ARTIFICIAL INTELLIGENCE IN CELL CULTURE STANDARDIZATION: FROM MONITORING TO PREDICTION

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Introduction. Cell cultures form the foundation of tissue engineering and cell-based transplantation, fields in which each produced batch must be viabile and therapeutically effective. Traditionally, culture monitoring relies on manual microscopic evaluation and biochemical assays. These approaches may lead to batch-to-batch variability, delayed detection of process deviations, and are highly dependent on operator's experience. The integration of artificial intelligence (AI), through Deep Learning (DL) and Machine Vision (MV) techniques, enables continuous analysis of morphological and metabolic data. This allows a gradual transition from strictly descriptive monitoring to a predictive approach oriented toward the standardization and optimization of cell cultures. The purpose of this study is to evaluate how AI can improve cell culture monitoring through the development of predictive models.
Materials and methods. This study is based on a narrative review of the literature using the PubMed, Google Scholar and MDPI databases with predifined keywords. Open-access, full-text articles published between 2020 and 2026 were included. A total of 11 relevant articles were identified.
Results. The analyzed studies demonstrate that neural networks applied to microscopic image analysis enable more precise identification of morphological changes compared to manual evaluation. Machine learning algorithms integrating metabolic parameters and environmental conditions can predict culture instability or decreased viability before these changes become evident through conventional assays. Additionally, „soft sensor" systems allow real-time estimation of parameters such as cell density and nutrient consumption without invasive interventions. Overall, predictive models reduce batch-to-batch variability and improve process reproductibility.
Conclusions. The integration of AI enables a shift from reactive culture monitoring to predictive process control. Advanced DL and MV models support early anomaly detection, reduction of batch variability, and improved reproductibility. Consequently, AI contributes to the development of autonomous bioreactor systems capable of delivering standardized tissues for safe transplantation.
Keywords. Artificial intelligence, deep learning, machine vision, stem cell culture, predictive modeling, quality monitoring.