BIOSENSOR TECHNOLOGY AND APPLICATIONS IN NEUROLOGY

Editors:
Rajnish Srivastava
Nitin Verma
Naresh Kumar Rangra
Naveen Singh
Sonalika Bhalla
Ankita Thakur

Bentham Books

Biosensor Technology and Applications in Neurology

Edited by

Rajnish Srivastava
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Nitin Verma
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Naresh Kumar Rangra
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Naveen Singh
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Sonalika Bhalla
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

&

Ankita Thakur
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Biosensor Technology and Applications in Neurology

Editors: Rajnish Srivastava, Nitin Verma, Naresh Kumar Rangra, Naveen Singh, Sonalika Bhalla & Ankita Thakur

ISBN (Online): 979-8-89881-714-5

ISBN (Print): 979-8-89881-715-2

ISBN (Paperback): 979-8-89881-716-9

Published by Bentham Science Publishers Pte. Ltd. Singapore, in collaboration with Eureka Conferences, USA.

First published in 2026.

need for a court order if at any point you breach any terms of this License Agreement. In no event will any delay or failure by Bentham Science Publishers in enforcing your compliance with this License Agreement constitute a waiver of any of its rights.

3. You acknowledge that you have read this License Agreement, and agree to be bound by its terms and conditions. To the extent that any other terms and conditions presented on any website of Bentham Science Publishers conflict with, or are inconsistent with, the terms and conditions set out in this License Agreement, you acknowledge that the terms and conditions set out in this License Agreement shall prevail.

Bentham Science Publishers Pte. Ltd.
No. 9 Raffles Place
Office No. 26-01
Singapore 048619
Singapore
Email: subscriptions@benthamscience.net

CONTENTS

FOREWORD

Neurological research is poised on the brink of a transformative revolution that will be brought about by the integration of biosensor technology and biomarker science. In" Biosensor Technology and Applications in Neurology", we further explore how the combination of biomarkers and biosensors can revolutionize the diagnosis and treatment of neurological disorders. When faced with disorders including Alzheimer's, Parkinson's, and multiple sclerosis, etc. the importance of clear diagnosis and timely diagnosis has never been higher. We believe this book to be an example of successful interdisciplinary cooperation as it unites neuroscientists, bioengineers, and clinicians in their attempt to define the future of neurological medicine. The exploitation of biosensors means that we can now identify, measure, and track biomarkers with an unrivaled level of sensitivity and specificity, which in turn has paved the way for earlier diagnosis, continuous monitoring, and more targeted therapies. This contribution serves as a source of inspiration as we strive to overcome challenges that characterize the translation of these technologies from a bench to bed side. We in our instance wish that the information contained in this book may act as a catalyst for more innovation so that the lives of millions of patients suffering from neurological disorders could be enhanced.

Amit Kumar Srivastava
Indian Council of Medical Research (ICMR)
National Institute of Health Research (NIHR)
Bhubaneswar, Odisha
India

PREFACE

Neurology is also migrating to a new paradigm of biosensor technology and biomarkers that are now being explored. Neurological diseases and disorders that for many years remained challenging to diagnose and treat are now leading targets of growing interdisciplinary research aided by evolving biosensor platforms. This book explores how such technologies can revolutionize everything. In this book, we outline how biosensing has emerged in parallel with biomarkers, to which more attention has been paid in recent years. The chapters within also provide a closer look at how these tools are revolutionizing our management of neurological disorders including Alzheimer's and Parkinson's diseases, epilepsy, and multiple sclerosis etc. Read through this book and learn about the new innovative procedures that range from early diagnosis of the disease and timely health monitoring to the development of custom-made treatments. This book will be valuable for researchers, clinicians, and industry professionals interested in embracing and advancing these emerging technologies. This collection has presented a wellspring of ideas that we trust will encourage teams working at the interphase of social science and neurology. We aim to encourage more research collaboration and cross-disciplinary advancements toward more effective diagnosis, treatment, and management of neurological diseases.

Rajnish Srivastava
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Nitin Verma
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Naresh Kumar Rangra
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Naveen Singh
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

Sonalika Bhalla
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

&

Ankita Thakur
Chitkara University School of Pharmacy
Chitkara University, Baddi
Himachal Pradesh
India

List of Contributors

Alok Kumar Agrawal	Chitkara University School of Engineering and Technology, Chitkara University, Baddi, Himachal Pradesh, India
Aman	Department of Pharmaceutical Chemistry, ISF College of Pharmacy and Research, Moga, Punjab, India
Anwesha Das	Department of Pharmacy, Sanaka Educational Trust Group of Institutions (SETGOI), Durgapur, West Bengal, India
Arijit Nandi	Department of Pharmacy, Sanaka Educational Trust Group of Institutions (SETGOI), Durgapur, West Bengal, India Institute for Molecular Bioscience, The University of Queensland, St Lucia, Queensland, Australia
Aruna Sharma	School of Pharmacy, Chitkara University, Baddi, Himachal Pradesh, India
Bibhu Prasad Nanda	Analytical R&D, NAARI Pharma Pvt. Ltd., Rudrapur, Uttarakhand, India
Debajyoti Roy	Faculty of Pharmacy, C.V. Raman Global University, Bhubaneswar, Odisha, India
G. Vinothkumar	Multi-Disciplinary Research Unit (MRU), Rangaraya Medical College, Kakinada, Andhra Pradesh, India
Hurmat Khan	School of Pharmacy, Chitkara University, Baddi, Himachal Pradesh, India
M. S. Jancy	Department of Medical Research, SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
Jatin Kumar	School of Pharmacy, Chitkara University, Baddi, Himachal Pradesh, India
Khadga Raj Aran	Department of Pharmacology, ISF College of Pharmacy, Moga, Punjab, India
Komal Thapa	School of Pharmacy, Chitkara University, Baddi, Himachal Pradesh, India
Maitrayee Ghosh	Amity Institute of Pharmacy, Amity University, Noida, Uttar Pradesh, India
Meghna Dhupar	Department of Pharmacy Practice, ISF College of Pharmacy, Moga, Punjab, India
Mohanraj Nehru	Department of Biochemistry, JR Medical College and Hospital, Tindivanam, Tamilnadu, India
Neha Kanojia	School of Pharmacy, Chitkara University, Baddi, Himachal Pradesh, India
Nithya Rao	Department of Psychology, School of Psychological Sciences, CHRIST University, Bengaluru, Karnataka, India
P. Rohini	Department of Physiology, SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
P. Venkataraman	Department of Medical Research, SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, kattankulathur, Tamil Nadu, India
Pratyush Porel	Department of Pharmacology, ISF College of Pharmacy, Moga, Punjab, India

Priyanka Rani	Faculty of Pharmaceutical Sciences, DAV University, Jalandhar, Punjab, India
Rohit Bhatia	Chitkara College of Pharmacy, Chitkara University, Rajpura, Punjab, India
Sachin Karmakar	Department of Pharmacy, Sanaka Educational Trust Group of Institutions (SETGOI), Durgapur, West Bengal, India
Shilpa Borehalli Mayegowda	Department of Psychology, School of Psychological Sciences, CHRIST University, Bengaluru, Karnataka, India
Subhash Chander	Amity Institute of Pharmacy (AIP), Amity University Haryana, Gurugram, Haryana, India
Sumedh Bhat	Department of Psychology, School of Psychological Sciences, CHRIST University, Bengaluru, Karnataka, India
Tanzeem Nigar	Department of Pharmacy, Sanaka Educational Trust Group of Institutions (SETGOI), Durgapur, West Bengal, India

