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Neuroengineering for Healthcare: Insights, Obstacles, and Potential Funding Sources for Biomedical Engineering Projects

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Abstract:
Neuroengineering is an emerging field that holds the promise of revolutionising healthcare with new diagnostic and therapeutic technology. The convergence of neuroscience and biomedical engineering is leading the way for some of the most exciting advances in medicine today. The use of engineering practices within the complex structure of the human nervous system is helping to advance the treatment of formerly untreatable neurological illnesses. Many common barriers to innovation, including lack of understanding, increasing regulatory burdens, and lack of funding, prevent progress. The rapid emergence of new technology helps us understand how to innovate and learn from our colleagues in other fields. This review discusses recent advances in neuroengineering technologies and potential funding for biomedical projects. Overcoming translational barriers with integration of disciplines and technological innovation will be key to future success.

Keywords: Neuroengineering, neuroscience, biomedical engineering, healthcare.

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INTRODUCTION

Neuroengineering has emerged as a key interdisciplinary field to address the challenges in the healthcare sector by combining principles from neuroscience, engineering, computational modeling, and advanced technologies (D'Angelo and Jirsa, 2022; Xiong *et al.*, 2023). Neuroscience involves the study of the nervous system from a biological perspective, through psychology, to the combination of biology and computer science. As we probe more deeply into the complexity of the brain, we uncover insights that can revolutionize everything from medicine to computer technology and our understanding of human nature (Asif *et al.*, 2024; Mohammadi *et al.*, 2024; Rolls, 2026). Brain imaging is an innovation of the current age that has transformed how psychologists understand the brain. Brain imaging techniques, including functional magnetic resonance imaging (FMRI), positron emission tomography (PET), and Magnetoencephalography (MEG), have all been used in recent years to identify areas of the brain responsible for certain cognitive functions such as language centres in the brain (Mohammadi *et al.*, 2024). Neuroscience can help us to unravel the mechanisms of mental health disorders like depression, anxiety, schizophrenia and autism spectrum disorder through the development of better intervention strategies. The most exciting advances in Neuroscience have been in our understanding of brain plasticity, or the brain's capacity to change its wiring across the lifespan. This provides the basis for continual learning and recovery from brain injury (Gordon *et al.*, 2024; Mohammadi *et al.*, 2025).

Biomedical research is a complex, time-intensive endeavour that unfolds in multiple stages, including basic research, clinical trials, and the eventual transition to market-ready solutions (Iqbal, 2021; Kilic, 2026a; Kilic, 2026b; Rahman *et al.*, 2020). Biomedical engineering offers a wide range of applications, including the production of wearable technology and prosthetic limbs. It may enhance the healthcare system, resulting in more sophisticated and practical treatments and accurate diagnostics. It is frequently unclear, little acknowledged, and poorly understood how important biomedical engineering is in hospitals. The absence of a single acknowledged title is partially to blame for this. There are many other names for biomedical engineering, including clinical engineering, electrical and biomechanical engineering, rehabilitation engineering, and many more. The terms Medical Engineering Technician and Clinical Biomedical Engineer have been used more recently. Currently, there isn't a unified framework that makes it possible to analyse this workforce nationally or grow these positions. Employees may report directly to clinical services like renal dialysis services or rehabilitation and enablement services, or they may be handled within an estate and facilities department, a medical physics department, or a clinical engineering department (Jones and Nazarpour, 2018; Pandian *et al.*, 2024).

Neuroscience innovations and biomedical engineering

The convergence of bioengineering, neurotechnology, and computational neuroscience, collectively termed neuroengineering, offers promising solutions to repair circuits, restore function, and enhance quality of life (Iskusnykh *et al.*, 2022; Ranasinghe *et al.*, 2024). Advances in neuroscience continue to reshape the management of cerebrovascular disease, neurodegenerative disorders, epilepsy, movement disorders, neuroimmunology, neurocritical care, and neurological rehabilitation. Key innovations in neuroscience center on advanced mapping and recording tools, brain-computer interfaces (BCIs), AI integration (NeuroAI), cell-type and circuit atlases, neuromodulation techniques, and applications to neurological disorders (Pajo, 2025).

