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Enhanced Image Processing of Implanted Hydrogel Scaffold Images Using Propagation-Based Imaging Computed Tomography

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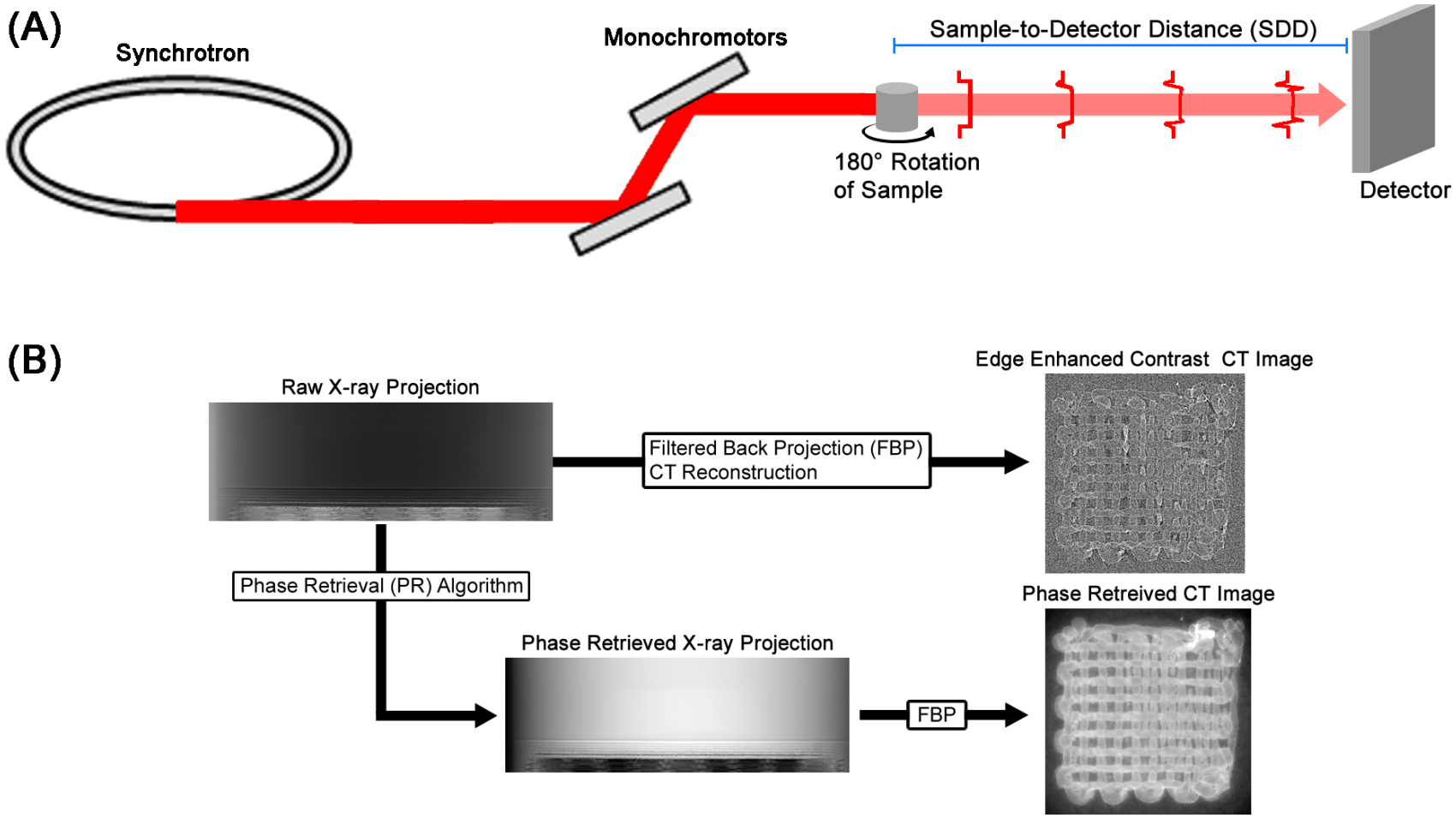
Introduction

- Synchrotron Radiation Propagation Based Imaging (SR-PBI)
- Phase retrieval (PR)
- Computed tomography (CT)

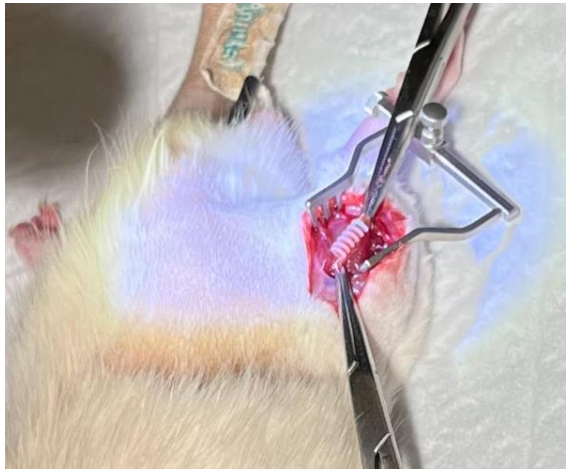


Introduction

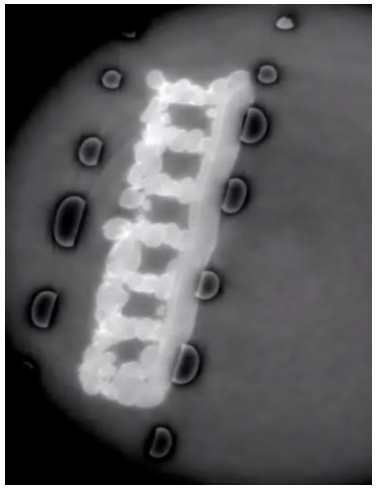
- Tissue scaffolds
  - Plays a role in tissue repair
  - Structural support
  - Potentials in personalized medicine
- Visualization techniques
  - Non-destructively evaluate hydrogel scaffolds
  - Especially for longitudinal studies