CHAPTER 1

Biomarkers in Neurological Disorders: Current Landscape

Mohanraj Nehru[1], M. S. Jancy[2], P. Rohini[3], G. Vinothkumar[4] and **P. Venkataraman[2,*]**

[1] *Department of Biochemistry, JR Medical College and Hospital, Tindivanam, Tamilnadu, India*

[2] *Department of Medical Research, SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, kattankulathur, Tamil Nadu, India*

[3] *Department of Physiology, SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India*

[4] *Multi-Disciplinary Research Unit (MRU), Rangaraya Medical College, Kakinada, Andhra Pradesh, India*

Abstract: Neurological disorders pose a significant threat to social health and contribute to mortality and morbidity. Biomarkers are crucial for improving clinical diagnosis and monitoring effective disease-modifying therapies, which are found in circulatory blood and cerebrospinal fluid, nucleic acids, tissue, and imaging. Research has connected RNA types to both familial and sporadic forms of neurodegenerative disorders, in addition to DNA, which is still the primary biomarker for detecting familial forms. Imaging methods are aiding both target engagement and early diagnostic biomarker development. Drug research and clinical trials for neurological illnesses may benefit from the use of biomarkers, which can show target engagement and the effectiveness of drugs. However, due to the complexity of the brain, inconsistencies between experimental and clinical data, inaccurate clinical diagnostics, a lack of functional endpoints, high costs, and difficulty in understanding the methods, the search for biomarkers for neurological disorders remains a formidable challenge. Despite these obstacles, there is a widespread desire for biomarker research. Biomarkers have greatly improved neurological disease management by allowing for earlier intervention and individualized treatment plans. Through ongoing research and technical developments, biomarkers will further improve diagnostic precision, treatment effectiveness, and patient outcomes. This chapter gives a synopsis of the current state of neurodegenerative disease biomarkers and discusses where they may go from here in terms of clinical practice and studies.

[*] **Corresponding author P. Venkataraman:** Department of Medical Research, SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, kattankulathur, Tamil Nadu, India; E-mail: venkatap@srmist.edu.in

Rajnish Srivastava, Nitin Verma, Naresh Kumar Rangra, Naveen Singh, Sonalika Bhalla & Ankita Thakur (Eds.)

Keywords: Alzheimer's, Biomarkers, Multiple sclerosis, Neurological disorders, Parkinson's.

INTRODUCTION

Neurological disorders, whether lethal or non-lethal, are significant contributors to the burden of both non-communicable and communicable diseases. Neurological disorders are a leading cause of disability and among the major contributors to global mortality [1]. Neurological disorders are conditions that affect the entire nervous system, including the CNS, brain structures, peripheral nerves, and muscles. Neurological disorders have a multifactorial aetiology; the majority of them are strongly associated with genetic and environmental factors [2].

According to WHO guidelines, neurological disorders are categorized as:

- Neurotraumatic diseases: These include stroke, spinal cord injury, and Traumatic brain injuries (TBI).
- Neurodegenerative diseases: These include AD, PD, and HD.
- Neuropsychiatric diseases: These include epilepsy and depression.

The categorization of neurological disorders is pictured in Fig. (**1**).

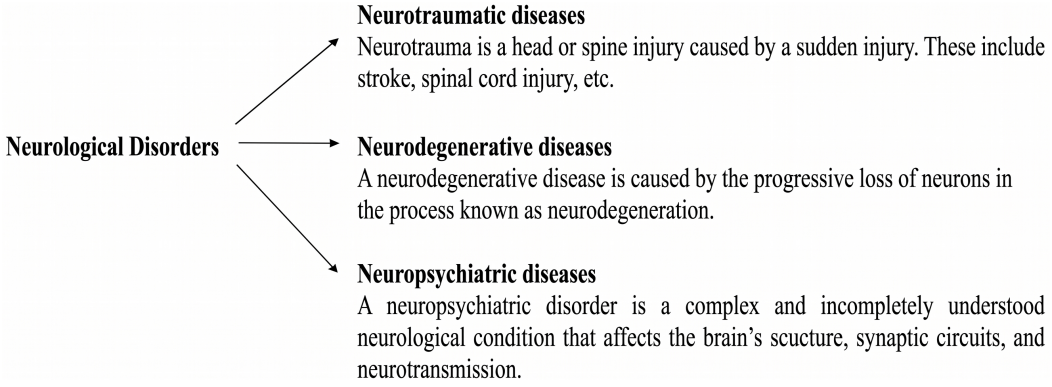

Fig. (1). Categorization of neurological disorders.

BIOMARKERS

In recent years, biomarkers have increasingly been used across various clinical applications, such as clinical diagnostics and clinical trials. Biomarkers can objectively assess and indicate physiological or pathological responses to therapeutic interventions, reflecting altered physiological processes and providing benefits for the diagnosis and treatment of diseases. Pharmaceutical development and clinical trials are essential for the enhancement of healthcare and the

progression of medical knowledge. Biomarkers play a vital role in determining pharmacological mechanisms, effectiveness, toxicity, and patient response. Diseased organs or the body produce biomarkers in response to various diseases. Biomarkers are measurable biological indicators that reflect physiological or pathological processes, as well as responses to therapeutic interventions [3].

Types of Biomarkers

Biomarkers are categorised into prognostic, predictive, pharmacodynamic, or surrogate biomarkers. Prognostic biomarkers are used to identify risk factors and find people who have unique risk factors that aren't found in the general population. These biomarkers may show how a condition starts and gets worse. Amyloid β peptide 1-42 (Aβ42) is a prognostic biomarker that assesses patients' likelihood of developing Alzheimer's disease (AD) [4]. Predictive biomarkers are used to identify the varied outcomes of a given medication or treatment. Biomarkers predict patient outcomes, aiding doctors in determining the most effective treatment for each patient. Abnormal concentration of Aβ42 and tau phosphorylation in cerebrospinal fluid (CSF) may show late-onset AD, which is different from mild cognitive impairment in older adults [5, 6]. Pharmacodynamic biomarkers are used to understand the work progress of a drug, which helps to choose the right dose to avoid side effects and low clinical response rates. They measure post-treatment drug response, indicating the drug's effectiveness on target organs and tissues. Tumor necrosis factor- α (TNF-α) and Interleukin-6 (IL-6) levels in the blood indicate inflammation, which can be used to evaluate the effects of medication on target organs and disease progression [7]. Surrogate biomarkers are substitute clinical endpoints to assess the effectiveness of certain therapies. They forecast clinical benefits based on pathophysiologic, epidemiologic, therapeutic, or other criteria. Clinically employed biomarkers primarily target peripheral system diseases, with limited availability for central nervous system (CNS) disorders due to their low specificity, sensitivity, and validity [8].

