

AI-optimized electrochemical aptasensors for stable, reproducible detection of neurodegenerative diseases, cancer, and coronavirus

Abstract

AI-optimized electrochemical aptasensors are transforming diagnostic testing by offering high sensitivity, selectivity, and rapid response times. Leveraging data-driven AI techniques, these sensors provide a non-invasive, cost-effective alternative to traditional methods, with applications in detecting molecular biomarkers for neurodegenerative diseases, cancer, and coronavirus. The performance metrics outlined in the comparative table illustrate the significant advancements enabled by AI integration. Sensitivity increases from 60 to 75 % in ordinary aptasensors to 85–95 %, while specificity improves from 70–80 % to 90–98 %. This enhanced performance allows for ultra-low detection limits, such as 10 fM for carcinoembryonic antigen (CEA) and 20 fM for mucin-1 (MUC1) using Electrochemical Impedance Spectroscopy (EIS), and 1 pM for prostate-specific antigen (PSA) with Differential Pulse Voltammetry (DPV). Similarly, Square Wave Voltammetry (SWV) and potentiometric sensors have detected alpha-fetoprotein (AFP) at 5 fM and epithelial cell adhesion molecule (EpCAM) at 100 fM, respectively. AI integration also enhances reproducibility, reduces false positives and negatives (from 15–20 % to 5–10 %), and significantly decreases response times (from 10–15 s to 2–3 s). These advancements improve data processing speeds (from 10 to 20 min per sample to 2–5 min) and calibration accuracy (<2 % margin of error compared to 5–10 %), while expanding application scope to multi-target biomarker detection. This review highlights how these advancements position AI-optimized electrochemical aptasensors as powerful tools for personalized treatment, point-of-care testing, and continuous health monitoring. Despite a higher cost (\$500–\$1,500/unit), their enhanced portability and diagnostic performance promise to revolutionize healthcare, environmental monitoring, and food safety, ultimately improving public health outcomes.

Keywords

AI; Aptasensors; Cancer; Coronavirus; Electrochemical; Integrated biosensor; Molecular cells; Neurodegenerative