Prepared scaffolds in microcentrifuge tubes

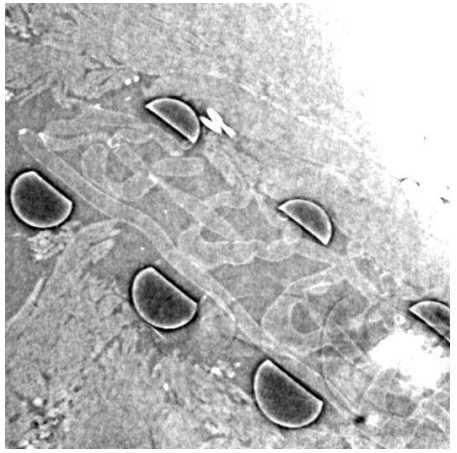
Implantation in at nerve injury site



CT slice of scaffold *In vitro*



CT slice of scaffold *ex*

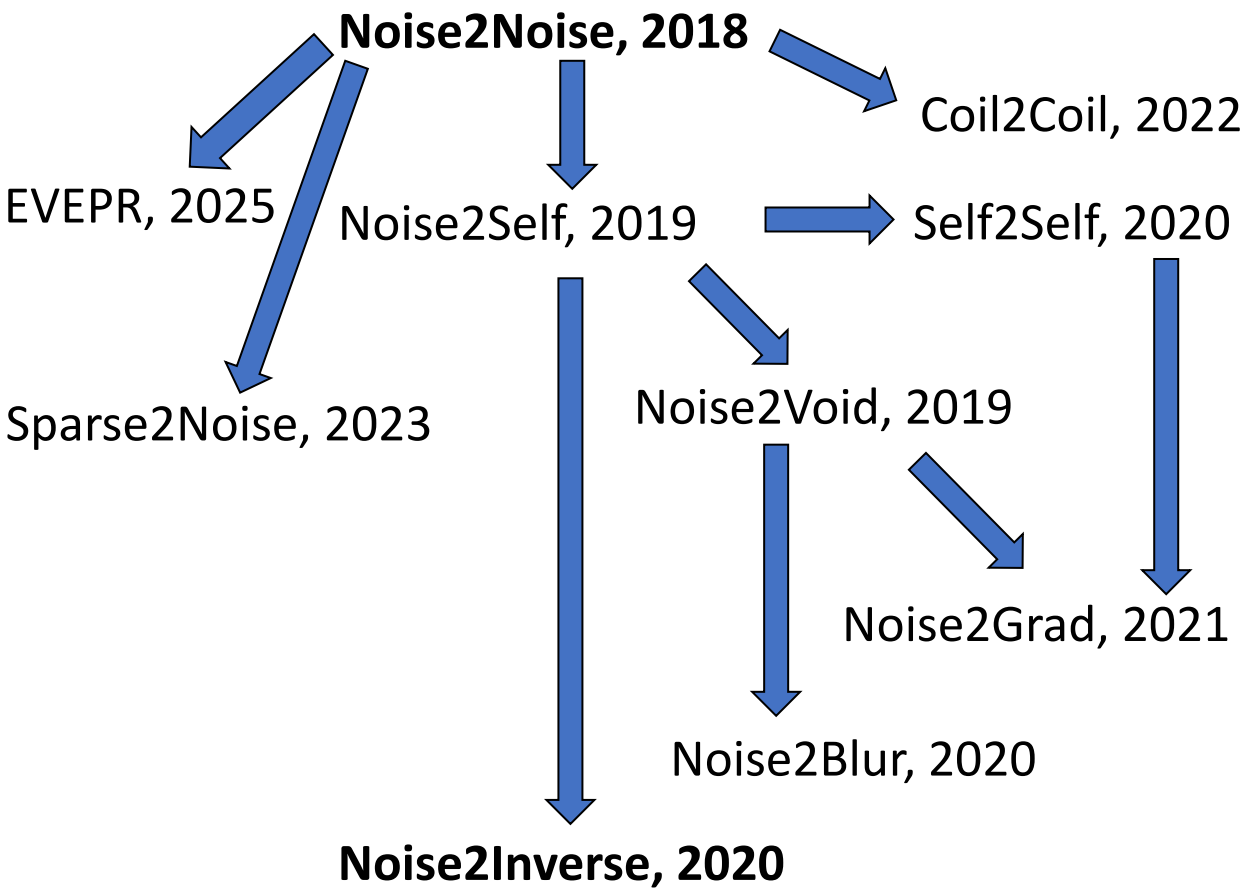


Introduction

Convolution neural networks (CNNs) to reduce image artefacts

$$L(\theta) = \mathbb{E}_{y_1,y_2}[|(f_\theta y_1) - y_2|]$$

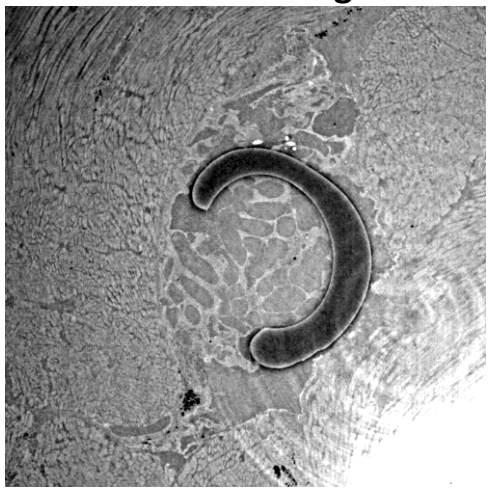
- Neural network, f_θ
- Parameterized by θ
- Artefact corrupted images, y_1 and y_2
- Artefact is independent
- Loss function, $L(\theta)$