Applications of Biomarkers

Biomarkers assess disease progression, screening, risk evaluation, staging, grading, and treatment selection. They possess both advantages and disadvantages, necessitating meticulous evaluation prior to clinical use. Biomarkers may improve diagnosis, prognosis, and treatment; optimal biomarkers facilitate personalised medicine and enhance clinical outcomes. Their extensive use guarantees that patients get effective therapies, reduces superfluous interventions, and decreases healthcare expenses. Biomarkers are crucial for disease diagnosis, staging, and therapy determination. Certain biomarkers possess

CHAPTER 2

Epilepsy: Real-time Monitoring with Biomarker and Biosensor Technology

Sachin Karmakar[1], Tanzeem Nigar[1], Anwesha Das[1], Arijit Nandi[1,2] and **Subhash Chander[3,*]**

[1] *Department of Pharmacy, Sanaka Educational Trust Group of Institutions (SETGOI), Durgapur, West Bengal, India*

[2] *Institute for Molecular Bioscience, The University of Queensland, St Lucia, Queensland, Australia*

[3] *Amity Institute of Pharmacy (AIP), Amity University Haryana, Gurugram, Haryana, India*

Abstract: The chapter titled "Epilepsy: Real-Time Monitoring with Biomarker and Biosensor Technology" introduces the transformative potential of this technology in epilepsy, a neurological disease characterized by recurrent seizures. This chapter focuses on the need for identification of the most pertinent requirement-real-time monitoring systems for seizure-associated biomarker detection, through which timely intervention would be possible. The chapter addresses various biosensor modalities, including wearable devices using electroencephalography, accelerometry, and photoplethysmography to capture physiological signals indicative of seizures. The introduction highlights the enhancement of patient compliance and data accuracy through the hybridization and miniaturization of biosensors. The chapter discusses the possible role of these hybrid theranostic systems in diagnosing and continuously monitoring disease progression in a personalized manner. The chapter also covers the challenges encountered in developing efficient biosensors for epilepsy and proposes directions for future research. By discussing some significant new advancements in biosensing technology, this chapter seeks to engage both scholars and practitioners toward finding novel solutions in the treatment of epilepsy. The promising potential of these technologies to effectively enhance the quality of life for individuals with epilepsy over the long term is well-supported by published scientific studies, highlighting their new translational possibilities for exploration in epilepsy research.

Keywords: Biomarker, Biosensors, Electroencephalography, Epilepsy, Real-time monitoring, Seizure, Wearable devices.

* **Corresponding author Subhash Chander:** Amity Institute of Pharmacy (AIP), Amity University Haryana, Gurugram, Haryana, India; E-mail: schander@ggn.amity.edu

Rajnish Srivastava, Nitin Verma, Naresh Kumar Rangra, Naveen Singh, Sonalika Bhalla & Ankita Thakur (Eds.)

INTRODUCTION

Overview of Epilepsy

The term 'Epilepsy' is inferred from the Greek word '*epilepsia*', which translates to seizure or assault. Since the beginning of human history, seizures and epilepsy have been recognized as prevalent conditions. At first, epilepsy was believed to be a spiritual illness, and the earliest known comprehensive description of epilepsy dates to 2000 BC. It was not until the fifth century BC that Hippocrates' The Sacred Disease described it as a brain ailment [1]. Gene alterations, acute brain injury (such as stroke, trauma, brain tumors, or status epilepticus), infections of the central nervous system (CNS), autoimmune conditions, and metabolic diseases are some of the known causes of epilepsy [2]. The propensity to experience frequent, unprovoked seizures is known as epilepsy. A sudden, overwhelming outburst of electrical activity in the brain that momentarily changes behavior is called a seizure. Neurons create networks with other neurons and exchange neurotransmitters and electrical messages [1]. Neurons and neuronal networks malfunction in epilepsy, resulting in occasionally severe symptoms of seizures.

The structure and function of the brain are inherently susceptible to seizures when exposed to convulsant medications or environmental triggers [3]. This is why people and other animals without epilepsy can have "symptomatic" seizures. Since the epileptic brain produces seizures in the absence of such a trigger, it has structural and/or functional abnormalities that render it vulnerable to voluntary seizures. These abnormalities can even result in varied behavior and/or perception between seizures, as evidenced by the relatively new idea of "Epilepsy Spectrum Disorder" [4]. An ongoing increase in neuronal excitability is the common characteristic of all epileptic syndromes. Trauma, oxygen deprivation, tumors, infections, and metabolic disorders are just a few of the causes that can be linked to abnormal cellular discharges [5]. However, in roughly half of the epileptic patients, no particular cause is identified. The pathophysiological mechanisms and underlying causes of certain types of epilepsy, such as monogenic epilepsies and epilepsies resulting from disorders of neuronal migration, are (partially) understood. Presently available information is only partial for several other forms of epilepsy [6].

Significance of Real-Time Monitoring

Sudden Unexpected Death in Epilepsy (SUDEP) can be decreased in individuals with epilepsy by early detection and warning of an approaching seizure. Present-day remote monitoring seizure detection devices for people with epilepsy have made it possible to enable real-time tracking of critical health indicators

associated with seizure alert notifications [7]. The dynamics and key rhythms of epileptic seizures and activity have been dramatically revealed by chronically implanted intracranial electroencephalography (EEG) systems. However, due to cost and risk concerns, as well as their limited spatial sampling capabilities, these systems are not yet fully operational for widespread use. These devices identify many electrographic seizure patterns that lack obvious behavioral correlates, as well as unreported seizures [8]. Nonetheless, chronic EEG is still essential for the development and validation of stand-alone wearable systems, and this electrographic epileptic activity is extremely applicable to seizure forecasting and epilepsy control [9]. Wearable, non-invasive biosensors have the best chance of immediately meeting the needs of most epileptics. The proliferation of wearable, lightweight sensors is driven by wireless data telemetry, rechargeable battery technology, and the availability of low-cost, miniaturized electronic components [10]. Sensors for continuous, non-invasive photoplethysmography (PPG, measure blood volume pulse signal), electromyography (EMG), accelerometry, electrocardiography (EKG), electrodermal activity (EDA), and skin temperature in a variety of form factors are currently commercially accessible (Fig. **1**) [11 - 13].

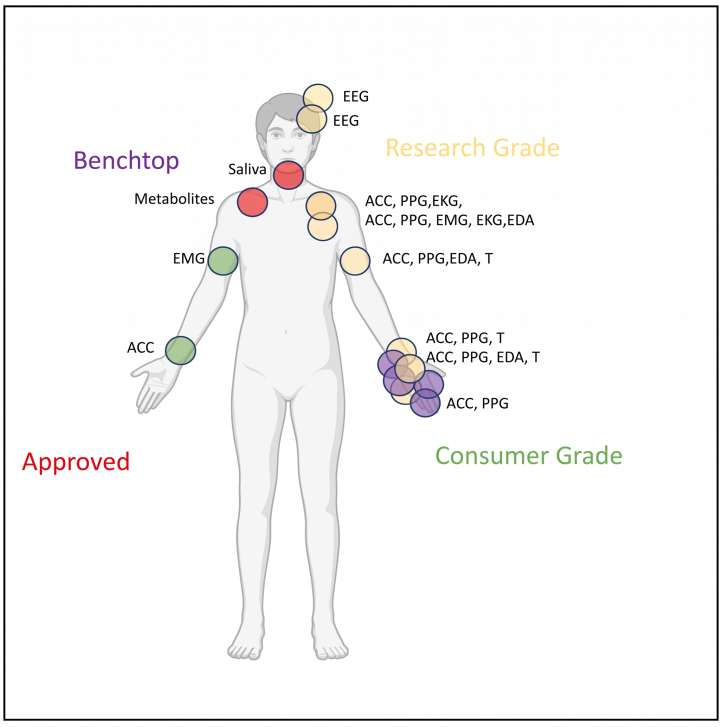

Fig. (1). Different types of monitoring in epilepsy.

