In situ real-time assessment of biomaterial deformation using synchrotron tomography

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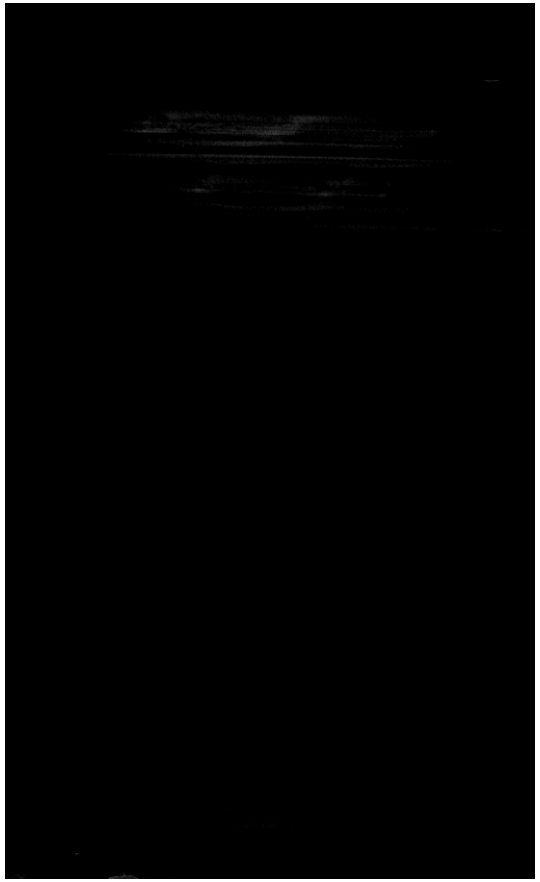
Background research