Introduction

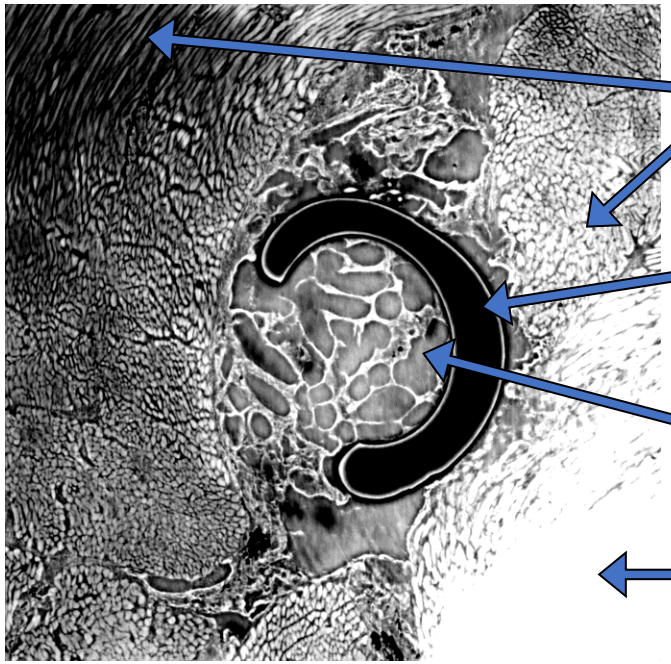
There is a need to improve deep learning denoising performance in *ex vivo* samples acquired with SR-PBI

Phase Retrieval Image



Grey Value Histogram

Noise2Noise with bone



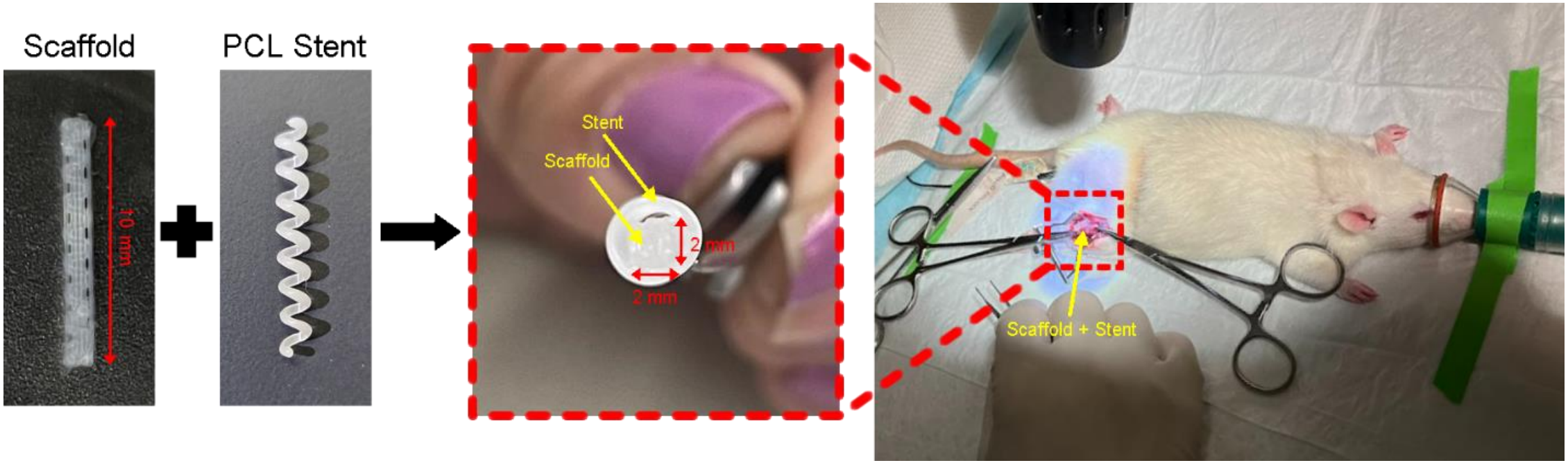
Muscle having different contrasts → Achieve consistency in muscle contrast