CHAPTER 3

Biomarkers and Biosensor Innovations in Multiple Sclerosis

Pratyush Porel[1], Meghna Dhupar[2] and **Khadga Raj Aran[1,*]**

[1] *Department of Pharmacology, ISF College of Pharmacy, Moga, Punjab, India*

[2] *Department of Pharmacy Practice, ISF College of Pharmacy, Moga, Punjab, India*

Abstract: Multiple sclerosis (MS) is an autoimmune disorder characterized by demyelination, axonal loss, and neuroinflammation, primarily affecting the white matter of the brain. This complex pathology leads to neurodegeneration and disruption of neural communication, underscoring the need for effective diagnostic and therapeutic strategies. Recent studies are mainly focused on finding and developing reliable biomarkers and biosensors, which can facilitate early diagnosis, enable continuous monitoring of disease progression, and evaluate the therapeutic efficacy. Based on protein and gene expression, biomarkers in MS can be classified into proteomic, genetic, and imaging biomarkers. Proteomic biomarkers reflect changes in specific proteins associated with axonal damage, neuronal damage, glial cell dysfunctions, and neuroinflammatory processes. While genetic markers, such as HLA-DRB1 alleles, provide insight into MS susceptibility, imaging biomarkers utilize neuroimaging techniques to visualize lesions and structural brain changes. Furthermore, recent developments for blood and cerebrospinal fluid (CSF) analysis, particularly for oligoclonal bands and neurofilament light chain (NfL), have emerged as a critical diagnostic tool. Biosensors, integrating biological components with electronic systems, offer innovative avenues for real-time monitoring of MS biomarkers. These devices can detect specific proteins, metabolites, or inflammatory mediators in bodily fluids, providing a non-invasive approach to track disease activity. The integration of biomarkers and biosensors holds promise for transforming MS management by enabling personalized treatment strategies and improving quality of life. This chapter will focus on recent developments in innovative biomarkers and biosensors that hold promise as theranostic tools for early detection of MS. By enhancing our ability to identify the disease in its initial stages, these advancements could significantly improve patient outcomes and inform timely intervention strategies.

* **Corresponding author Khadga Raj Aran:** Department of Pharmacology, ISF College of Pharmacy, Moga, Punjab, India; Tel: +91-8288979902, E-mail: bishalarann@gmail.com

Rajnish Srivastava, Nitin Verma, Naresh Kumar Rangra, Naveen Singh, Sonalika Bhalla & Ankita Thakur (Eds.)

Keywords: Biosensor, Biomarker, Clinical trials, CHI3L1, CXCL3, Demyelination, Electrochemical biosensors, Glial fibrillary acid protein, Genetic polymorphism, Genomic biomarkers, HLA-DRB1, Multiple sclerosis, Metabolomic biomarkers, Neuroimaging, Neurofilament light chain, Optical biosensors, Oligoclonal bands, Proteomic biomarkers, Rs2104286, Rs987107.

INTRODUCTION

A biomarker is primarily defined as an attribute that could be evaluated to indicate normal physiological mechanisms, pathogenic processes, and sensitivities to exposure or any intervention. The Food and Drug Administration (FDA) has categorized biomarkers into several types: predictive, diagnostic, prognostic, monitoring, and treatment [1]. Over the last decade, researchers have mainly focused on finding and developing reliable biomarkers and biosensors for neurological complications, which can facilitate early diagnosis, enable continuous monitoring of disease progression, and evaluate therapeutic efficacy. An ideal and effective biosensing element is designed by focusing on a non-invasive method with high sensitivity, accuracy, and specificity toward the target [2]. Among the spectrum of neurological disorders, multiple sclerosis (MS) is the most devastating autoimmune disorder, characterized by demyelination, axonal loss, and neuroinflammation, which greatly affects the white matter area of the central nervous system (CNS). Due to its complex pathophysiology, currently, there is an urge to develop effective diagnostic and therapeutic tools, that can address multimodal aspects [3]. Based on the pathology, onset, and progression of the disease, MS biomarkers can be divided into three distinct categories: proteomic, genomic, and imaging biomarkers. According to recent clinical studies, along with CSF-based biomarkers, imaging biomarkers based on McDonald's diagnostic criteria are emerging with promising future outcomes. In addition to modern and sophisticated imaging techniques, such as functional magnetic resonance imaging (fMRI), the clinical practice also relies on oligoclonal bands (OCBs), IgG profiling from cerebrospinal fluid (CSF) sampling, and neurofilament light chain (NfL), which are novel biomarkers for tracing axonal damage [4, 5]. In proteomic biomarkers, kappa free light chains (κFLC), chitinase-3-like-1 (CHI3L1), C-X-C motif chemokine ligand 13 (CXCL13),and glial fibrillary acidic protein (GFAP) are also emerging for clinical implementation [6]. Additionally, the HLA-DRB1 gene remains the most prominent genetic marker, and some cytokine gene polymorphisms, including the rs987107 polymorphism of IL7RA and the rs2104286 and rs12722489 polymorphisms of IL2RA, hold promise to refine the genetic landscape of biomarkers in MS [7]. This chapter focuses primarily on emerging biomarkers and biosensors that are either under development or already integrated into clinical practice. Finally, the chapter concludes with a fruitful discussion that

addresses various challenges and limitations, including ethical considerations and regulatory constraints on the pace of development of novel diagnostic tools in MS.

CURRENT BIOMARKERS IN MULTIPLE SCLEROSIS

Neuroimaging Biomarkers

Biomarkers are designed to detect the expression of various physiological factors, including proteins and genes, through effective analysis of body fluids such as blood, CSF, and saliva. In the context of MS, numerous biomarkers are in high demand for broader clinical applications and are seeking to establish themselves in clinical practice. The applications, advantages, and limitations of using neuroimaging biomarkers are discussed in Fig. (**1**). Among all imaging techniques, MRI and contrast-enhancing lesions are the most important clinical tools for diagnosis and monitoring of MS, enabling critical visualization of hyperintense lesions on proton density- and T2-Weighted MR images [8].

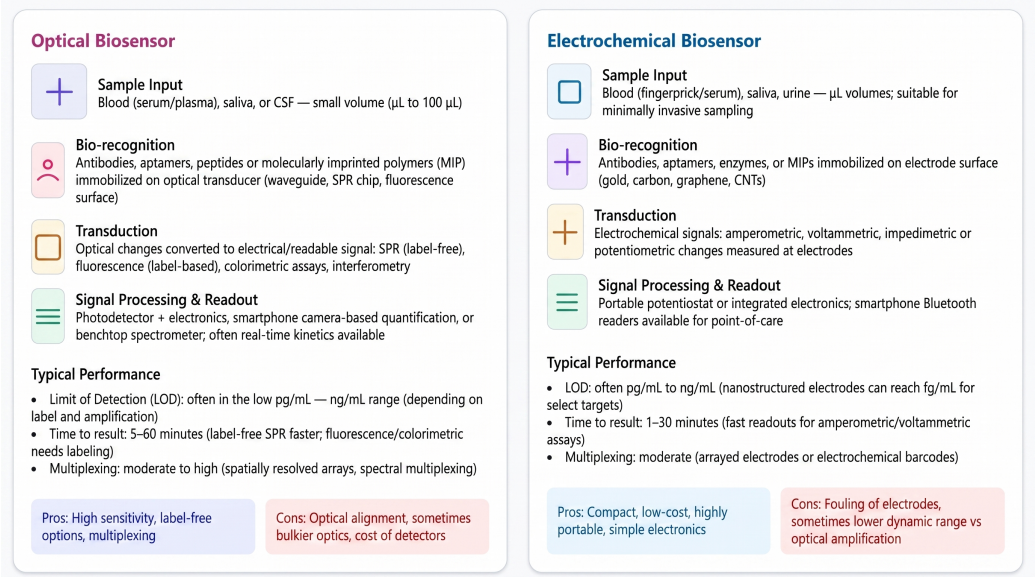

Fig. (1). Schematic diagram comparing optical and electrochemical biosensors for multiple sclerosis.