Neuroscience has transformed medicine and made significant progress in tackling mental illness, cognitive impairment, and neurological diseases. Imaging technologies such as MRI and the more specific functional MRI (fMRI) scan reveal activity within the brain in real time and have been used to improve diagnosis and treatment of conditions like Alzheimer's disease, epilepsy, and brain cancer. Neurotechnology

and artificial intelligence (AI) are paving the way for innovations in brain functions, with brain-computer interfaces providing hope for patients who suffer from paralysis. The scope of applications is not limited to medicine. The science of learning and memory is informing instructional practices in education (Hasan *et al.*, 2025; Onciul *et al.*, 2025).

During the past two decades, biomedical engineering has become a significant field that connects the advancement of new technology with the demands of human health care. The capacity to monitor human health in both non-invasive and invasive ways is currently available in every medical facility, albeit to differing degrees of complexity. The various scales at which human physiology may be examined offer a deep understanding of health and illness (Subramaniam *et al.*, 2024). Biomedical engineering is very important in enhancing healthcare resources through the design of healthcare applications, diagnostic equipment, and electronic health applications. The biomedical engineering industry is an important prospect that can decrease the reliance on imported medical technologies, expand access to healthcare, and induce the development of a high-value industry. Nonetheless, concurrent with the increase in healthcare need and the technological demand, the sector is undeveloped because of both structural and financial limitations. Funding for biomedical research may be drawn from a diverse array of sources. Biomedical research is a key component of innovation and advancement in the rapidly evolving field of health and medicine (Neema and Chandrashekar, 2021).

Financing the healthcare sector

The healthcare sector is among the most vital components of any economy, heavily shaped by the prevalence and management of various illnesses (Ashraf and Iqbal, 2022; Iqbal, 2022; Iqbal *et al.*, 2019; Iqbal *et al.*, 2021; Kilic, 2026a). Nevertheless, it encounters distinct challenges regarding financing (Alkhatib and Darabseh, 2025). Healthcare providers, including hospitals, clinics, nursing homes, and medical practices, necessitate significant funding to sustain and enhance their facilities, acquire medical equipment, and employ qualified professionals. Furthermore, ongoing working capital is essential to oversee daily operations and guarantee high-quality care for patients (Hanson *et al.*, 2024; Nair *et al.*, 2024). Healthcare financing refers to the mobilisation and allocation of funds for the health system to meet the healthcare needs of the population (Etienne *et al.*, 2010). There is no single best way of financing healthcare, and the methods used to finance healthcare are influenced by the political, cultural, social and economic factors of each country (Kutzin, 2013). In the fast-paced environment of healthcare, hospital administrators play a critical role in directing funds that affect the quality of care patients receive and the overall efficiency of medical facilities. The purchase of new gadgets, establishment of diagnostic areas, and expansion of clinics are important investments, but administrators also need to appreciate the importance of spending on other critical areas that can promote medical excellence and encourage optimal patient outcomes. Investing in patient-centric programs can greatly enhance patient satisfaction and the overall healthcare experience (Pradhan *et al.*, 2024).

In a time characterized by swift progress in medical technology and rising expenses, novel financing models in health care can play a crucial role. Financial innovation serves as a vital yet underutilized resource that can be leveraged to enhance humanitarian efforts in crises, while simultaneously fortifying public health systems for the future (White, 2001). AI transforms hospital financial planning and budgeting by processing and interpreting enormous volumes of health data. This new wave of technology integration promises to manage healthcare resources with previously unheard-of accuracy and efficiency. Hospitals can now estimate patient intakes, optimise personnel, and manage inventory with previously unachievable precision by utilising AI's analytical capabilities. This improves overall patient care quality and results in cost savings. Additionally, AI-driven systems play a crucial role in spotting patterns in patient care, which helps hospitals better distribute funding to

regions that need the greatest care (Sallam *et al.*, 2023).

