A novel method for determining thoraco-abdominal organ location using low dose X-ray: Applications for body armour design.

Rob Davidson — Faculty of Health, University of Canberra

Celeste Coltman — Research Institute for Sport and Exercise & Faculty of Health, University of Canberra

Mark Pickering — School of Engineering and Information Technology, University of New South Wales

CONTENT

- Body Armour: coverage
- Organ Location: limitations
- Solution
- Results
- Discussion
- Future Work

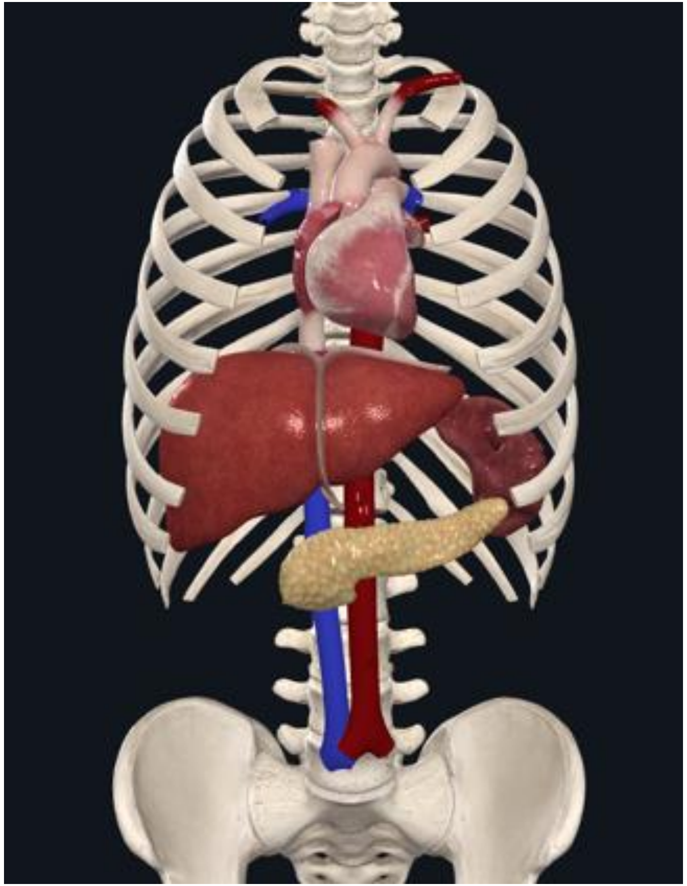
Function of Body Armour

- Personal Protective Equipment (PPE)
- Protect vital organs of thorax & abdomen [1, 2]
- Protection-mobility tradeoff
- Evidence based design

[1] Laing & Jaffrey. TR-3636 (2019)
[2] Breeze et al. *J R Army Med Corps* (2015)

Coverage requirements

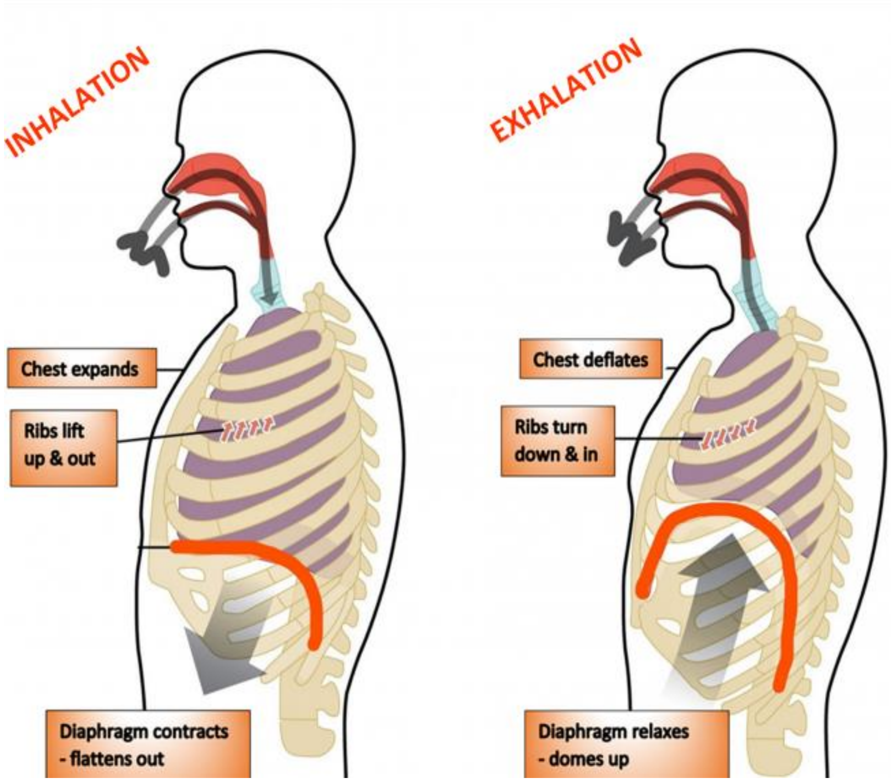
- No universal requirements
- National Institute of Justice:
  - Standards for stab resistance coverage of vital organs: heart, liver, kidneys and spleen
- Breeze[2]:
  - Essential organs: heart, great vessels, liver and spleen



[2] Breeze et al. *J R Army Med Corps* (2015)

Organ Location

- Medical imaging literature – centre mass of organs
- Lack of data: boundaries of organs – dependent on body size and shape / male versus female
- Consideration of breathing and postural conditions [1]
- Erect versus prone



[1] Laing & Jaffrey. TR-3636 (2019)

Limitations of determining organ location

- Inappropriate imaging modalities: CT, MRI and ultrasound
  - Invasive / risks
  - Expensive
  - Inappropriate

- Goal is to be able to develop a method that can be easily used for all soldiers

Alternate solution?