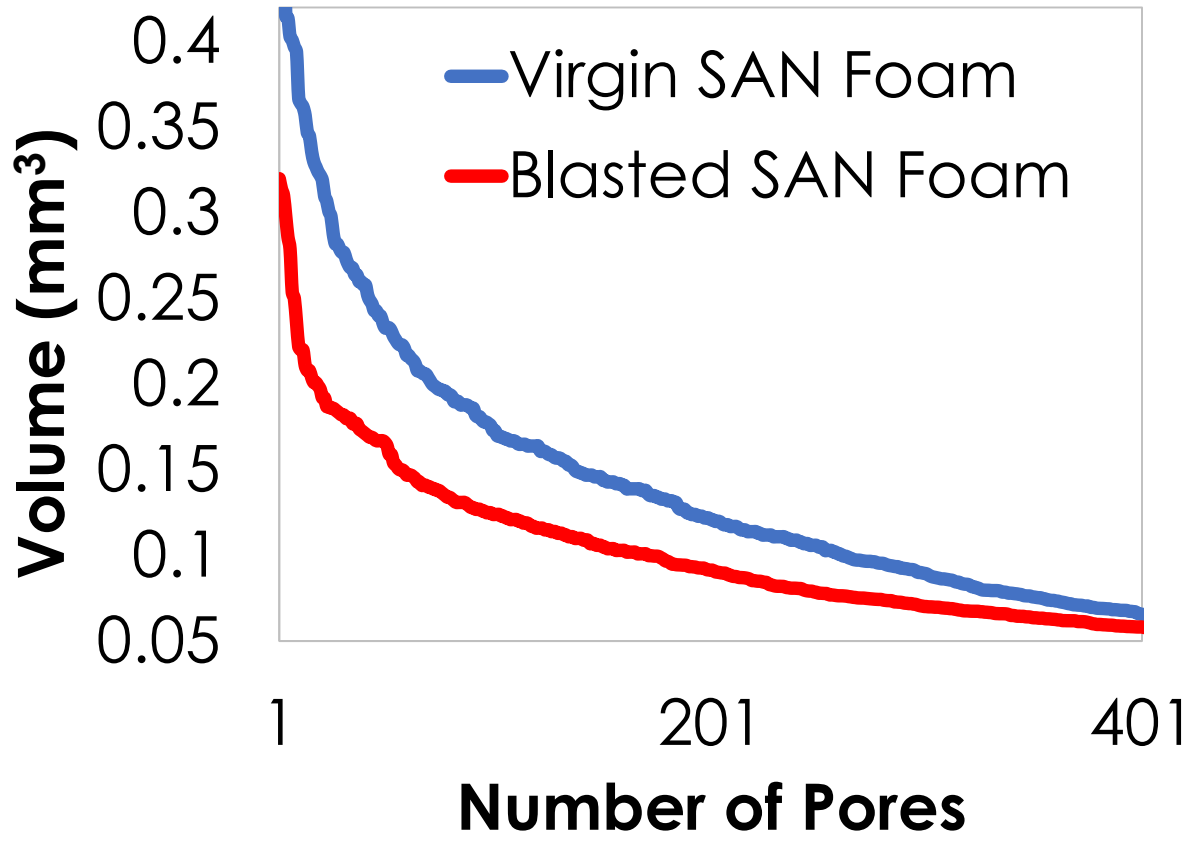
30 kg C4 at 8 m stand-off
Air Blast

1 kg C4 at 1 m stand-off at 6 m depth
Underwater Blast

Motivations for micro-CT work



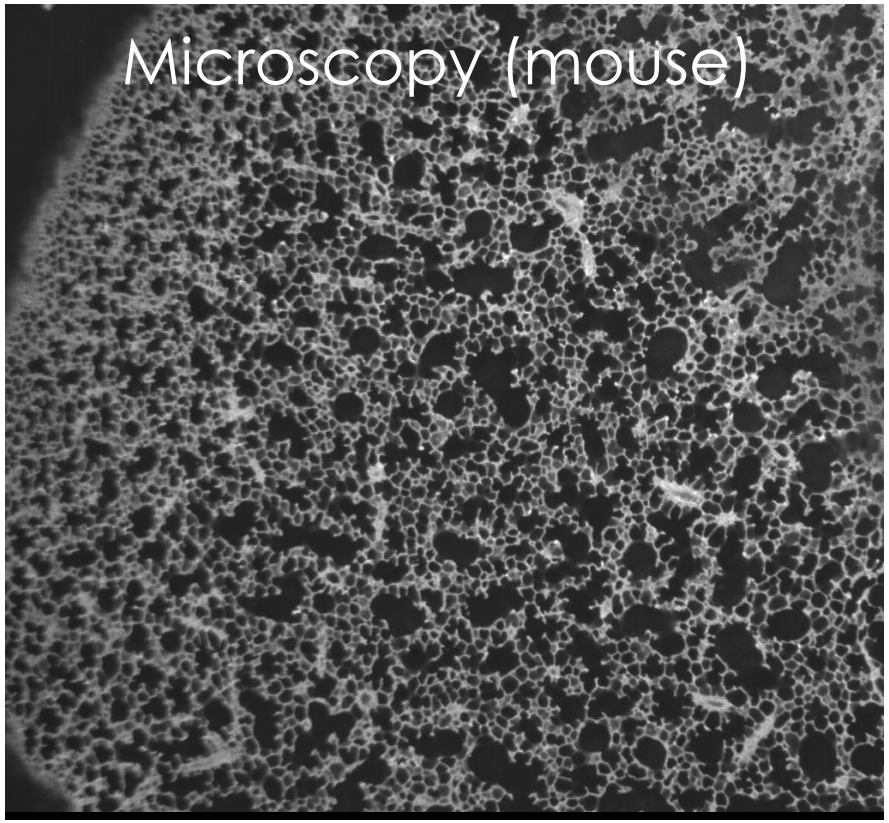
Blasted sample

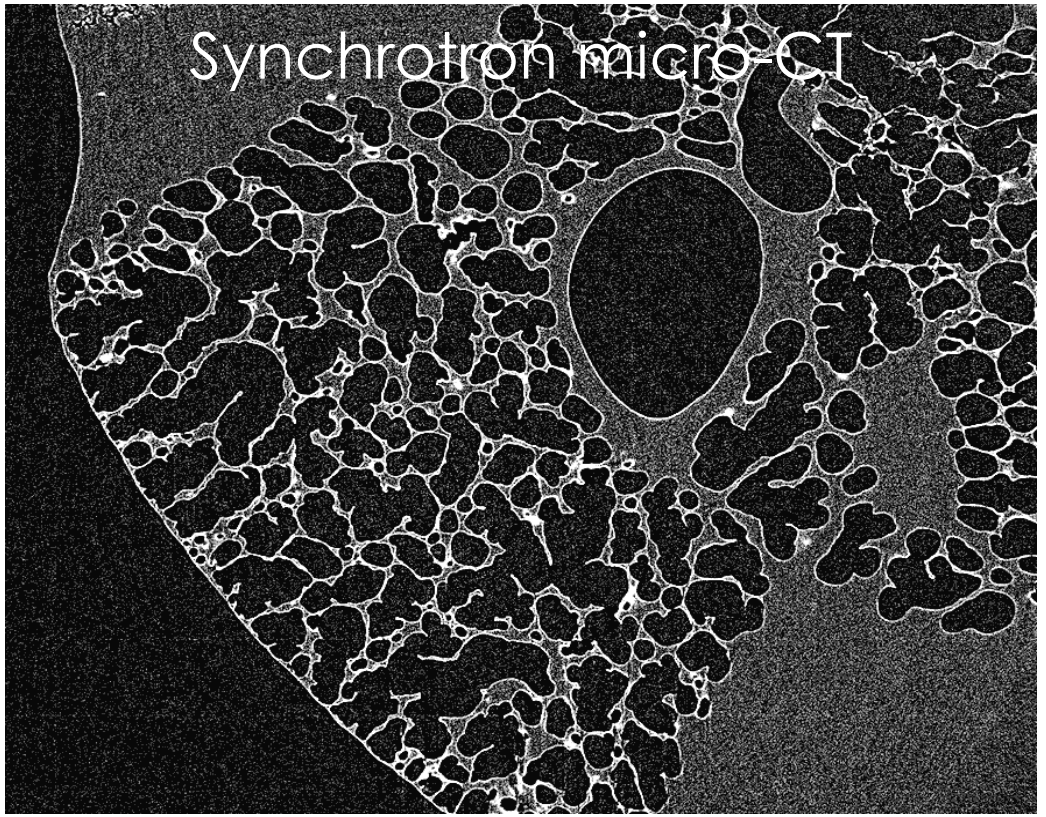


Arora et al., 2019 (to be submitted)

Collaboration with: Prof Penumadu, University of Tennessee (USA)

