

Invited Editorial

Personalized Neurology: Current Advances and Future Perspectives

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Abstract: Neurological disorders remain a leading cause of global disability and are associated with significant biological and clinical diversity, which reduces the efficacy of standardized treatment approaches. Developments in genomics, multi-omics, biomarkers, imaging, artificial intelligence, and digital phenotyping are transforming neurology from syndrome-based management to individualized diagnosis, prognosis, and therapy. Genomic sequencing and pharmacogenomics improve diagnostic yield and support targeted interventions, whereas biomarkers such as phosphorylated tau and neurofilament light chain enhance early detection and monitoring of neurodegenerative and immune-mediated diseases. Artificial intelligence can integrate multimodal clinical data to support diagnostic accuracy and predict disease trajectories, and wearable and smartphone-based monitoring provide continuous real-world measures of function and treatment response. Even with these advances, routine translation continues to be constrained by cost, data inequity, assay standardization gaps, regulatory complexity, and issues surrounding consent and governance. Building representative biobanks, harmonizing biomarker standards, validating tools prospectively, and strengthening clinician training will be essential to achieve equitable precision neurology.

Keywords: Personalized neurology; Precision medicine; Biomarkers; Artificial intelligence; Digital health

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Introduction

Despite tremendous advances in the medical field, neurological disorders remain among the leading causes of disability and mortality worldwide, imposing an increasing clinical and socioeconomic burden [1]. Traditional neurological care has largely relied on standardized diagnostic categories and uniform therapeutic approaches; however, patients with identical diseases may exhibit distinct differences in their genetics, molecular pathology, disease course, and treatment responses [2]. The above shortcomings have resulted in the growing popularity of personalized neurology, which seeks to tailor prevention, diagnosis, and therapy to the biological and clinical profile of each patient [3].

Genomics and Pharmacogenomics in Neurological Care

The advent of genomic technology has revolutionized the diagnosis of neurological disorders. Next-generation sequencing has helped identify pathogenic variants for inherited neurological disorders, such as hereditary ataxia, muscular dystrophy, epileptic syndrome, and motor neuron disease. In addition to genetic syndromes, genome-wide association studies have uncovered susceptibility loci for various diseases, including Alzheimer's disease, Parkinson's disease, migraine, and multiple sclerosis. These insights improve diagnostic accuracy, support family screening and counselling, and guide individualized therapeutic decisions. Pharmacogenomic testing has also become increasingly important in predicting treatment efficacy and minimizing adverse drug reactions [4].

Multi-Omics and Biomarker-Driven Diagnosis

The integration of transcriptomic, proteomic, metabolomic, epigenomic, and microbiomic analyses has expanded the understanding of neurological disease mechanisms beyond genomics alone. Biomarkers from body fluids, such as phosphorylated tau, neurofilament light chain, various forms of amyloid-beta, and glial fibrillary acidic protein, are increasingly used to support early detection, disease staging, and treatment monitoring in neurodegeneration and immune-mediated disorders. In conditions such as multiple sclerosis, stroke, and autoimmune neurological diseases, biomarker-driven approaches are beginning to complement clinical and imaging assessments. As these platforms mature, precision diagnostics are likely to become part of routine neurological practice [5].

Artificial Intelligence and Data-Driven Neurology

Artificial intelligence has emerged as a key driving force behind the emergence of personalized neurology. Machine learning and deep learning methods can analyze imaging, genetic, electrophysiological, and clinical data at a scale not feasible by conventional methods, thereby improving pattern recognition and prognostic prediction. AI-assisted interpretation of magnetic resonance imaging, electroencephalography, retinal imaging, and digital pathology has shown promise in early detection and diagnostic support. However, AI should be viewed as a decision-support tool rather than a replacement for clinical expertise [6].

Digital Biomarkers and Remote Neurological Monitoring

With the help of modern technologies, the scope of personalized medicine is slowly but surely growing beyond the limits of clinic premises. It is now feasible to continuously monitor gait, number of seizures, cognitive function, sleep, and motor activity using wearable sensors, smartphone applications, tele-neurology platforms, and remote monitoring systems. These digital biomarkers can help detect deterioration earlier and measure treatment response more objectively. This is especially useful for patients with chronic neurological diseases who face barriers to frequent specialist follow-up [7].

Precision Therapeutics and Emerging Treatment Strategies

Precision medicine holds great promise in the field of neurology. Gene replacement, antisense oligonucleotides, RNA interference, genome editing, and cell-based therapies have already shown major success in selected disorders [8]. Some examples include treatments for spinal muscular atrophy, neuromyelitis optica spectrum disorder, Alzheimer's disease, and migraines, illustrating the shift from symptom control toward mechanism-based intervention. Other approaches, such as drug repurposing, discovery by computation, and precision clinical trials, may further accelerate targeted treatment development across neurological diseases [9].

Challenges in Clinical Translation and Implementation

Despite of all the advances made, there are still several hurdles that exist and hinder the development of precision neurology. The high cost of sequencing, imaging, biomarker testing, and targeted therapies is not always affordable for patients, particularly those in low- and middle-income countries. Standardization of assays, interoperability of electronic health records, and data integration into clinical workflows also require further development [10]. Ethical concerns related to privacy, informed consent,

algorithmic bias, and equitable access must be addressed before precision neurology can be widely and safely adopted [11].

Future Perspectives: Towards Equitable Precision Neurology

Future advances will require collaboration across multiple disciplines involving neurologists, geneticists, bioinformaticians, neuroscientists, engineers, data scientists, regulators, and policymakers. The use of large-scale biobanks, federated learning platforms, harmonized clinical databases, and the infrastructure of digital health will support the validation of biomarkers and AI tools across diverse populations. Equally important will be clinician education, regulatory clarity, and reimbursement pathways that support equitable implementation [12].

Conclusion

Personalized neurology is rapidly moving from concept to clinical reality; however, its success will depend on rigorous validation, responsible governance, and equitable access. The ultimate goal is not technology alone but better neurological care that is more accurate, responsive, and patient-centered.

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