- Existing methodologies[3]
- For this work:
  - Low dose PA and lateral chest / upper abdomen x-ray images
  - 3D surface scan

[3] Scarvell, Pickering & Smith, *J Orth Res* (2019)

Method

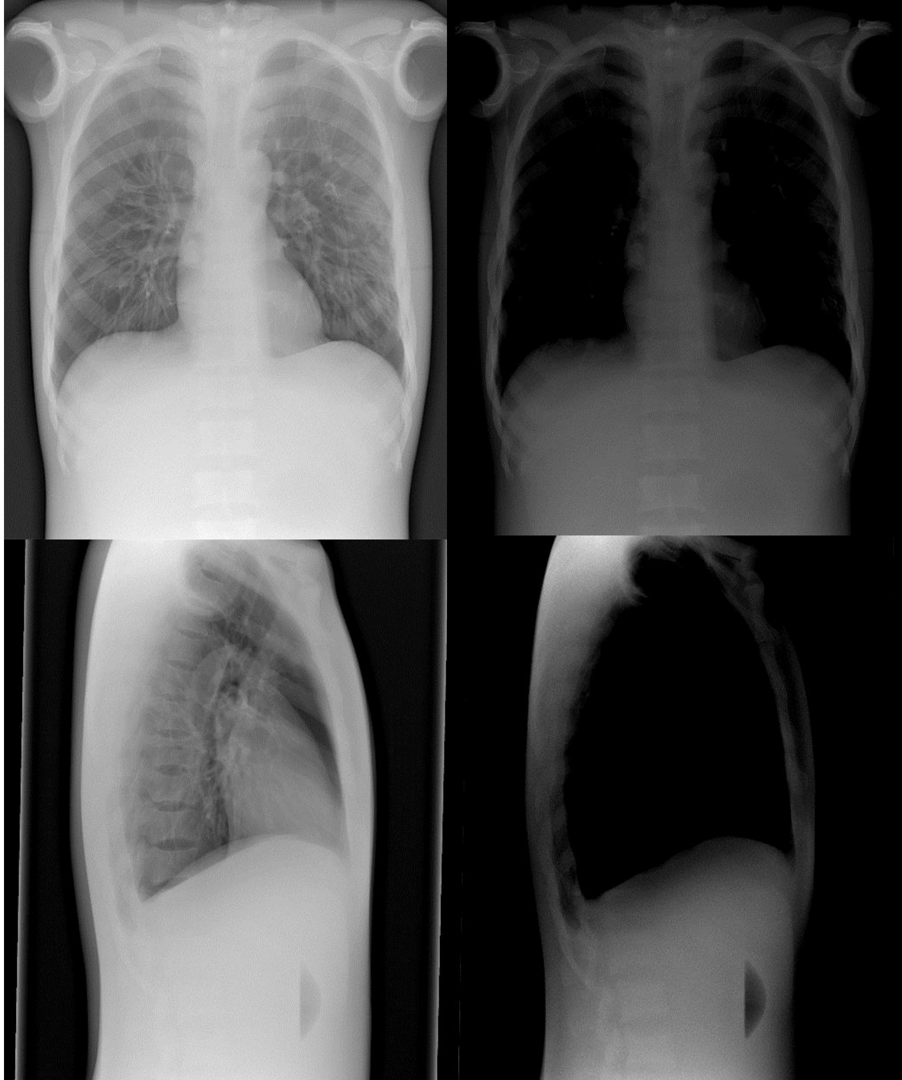
- PBU-60 whole body anthropomorphic phantom (Kyoto Kagaku Co. Ltd., Kyoto, Japan)
  - Includes lungs, heart, great vessels, liver, kidneys and spleen

Phantom

3D CT scan

Method

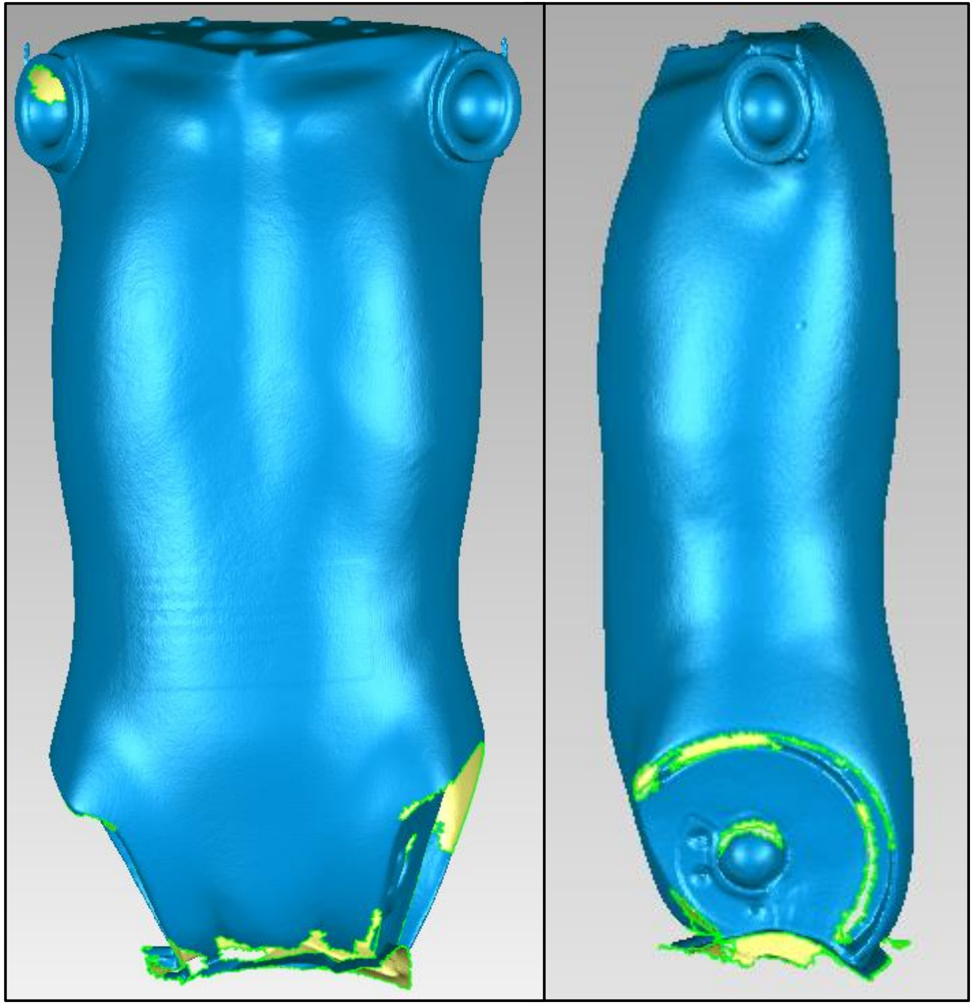
- PBU-60 whole body anthropomorphic phantom
  - Includes lungs, heart, great vessels, liver, kidneys and spleen
- Planar X-ray images, PA and Lat., and known image magnification factors.
  (X-ray unit: Carestream Health, Rochester, USA)



