Digital lung sound characteristics related to airflow turbulence intensity: a methodological proof-of-concept

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BACKGROUND

Respiratory sounds are induced by turbulence of airflow at the level of lobar and segmental bronchi. Airway narrowing increases airflow turbulence and is thought to produce lung sounds at a higher frequency and intensity. Although this physiological principle is widely accepted, the generation of these sounds has never been demonstrated in human subjects.

AIM

To investigate a new approach relating lung sounds to airflow turbulence intensity using computational fluid dynamics (CFD).

METHODS

- Digital lung sounds:
  - Recorded with a digital stethoscope at 6 chest locations.
  - After denoising, frequency distributions were calculated from their normalised signal power.
- Functional respiratory imaging (FRI):
  - A CT scan was taken at 2 breathing levels, total lung capacity and functional residual capacity, to simulate airflow in a patient-specific model.
  - Turbulence intensity in the airway, as a dimensionless scale characterizing flow turbulence, was determined using CFD.

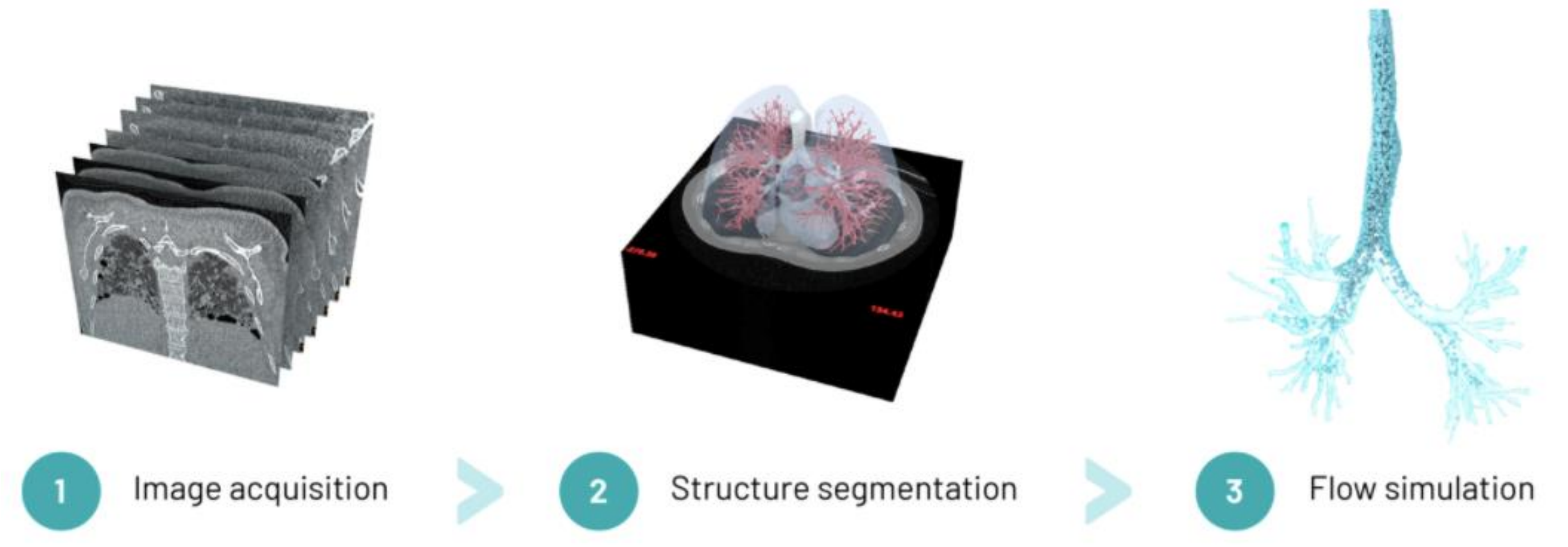

Figure 1. Functional Respiratory Imaging (FRI)

RESULTS

- 34-year-old male with CF
- Left-to-right comparison showed more energy in frequencies >250Hz over the right lung, especially over the upper anterior chest.
- A potential relation was found with the CFD analysis showing most prominent peaks in turbulence intensity in right upper and lower segmental bronchi.