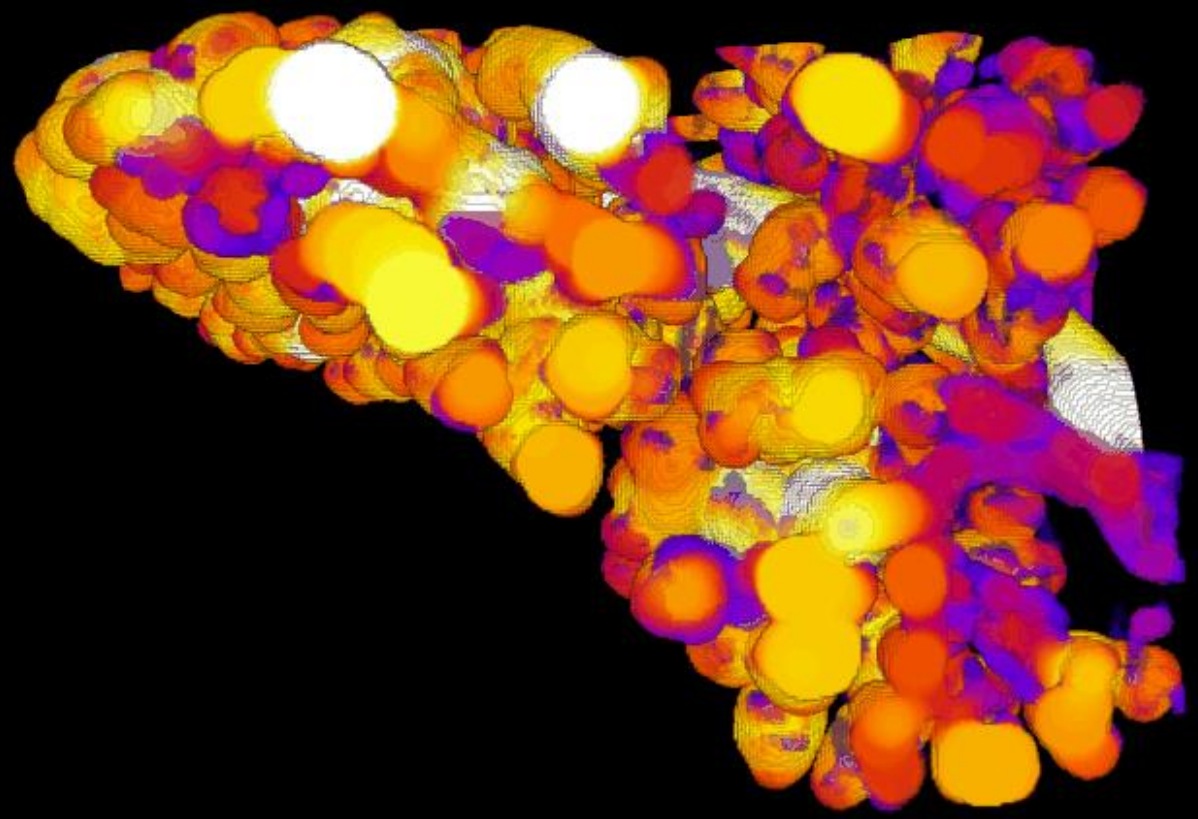
Advantages of synchrotron micro-CT





- Macroscopic observations in greyscale values – routinely done
- Microstructure observed without the need to fix the sample

