# A method to extrapolate the geometrical properties of human ribs using micro-CT and clinical-CT images.

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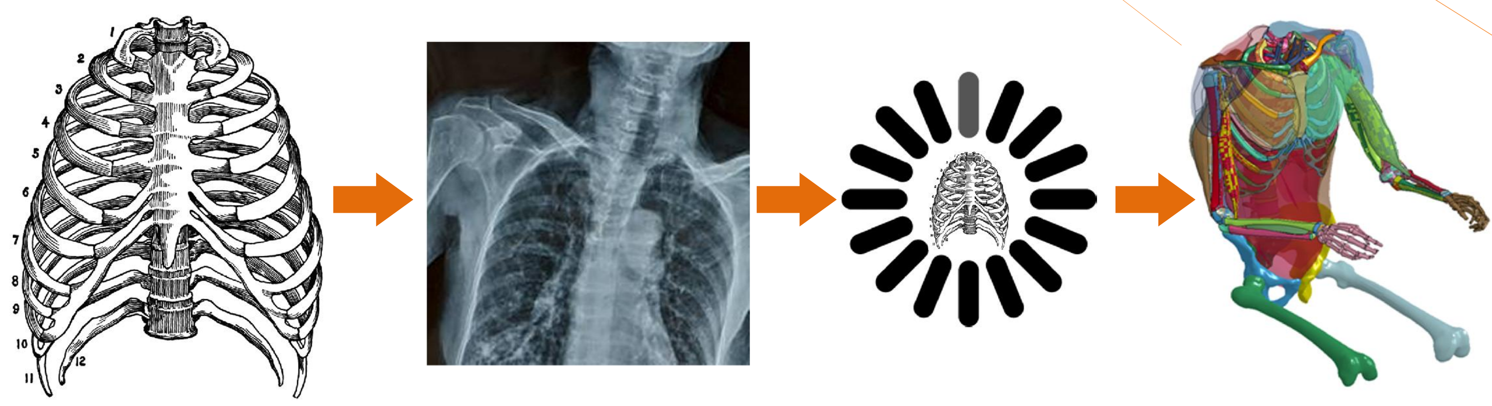
## INTRODUCTION

- Thorax injuries are second after head injuries as a casuse of death during frontal car crash accidents.
- Finite Element (FE) Models are the future of thorax injuries investigation.
- Current FE models of the human thorax need improvement:
    - More accurate geometry of the ribcage
    - More biofidelic response of ribs
    - Including rib fracture mechanisms

**AIM of the WORK:** Implement a method to extrapolate the geometrical properties of human ribs using micro-CT and clinical-CT images.

### Building FE model of the thorax



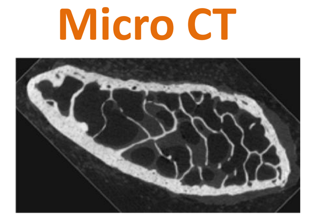
Human body — X-Ray imaging — Image processing — FE model

### X-Ray analysis

**Clinical CT**

| Clinical CT | | Micro CT |
|---|---|---|
| Large Field of View: Full body scans, living subjects | ADVANTAGES | High resolution: 0.02 mm/voxel |
| Low resolution 0.3 mm/pix | LIMITATIONS | Small Field of View: Ø5 cm x 15 cm, PMHS parts only |

**Micro CT**



### Research question:

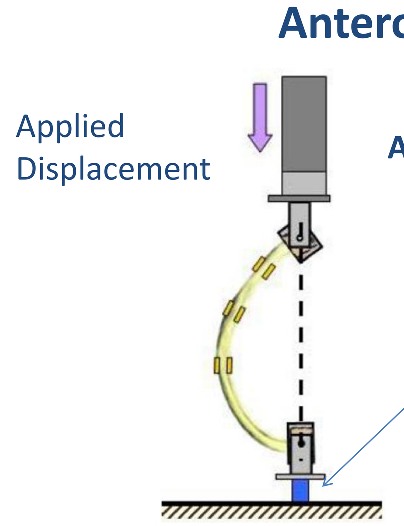
**Can we combine two methods – use clinical CT to scan the body and local micro CT images to determine the clinical CT error?**

