

# Multimodal Vibrational Spectroscopy Evaluating Atrial Tissue

James Grant, St Vincent's Hospital Melbourne, Melbourne, Australia

## Abstract

Atrial fibrillation (AFib) results from a combination of structural, electrical, and metabolic remodelling within the atrium, and is the most common cause of stroke in the community.

Abnormalities were initially proposed to just be at the level of the myocardium (heart muscle). There is emerging evidence that atrial adipose tissue (AAT) plays a significant role in AFib pathogenesis through pro-inflammatory and pro-fibrotic environments. Conventional lipid analysis is limited and poorly suited with the operative environment. They can require off-site processing with turn-around times that preclude real-time intra-operative decision-making. Vibrational spectroscopy can provide fast, chemically specific phenotyping of cardiac tissues and adjacent adipose tissue. As a pilot study, we used vibrational spectroscopy, from a point-of-care approach, to evaluate its effectiveness in atrial adipose tissue detection and in characterising lipid profiles in AFib.

We explored a cross-sectional study AAT spectral features associated with AFib phenotype and a prospective intra-operative translation study using handheld near-infrared spectroscopy to derive spectral markers and a risk score for post-operative AFib (POAF). Data was generated from operatively excised Left Atrial Appendage (LAA) specimens (16 patients: 8 controls, 8 AFib; 32 samples) stored at -80 °C and analysed with Raman and FT-NIR spectroscopy (1,728 spectra). PCA and PLS-DA were used for compartment discrimination (AAT vs adjacent tissues) and to quantify lipid and protein related spectral features relevant to atrial remodelling.

PLSDA achieved a sensitivity 100%, specificity 98.5%, and Area under the Curve (AUC) of 1.0 in differentiating AAT from epicardial and endocardial myocardial tissues. Spectroscopic analysis of AAT highlighted chemically specific measurements of lipid (unsaturation/oxidation; CH<sub>2</sub>/CH<sub>3</sub> balance) and protein/collagen features that plausibly map to AFib substrates.

The translational question is not whether these signals exist, but whether they can be measured reproducibly across tissue types and disease states,

whether they can be generalised at the patient level, and whether they can be implemented in theatre-compatible workflows. Importantly, we need to realign the high bar for complete certainty and focus more on practicality and feasibility. Additional areas of expansion may be evaluation of atrial amyloid, which is an emerging tissue biomarker in AFib.