Synchrotron tomography of lung

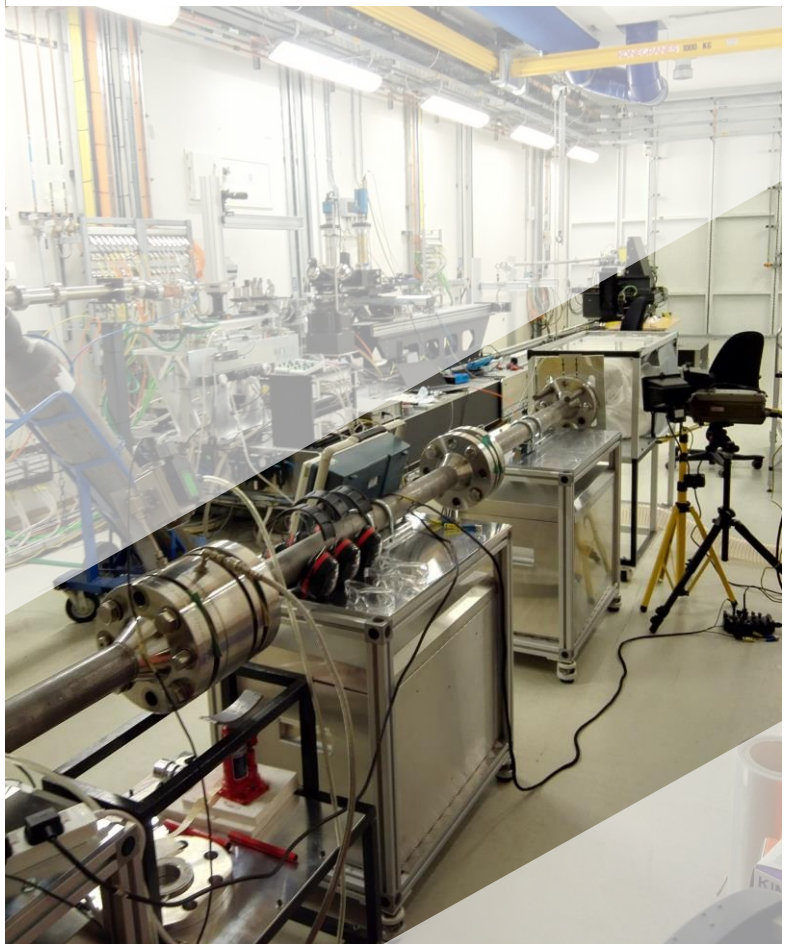


Tomography imaging of rat lung Branch line I13-2,
Diamond Light Source

Explosive detonation recorded by Slowmo/H. Arora at Radnor Range Ltd., UK

Blast lung study at the synchrotron

Shock tube experiments on cadaveric Sprague-Dawley rats



Barnett-Vanes et al., Trauma, 2016

Eftaxiopoulou et al., Injury, 2016

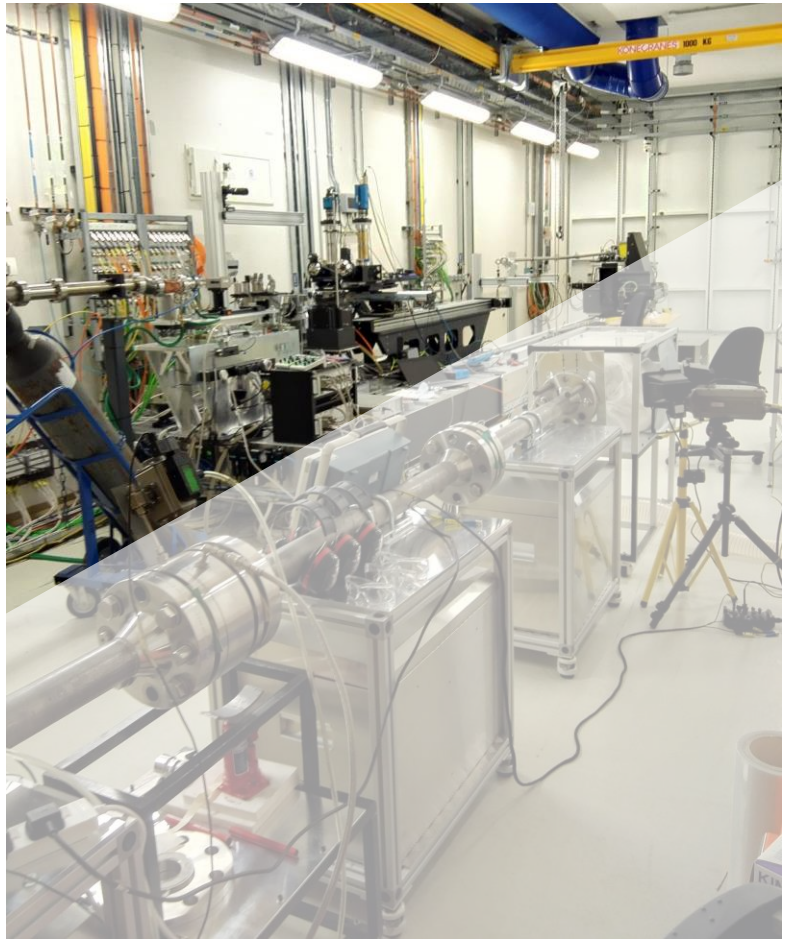
Logan, **Arora** and Higgins, JoVE, 2017

