Spectroscopic Insights into the Molecular Basis of Cardiorenal Syndrome

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Cardiorenal syndrome (CRS) is a multifactorial condition characterized by a bidirectional interaction between cardiac and renal dysfunction, driven by hemodynamic, neurohormonal, inflammatory, and metabolic mechanisms.[1] Despite significant advances in understanding its pathophysiology, early detection of CRS progression remains challenging, underscoring the need for sensitive molecular biomarkers. Vibrational spectroscopy techniques, including Fourier-transform infrared (FTIR) and Raman spectroscopy, offer powerful, label-free approaches for probing biochemical alterations in biological tissues, yet their application to cardiorenal disease remains limited.[2]

In this study, FTIR micro-imaging was employed to identify molecular signatures associated with cardiorenal pathology and to assess their modulation following pharmacological intervention with Entresto, the first approved angiotensin receptor–neprilysin inhibitor. [3] Cardiorenal interactions were modeled in male Wistar rats through uninephrectomy to induce renal stress, followed by cardiac ischemia–reperfusion injury to mimic myocardial damage. Molecular alterations were primarily investigated in the left ventricular myocardium, a critical contributor to CRS progression. Renal tissue alterations were assessed separately in the cortical, medullary, and vascular functional compartments. Spectroscopic analysis enabled the detection of disease-associated biochemical changes linked to fibrosis, protein remodeling, and metabolic imbalance, as well as their partial normalization following treatment. These findings demonstrate the capability of FTIR micro-imaging to sensitively capture molecular-level tissue alterations associated with CRS and therapeutic response.

Overall, this work highlights the potential of vibrational spectroscopy as a robust, objective, and efficient tool for studying cardiorenal pathophysiology and monitoring treatment efficacy. Given the increasing prevalence of CRS and the lack of early diagnostic markers, spectroscopy-based approaches may provide a valuable complement to conventional histological and biochemical techniques, supporting improved diagnosis and therapeutic monitoring in cardiorenal disease.

References

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