Stent → Maintain contrast of PCL stent and surrounding tissue

Hydrogel scaffold → Improve contrast between scaffold and surrounding tissue

Presence of bone → Mask the bone with the surrounding tissue

Methods

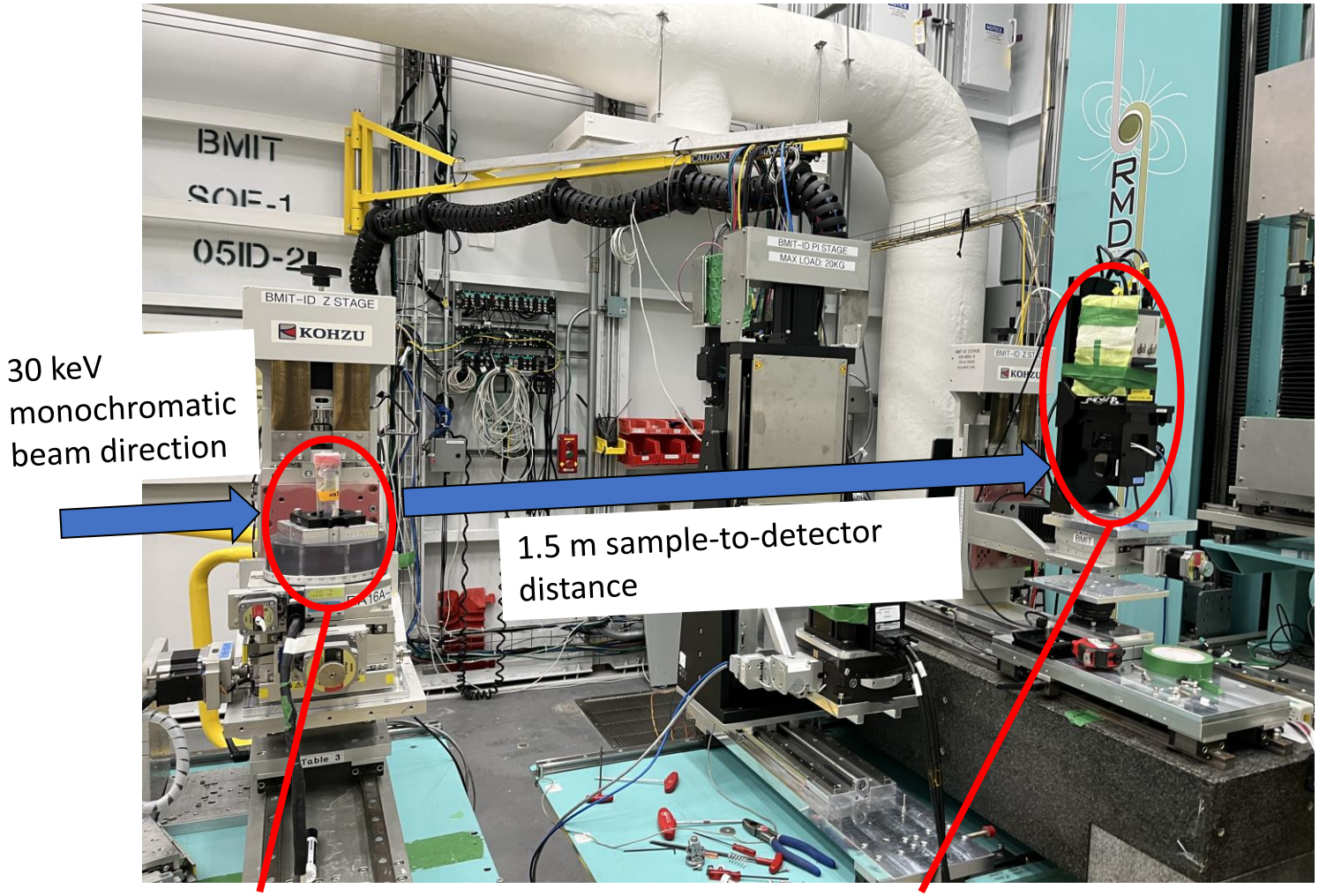


- Hindlimb of Sprague-Dawley rats
- Sciatic nerve was exposed and bisected
- Scaffold inside polycaprolactone (PCL) stent was sutured to the nerve
- Wound closed and rats were allowed to recover before euthanasia

Methods

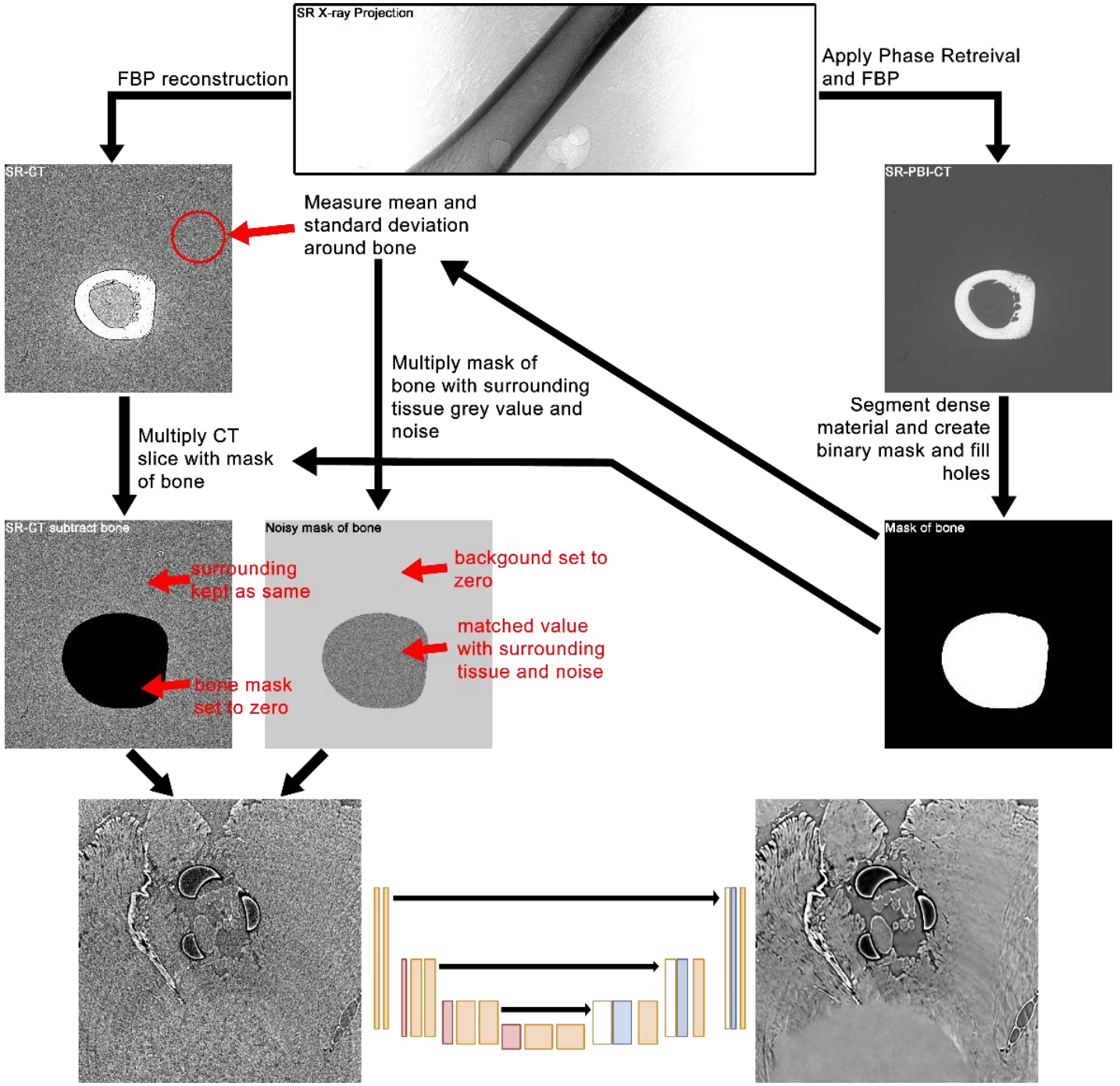
- Field-of-view of 26.6 by 6.5 mm
- Exposure time of 25 ms
- 3000 projections per dataset
- Acquisition time of 75 s per dataset