Arora et al., Frontiers in Materials, 2017

Ranunkel, Gűder & **Arora**, ACS Appl. Bio Mater 2019

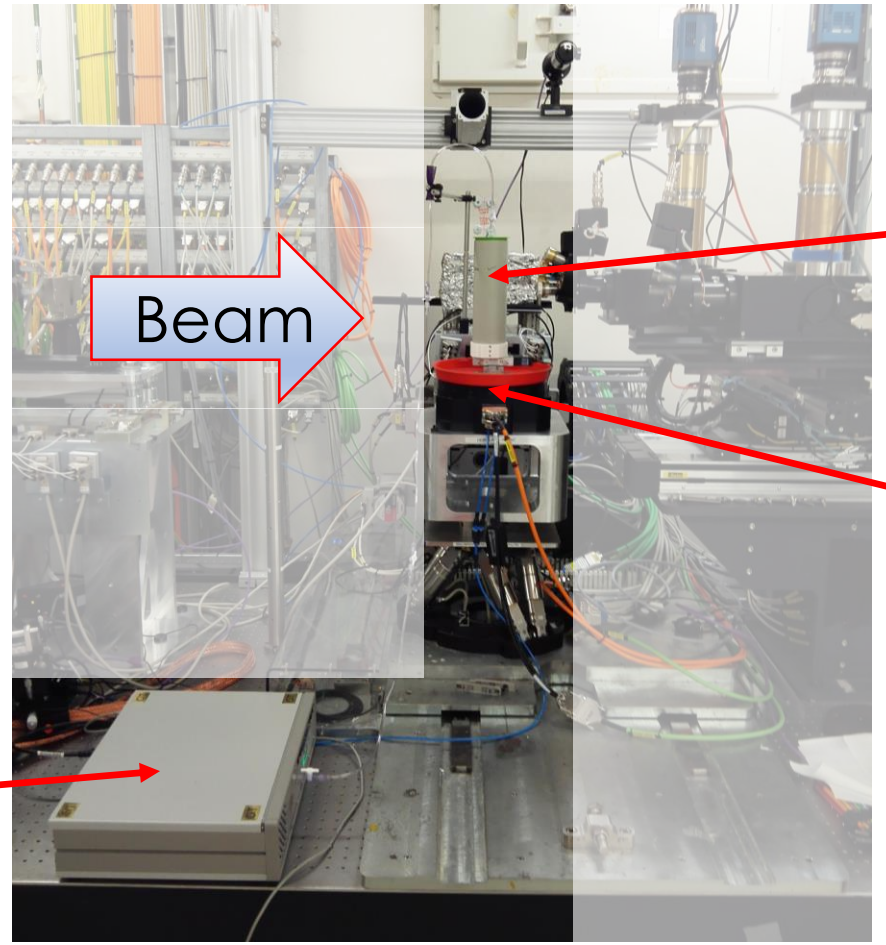
Blast lung study at the synchrotron

Synchrotron tomography imaging



Blast lung study at the synchrotron

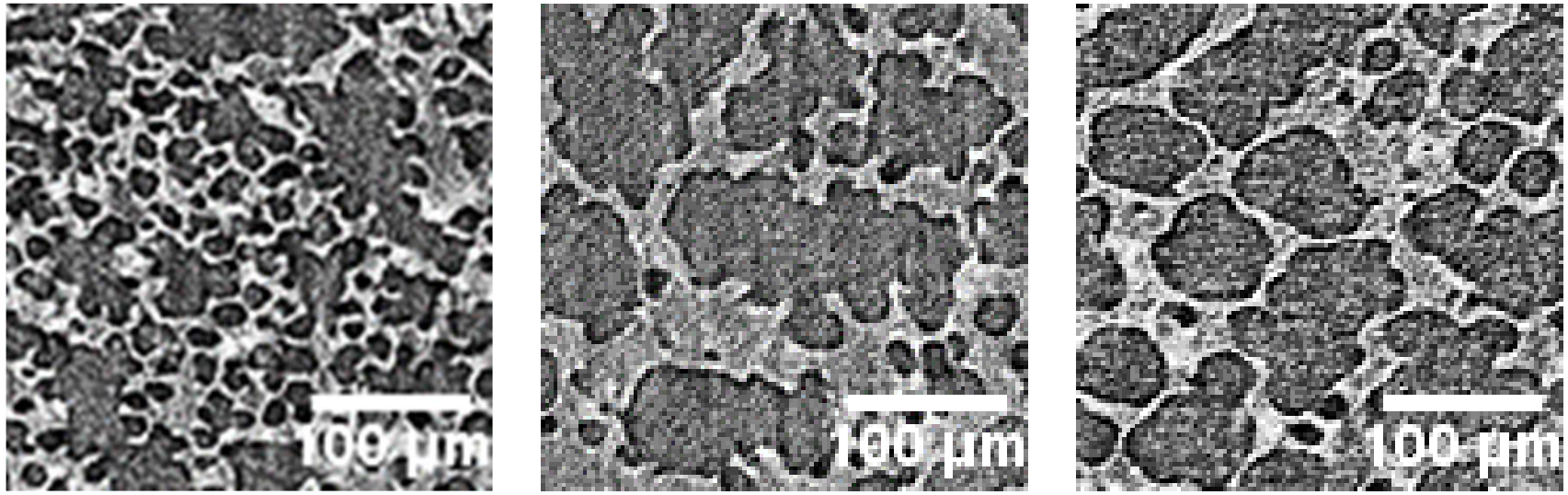
Synchrotron tomography imaging



Effect of blast loading profile on injury

Healthy

Blast Specimens