Hypertense T2-weighed Lesions

Around 85% of young adult-aged MS patients are diagnosed with a prognosis towards clinically isolated syndrome (CIS), which is frequently indicated by white matter lesions on MRI [9]. The literature varies on the relationship between T2-weighted white matter lesion load and clinical impairments as indicated by the

CHAPTER 4

Biosensor and Biomarker Advancement for the Early Detection of Autism

Sumedh Bhat[1], Shilpa Borehalli Mayegowda[1,*] and **Nithya Rao[1]**

[1] *Department of Psychology, School of Psychological Sciences, CHRIST University, Bengaluru, Karnataka, India*

Abstract: Developmental disabilities are severe and have an impact on the mental impairment of an individual, which can be caused by either a physical or mental condition or both. One such neurodevelopmental condition is autism, which can be seen or observed by social communication impairments and repetitive behaviours. Recent advancements in biomarker research for autism spectrum disorder (ASD) show promising results for early detection and improved treatment strategies. Several studies have helped explore various biomarker types, including neuroimaging, genomics, proteomics, metabolomics, and immune system markers. Emerging evidence suggests that ASD-related alterations may follow the hierarchical organization of brain development, with sensorimotor changes potentially preceding social and cognitive impairments. Very recently, nitric oxide has been considered a probable target for ASD drug development. While many biomarkers remain preliminary, they span physiological, neurological, behavioural, genetic, and gastrointestinal domains. Some biomarkers may be detectable before birth or after diagnosis, potentially predicting treatment responses. Combining multiple biomarkers may prove most effective for early ASD identification and personalized treatment guidance. The following chapter will focus on elaborating on these fields of advancement, delving into the depths of exploring ASD.

Keywords: Biomarkers, Cognitive impairments, Gut-brain axis, Neurotransmitters, Neuroinflammation.

INTRODUCTION

ASD is a multifaceted neurodevelopmental form, with its hallmark symptoms comprising the occurrence of monotonous activities and challenges with social communication. Its global prevalence has been rising, with current evaluations signifying that about one out of 36 kids in the USA suffers from this disorder [1].

* **Corresponding author Shilpa Borehalli Mayegowda;** Department of Psychology, School of Psychological Sciences, CHRIST University, Bengaluru, Karnataka, India; Tel: +91-90385 61307;
E-mail: shilpa.borehalli@christuniversity.in

Rajnish Srivastava, Nitin Verma, Naresh Kumar Rangra, Naveen Singh, Sonalika Bhalla & Ankita Thakur (Eds.)

It is critical that ASD is identified at an early stage, as this enables early interventions that have proven effective in improving developmental pathways, cognition, and adaptive abilities [2]. Although early diagnosis is essential, current clinical assessment largely relies on observational behaviour, which is inherently subjective and often leads to late diagnoses. Researchers have been exploring the use of various biomarkers as objective indicators of ASD, with the potential to enhance diagnostic accuracy and enable earlier diagnosis to address this problem [3]. Biomarkers are measurable indicators of biological or physiological processes and play an essential role in advancing precision medicine for ASD. Several categories of biomarkers, including neuroimaging, genetic, metabolic, immune, and microbiome-based markers, have been investigated for their diagnostic potential [4]. These biomarkers open a window to the pathophysiology of ASD and potential treatment targets. Biosensor technology is a highly convenient and, to date, efficient means of biomarker detection. Biosensors are analytical devices that convert biological interactions to signals that can be measured, providing real-time, non-invasive diagnosis. The newer technologies in biosensing, *i.e*., wearable biosensors and electrochemical sensors, have been promising in the detection of ASD biomarkers [5]. The application of artificial intelligence (AI) in combination with biosensors also enhances diagnostic precision using computer-based pattern recognition and decision-making based on biodata [6].

Developmental abnormality or disability refers to a severe and permanent impairment of an individual, which can be caused by either a physical condition, a mental condition, or a combination of both. This impairment generally occurs during the developmental stage and is most likely permanent, resulting in severe limitations in occupational functioning, social interactions, and daily living [7, 8]. This condition affects approximately 2.3% of the United States population, with a range of 8 to 10 years, and approximately 2.2% of the adult population [9]. ASD is a compilation of collection of numerous diverse disorders comprising “Asperger's Disorder, Pervasive Developmental Disorder and some autistic disorders with few development factors including age and IQ of an individual, along with environmental factors (such as availability and access to individualized educational, speech, language, and behavioural therapies), both contribute to the obscurity and variability of ASD. In spite of the presenting symptoms of ASD being neurologically based, these symptoms often manifest in the individual’s behaviour that tends to vary based on their age, sex, linguistic capabilities, and intellectual abilities [10]. This condition can also be described as decreased responsiveness during interactions and the occurrence of repetitive behaviours, such as not responding when their name is called, hand flapping, and arranging toys in a specific order [11].

CURRENT CHALLENGES IN ASD DIAGNOSIS

Despite its desirability, it is challenging to diagnose ASD in a timely and precise manner. Some of these challenges occur due to shortcomings in the current diagnostic criteria and standardised tools for assessment [12]. Although at present a stable diagnosis of ASD can typically be made between 20 and 24 months of age, there is often a significant delay between when parents first notice signs, the official diagnosis, and the initiation of intervention. While ASD can be heritable, there is no precise biological indicator for the existence of ASD, nor has a specific, identifiable gene been identified. The sharp increase in ASD cases cannot be attributed solely to developments in the identification process. A more comprehensive understanding requires the simultaneous examination of the interactions and connections among individual attributes and genetic and environmental influences [13]. Currently, ASD identification depends on specific criteria which have been designed by DSM-5 by the American Psychiatric Association. These criteria include the developmental history of the affected child, behavioural observations, and cognitive functioning [14]. Autism has raised broad interest among researchers because of its lifelong hindrance as a disorder, and the lack of a permanent cure until now. Underlying diagnostic characteristics or features are present in the development phase, but some signs may be masked or hidden by treatment, compensation, intervention, or special aids. Therefore, ASD can still be primarily diagnosed through symptoms classified within the specific learned skill and behavioural parts supported by the child's learning trained by he/she caretaker. There is a lack of documentation of females suffering from autism, which occurs as ASDs may go overlooked, misdiagnosed, or identified and further diagnosed at a later stage. Limited information exists regarding the course and distribution of ASD symptoms across different points in the lifespan [15]. Signs of ASD and related challenges with daily functioning usually appear in a child's early development. However, with the right support and interventions, a child's behaviour and communication can improve.

A study by Mottron [16] suggests that the challenges contribute to the extreme variability with an unexpectedly high risk, which generally tends to hamper research progress. Frith [17] re-emphasises that the DSM-5 criteria pose challenges to research, particularly with the involvement of participants, and the "elastic" conceptualisation of ASD that distorts the lines among different difficulties. Muskens *et al*. [18] showed a significant correlation between ASD and the severity of symptoms and GID frequency. They highlight the fact that individuals who have ASD and find it difficult to verbally convey their pain and symptoms often display disruptive behaviours, which can be concealed along with medical challenges and prevent their somatic conditions from being detected.

