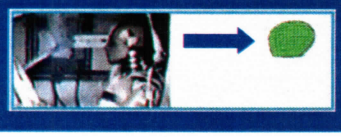
Medical College of Wisconsin for providing carotid artery test data

Thank you!
Questions?

Virginia Tech CIB Wake Forest
Center for Injury Biomechanics

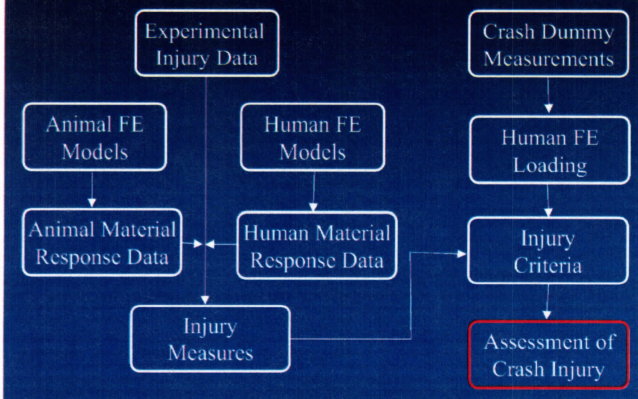
SIMon

- Directly imposes crash dummy responses on body region specific FE models
- Utilizes biomechanically based injury measures
  - Localized tissue deformations
  - Based on testing soft tissues at high rate



NHTSA
People Saving People
http://www.nhtsa.dot.gov

Idea behind SIMon



Modeling Plan

- SIMon approach for injury prediction
  - Validated neck model used to extract occupant kinematics
  - Kinematic motion imposed on bony structure of cervical spine
  - Other contact mechanisms added (i.e. four point belt soft tissue compression)
  - Carotid artery response observed
  - Injury risk evaluated