Unsupervised airway measurement to predict survival in bronchiectasis

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Background

Bronchiectasis

Abnormal airway dilation, termed bronchiectasis, is a feature of many chronic airway diseases. It is identified qualitatively on computed tomography (CT) in the clinic. However, quantitative analysis would make measurements of disease severity more precise and objective, facilitating drug development.

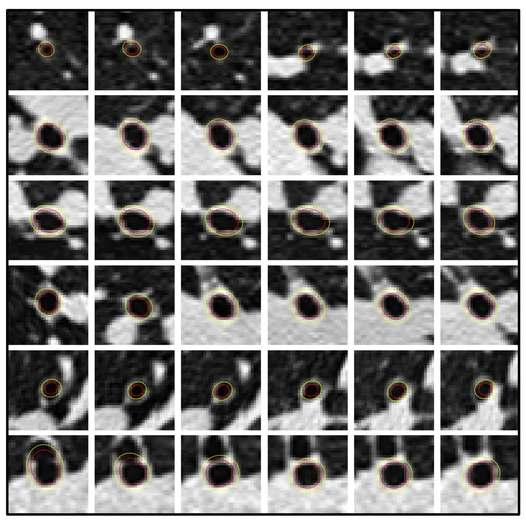
Airway Measurement

Measuring bronchiectasis involves measuring the airway diameter contiguously. The Full Width Half Maximum (FWHM) method typically used to measure airways often overestimates airway lumen diameter in small airways, making it difficult to measure bronchiectasis on CT. Airway diameters are often close to the limit of resolution and significantly vary in appearance between datasets.

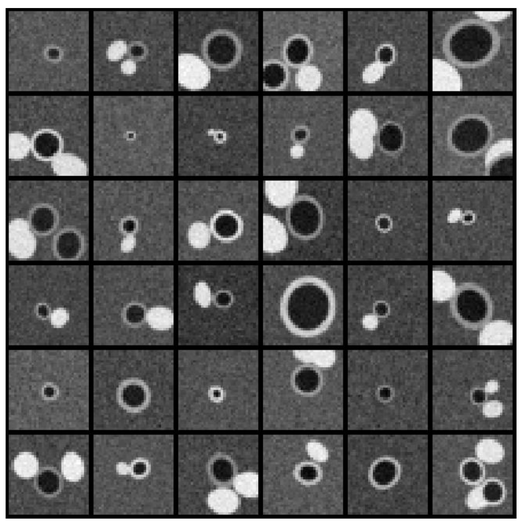
Results

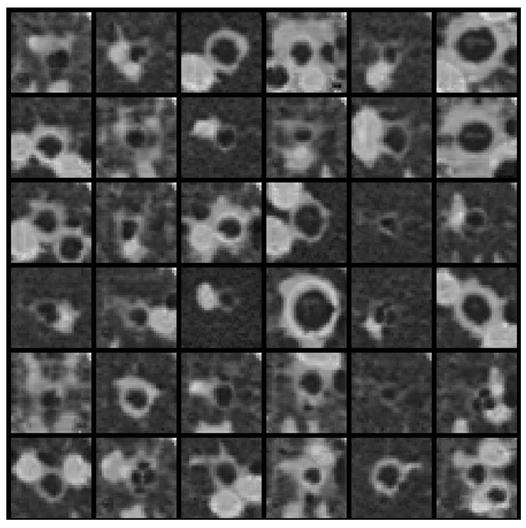
Survival model results

It was found that the GAN-CNN method better predicts survival ($p<0.02$) compared to the FWHM method ($p<0.36$) in airways within the peripheral lung, which are typically smaller.



TOP RIGHT Example of ellipse fitting at inference on real data by CNN.





LEFT a synthetic batch and BOTTOM RIGHT its refined output from the trained GAN.