CHAPTER 5

Application and Advancements of Biosensor Technology in the Diagnosis of Depressive Behaviour

Priyanka Rani[1], Bibhu Prasad Nanda[2], Aman[3] and **Rohit Bhatia[4,*]**

[1] *Faculty of Pharmaceutical Sciences, DAV University, Jalandhar, Punjab, India*

[2] *Analytical R&D, NAARI Pharma Pvt. Ltd., Rudrapur, Uttarakhand, India*

[3] *Department of Pharmaceutical Chemistry, ISF College of Pharmacy and Research, Moga, Punjab, India*

[4] *Chitkara College of Pharmacy, Chitkara University, Rajpura, Punjab, India*

Abstract: Biosensor technology is fast becoming an innovative device for the diagnosis and treatment of depressive behavior, with the ability to conduct real-time, accurate monitoring of mental health biological markers. Such biosensors are concerned with key biomarkers such as cortisol, serotonin, and brain-derived neurotrophic factor [BDNF] that are related to stress and mood regulation. The most widely used biosensors in this field include electrochemical, optical, and wearable devices for monitoring biochemical alterations exclusive of depressive diseases. Non-invasive monitoring is currently attracting interest for continuous surveillance of shifts in mood patterns and their treatment outcomes. Wearable biosensors are becoming increasingly popular because they can enable remote, tailored healthcare by allowing clinicians to view real-time feedback regarding patients' physiological and psychological conditions. Many challenges persist despite existing advances. They include the heterogeneity of mental illnesses, the need for multi-biomarker combinations, and the verification of sensor sensitivity and accuracy in the field. Also, ethical factors surrounding the privacy and security of data pose additional obstacles to large-scale applications. Near-term progress in biosensor technology will involve using artificial intelligence to enhance information analysis and developing multifunctional biosensors that can simultaneously screen for more biomarkers. These technologies are poised to revolutionize mental care by enabling early detection of illness, personalized treatment regimens, and real-time surveillance. The article describes the widening use of biosensors in diagnosing and treating depression and how they are used in modern medicine to uncover an auspicious direction for improved, targeted, and patient-focused mental health treatment.

[*] **Corresponding author Rohit Bhatia:** Chitkara College of Pharmacy, Chitkara University, Rajpura, Punjab, India; E-mail: bhatiarohit5678@gmail.com

Rajnish Srivastava, Nitin Verma, Naresh Kumar Rangra, Naveen Singh, Sonalika Bhalla & Ankita Thakur (Eds.)

Keywords: Biosensors, Biomarkers, Brain-derived neurotrophic factor, Electrochemical, Neurotransmitters.

INTRODUCTION

Depression is a complex psychiatric disorder characterized by long-term sadness, restlessness, and impairment of daily functioning [1]. Depression, once largely considered a problem only in adults, has come to be a major issue in all age groups, including teenagers and children [2]. This mood typically lasts for many years, significantly influencing an individual's day-to-day functioning, relationship with others, and perception of the world and self [3]. The COVID-19 pandemic, in particular, has experienced an unforeseen rise in the diagnoses of depression, and the issue is symptomatic of a call for a broad mental health policy [4]. The 2019 disability-adjusted life-year rates caused by depression and anxiety, age-standardized for the whole world, were 585 and 359 per 100,000 population, respectively, which accounted for the two biggest rates of mental disorder-attributable disability-adjusted life years [5]. In 2023, depression was found to be prevalent at 5% globally, and 4% of the population had anxiety disorders. Furthermore, 18.4% and 33.7% of the population will be likely to have depression and anxiety, respectively, in their lifetime [6, 7]. By the year 2030, as estimated by the World Health Organization, depression is going to be the second most disabling health condition, affecting 280 million adults worldwide [8]. The economic and social burden of depression is high, associated with increased absenteeism, reduced productivity, and an increased risk of enduring physical health issues. The combined economic burden, in terms of healthcare costs and lost productivity, will exceed trillions of dollars per year [9].

Early and proper detection of depression is fundamental to proper treatment and management. The earlier one detects depression, the earlier patients can receive the appropriate care, reducing the risk of the condition advancing and resulting in worse outcomes [10]. If not treated, depression can ruin a person's physical health, emotional state, and general quality of life [11]. It can also lead to the development of secondary issues like drug addiction, increased risk for suicide, and the development of other mental illnesses [12]. Diagnosis is of utmost importance since depression often co-occurs with other illnesses like anxiety, bipolar disorder, or even bodily illnesses, so it is tough to diagnose without extensive assessment [13]. In addition, early intervention allows for more tailored treatment, increasing long-term recovery and decreasing the risk of future occurrence [14]. Studies point out that immediate treatment not only reduces present symptoms but also allows individuals to recover functioning in personal, social, and occupational life [15].

Early diagnosis can even avoid the chronicization of depression. Research has shown that depression without treatment is more likely to be a recurrent disorder, making it a long-term burden for individuals as well as for healthcare systems [16, 17].

The Application of Biosensor Technology in Diagnosing Mental Illnesses

Biosensor technology is used to diagnose depression because it presents objective, real-time information regarding physical changes associated with mood disorders. Unlike other older methods, such as self-reports or clinical interviews, which may be biased and based on personal experiences, biosensors present a more straightforward and quantifiable way of understanding depression states. They assist in the following ways :

Physical Cues Monitoring: Biosensors track reduction in heart rate, body temperature, skin conductance, and brain activity, which are susceptible to the effects of depression. For example, reduced heart rate variability and disturbed skin conductance are common in people suffering from depression.

Real-time Tracking: These devices continuously monitor physiological signals, providing amore accurate, real-time view of a person's emotional state. This can help monitor depression over time and measure responses to treatment.

Objective Diagnosis: Instead of relying just on self-reports, biosensors measure physical markers, helping doctors diagnose depressive behaviors more objectively and reducing the impact of bias or inaccurate reporting.

Integration with AI for Early Detection: When combined with AI, biosensor data can be analyzed to detect patterns or early signs of depression, potentially before symptoms become clinically noticeable. AI algorithms can predict depressive episodes based on changes in physiological data, providing proactive intervention.

Non-invasive and Wearable: Most biosensors are non-invasive and can be worn continuously, allowing for long-term monitoring. This enables healthcare providers to gather more comprehensive data on an individual's mental health, leading to more personalized treatment plans [18 - 20].

Fundamentals of Biosensor Technology

A biosensor is an analytical device that detects biological substances, converting their presence into measurable signals. It combines a biological component (bioreceptor) with a physicochemical detector (transducer) to provide quantitative data on specific biological interactions. The core principle involves detecting a

CHAPTER 6

Data Analytics and Machine Learning in Biosensor-Based Neurological Disease Diagnostics

Debajyoti Roy[1], Maitrayee Ghosh[2] and **Alok Kumar Agrawal[3,*]**

[1] *Faculty of Pharmacy, C.V. Raman Global University, Bhubaneswar, Odisha, India*

[2] *Amity Institute of Pharmacy, Amity University, Noida, Uttar Pradesh, India*

[3] *Chitkara University School of Engineering and Technology, Chitkara University, Baddi, Himachal Pradesh, India*

Abstract: Biosensors have developed to be an indispensable technology for capturing dynamic biochemical and biophysical signals, and to provide unprecedented access to the molecular signatures of neurologic disorders. In this chapter, we provide an overview of data analytics and machine learning (ML) approaches in analyzing data derived from biosensors for neurologic disease diagnosis and monitoring. We begin by describing various types of biosensors, such as electrochemical, optical, and others, to point-of-care and rapidly detect major neurologic biomarkers. We then discuss advanced signal processing strategies, such as strategies for noise reduction, feature engineering, and data fusion to transform raw sensor outputs to clinically valuable information. We then discuss various ML models, such as standard supervised models to deep learning models, that have been used to classify disease states, predict disease progression, and enhance diagnostic sensitivity. The chapter also describes case studies on successful implementations in Alzheimer's and Parkinson's disease. Finally, we discuss current limitations such as data quality, interpretability, and clinical workflow incorporation, and provide future directions for future studies. The transdisciplinary overview underscores the disruptive potential of combining biosensor technology and computational analytics to provide precision neurologic diagnostics.

