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Nano-biomarker-Based Surface-Enhanced Raman Spectroscopy for Non-Invasive Discrimination of Kidney Transplant Rejection Types

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Introduction: Accurate identification and differentiation of rejection types in kidney transplant patients is crucial in clinical practice. While renal biopsy is currently the gold standard for diagnosis, its disadvantages necessitate the development of novel non-invasive approaches. This study applies Surface-enhanced Raman spectroscopy (SERS) to blood samples from transplant recipients to detect molecular changes associated with rejection. It explores the potential of SERS to differentiate between antibody-mediated rejection (ABMR) and T-cell mediated rejection (TCMR) based on molecular fingerprints distinguished from normal.

Methods: We collected serum from 3 distinct groups: Control (n=9), ABMR (n=14), and TCMR (n=3), each substantiated by pathological findings. A nanorod array-based surface-enhanced Raman chip was fabricated; a single-drop (5uL) of serum was deposited on gold-ZnO nanoparticle-coated Si chips and 785nm wavelength laser was irradiated to obtain Raman spectra. The principal component analysis (PCA) and Partial Least-Squares Discriminant Analysis (PLS-DA), a machine learning algorithm, were applied to establish Raman spectroscopy-based diagnostic criteria.

Results: The average Raman spectra for each study group, when normalized at 1000 cm-1, displayed unique peaks illustrating the capacity of Raman spectroscopy to distinguish between rejection types. A diagnostic classifier was developed using PCA to segregate the resultant spectra into rejection and control categories. By scoring based on principal components and deploying the PLS-DA machine learning algorithm with 50 principal components, the samples were successfully further classified into control, TCMR, and ABMR groups. The diagnostic accuracy, determined by the area under the curve, was recorded at 95.2% for ABMR and 98.5% for TCMR, respectively.

Conclusion: Our research demonstrated that the implementation of a SERS-based nano-chip holds immense promise as a novel non-invasive method for early detection of various rejection types, facilitating prompt medical intervention as needed.