Development of 3D Geometry of the Ovine Thorax for Finite Element Modeling

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Introduction

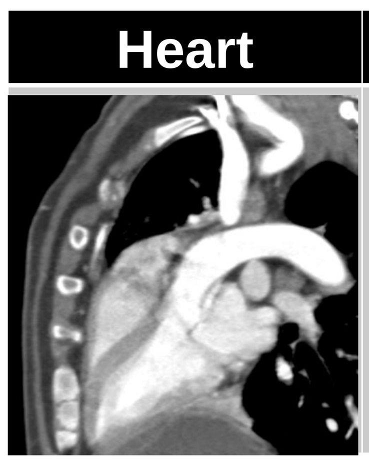
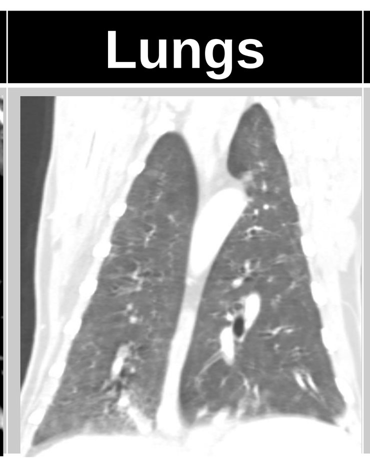
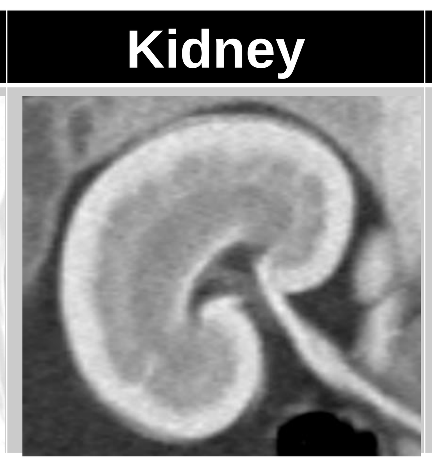
The long-term goal of this study is to develop a finite element (FE) computational model of an ovine thorax for the study of Behind Armor Blunt Trauma (BABT). We present a CT scanning and geometry development method used in the generation of 3D CAD for the animal model.

CT Scan Methods

All scanning was conducted under WFU IACUC A20-161. CT scan data was acquired of two male Katahdin sheep, 25-30 kg, in sternal recumbency using a Siemens Somatom Definition Flash CT scanner at the Wake Forest Baptist Medical Center Clarkson Campus. The scan used a wedge-3 filter, exposure time of 500 ms, 100kV, 500mA, slice thickness of 0.6 mm, and a matrix of 512 x 512. Contrast agent (1mL/lb Omnipaque 350) was delivered at a rate of 2 mL/s using a power injector through the cephalic vein. Scans were taken at baseline, 20 s, 80 s, and 5 min post contrast to accentuate arterial and portal/venous structures. All scans were reconstructed with bone and soft tissue windows.

Figure 1: A 3-dimenasional sagittal view, using a lumbar filter, of the CT scan collected 20s post contrast.

Table 1: Visibility of select organs for the 20s post contrast tissue reconstructions of the sheep scans. The lung images were taken using a lung window to highlight the details inside the lungs, all other images were taken using the default grayscale window.

Heart	Lungs	Kidney	Liver
			

Segmentation Methods

Geometry was focused on structures of interest in BABT study from a single animal: the ribcage, sternum, spine, humerus, scapula, costal cartilage, heart, lungs, vasculature, abdominal organs, soft tissue envelope, and skin. Anatomical features were segmented using Mimics v. 23 (Materialise, Leuven, Belgium) and post processed using Geomagic Studio v2014 (3D Systems, Rock Hill SC) to acquire polygonal surfaces. All segmenting was completed using the 20s post contrast scan. Masks were created using the semi-automatic dynamic region grow function and then manually edited against image data using multi slice edit. Following geometry development preliminary comparisons to the human thorax were made using the GHBMC M50-O v. 6.0 male thoracic model.