Methods

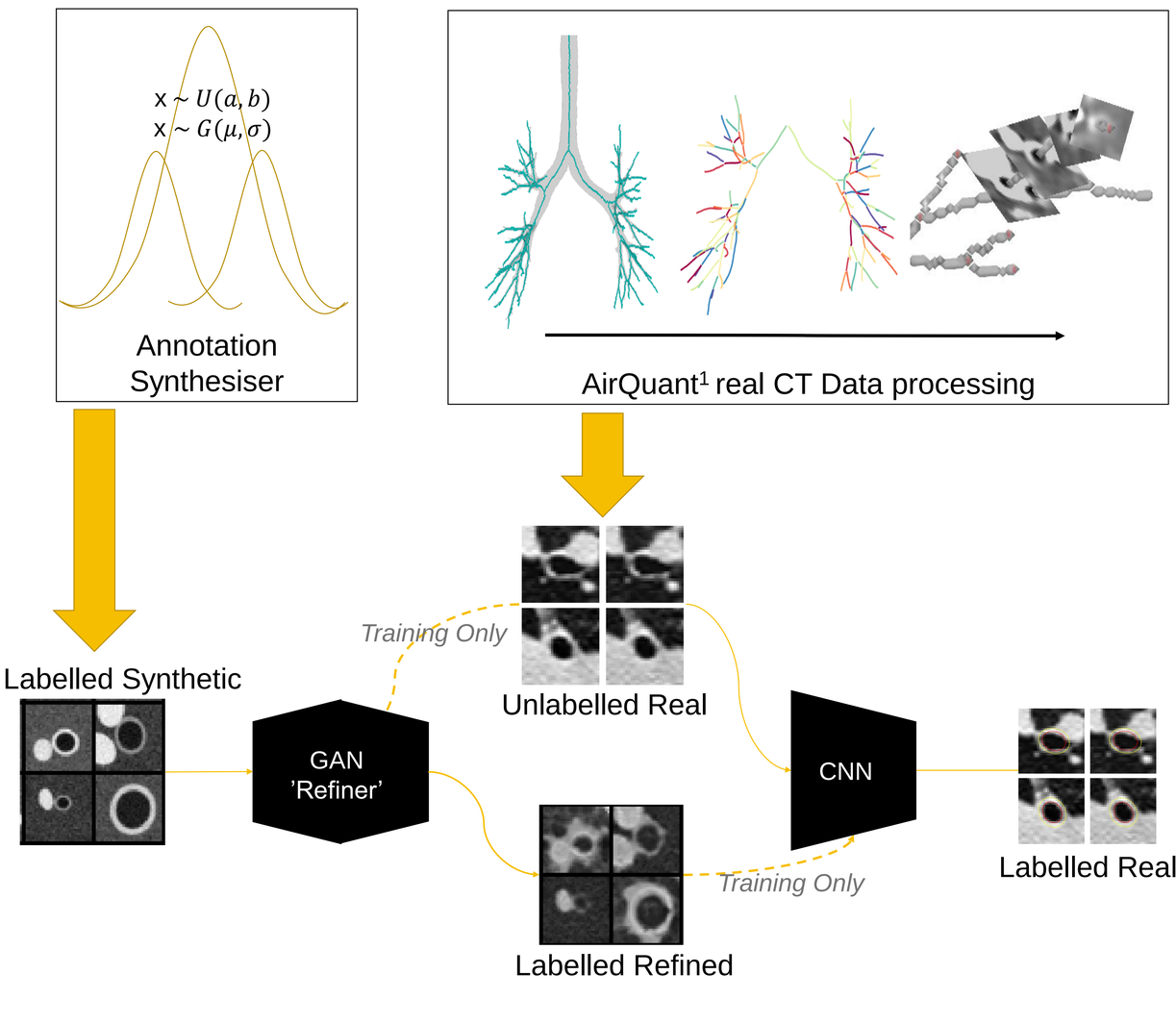
Overview

To over come difficulties in the measurement of airway patches we consider an unsupervised deep learning method that couples a Generative Adversarial Network (GAN) with an ellipse fitting Convolutional Neural Network (CNN) similar Nardelli et al. 2020 [1]. The GAN generates realistic airway labels to used to train the CNN to measure real airways. Fitting the parameters of an ellipse to the inner airway lumen and outer wall.

Perpendicular airway patches can be extracted from CT for measurement by interpolating along the airway skeleton using AirQuant [2]. Synthetic airway patches are made by sourcing characteristics from a probabilistic model devised on empirical observation. Specifying airway diameter, wall thickness, CT intensity, vessel presence etc. The schematic below demonstrates the overall set-up for unsupervised measurement.

Survival Prediction

The FWHM method is compared to the GAN-CNN method on **N=108** (~376000 patches) bronchiectasis patients using survival models that include comorbidities such as age, gender and smoking status for bronchiectasis metrics to see which better predicts survival.



Conclusions

- This study provides evidence for GAN-CNN as a viable method for generating bronchiectasis imaging biomarkers for survival prediction in small airways.
- GAN-CNN with ellipse fitting has better explained inference than basic airway diameter regression, important for clinical translation.
- A generative unsupervised approach can:
  - Remove the need for very expensive hand labelling of data.
  - Be adaptive to new datasets, especially when diseases have different appearances (e.g. more fibrosis).

SCAN ME

[1] Nardelli, Pietro et al. "Generative-based airway and vessel morphology quantification on chest CT images". *Medical Image Analysis* 63 (2020)
[2] Pakzad, Ashkan et al. "Evaluation of automated airway morphological quantification for assessing fibrosing lung disease". *arXiv [physics.med-ph]* (2021)

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Cystic Fibrosis Trust

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