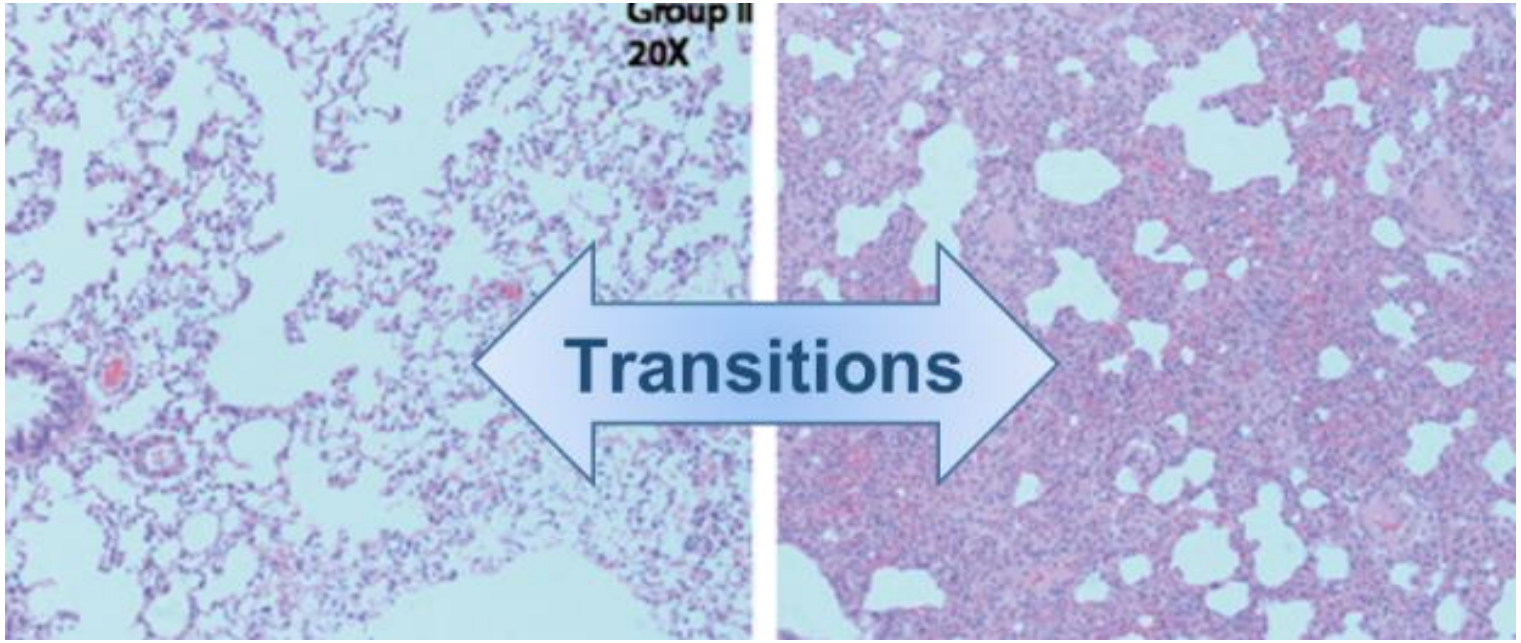


- Alveolar failure patterns related to the loading mechanics
  - Sparse or diffuse damage site formation
  - Shared boundary breakdown
- Detailed morphological analysis provides insight to injury mechanism

Vitharana…and **Arora**, 2019 (submitted)

Structural disruption and lethality

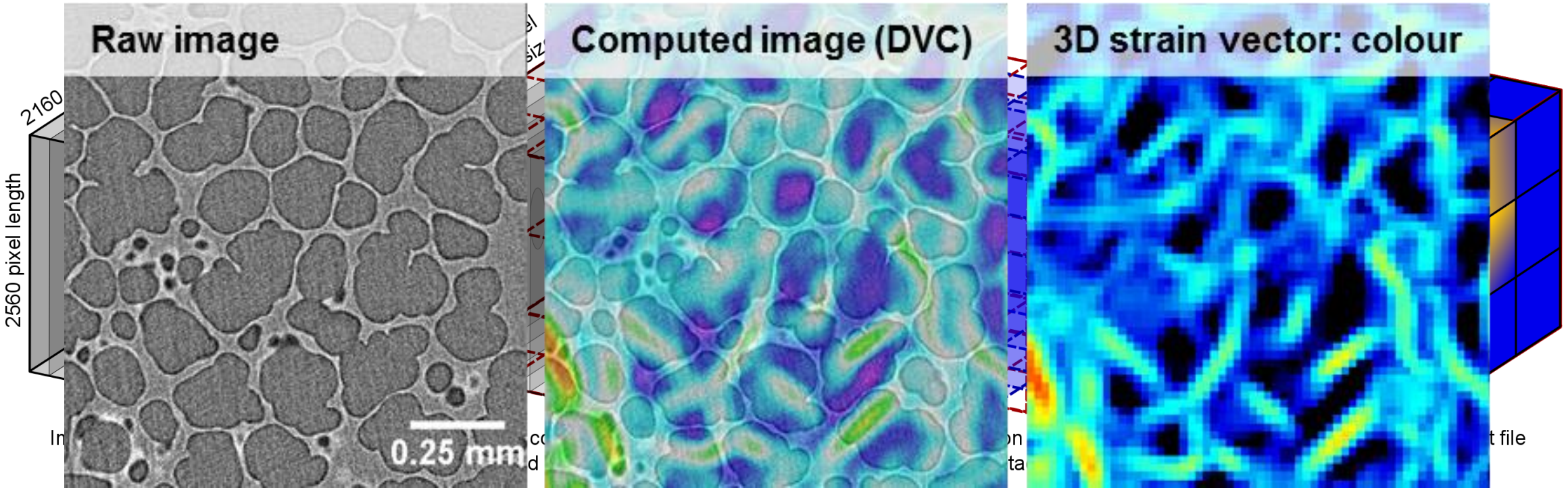
In vivo blast lung research observations