Inside the experimental hutch of the BMIT ID beamline at the Canadian Light Source

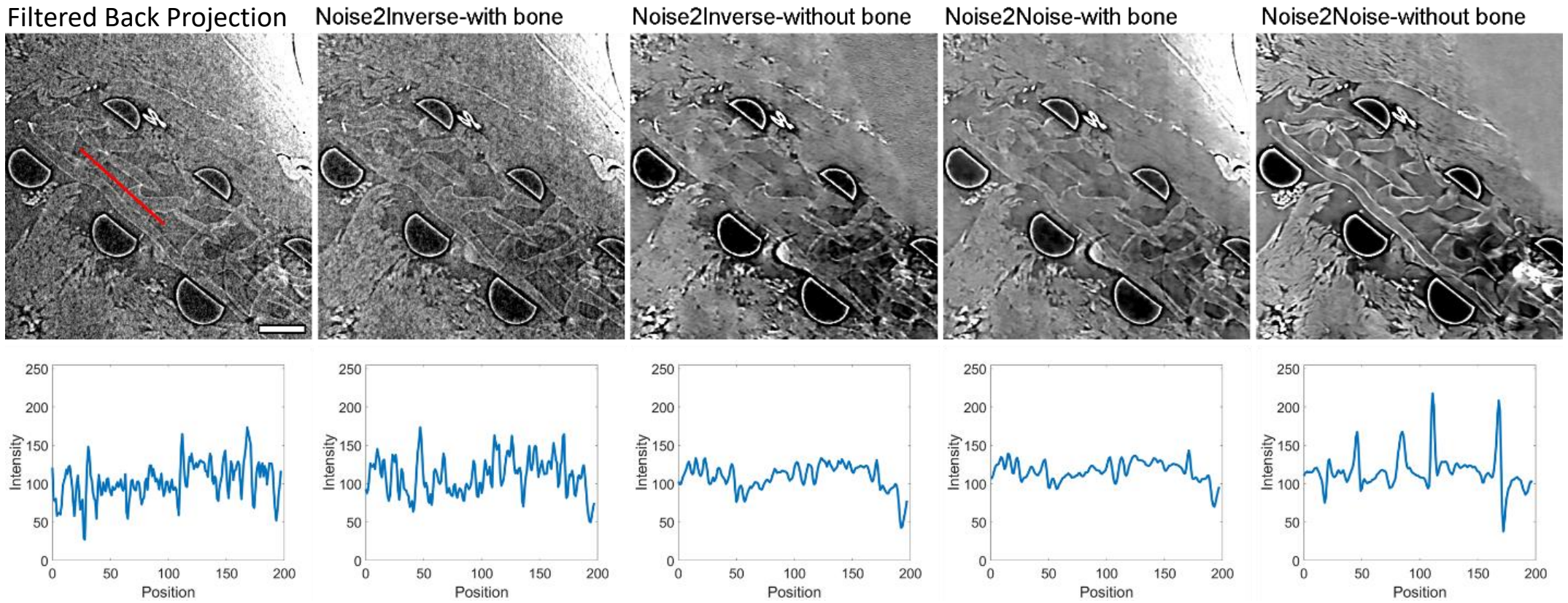


Methods

- Raw dataset reconstructed twice:
  - (1) with phase contrast
  - (2) without phase contrast
- Bone mask from (1) replace the bone in (2)
- Bone-masked result images used in Noise2Noise and Noise2Inverse



Results

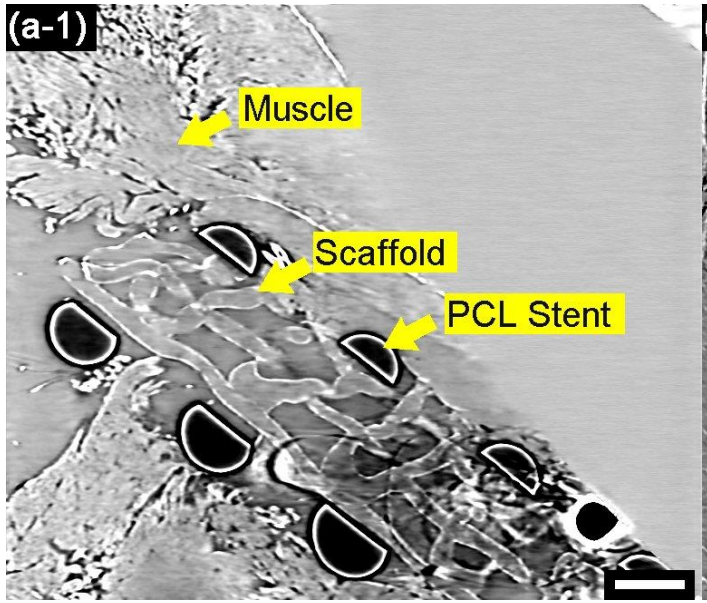


	Filtered Back Projection	Noise2Inverse with bone	Noise2Invese without bone	Noise2Noise with bone	Noise2Noise without bone
SNR	29.21 ± 1.97	42.61 ± 0.25	71.33± 0.58	110.32 ± 31.22	173.06 ± 40.61
CNR	0.54 ± 0.16	0.85 ± 0.19	1.25± 0.29	1.13 ± 0.25	2.19 ± 0.60
PIQE	7.61 ± 0.69	7.96 ± 1.06	7.85 ± 0.78	6.47 ± 0.96	5.44 ± 0.41