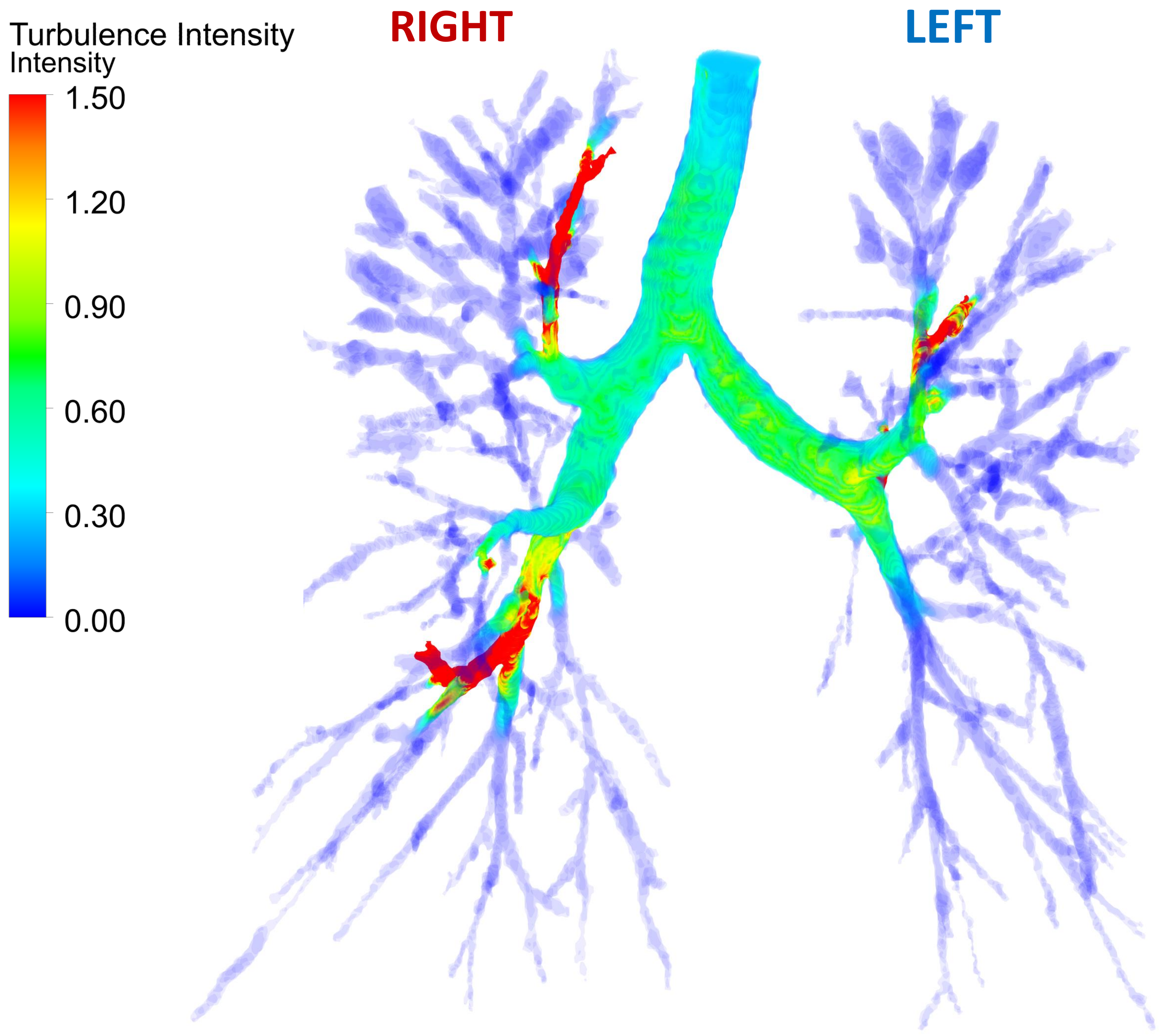

Figure 2. Turbulence intensity of airflow determined by computational fluid dynamics.