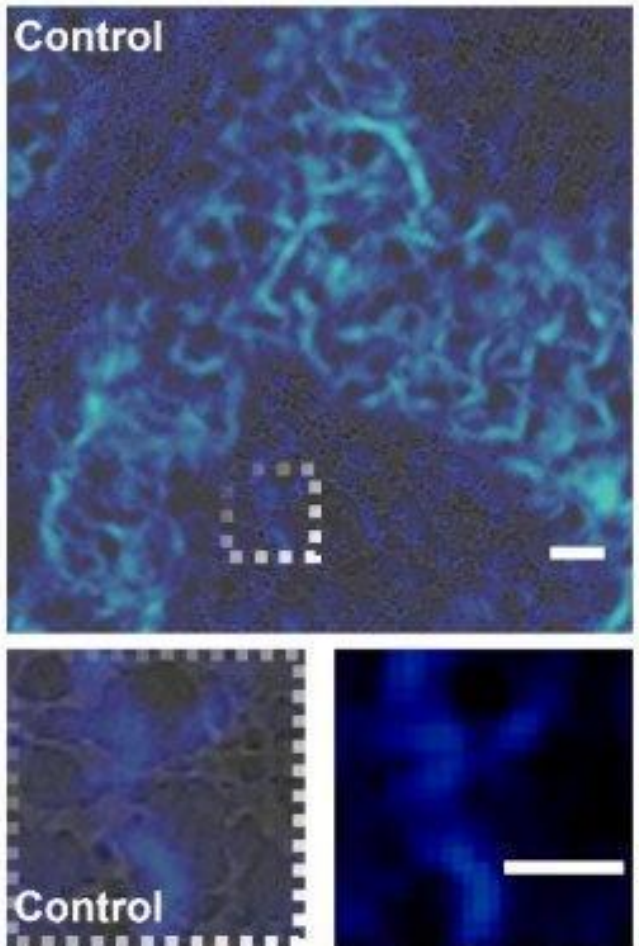
- Lethality established throughout literature
- What about the sub-lethal doses?

Barnett-Vanes et al., Trauma and Acute Care Surgery (2016)