planar X-ray images
PA & lateral
of phantom

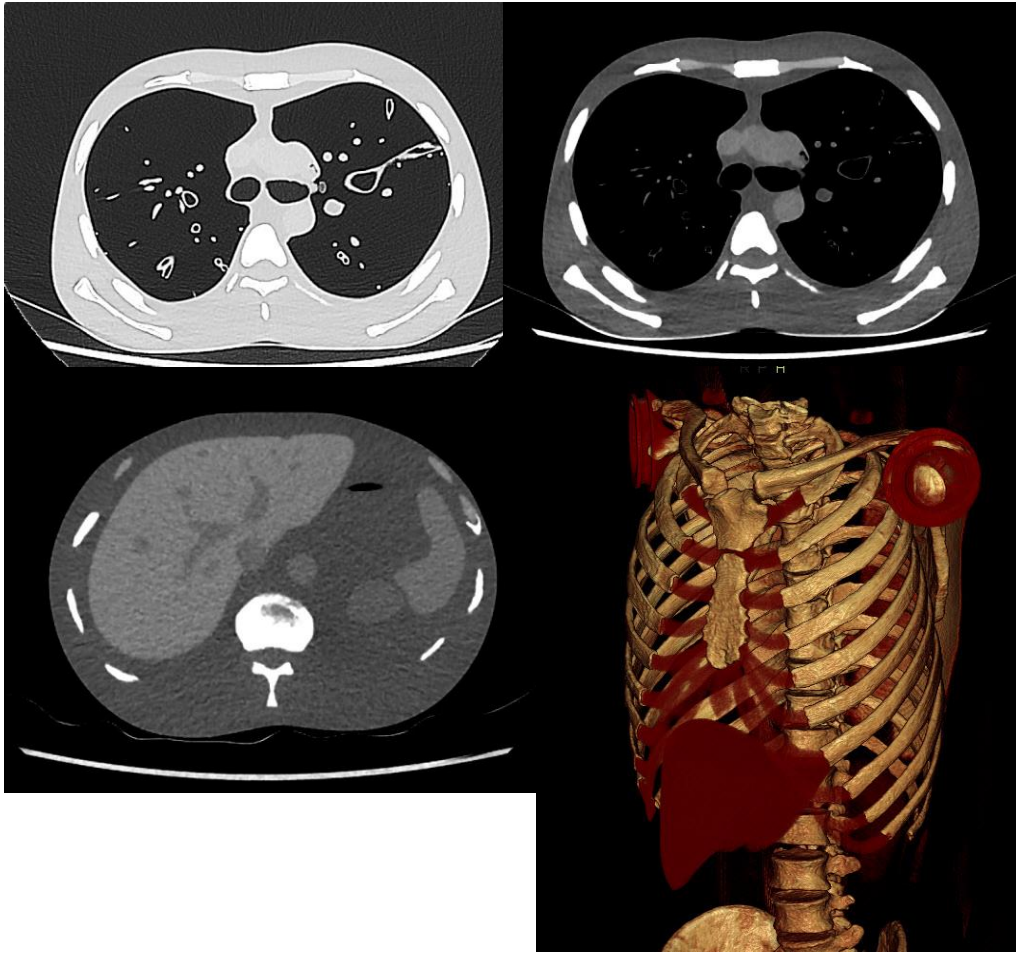
Method

- PBU-60 whole body anthropomorphic phantom
  - Includes lungs, heart, great vessels, liver, kidneys and spleen
- Planar X-ray images, PA and Lat., and known image magnification factors.
- External surface scan using a hand-held 3D scanner (Artec^{TM}, Leo 3D Scanner, Artec Group, San Jose)



Method

- PBU-60 whole body anthropomorphic phantom
  - Includes lungs, heart, great vessels, liver, kidneys and spleen
- Planar X-ray images, PA and Lat., and known image magnification factors.
- External surface scan using a hand-held 3D scanner
- CT scans and 3D reconstructions (Canon Aquilion One, Tochigi, Japan)



