Sandia National Laboratories

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LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Human Torso Model Development for Computer Simulation of Blunt Trauma, Blast Injury, Projectile Penetration, and their Mitigation
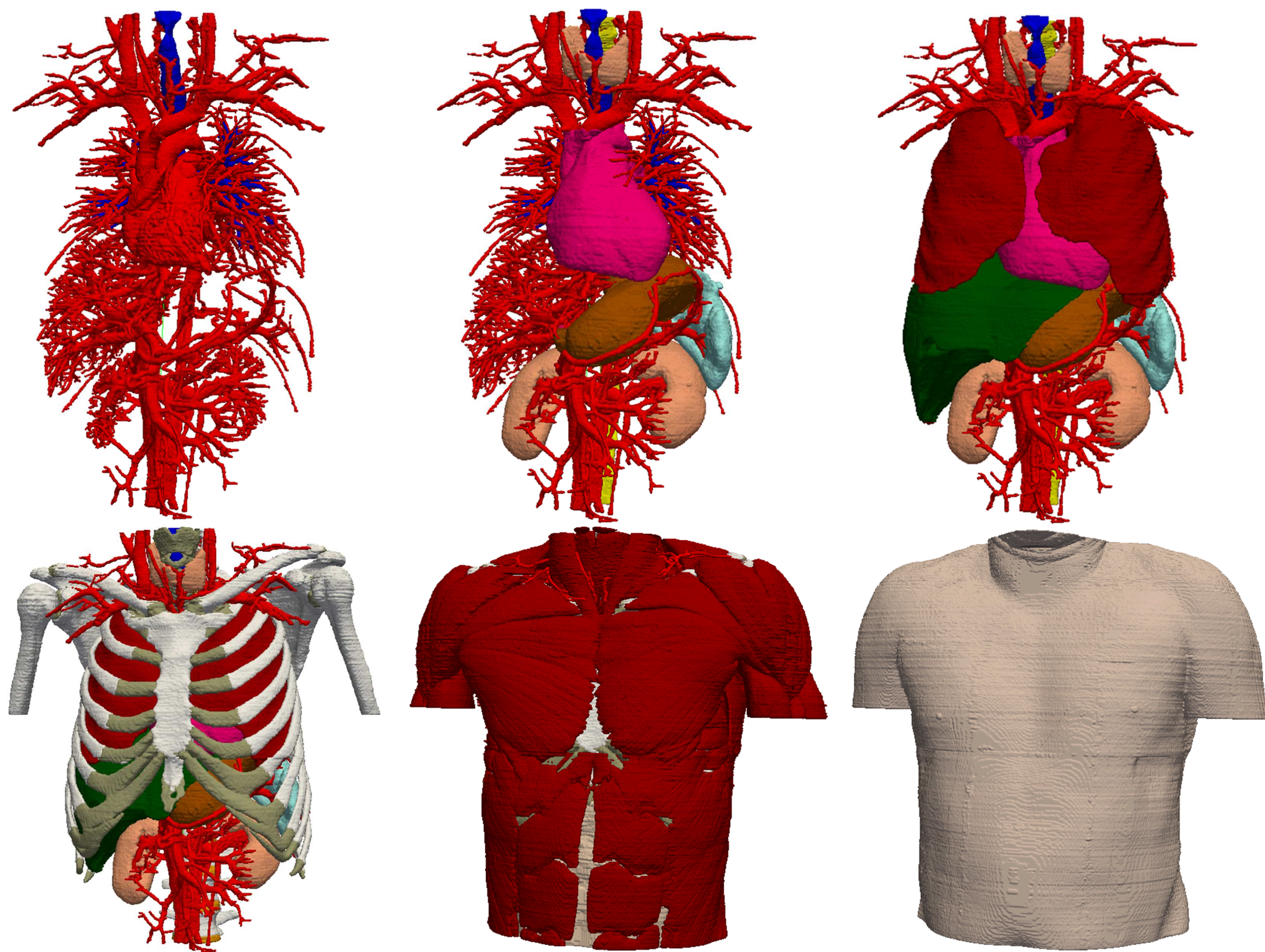
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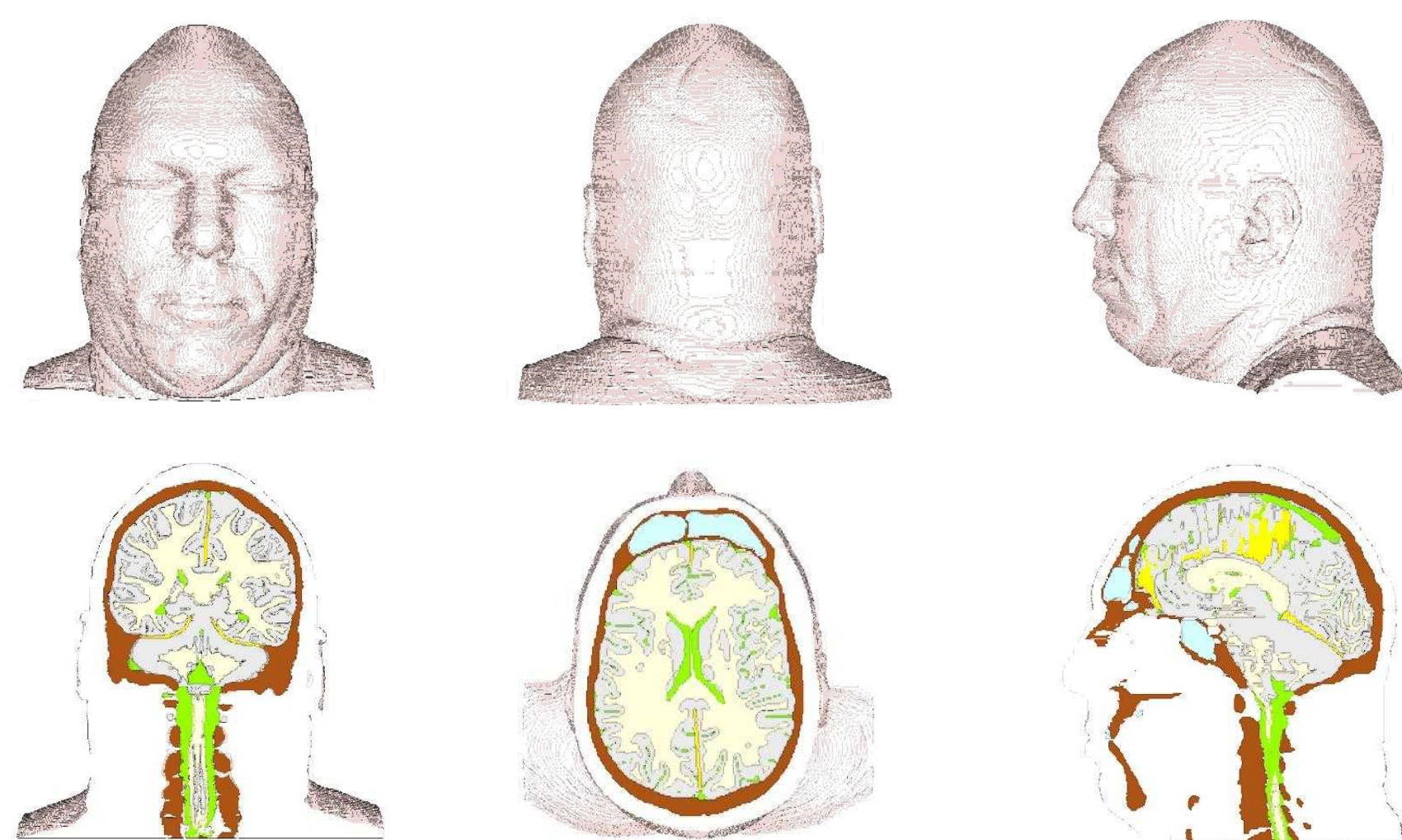
INTRODUCTION