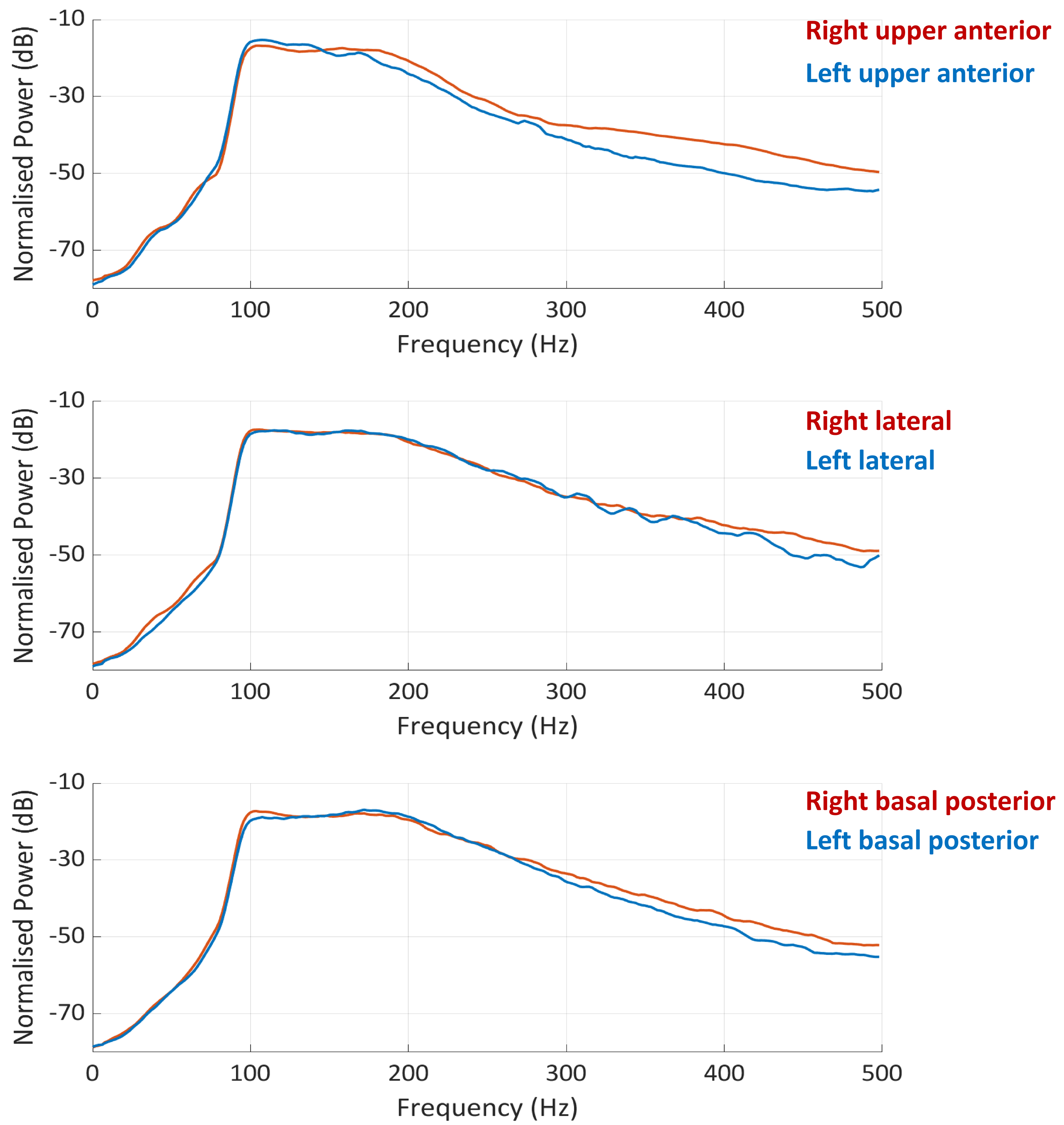

Figure 3. Left-to-right comparison of the frequency distribution of the anterior, lateral and posterior lung sound recordings, respectively.

CONCLUSION

Calculation of the turbulence intensity of airflow throughout the bronchial tree allows us to return to the origins of lung sounds. Preliminary results suggest that this innovative approach could play a role in the validation of computer aided lung sound analyses (CALSA) to monitor airway narrowing in the long-term. Validated algorithms for CALSA could support the clinical decision making by physicians and health care workers as lung sounds contain valuable information about the underlying pathophysiology, relevant for diagnosis and follow-up of various pulmonary diseases. Such validated tools for digital lung auscultation that provide objective quantitative outcomes are currently lacking in clinical practice.

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