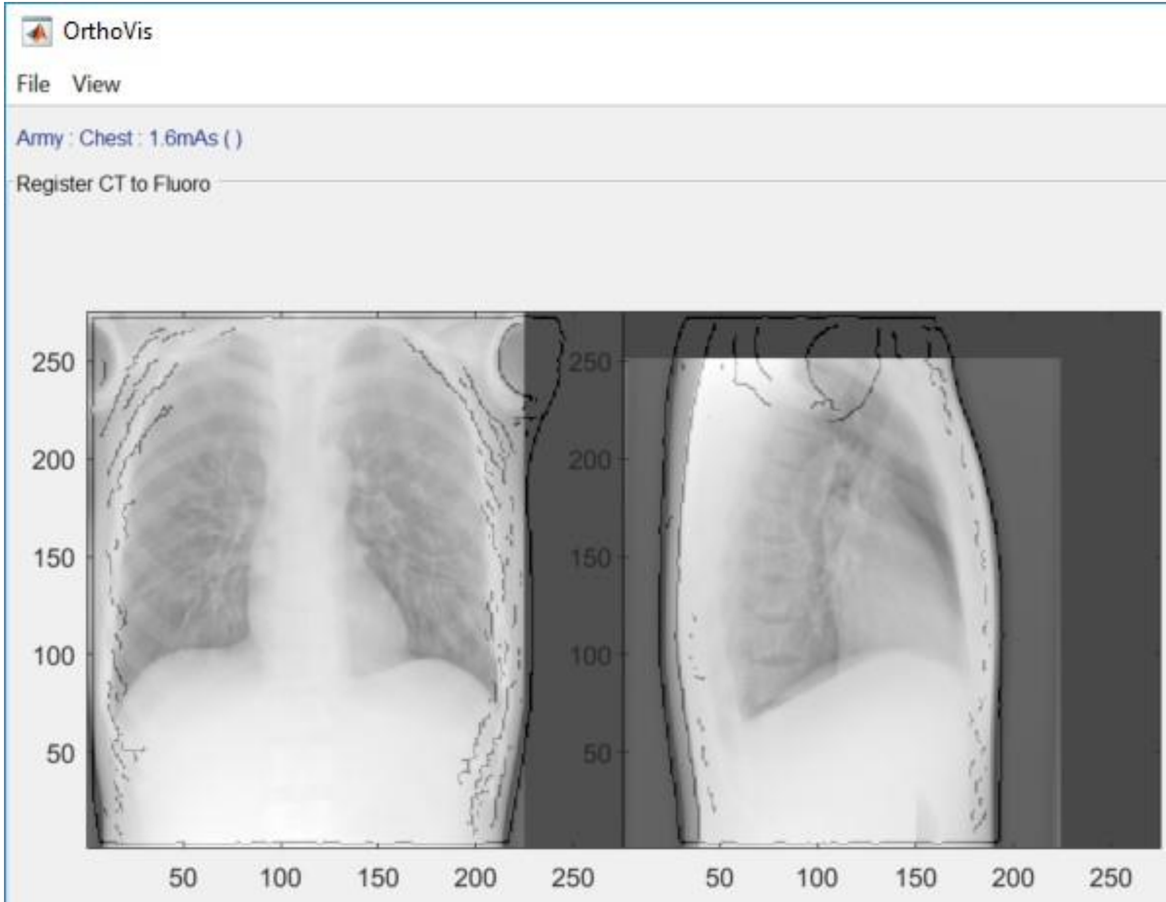
Method

- X-ray images saved in DICOM format; external surface scan in stereolithography (stl) format
- X-ray images were manually segmented using custom software (Orthovis v4 Matlab, The Mathworks, Inc., Natick, MA) [4]
- Multi-modality 2D–3D registration based on previous work [5] using segmented X-ray images and external surface scan
- Compare the created 3D registered model against ground truth, the CT scan data

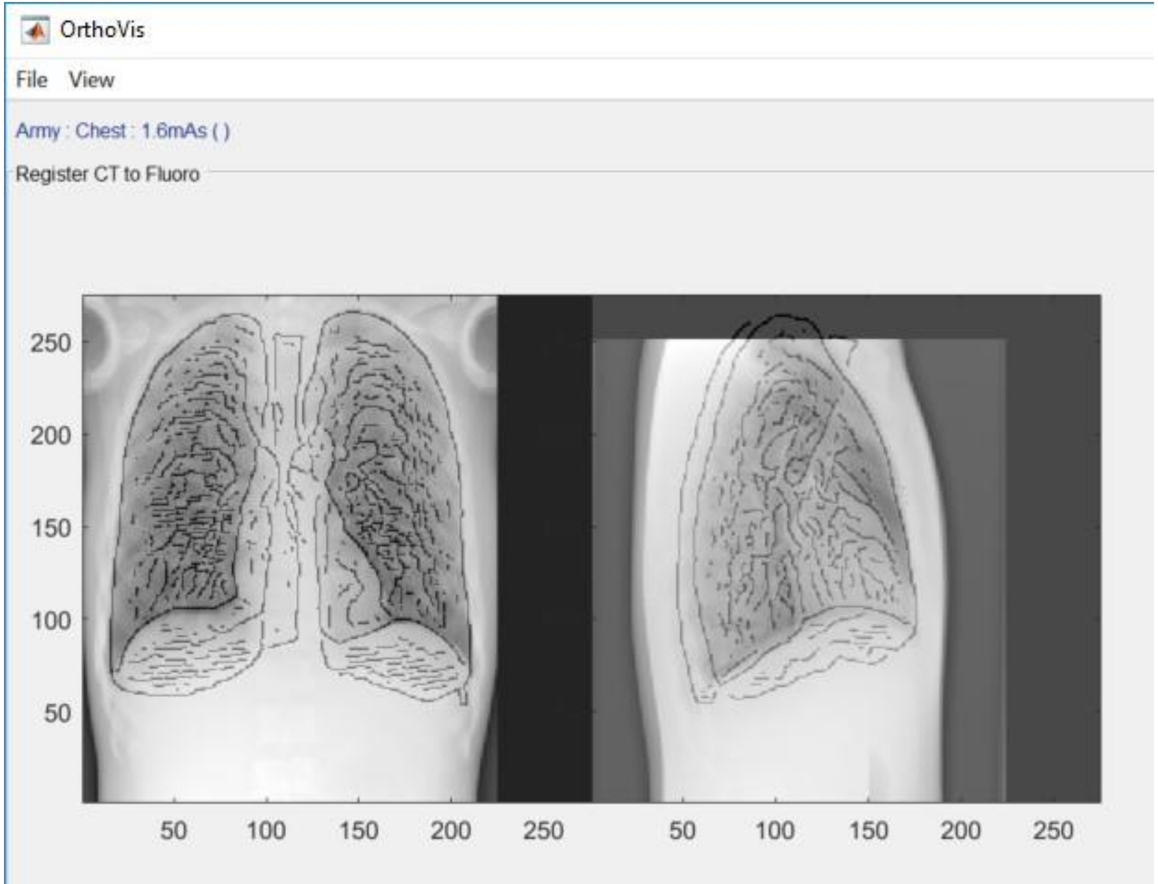
[4] Lynch et al. *J Biomech* (2019)
[5] Akter et al. *Comput Methods Biomech Biomed Eng Imaging Vis* (2015)