Keywords: Alzheimer’s, Biosensors, Machine learning, Neurological biomarkers, Parkinson's.

INTRODUCTION

Neurological disorders such as Alzheimer’s disease (AD), Parkinson’s disease (PD), and other neurodegenerative diseases are an ever-growing worldwide health threat. The worldwide incidence of such disorders sharply increased in recent decades, thanks to population aging and diagnostic technologies, paradoxically,

* **Corresponding author Alok Kumar Agrawal:** Chitkara University School of Engineering and Technology, Chitkara University, Baddi, Himachal Pradesh, India; E-mail: alok.agrawal@chitkarauniversity.edu.in

Rajnish Srivastava, Nitin Verma, Naresh Kumar Rangra, Naveen Singh, Sonalika Bhalla & Ankita Thakur (Eds.)

revealing ever larger numbers of affected individuals than in former times [1, 2]. Early and accurate diagnosis is universally recognized to be vital for successful treatment of disease, to allow clinicians to treat individuals in their preclinical or initial symptomatic phases and, in theory, to slow disease progression and ensure quality of life. Current diagnostic practices, however, tend to invoke combinations of neuroimaging, invasive sampling of biomarkers, and comprehensive neuropsychological testing, and are both costly and, in most health settings, unavailable for general population screening. Traditional diagnostic modalities in neurology include magnetic resonance imaging (MRI), positron emission tomography (PET), and cerebrospinal fluid (CSF) analysis. These modalities, though having good sensitivity and specificity, have several limitations. The neuroimaging modalities, though in most settings non-invasive, have expensive equipment and specialized personnel, and therefore have long waiting lists and excessive health expenditure [3]. Similarly, CSF analysis is carried out through lumbar punctures, whose accompanying dangers and discomfort to patients cannot be disregarded. Further, the interpretation of such diagnostic modalities is prone to variability and is subject to practitioners' skill. Such limitations suggest an imperative for cost-effective and low-cost diagnostic modalities, whose use is possible in point-of-care settings. Over the past 10 years, biosensor technology has become an innovative platform for medical diagnosis. Biosensors comprise an analytical sensor in which a physicochemical detector is coupled to a biological recognition component to analyze biomarkers in real time [4]. Various types of biosensors, including electrochemical, optical, and piezoelectric sensors, have developed to detect unique proteins, nucleic acids, and other molecules implicated in neurodegenerative diseases. For instance, electrochemical biosensors analyze amyloid-beta or tau protein content, which is vital in detecting Alzheimer's disease in initial phases, while optical biosensors ensure rapid and label-free detections [2].

The advantages of diagnostic tools in biosensors are multifaceted. These include their capability to offer rapid response, low-sample requirements, and their ability to monitor constantly through wearable systems. Furthermore, their use in transportable systems makes them highly sought for health facilities in decentralized settings where laboratory facilities are unavailable. These technologies are not only minimizing diagnostic procedure cost but also allowing for continual monitoring of patients and individual treatment regimens. Despite the prospects offered by biosensors, their raw data is cumbersome and high-dimensional. Biosensor signals might also be affected by extraneous signals, including environmental noise and signal drift, and variability in their source, and thus direct interpretation is rendered challenging [5]. The application of advanced data analytics comes in. Signal filtering, elimination of noise, and feature extraction are crucial in order to transform raw sensor outputs to clinically useful

data. For example, time-frequency analysis and wavelet decomposition have been employed in extracting diagnostic signals from sensor data while eliminating extraneous signals, hence making the measurement reliable [6].

Moreover, data fusion strategies, such as sensor fusion, allow for the fusion of data collected by multiple biosensors to provide an integrated representation of the physiological status of the patient. The integrated representation may disclose hidden correlations between disparate biomarkers, and hence improve diagnostic sensitivity. Machine learning (ML) is becoming an indispensable tool for analyzing advanced biomedical data. In neurologically diagnostic contexts for use in biosensors, ML models predict disease states and disease progression, and identify novel biomarkers in sensor data of high dimensions [5]. The conventional supervised learning methods, such as SVM and random forests, have proved to be effective in identifying and discriminating between several neurologic disorders using outputs from biosensors [1]. The recent deep learning models, such as, in particular, convolutional neural networks (CNNs), have proved to have excellent capabilities in analyzing imagery data and time-course biosensory signals, extracting in an automated way subtle patterns in them, and pointing to potential signs of disease in their initial phases [3].

For example, recent studies have shown that models developed on CNNs have been able to discriminate accurately between Alzheimer's patients in their early stages and healthy individuals on profiles of biomarkers derived from biosensors, and their performance is on par with what is achieved using conventional neuroimaging [6]. In addition, ensemble learning approaches have also been used to improve diagnostic models' robustness and generalizability to diverse patient populations. These innovations showcase the ability of ML to improve diagnostic precision, but also to provide individualized treatment regimens through the application of real-time data derived from biosensors. The convergence of biosensor technology, advanced data analytics, and machine learning represents a paradigm shift in the field of neurological diagnostics. This integrated approach—often referred to as “precision diagnostics”—aims to deliver tailored healthcare solutions that are based on the individual’s unique molecular and physiological profile [2]. By continuously monitoring biomarkers *via* wearable biosensors, clinicians can detect subtle changes in a patient’s condition before clinical symptoms become apparent. Machine learning algorithms further enhance this process by providing rapid, automated interpretation of complex data, thus enabling early intervention strategies that are both cost-effective and scalable [5].

For instance, a multi-modal diagnostic system that combines biosensor data with ML-driven analytics has been shown to predict the onset of Parkinson’s disease with high sensitivity and specificity [1]. Such systems are also being explored for

CHAPTER 7

Ethical, Legal and Social Implications of Biosensors in Neurological Disorders

Neha Kanojia[1], Komal Thapa[1,*], Hurmat Khan[1], Jatin Kumar[1] and **Aruna Sharma[1]**

[1] *School of Pharmacy, Chitkara University, Baddi, Himachal Pradesh, India*

Abstract: Biosensors have many advantages and disadvantages in diagnosing and treating neurological conditions. These tools improve early diagnosis, individualized treatment plans, and patient care by accurately monitoring neurological biomarkers. But using them brings up many ethical, legal, and social issues (ELSI) that need to be carefully thought through. Patient autonomy, informed consent, data privacy, and the possibility of excessive reliance on technology are the main ethical issues. Legal concerns include intellectual property rights, responsibility for device malfunctions, and biosensor regulation. Social implications include the possibility of misuse in domains such as monitoring, social acceptance of biosensor-based interventions, and inequalities in access. This study examines the various ELSI aspects of biosensor technology for neurological conditions, highlighting the necessity of a well-rounded approach to innovation that protects patient rights, encourages fair access, and guarantees responsible development and implementation.

Keywords: AI-driven technology, Biosensors, Ethical implications, Legal considerations, Neurological disorders.

INTRODUCTION

Globally, neurological conditions are responsible for a growing number of disabilities, particularly in developed nations. The three most common causes of neurological disorders are multiple sclerosis, Parkinson's disease, and Alzheimer's disease [1]. Clinical examination, imaging, and biomarker analysis are the primary methods used to diagnose the three disorders, which share neurodegenerative and neuroinflammatory characteristics. Progressive episodic memory loss that results in notable behavioural alterations is the hallmark of Alzheimer's disease (AD) [2, 3].