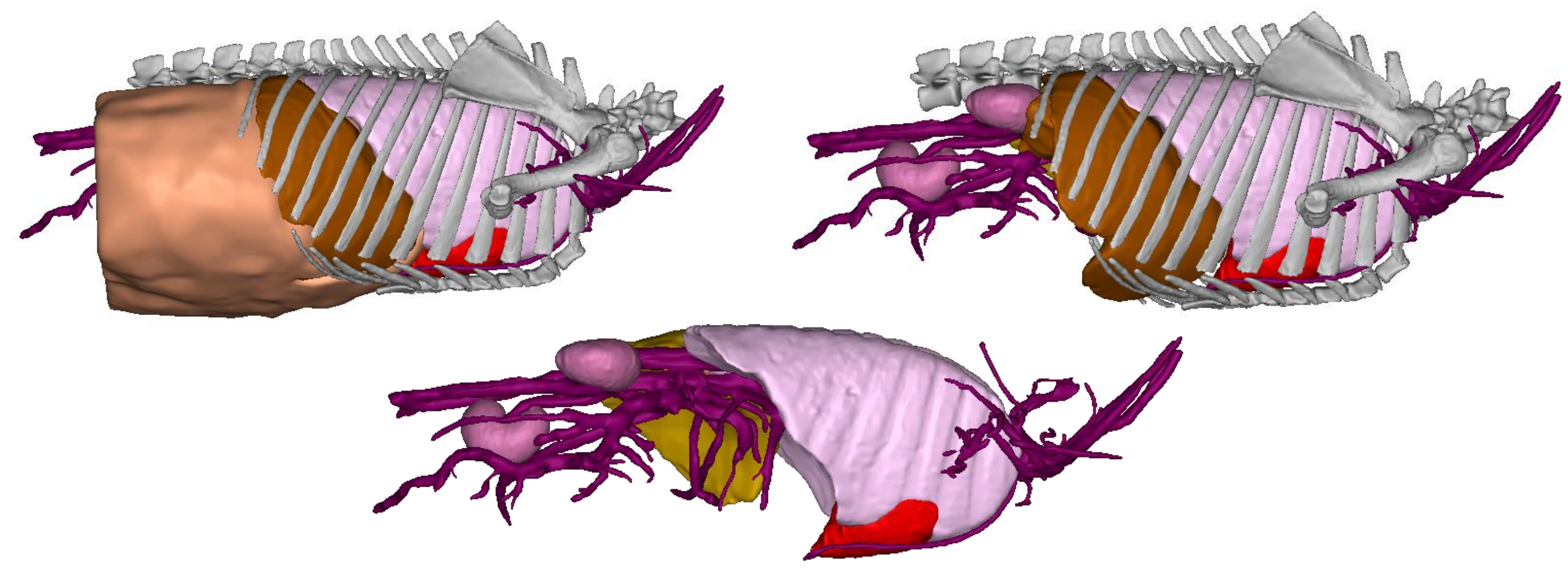


Figure 2: Segmented structures included in the model. A All of the structures. B Rumen removed. C. Skeleton removed.

Comparative Analysis

Because these animals will be used as human surrogates in BABT studies, comparative gross morphological differences between the sheep and average adult human male were made. The ovine rib cage measured 207 mm in LR width and 235 mm in AP breath at the level of vertebrae T9 as opposed to 408 mm and 239 mm respectively for the human subject (GHBMC M50-O). Sheep have 26 ribs compared to 24 in the human rib cage. The total lung volume of the sheep was 34.4% smaller than the human lung volume and the aortic diameter of the sheep was 51.6% smaller. Comparative gross anatomy is a first step to understanding mechanical metrics which will be extracted from future modeling efforts. The long-term goal of this study is the development of a dynamic FEA model of the ovine thorax for improved FE based injury metrics via comparison to experimental outcomes, and to perform in-silico testing of body borne countermeasures.

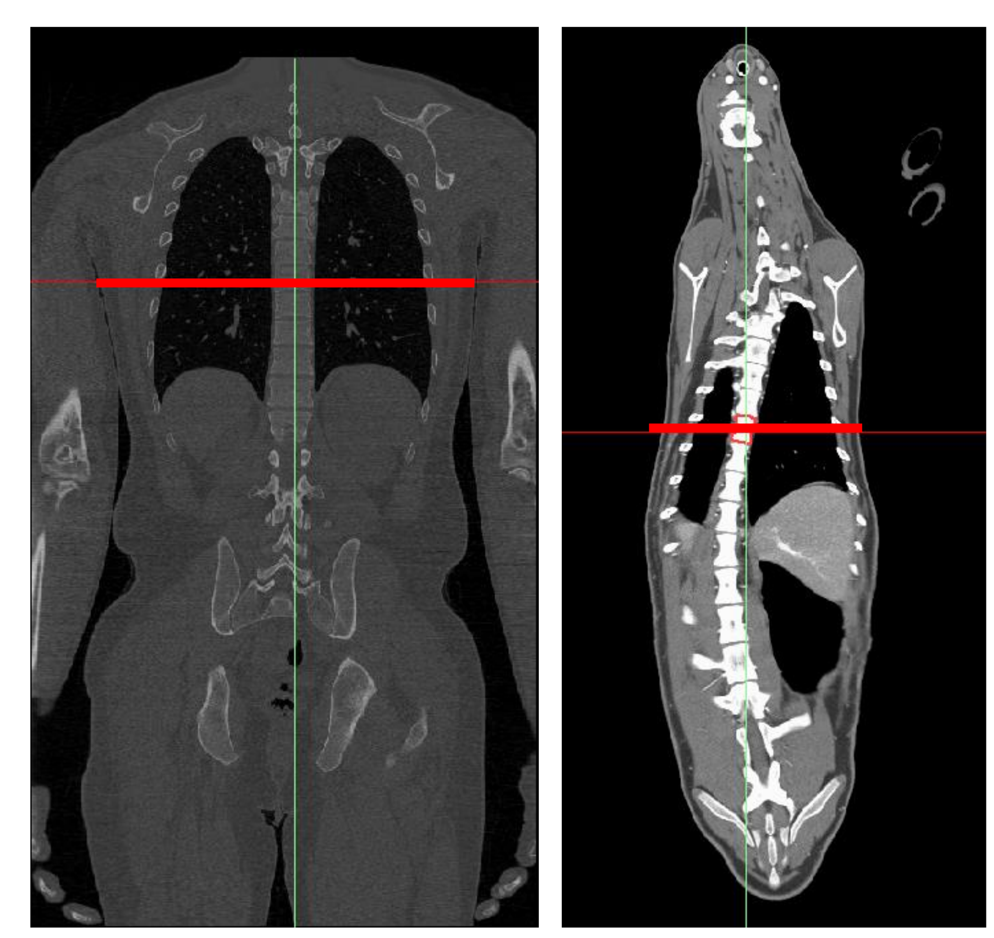


Figure 3: Location where LR width measurements were taken. Left: is GHBMC subject. Right: is sheep CT scan.

Next Steps

Model is currently in the process of being meshed and developed for initial simulations. All internal structures have been meshed and are being assembled as a reduced model for initial simulations. Once the full model is assembled it will be validated against experimental data. In the long term the model will be used to develop injury criteria to compliment BABT experimental outcomes and will be used to mitigate BABT injury.

Acknowledgements

This work was funded by the U.S. Army Research Lab under BAA #W911NF2120034. We gratefully recognize the guidance provided by Alan Goertz.