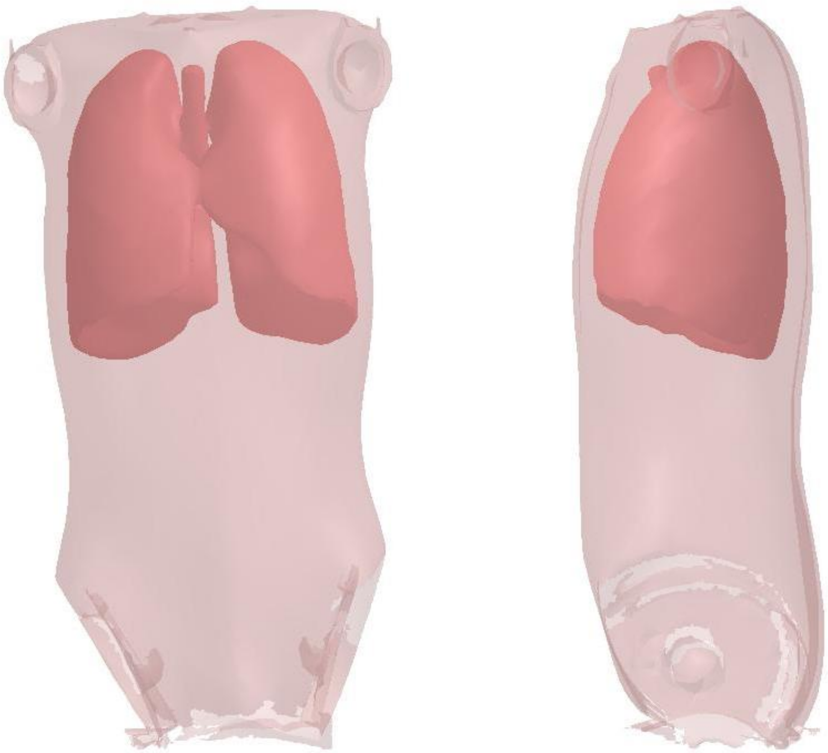
Method

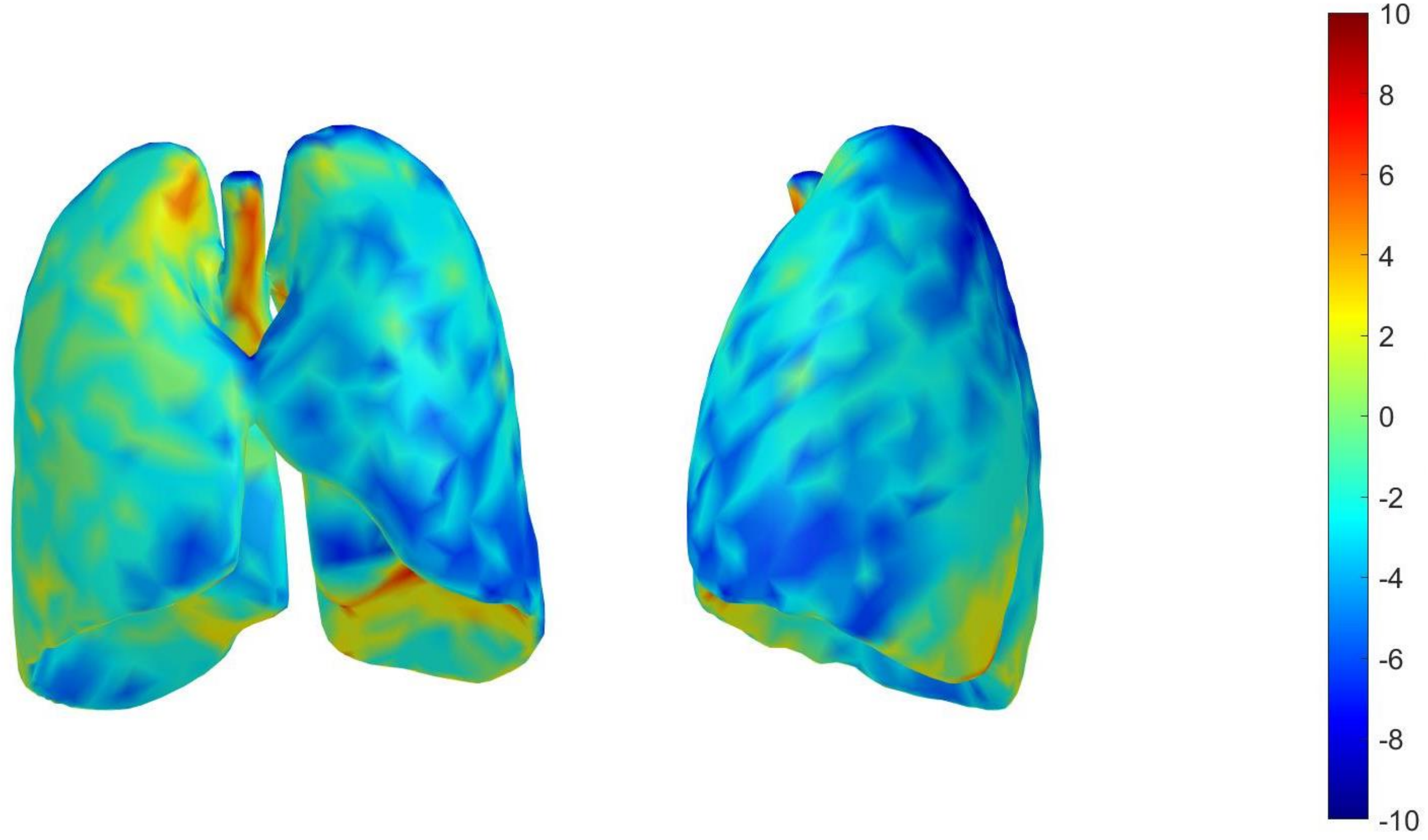
- Registration of 2D surface to 3D external scan in two planes:
  - Front (PA) and
  - Side (lateral)