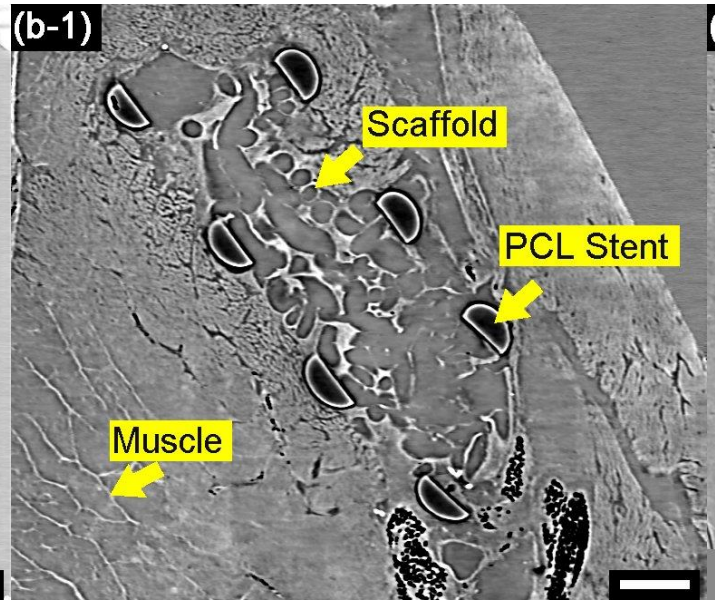
Results

PBI-µCT scans of rat hindlimb samples containing hydrogel scaffold implant at longitudinal time points:

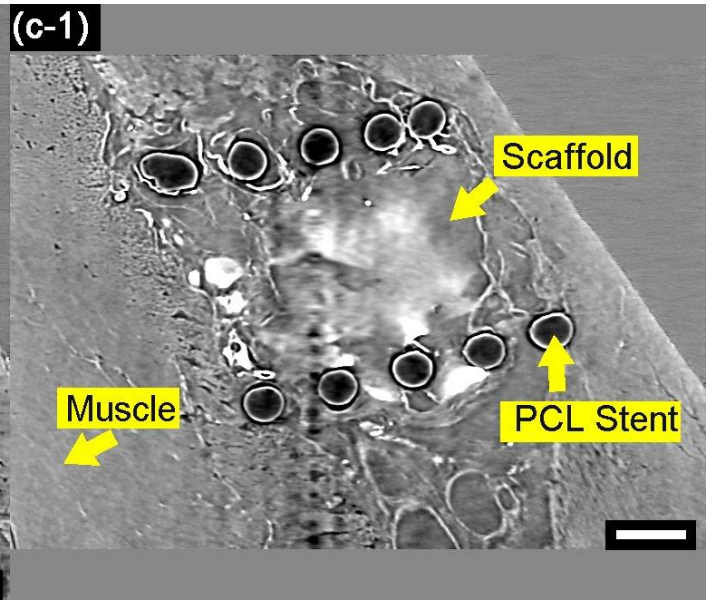
Baseline (0 hrs)



48 hrs in animal



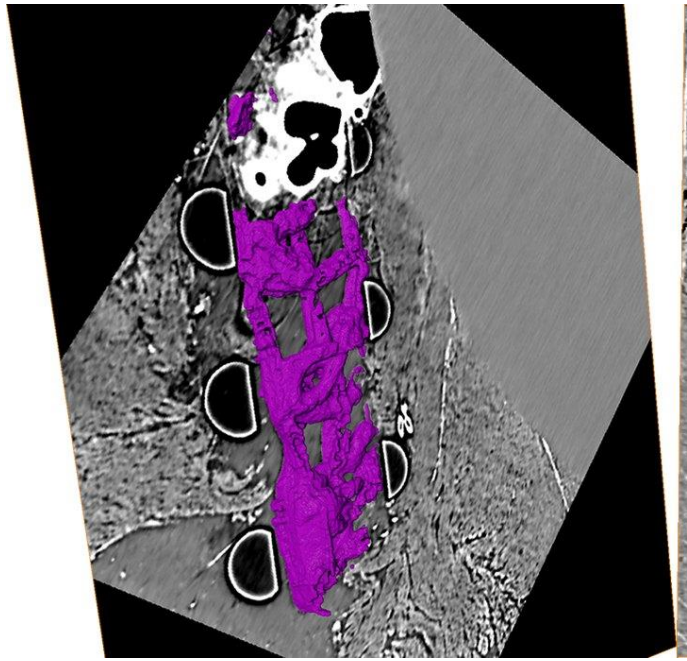
96 hrs in animal



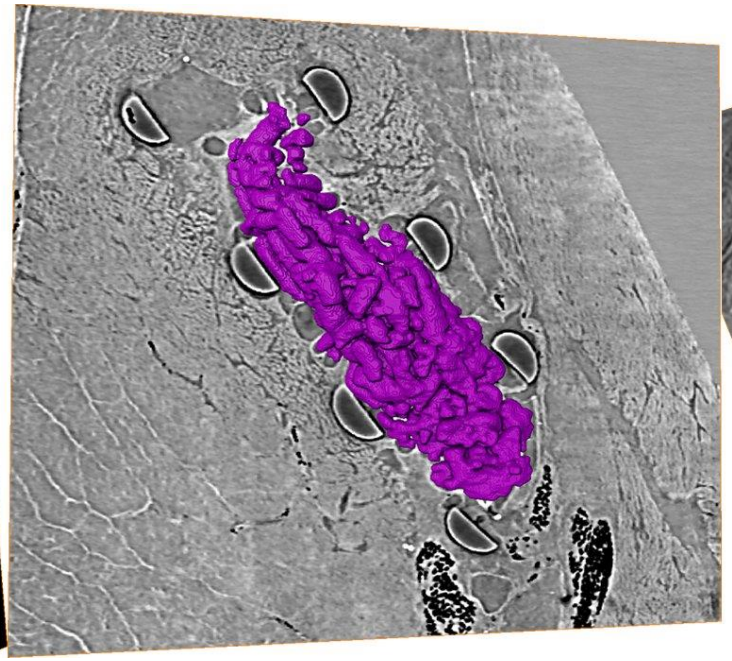
Results

Segmentation and 3D render of stent and scaffold at longitudinal time points:

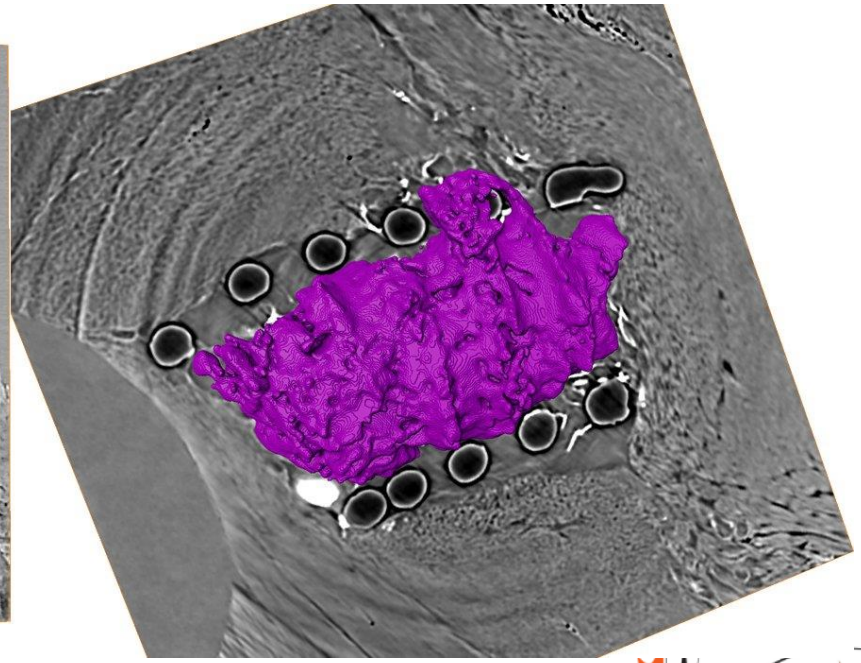
Baseline



2 days in animal

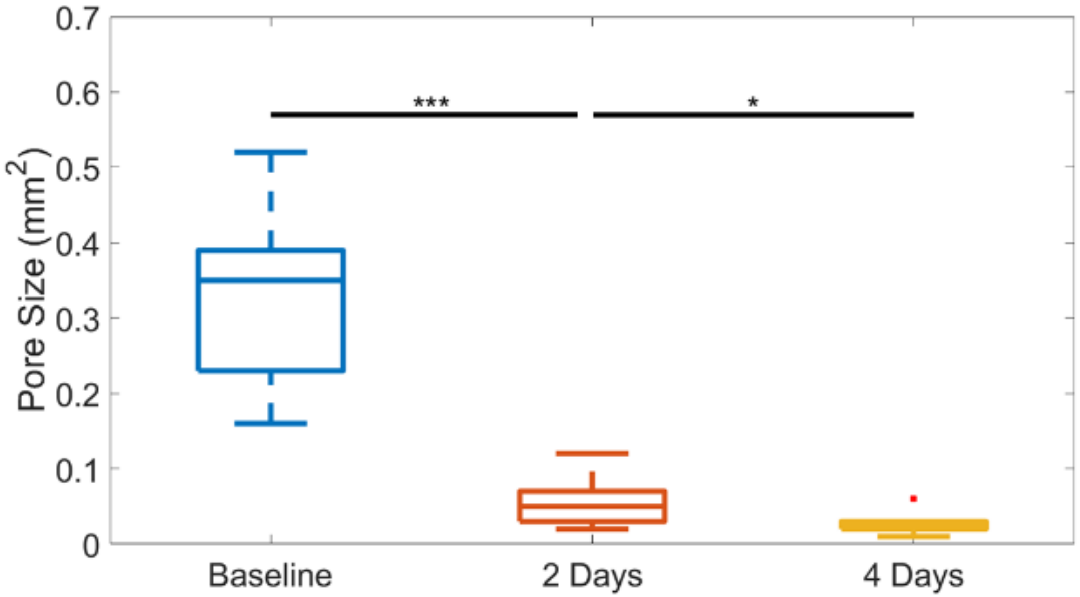


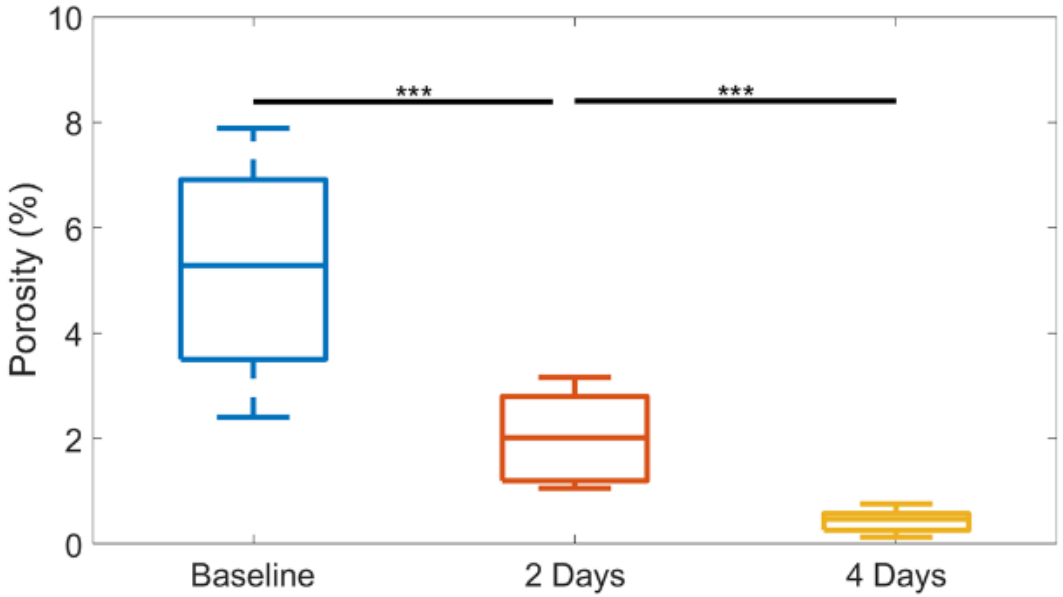
4 days in animal



Results

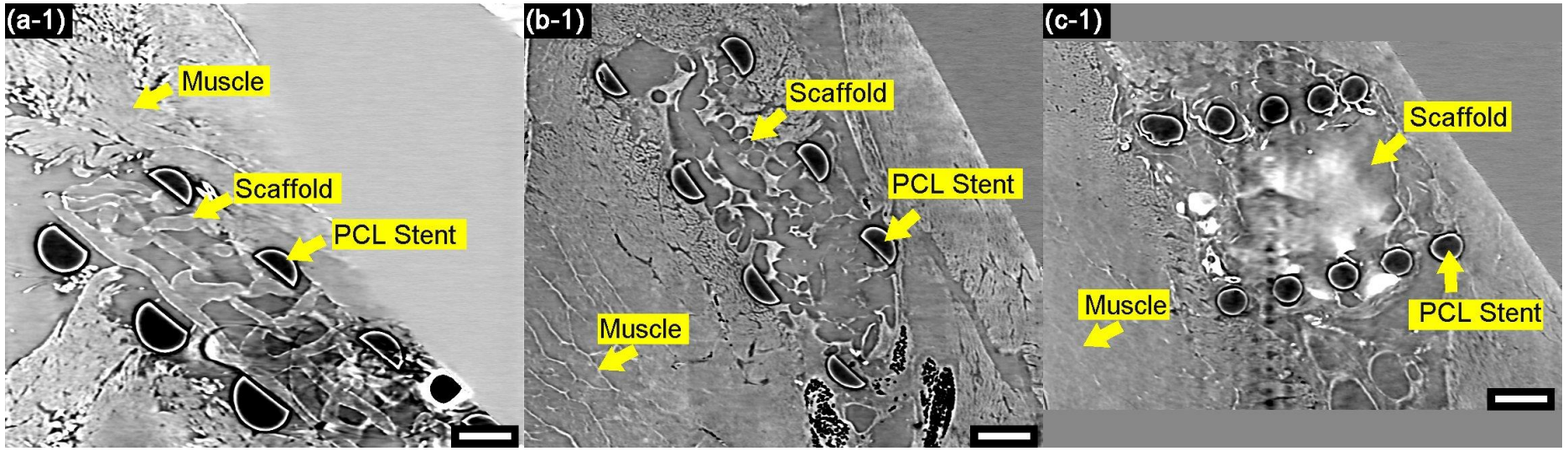
Segmentation and 3D render of stent and scaffold at longitudinal time points:



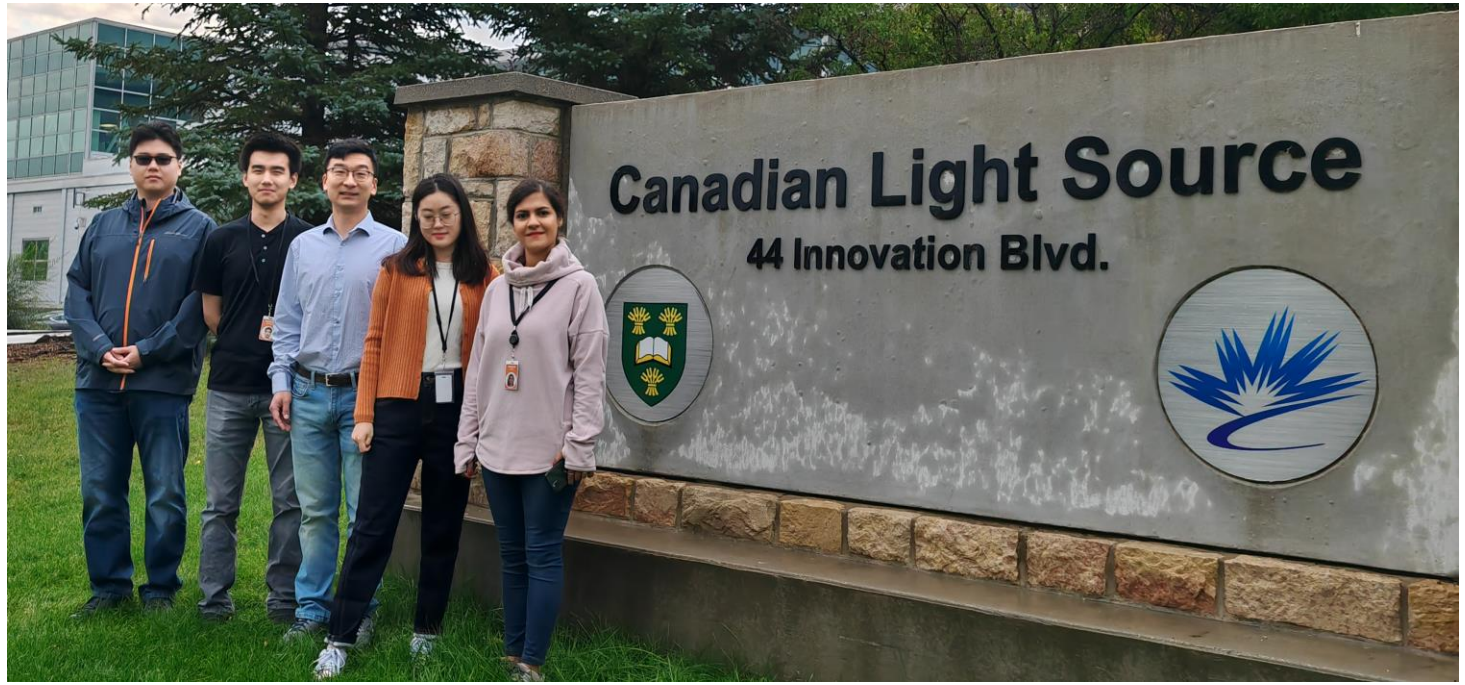


Conclusion

- Bone masking to enhance the results of deep learning denoising
- Allowed visualization of hydrogel scaffolds *ex vivo*, longitudinal time points
- Next step to study scaffolds in vivo



Acknowledgements



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