- We have developed high-fidelity models and simulation tools to study wound injury scenarios to the head, neck, & torso
  - Motivation: Investigation into would injury mechanics and virtual assessments of personal protection equipment (PPE) without the use of human cadavers or damage to expensive physical surrogates

MODELS

- **Digital Torso Model**
  - Anatomically correct distributions of bone, cartilage, intervertebral discs, vasculature/blood, airways, lungs, heart, kidneys, liver, stomach, spleen, spinal cord/CSF, muscle, & fat/skin in 1mm resolution

- **Digital Head-Neck Model**
  - Fully compatible with torso model for use in joined head, neck, & torso simulations.
  - Anatomically correct distributions of bone, white & gray brain matter, membranes (falx & tentorium), cerebral spinal fluid (CSF), sinus air, & scalp/muscle in 1mm resolution
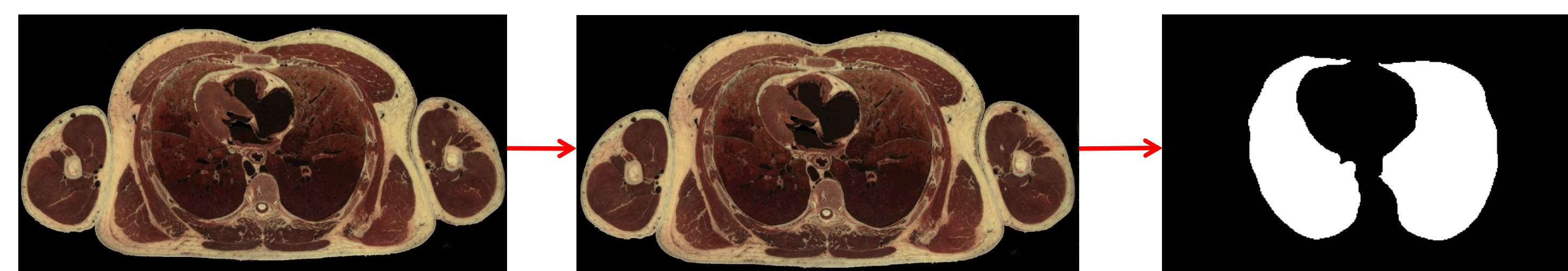

- **Model Development**
  - Individual tissue segmentation from the male Visible Human Project CT and color images

Bone Segmentation from CT Image:

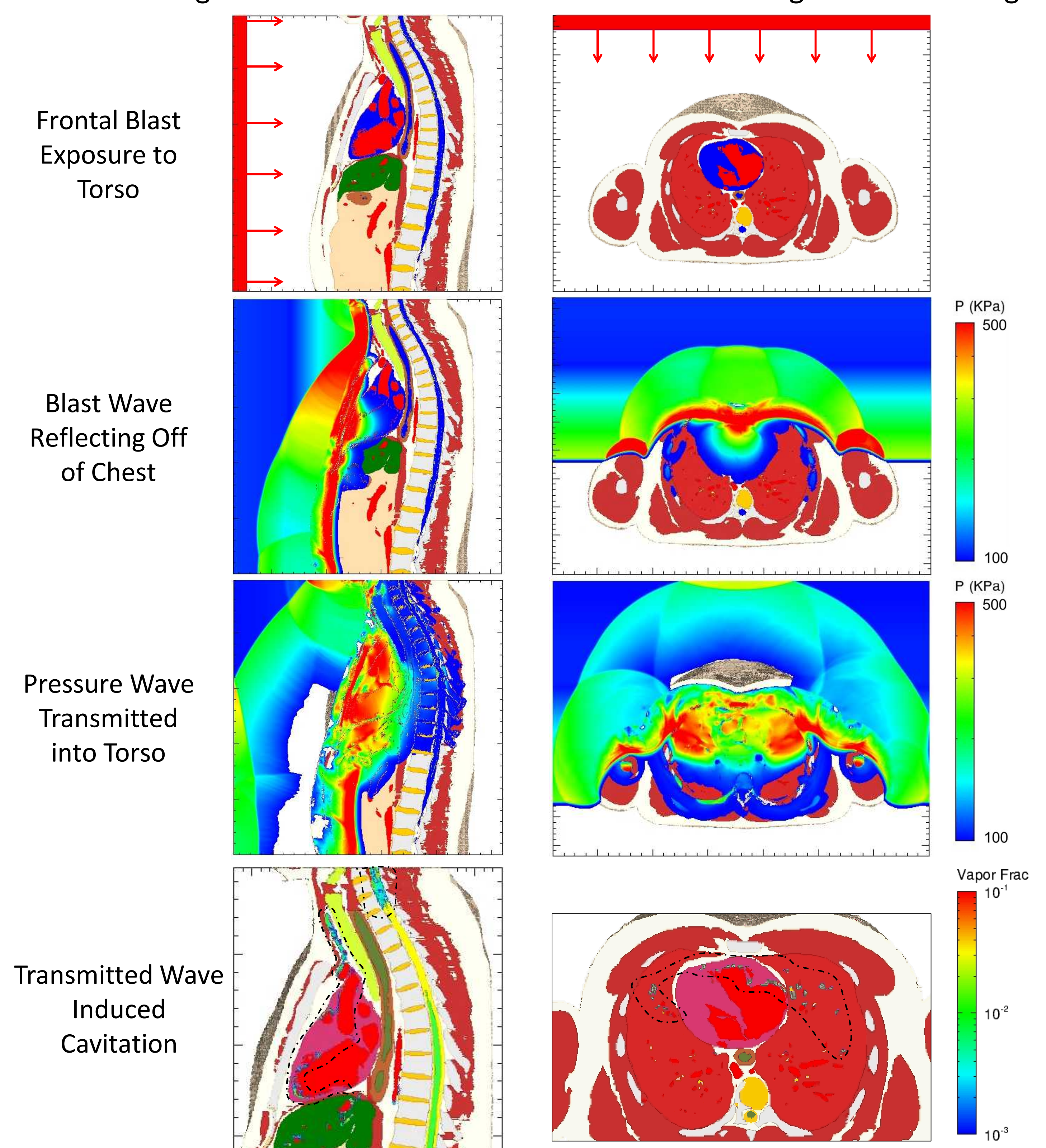Lung Segmentation from Color Image:

CONSTITUTIVE MODELS

- **Biological Materials**
  - Advanced equation-of-state (EOS) and deviatoric strength models employed to represent bone and soft tissue
    - Life-critical organs represented by finite-deformation, elastic or viscoelastic models
    - Fluid & fluid-saturated tissue represented by Tillotson-Brundage EOS
      - Accurately captures cavitation & associated effects

COMPUTATIONAL SIMULATION METHODS

- **Eulerian Methods**
  - Blast, Blunt Impact, Penetration using large strain rate shock physics code CTH
- **Lagrangian Methods**
  - Blunt Impact & Model validation with Sierra Mechanics code PRESTO
- **Coupled Lagrangian-Eulerian Methods**
  - Blast; using CTH (Eulerian domain) coupled to PRESTO (Lagrangian domain), controlled by ZAPOTEC II

SIMULATIONS

- **Explosive Blast Exposure**
  - 360 KPa blast (260 KPa overpressure)
    - Investigate tissue deformation and cavitation leading to tissue damage

Frontal Blast Exposure to Torso

Blast Wave Reflecting Off of Chest

Pressure Wave Transmitted into Torso

Transmitted Wave Induced Cavitation

- **Behind Armor Blunt Trauma (BABT)**
  - Caused by ballistic projectile stopped by PPE
    - Energy dispersed by armor and pressure wave propagated into body
- **Projectile Penetration**
  - Tissue damage caused by ballistic projectile perforating PPE

SUMMARY

- High fidelity models of the human head, neck, and torso, permit study into various injury scenarios; blast impact, blunt trauma, and projectile penetration
- Investigation into wound injury mechanics in life-critical organs and relative merit assessments of personal protection equipment can be conducted for the warfighter or athlete
- Physical experiments require the use of human cadavers or expensive physical surrogates, virtual simulations can be conducted ad infinitum. The torso model is currently undergoing verification and validation.

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