A hybrid model- and deep learning-based framework for functional lung image synthesis from non-contrast multi-inflation CT

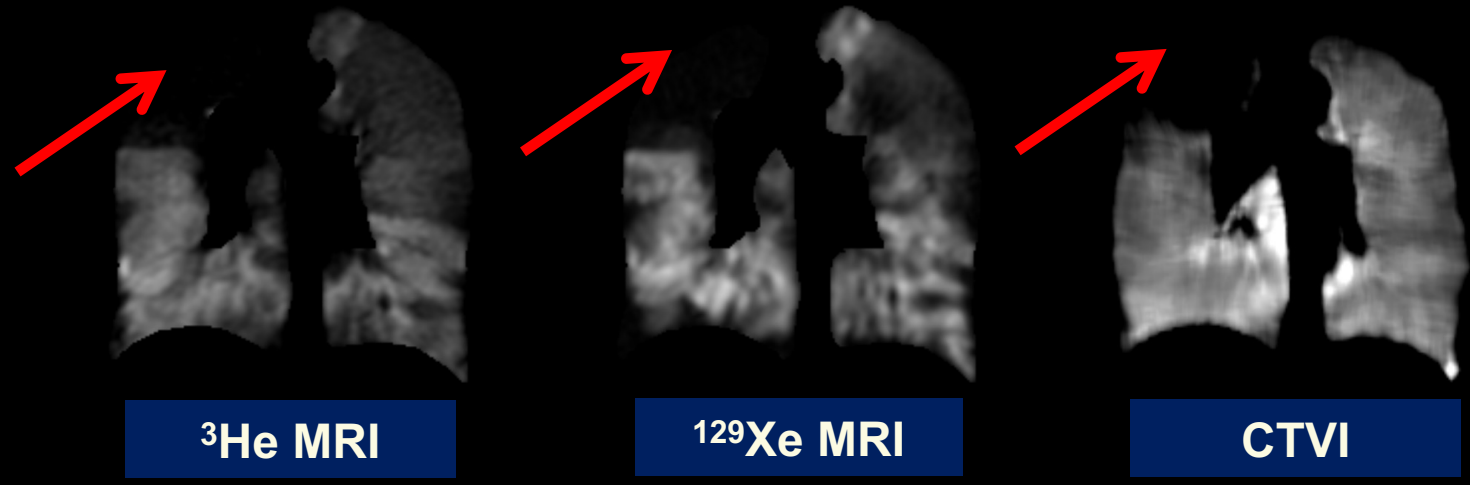
Joshua R. Astley[1,2], Alberto M. Biancardi[1], Helen Marshall[1], Guilhem J. Collier[1], Paul J.C. Hughes[1], Jim M. Wild[1], Bilal A. Tahir[1,2]

[1]POLARIS, Department of Infection, Immunity & Cardiovascular Disease and [2]Department of Oncology and Metabolism, University of Sheffield, UK

Introduction

- Hyperpolarised gas MRI is a functional lung imaging modality capable of visualising regional ventilation with exquisite detail. However, the modality requires highly specialised equipment and a contrast agent such as Helium-3 (^{3}He) or Xenon-129 (^{129}Xe).
- CT ventilation imaging (CTVI) aims to derive images of regional ventilation from multi-inflation CT, acquired during tidal breathing or breath-hold, without exogenous contrast.

E.g. Tahir et al 2018, IJROBP; Tahir et al 2019, Phys Med Biol



Aim

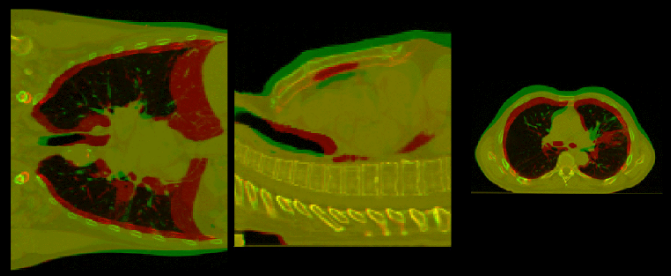
Can deep learning improve upon state-of-the-art model-based CTVI methods?

