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[P005] Poster

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[P03-403] Development of an Advanced Electrochemical Platform for In Situ Metabolic Profiling and Precision Therapeutic Evaluation of Triple-Negative Breast Cancer

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Keywords：Electrochemical method、Nanostructured electrode、Triple-negative breast cancer、Metabolic profiling、Drug screening

[Purpose]
Triple-negative breast cancer (TNBC) is characterized by aggressive behavior and significant metabolic plasticity, which allows it to survive by dynamically shifting between glycolysis and oxidative phosphorylation (OXPHOS). However, traditional metabolic assays are often destructive, labor-intensive, and poorly suited for real-time monitoring. The goal of this study is to develop the BReast Cancer Sensing via ElectroChemistry (BRCAS-EC) platform, a label-free electrochemical biosensing system designed for *in situ* metabolic profiling and rapid therapeutic evaluation of living cancer cells.

[Method]
The BRCAS-EC platform was fabricated by electrodepositing nanostructured gold onto Indium Tin Oxide (ITO) glass substrates to sensitively capture redox-active electron transfers associated with cellular metabolism. We evaluated the platform’s performance using five representative breast cancer cell lines (MDA-MB-231, Hs578T, MDA-MB-453, MCF-7, and T-47D) and non-tumorigenic epithelial cells (MCF-10A). Metabolic dependencies were quantified using Differential Pulse Voltammetry (DPV) and verified by treating cells with specific metabolic inhibitors such as 2-DG (glycolysis) and Oligomycin (OXPHOS). Furthermore, subtype-specific drug responses to targeted agents and biosimilars were monitored in real time.

[Results]
The BRCAS-EC platform demonstrated high analytical sensitivity with a detection limit of approximately 3,500 cells per chip and a strong linear correlation. TNBC cells exhibited significantly higher electrochemical signals compared to benign cells, reflecting their hyper-metabolic state. The system accurately determined glycolysis/OXPHOS dependency ratios, identifying TNBC as glycolysis-dominant (e.g., 78.52% for MDA-MB-231) and luminal types as OXPHOS-reliant. Notably, drug-induced metabolic responses were detected within 30 seconds and at significantly lower concentrations than required by standard viability assays.

[Consideration]
Mechanistic studies suggest that the detected redox signals primarily originate from heme-containing cytochrome proteins involved in the mitochondrial electron transport chain. The platform's superior sensitivity allows for the detection of metabolic dysregulation at sub-toxic levels before the onset of ATP depletion or cell death. Additionally, the BRCAS-EC system successfully identified TNBC cells within heterogeneous populations without any pre-processing or labeling, highlighting its potential for rapid diagnostic applications.

[Conclusion]
BRCAS-EC serves as a versatile and non-destructive electrochemical sensing platform for

real-time metabolic phenotyping and therapeutic assessment. By providing rapid and sensitive readouts of cellular redox activity, it offers a robust framework for personalizing treatment strategies and monitoring drug efficacy in aggressive breast cancers. Future technical optimizations for 3D organoids and patient-derived samples will further enhance its translational potential in functional diagnostics and precision oncology.