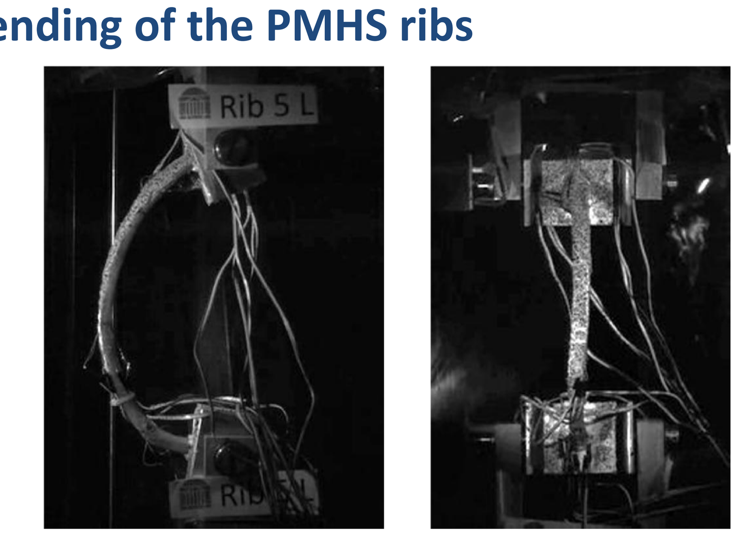
### Strategy:

1. Experiment: Antero-Posterior Bending
2. X-ray Imaging of the whole ribs – Clinical CT and micro CT of the slices
3. Development of the correction functions to correct the rib geometry and to achieve biofidelic behavior of the rib
4. Ribs geometry processing and evaluation of an adjustable FE beam model
5. Comparison of the experimental and numerical responses and validation of the FE model

## METHODS: Experimental Part

### Antero – Posterior bending of the PMHS ribs



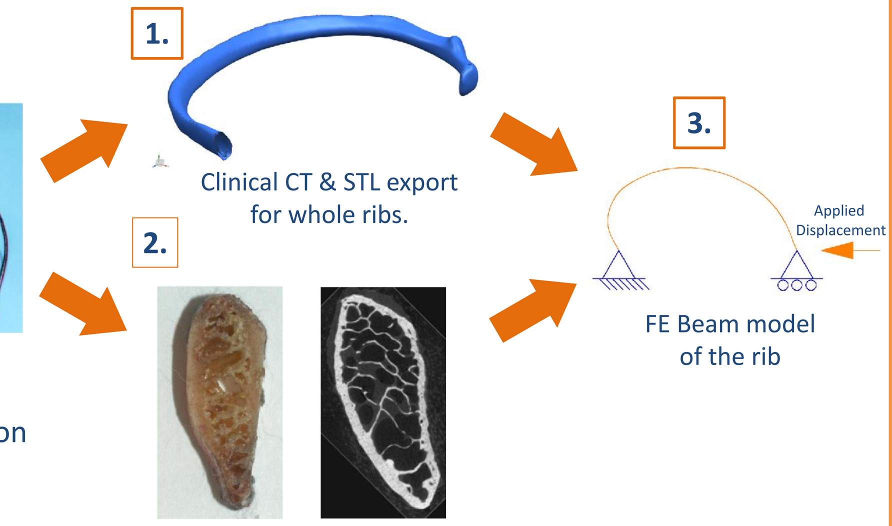




Actuator velocity 1 m/s; displacement up to failure

## METHODS: Specimens, Imaging, Data & Geometry Processing and FE model

**SPECIMENS & IMAGING**

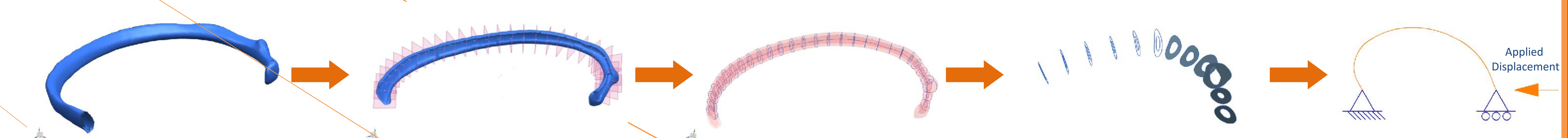

One human cadaver — Extraction of twelve left ribs — Instrumentation and preparation




34 cross-sections from anterior, posterior and medial locations. Imaging using clinical- and micro-CT modalities.

**GEOMETRY PROCESSING**

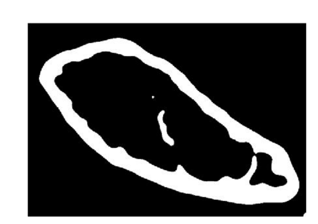
**1. Whole rib clinical CT**




Geometry: two surfaces derived from STL files: trabecular and outer contours — Determining the centroid and cutting planes — Extracting one hundred slices — Creating cross-section surfaces — FE beam model geometry of the rib with adjustable parameters: Moments of inertia and cortical area

