

Multi-Modal Spectroscopic Evaluation of Banked Frozen Cardiac Tissue

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Abstract

Purpose: Heart disease is the leading cause of hospitalisations, morbidity, and mortality globally, but there are no point-of-care instruments that can provide metabolic or morphological diagnoses in real time [1]. We demonstrate as proof of concept that point-of-care multimodal spectroscopy using Near-Infrared (NIR) and Raman-Spectroscopy (RS) can be used to diagnose human heart tissue in a variety of conditions with normal controls as comparators.

Methods: We generated 105 spectroscopic scans, which comprised of 4 NIR and 3 RS scans per sample to generate a “multimodal spectroscopic scan” (MSS) for each heart, done across 15 patients, 5 each from the dilated cardiomyopathy (DCM), Ischemic Heart Disease (IHD) and Normal pathologies. Each of the MSS scans was undertaken in 3 seconds. Data were entered into machine learning (ML) algorithms to assess accuracy of MSS in diagnosing tissue type [2].

Results: The median age was 50 years (IQR 49-52) for IHD, 47 (IQR 45-50) for DCM, 36 (IQR 33-52) for healthy patients ($p=0.35$), 60% of which were male. MSS identified key differences in IHD, DCM and normal heart samples in regions typically associated with fibrosis and collagen (NIR wavenumbers: 1433, 1509, 1581, 1689, 1725 nm; RS wavelengths: 1658, 1450 and 1330 cm^{-1}). In principal component (PC) analyses, these differences explained 99.2% of the variation in 4 PCs for NIR, 81.6% in 10 PCs for Raman, and 99.0% in 26 PCs for multimodal spectroscopic signatures. Using a stack machine-learning algorithm with combined NIR and Raman data, our model had a precision of 96.9%, recall of 96.6%, specificity of 98.2% and Area-Under-Curve (AUC) of 0.989 (Table 1). NIR and Raman modalities alone had similar levels of precision at 94.4% and 89.8% respectively (Table 1). MSS combined with ML showed accuracy of 90% for detecting dilated cardiomyopathy, 100% for ischemic heart disease and 100% for diagnosing healthy tissue.

Conclusion: Multimodal spectroscopic signatures, based on NIR and Raman spectroscopy, could provide cardiac tissue scans in 3-seconds to aid accurate diagnoses of fibrosis in IHD, DCM and normal hearts. This is an iterative proof of concept study that shows that Point of Care multimodal spectroscopy could be achievable by a bench top device using hand held probes. This paves the way for live imaging of cardiac tissue, either in the cardiac catheterization laboratory or the cardiac surgery operating room.

	AUC	Precision	Recall	Specificity
(a) NIR Model				
Logistic Regression	0.980	0.944	0.933	0.967
SGD	0.550	0.281	0.400	0.700
SVM	0.840	0.806	0.800	0.900
Stack	0.933	0.794	0.800	0.900
(b) Raman Model				
Logistic Regression	0.985	0.940	0.929	0.960
SGD	0.892	0.869	0.857	0.932
SVM	0.992	0.940	0.929	0.960
Stack	0.954	0.869	0.857	0.932
(c) MSS: Multimodal (NIR + Raman) to detect DCM vs. IHD vs. Normal patients				
Logistic Regression	0.975	0.841	0.828	0.917
SGD	0.847	0.803	0.793	0.899

SVM	0.971	0.853	0.828	0.917
Stack	0.961	0.853	0.828	0.917
(d) MSS: Multimodal (NIR + Raman) to detect Pathological vs. Normal patients				
Logistic Regression	0.961	0.969	0.966	0.984
SGD	0.944	0.967	0.966	0.923
SVM	1.000	1.000	1.000	1.000
Stack	1.000	0.944	0.931	0.969

Abstract Table 1 – Machine learning performance metrics for validation data sets of (a) Near Infrared (NIR), (b) Raman and (c and d) Multimodal data using Logistic Regression, Stochastic Gradient Descent and Support Vector Machines, with combined “stack” (LR + SGD + SVM)

References

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