[*] **Corresponding author Komal Thapa:** School of Pharmacy, Chitkara University, Baddi, Himachal Pradesh, India; E-mail: komalthapa@chitkarauniversity.edu.in

Rajnish Srivastava, Nitin Verma, Naresh Kumar Rangra, Naveen Singh, Sonalika Bhalla & Ankita Thakur (Eds.)

A histological diagnosis of AD is definitive, but a clinical evaluation is the sole way to diagnose probable or suspected AD dementia [4]. Additionally, positron emission tomography (PET) is also a valid indication of the causative process of AD [5]. The presence of amyloid plaques (neurofibrillary plaques) in the brain has historically been linked to AD disease. These findings are observed in the CSF. The formation of toxic oligomers (AβO), which in turn cause synaptic dysfunction and neuronal cell death, is thought to result from an imbalance between the generation of Aβ1−42 [by γ and β-secretase 1 (BACE1) cleaving amyloid precursor protein] and its clearance, which causes amyloid plaques [6]. Increased synthesis of Aβ1-42 promotes the formation of amyloid plaques in dominant hereditary types of AD (including mutations in γ-secretase subunits, PSEN1 and PSEN2), whereas poor Aβ clearance is the primary cause in sporadic AD [7, 8]. A movement disorder with the clinically identifiable trio of motor symptoms—bradykinesia, or "slow movement," along with resting tremor and/or rigidity that is first limited to one limb or hemibody before gradually spreading to the rest of the body—is caused by the ensuing striatal dopamine shortage. Nevertheless, Parkinson's disease (PD) is also associated with alterations such as sleep, psychiatric/cognitive disorders, hyposmia, and dysautonomia that contribute to total impairment and may occur before motor dysfunction [9]. These most likely show how α-syn aggregates are distributed throughout the neurological system. The only way to diagnose PD is clinically. Standard clinical practice does not analyze biomarkers, such as α-syn, in serum or CSF. However, PD is known to have neuropathological characteristics of α-syn aggregates in particular brain areas [10].

The cause of multiple sclerosis (MS), a chronic inflammatory demyelinating disease of the central nervous system, is unknown, although environmental factors and genetics may play a role [11]. Initial symptoms vary depending on which part of the central nervous system is impacted. Clinical or radiographic evidence of lesion propagation throughout time and/or space is necessary for the diagnosis of multiple sclerosis. Serum and CSF tests help rule out other diseases, but magnetic resonance imaging (MRI) is the standard diagnostic method. Although it is not MS-specific, the presence of CSF-restricted oligoclonal bands (OCBs) aids in the diagnosis of MS [12]. Systemic inflammatory disorders with CNS expression, CNS infections, and certain hereditary disorders are among the other diseases that have CSF-restricted OCBs [14]. Even though the trigger for inflammation may be unique for each of the previously mentioned diseases. One important step in these neuroinflammatory processes is the activation of microglial cells. Microglia perform immune surveillance tasks in healthy conditions, but they alter their shape and transcriptome profile to repair tissue in response to infection or tissue damage [15]. Microglial cells use pattern recognition receptors, such as TREM2, to identify environmental cues that tell them to start inflammatory responses.

Accuracy in diagnosis and prognosis may be improved by analysing inflammatory profiles in conjunction with traditional disease-specific biomarkers, neurotoxicity, and, eventually, death of neurons [16].

Biomarkers of Neurodegeneration and Neuroinflammation

A lot of work has been done in recent years to find biomarkers associated with CNS disorders in clinically relevant samples. A measurable, physiologically plausible quantity that typically serves as an indicator of an underlying illness mechanism is called a biomarker [17]. To enable disease risk categorization, the perfect biomarker should also be easily available, extremely sensitive, and specific, and its levels should correspond with the course of the disease and/or the response to treatment [18]. The Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve, which plots sensitivity against (1-specificity), is a helpful indicator of the ideal cut-off point selection [19]. According to recent research, the accuracy of disease diagnostic tests is increased when numerous biomarkers are combined because this raises the AUC value [20, 21]. However, the majority of this biochemical profiling has been based on liquid chromatography-mass spectroscopy and microarray technologies, which are not appropriate for point-of-care testing, even though they are good for evaluating huge biomarker panels. Conversely, the low concentrations of possible biomarkers in the test fluid and their intrinsic variability among control and patient samples frequently make it difficult to identify and validate them. New methods with higher sensitivity and lower limits of detection (LOD) are therefore required [22, 23]. Fig. (**1**) shows various biomarkers used in neurodegenerative disorders.

Clinical Implications of Biomarkers

Bipolar disorder and schizophrenia have been shown to have impaired brain metabolism using this method [24]. However, to distinguish between healthy and pathological states, clinicians normally use a conventional set of blood analytes, such as gases, ions, metabolites, enzymes, and antigens/antibodies, which capture only a small portion of the information found in the global bionome. A far more comprehensive bionic signature that records worldwide biochemical changes in well-being, disease, and medication may soon replace such a limited blood analysis [25]. A well-chosen multiparameter diagnostic should improve the test's specificity and sensitivity. A diagnostic test based on serum was just established to help confirm a diagnosis of schizophrenia, namely, “Algorithm development for diagnostic biomarker assays” by Izmailov *et al*. and “The application of multiplexed assay systems for molecular diagnostics” by Schwarz *et al*. The Luminex xMAP technology, a multiplexed immunoassay platform, was used in

SUBJECT INDEX

E

F

G

H

I

L

M

N

O

P

R

S

T

U

V

W

X

Rajnish Srivastava

Dr. Rajnish Srivastava is a Professor at the Chitkara University School of Pharmacy, with expertise in regulatory toxicology, nanostructured drug delivery, and preclinical pharmacology. His research emphasizes advanced drug delivery systems and novel therapeutic strategies for neurological, metabolic, and dermatological disorders. He has published extensively, holds several patents, and serves as a reviewer for numerous international journals.

Nitin Verma

Dr. Nitin Verma is Professor and Principal at the Chitkara School of Pharmacy, Chitkara University. With over 23 years of academic, research, and administrative experience, his work focuses on toxicology, chemical risk assessment, PFAS, and computational toxicity. He has published widely, contributed numerous book chapters, and received several prestigious national and international awards.

Naresh Kumar Rangra

Dr. Naresh Kumar Rangra is an Associate Professor at Chitkara University, Himachal Pradesh, and Program In-charge of M.Pharm. (Pharmaceutical Chemistry). He also heads the Chitkara University Central Sophisticated Instrumentation Facility. His research focuses on natural products, medicinal chemistry, pharmaceutical analysis, and nanoformulations for therapeutic applications. He has received several academic awards and actively contributes as a reviewer, resource person, and researcher.

Naveen Singh

Mr. Naveen Singh is a Junior Research Fellow at the Chitkara School of Pharmacy, Chitkara University, pursuing a Ph.D. in Pharmaceutical Sciences. His research interests include neuropharmacology, phytopharmacology, environmental toxicology, and diabetes-related complications. He has published research articles, book chapters, and holds multiple patents.

Sonalika Bhalla

Ms. Sonalika Bhalla is a Junior Research Fellow at the Chitkara School of Pharmacy, Chitkara University, and a Ph.D. scholar in Pharmaceutical Sciences. Her research focuses on neuropharmacology and analytical techniques. She has authored research and review articles, conference papers, and book chapters.

Ankita Thakur

Ms. Ankita Thakur is a Junior Research Fellow at the Chitkara School of Pharmacy, Chitkara University. A Gold Medalist in Pharmaceutics, her research focuses on nano-based drug delivery systems to enhance drug solubility, stability, and bioavailability. She has published research papers and contributed book chapters.