**GEOMETRY PROCESSING**

**2. CT images**



**GEOMETRICAL PROPERTIES:**

- Cortical Area
- Trabecular Area
- Overall Area
- Principal Moments of Inertia

Properties distribution along the ribs and comparison: Clinical-CT vs. Micro-CT

Deviation formula:

$$\frac{Clinical\ CT\ val. - \mu CT\ val.}{\mu CT\ val.} \times 100\%$$

**DEVELOPMENT OF CORRECTION FUNCTIONS:**

**5 METHODS**

**FE MODEL**

**3. FE beam model**

**BEAM GEOMETRY:**

- Rib centroid
- ~100 beam elements, fully adjustable
- Assigned geometrical properties based on the cross-section analysis
- BCs: two pin joints

**MATERIAL PROPERTIES:**

- Elastic, perfectly-plastic (without failure)
- Young's modulus E = 10.18 GPa
- Poisson's ratio υ = 0.3
- Yield stress σy = 98 MPa

**ANTERO – POSTERIOR BENDING:**

- Quasi-static solution
- LS-Dyna R4.2.1 implicit code

## RESULTS

| TABLE 1<br>Clinical-CT vs. Micro-CT: GEOMETRICAL PROPERTIES DEVIATION RESULTS | | | | |
|---|---|---|---|---|
| Parameter | Min | Max | Mean | Std. Deviation |
| 1st PMoI | 20.6% | 73.3% | 49.7% | 13.3% |
| 2nd PMoI | 19.2% | 92.8% | 56.8% | 19.5% |
| Overall area | 2.0% | 13.7% | 7.6% | 2.9% |
| Cortical area | 17.8% | 66.9% | 40.2% | 12.5% |
| Trabecular area | 1.7% | 34.0% | 13.3% | 7.3% |

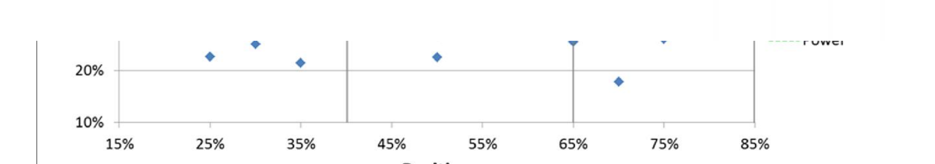



Fig. The evaluation of the correction functions for the cortical area.

## RESULTS cont.

Fig. The example of the properties distribution for the 5L rib when applying functions. Distribution results are also available for the ribs 3 and 4.

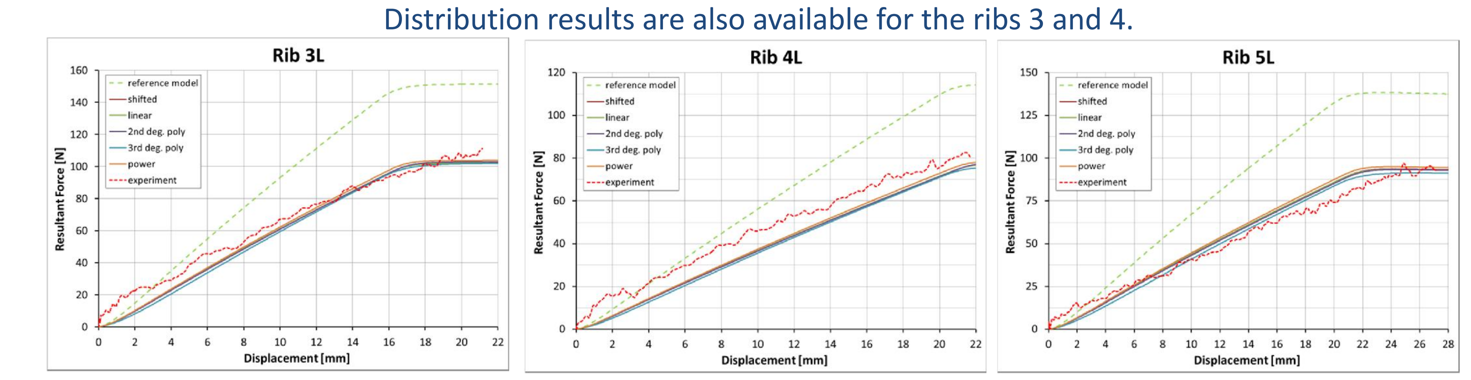



Fig. The numerical model responses compared to the experimental results.

## DISCUSSION

- **Using a beam model allows adjustments of the each cross-section parameter separately;**
- **Thresholds often require hand correction which is time consuming;**
- **Study was conducted on the single ribs only – needed evaluation for the whole ribcage;**
- **The biggest issue is the x-ray images threshold and export – a few extra pixels can significantly change geometry parameters changing the area, moments of inertia and the shape.**

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