Methods

Generation of CTVI

1. Acquire inspiratory & expiratory CT
Can be from 4DCT or breath-hold

2. Perform deformable image registration

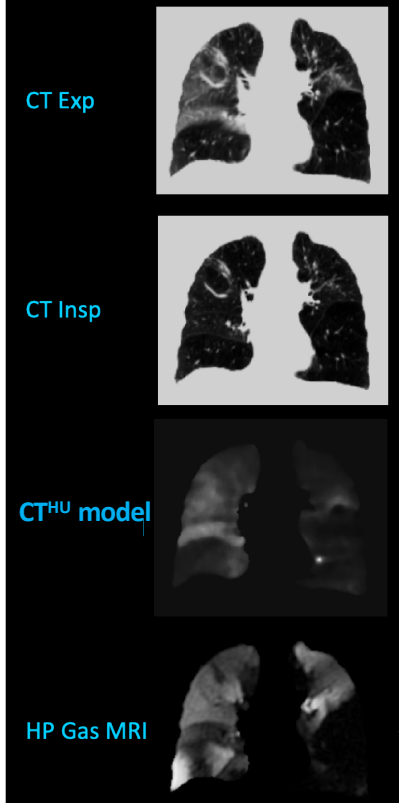


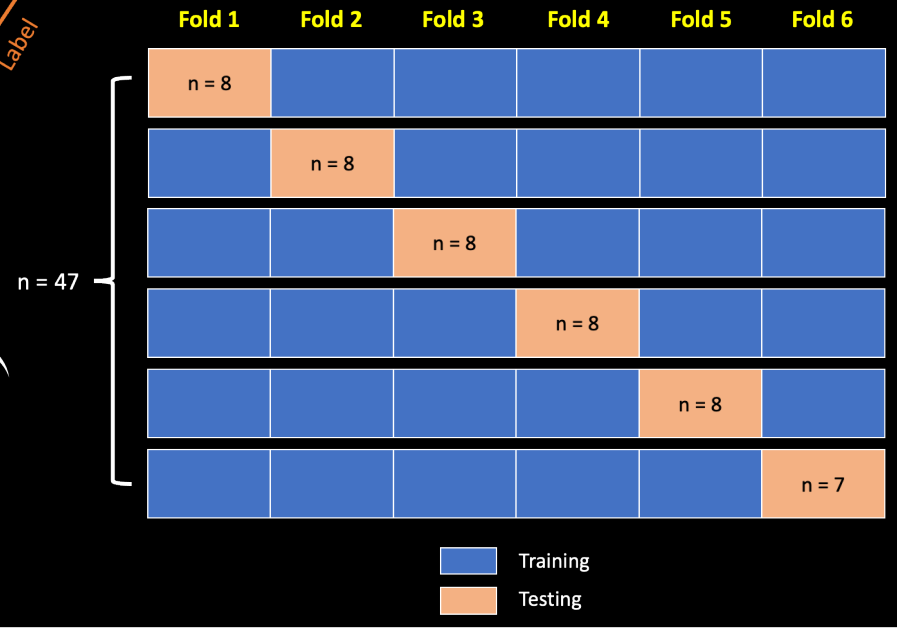
3. Computational modelling

$$\frac{\Delta V}{V_{exp}} = 1000\frac{\overline{HU}_{ins} - HU_{exp}}{HU_{exp}(1000 + HU_{ins})}$$

CT^{HU} model

Deep learning methods





6-fold cross validation

We used four combinations of input channels for the CNN:

1) Expiratory CT + inspiratory CT + CTVI
2) Expiratory CT + inspiratory CT
3) Expiratory CT
4) Inspiratory CT

Results / Conclusion

Synthetic ventilation generation methods	Spearman's ρ	MSE
	Mean ± SD	Mean ± SD
CT^{HU} model	0.39 ± 0.18	N/A
DL (expiration CT)	0.41 ± 0.18	0.032 ± 0.01
DL (inspiration CT)	0.37 ± 0.20	0.027 ± 0.01
DL (expiration CT + inspiration CT)	0.42 ± 0.18	0.027 ± 0.01
DL (expiration CT + inspiration CT + CT^{HU} model)	**0.46 ± 0.16**	**0.025 ± 0.01**

The hybrid model/Dl method achieved a mean Spearman's correlation on 47 scans of 0.46 and significantly outperformed other DL methods as well as CTVI modelling.

Qualitatively, we can see for 3 cases that the hybrid model / DL-based approach is able to accurately replicate defects present in the hyperpolarised gas MRI scans.