Results – lung fields



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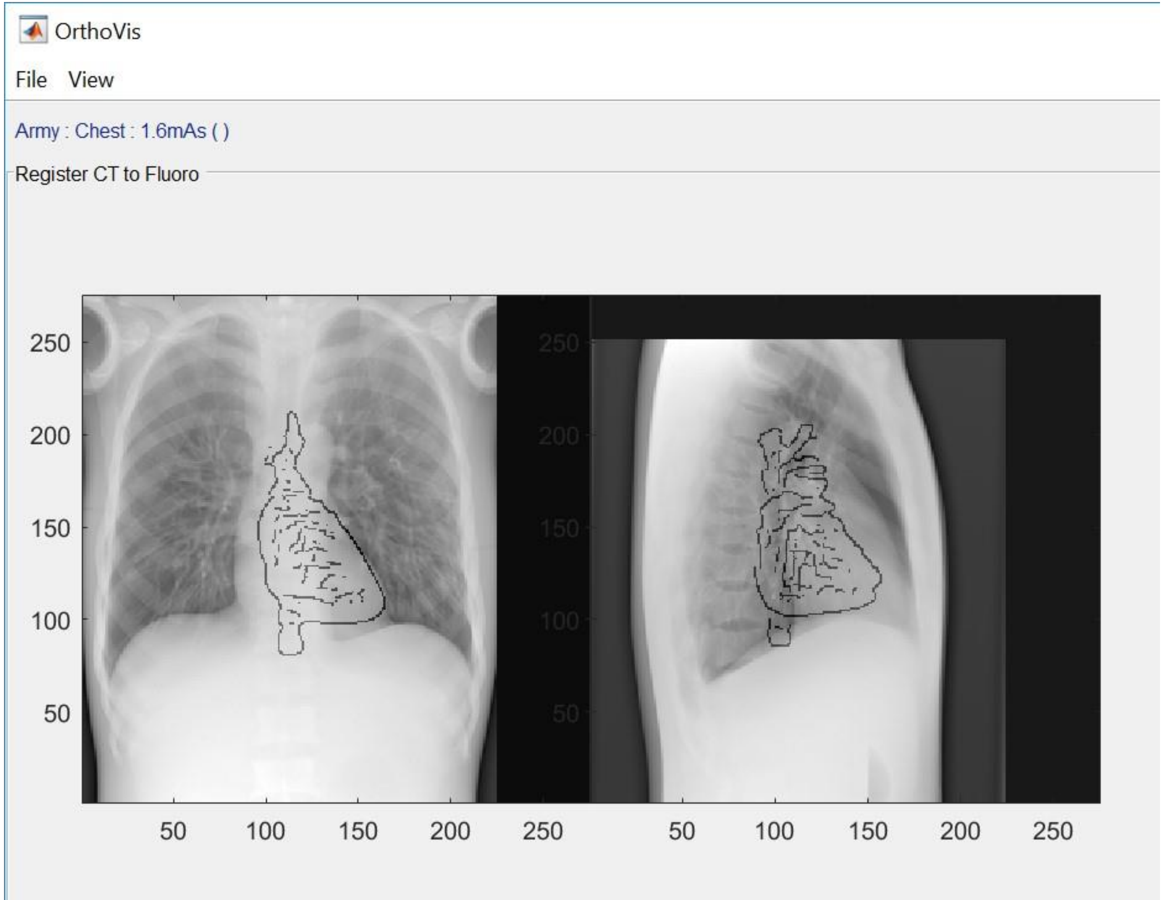
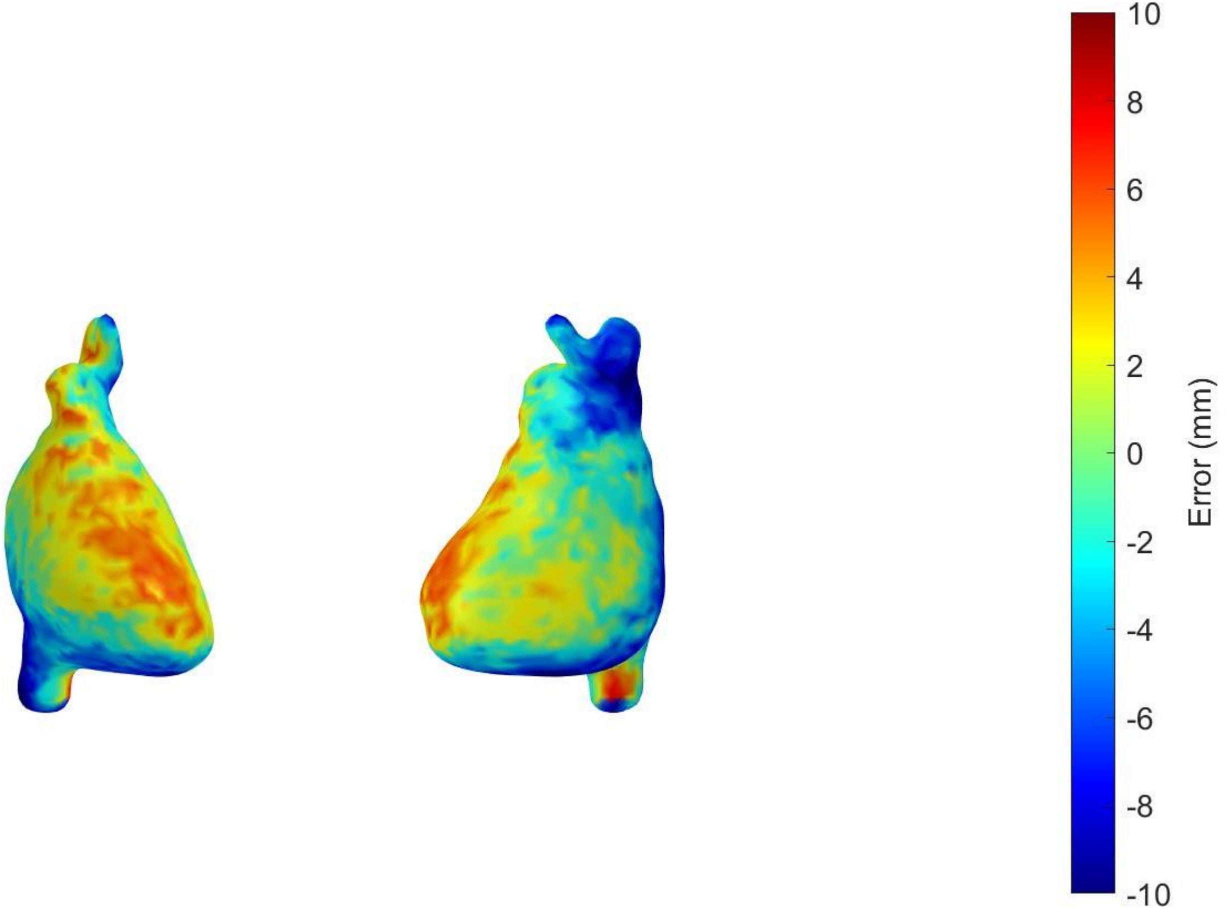
Error (mm)

