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.

Component Neck Models

- Detailed design of local neck geometry and interactions
- Computationally more efficient than 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

Carotid Anatomy

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

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)

**Specimen Modeling**

LCCA

- 9.5 mm
- 22 mm
- Depth: 1.77 mm
- Element size: cubic elements

**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

Idea behind SIMon

- Experimental Injury Data
- Crash Dummy Measurements
- Animal FE Models
- Human FE Models
- Animal Material Response Data
- Human Material Response Data
- Injury Measures
- Assessment of Crash Injury

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