Deeper exploration of tissue mechanics

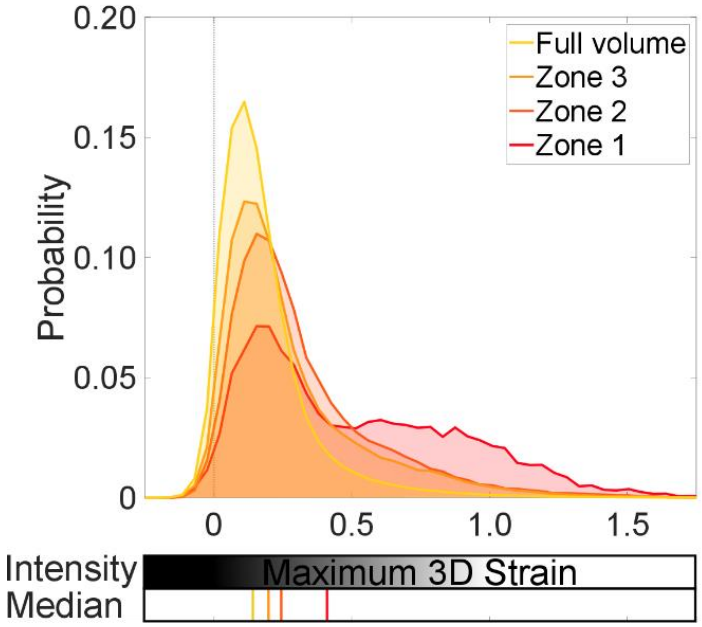


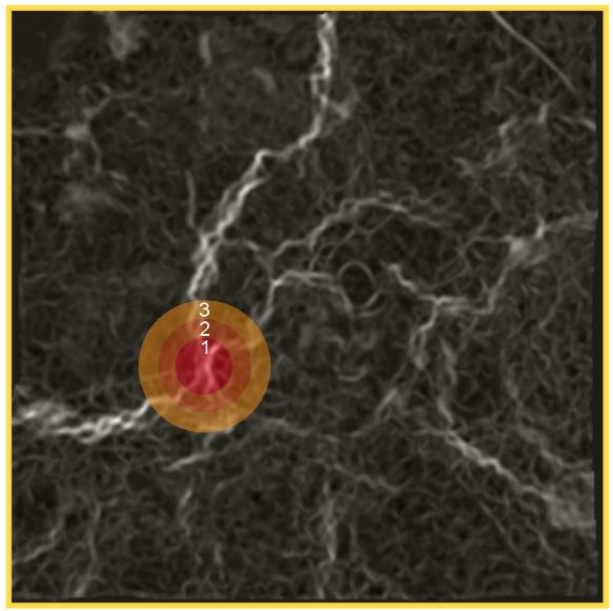
3D strains quantified in damaged lungs



Arora et al., Frontiers in Materials, 2017

Future directions for lung injury research



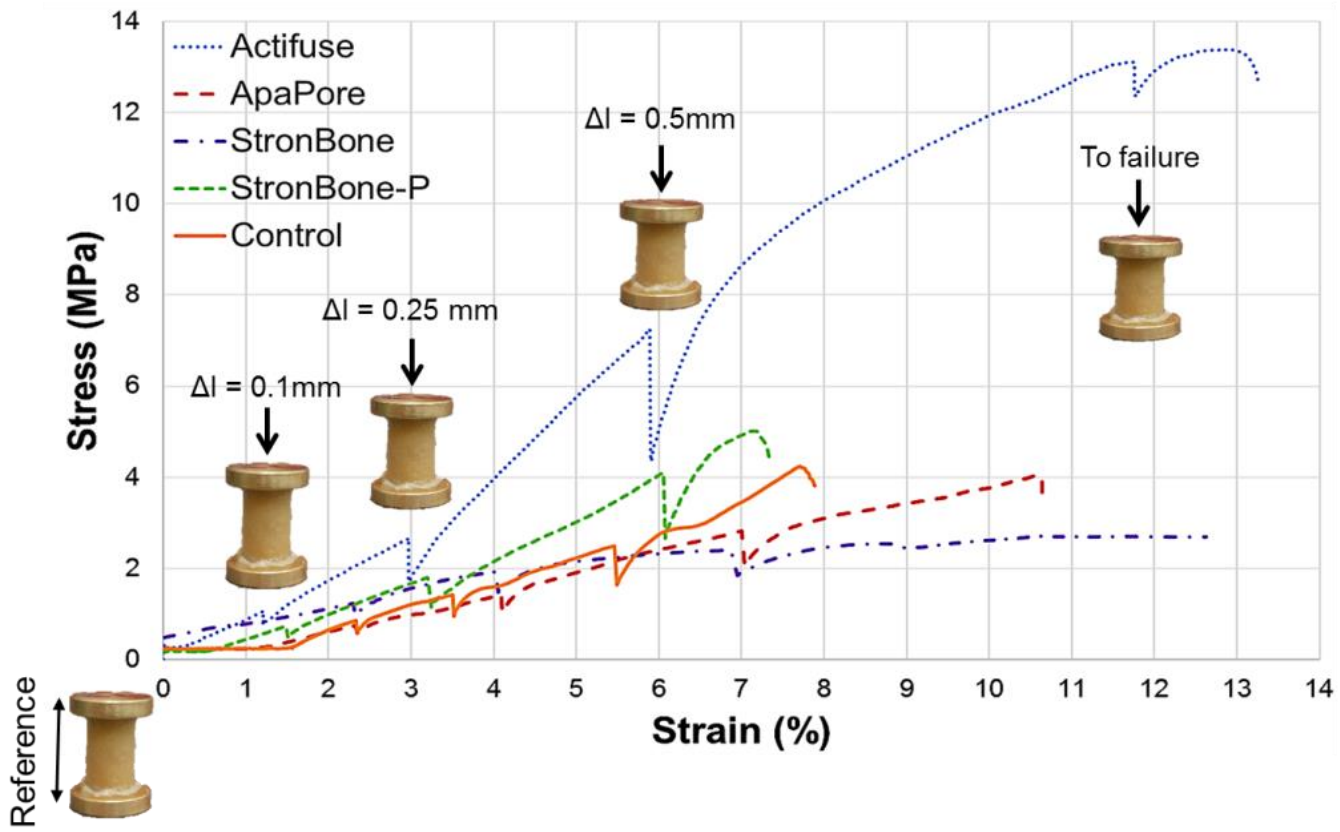


- Hotspots of high strain in injured tissue - sphere of influence of injury
- Developing protocols for new injury classification
- Validation for detailed damage models in soft tissue
- Continued development of lung tomography model
  - Collaborations in other lung pathologies
  - Visiting SPring-8 July 2019

Arora et al., Frontiers in Materials, 2017

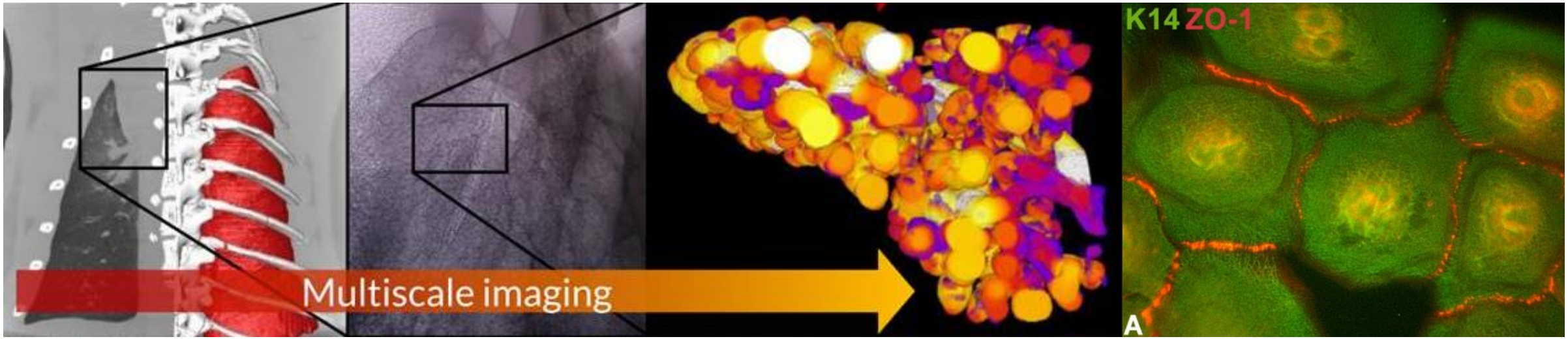
Interrupted vs continuous imaging

- Conventional methods for in situ imaging use interrupted mechanical tests
- Biomaterials and other common materials are viscoelastic
- Relaxation / creep can affect image quality
- Not realistic / ideal loading conditions



Summary

- Micro-CT is commonly used in a wide variety of applications
- Synchrotron sources allow for high-speed, high phase contrast, high-throughput, high-resolution imaging (relatively large field of view)
- Interrupted tests can still inform on the mechanical state
- Continuous imaging can give more realistic strain states during imaging of failure; scan times currently 10-30s; to jump >10x faster soon



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Advanced Imaging of Materials Centre

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Andrew Bodey

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