Results – heart

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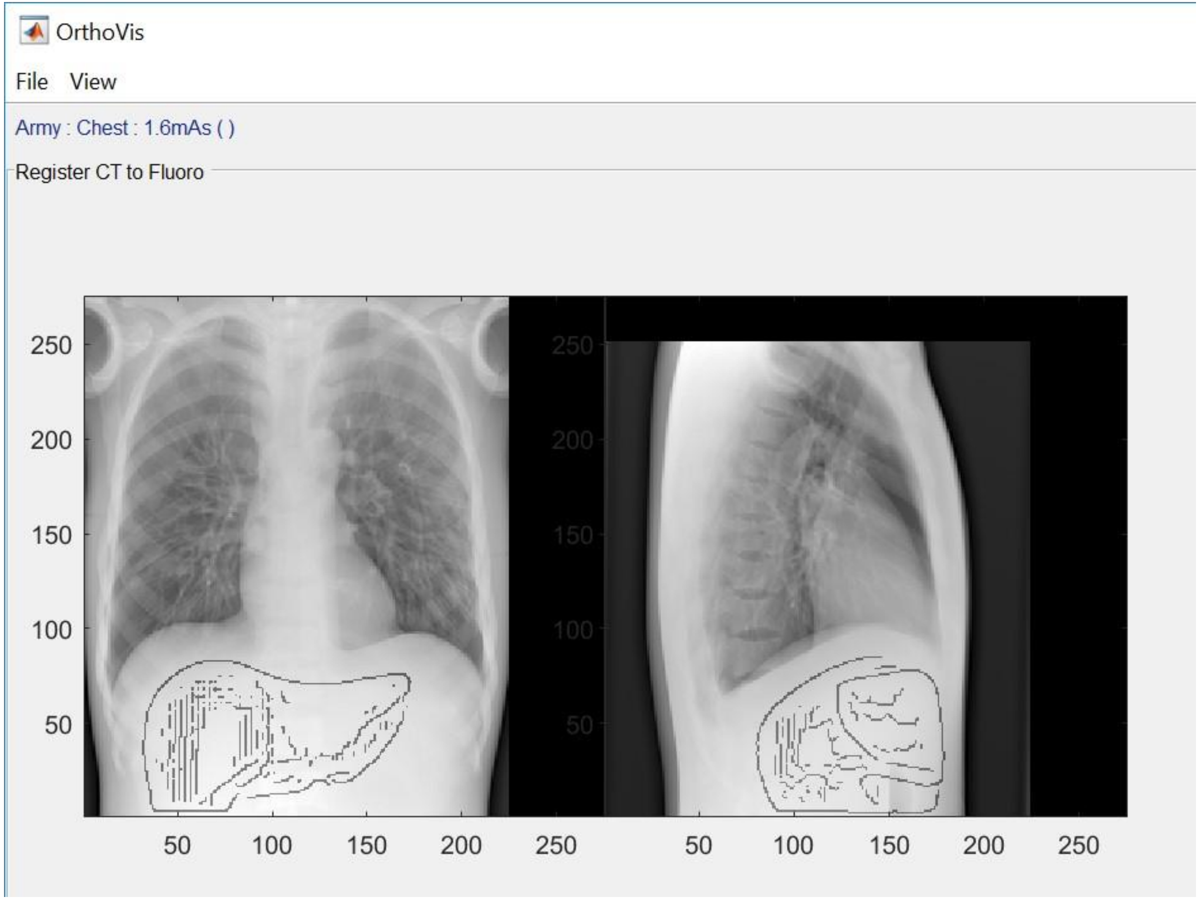
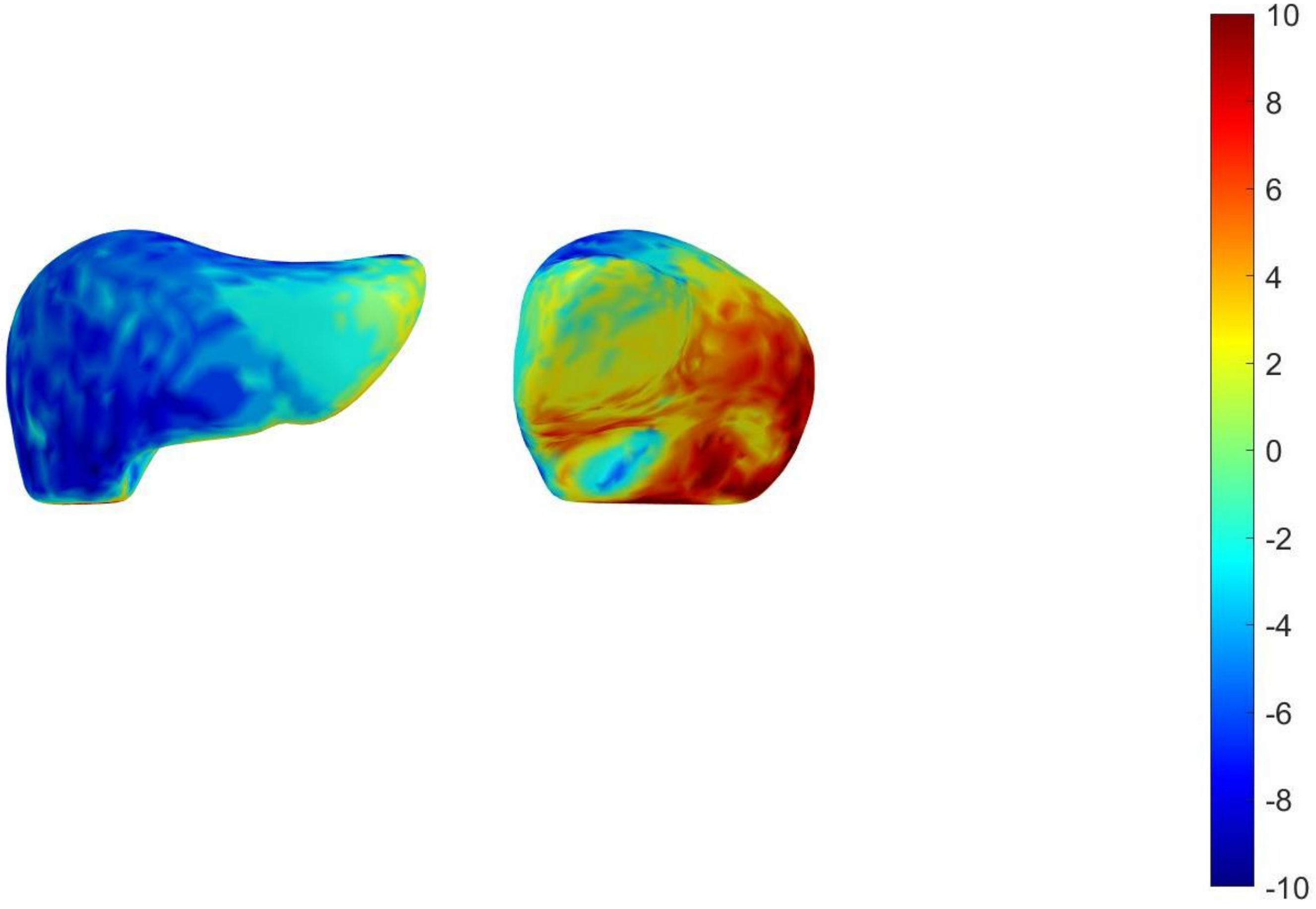
Results – liver

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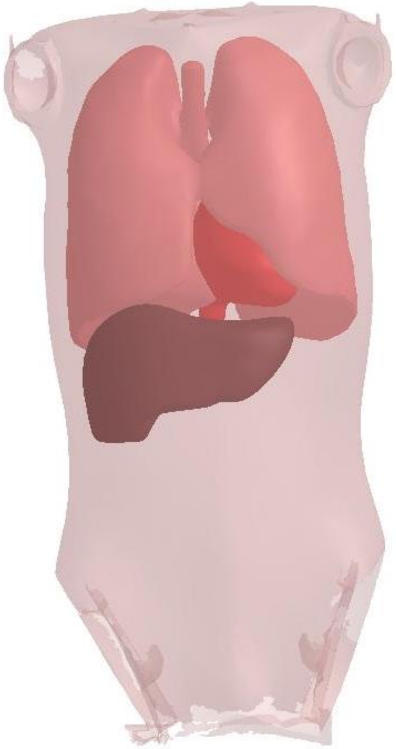
Results – lung, heart and liver



Discussion

- Proof of concept work shows promising initial results of organ localisation from two low dose planar X-ray images[6] and a 3D external surface scan
  - chest / abdo X-rays ≈ 0.7 mSv
  - chest / abdo CT scans ≈ 15 mSv
- Potential to classify soldiers into body shape groups based on organ location and external body shape
- Limitations
  - Anthropomorphic phantom only closely represent human X-ray attenuation characteristics
  - No breathing and postural changes

[6] ARPANSA (2019)

Future Work

- Test method on humans and correlate to images acquired in a vertical MRI scanner
  - Show influences of gravity and breathing
- Build data sets of soldiers' body shapes / sizes and organ locations, both male and female

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Celeste Coltman	Research Institute for Sport and Exercise & Faculty of Health, University of Canberra
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