Key strategies for financing biomedical projects in the healthcare sector

Access to the right financing is one of the most urgent problems of biomedical engineering projects, of which start-ups and small and medium-sized enterprises (SMEs) are not the exception. Biomedical research is extremely capital-intensive, with research and development (R &D) taking a long time, and is associated with strict regulatory and certification requirements. Such features present more risk to finance and render such projects undesirable to the traditional banks that are predisposed to rely on collateral, predictable cash flow, and lending with interest (Sharif and Baig, 2023).

The function of financial intermediaries in biomedical funding has gotten comparatively little attention. For instance, banks, the hub of the financial intermediation industry, are a crucial source of finance for many kinds of businesses. Intermediaries like venture capital (VC) and private equity (PE) firms, who also have ownership over the rights of the businesses they sponsor, are additional sources of funding. Furthermore, facilitating the transfer of capital from investors to businesses by lowering obstacles is a fundamental economic role of many financial intermediaries (Coval and Thakor, 2005; Donaldson *et al.*, 2018).

Trade credit serves as an essential yet frequently neglected financial resource within the healthcare sector. Buyers can receive medicines and medical supplies from suppliers with a payment plan extending up to 90 days after delivery. This gives suppliers the ability to maintain sales of inventory when there is limited cash flow for an extended period of time. For example, a pharmacy that purchases antibiotics on credit may dispense the product to its patients before remitting payment to the supplier, generating revenue and allowing the pharmacy to continue operating without interruptions due to stock outages, thereby improving patient care and stabilizing the operation of the pharmacy (Yazdanfar and Öhman, 2017).

Trade credit can enhance cooperation throughout the entire healthcare supply chain, helping suppliers offer customers more attractive credit terms and creating stronger, dependent relationships based on trust and reliability. For example, many pharmaceutical distributors provide credit to their customers as a means of building loyalty, helping improve inventory management, and reducing waste. Furthermore, trade credit is important for helping healthcare companies adjust to shifting market trends caused by things such as an outbreak of new diseases or changes in regulations. With trade credit available, independent clinics can purchase new equipment or increase the amount of supplies they have on hand without having to wait for their cash reserves. Trade credit allows for innovation within the healthcare industry, providing research laboratories with an opportunity to purchase expensive research reagents with credit and creating more opportunities for producing new medical therapies. As an industry that relies heavily on having the necessary resources available at the right time, trade credit supports healthcare providers' ability to be able to continue operating their businesses in a highly responsive and resilient manner by providing a mechanism for obtaining the necessary inventory (Luo and Zhang, 2012).

The functional and strategic facets of healthcare economic management (HFM) are being mutated by machine intelligence (AI). Healthcare financial administration is essential to asserting healthcare methods' viability, impartiality, and adaptability in the face of increasing challenges such as public deterioration, the incidence of never-ending sicknesses, and rising situation costs (Rao *et al.*, 2022). AI-powered solutions can help address decision-making, administrative efficiencies, and financial optimization as health systems globally work to tackle cost reduction, resource management, and financial sustainability. There are other applications of AI in health care financing apart from credit scoring. With the help of machine learning algorithms, it is possible to forecast healthcare cost trends, which can help insurers price premiums more appropriately and help health systems better manage their budget.

Anomaly detection can also be used to identify odd billing charges or fraudulent insurance claims to minimize avoidable expenses. At an individual level, AI-powered apps could offer financial planning tips for people looking to save up for future health expenses or select optimal insurance plans (Nahar *et al.*, 2025).

Public-Private Partnerships (PPPs) have emerged as a key strategy for financing and delivering healthcare worldwide, particularly in developing nations (Mihayo, 2016). In these agreements, governments work in partnership with private enterprises to create and oversee healthcare initiatives, which may include constructing hospitals, enhancing pharmaceutical supply chains, or broadening medical services to areas that lack sufficient resources. The objective is straightforward: to utilize private sector investment and expertise to promote public health objectives (Hrytsenko *et al.*, 2021). PPPs can take several distinct forms, from initiatives dominated by the public sector to ones that are entirely under the hands of the private sector. A PPP arrangement is defined as a long-term agreement between public and private partners for the provision of infrastructure or public services, in which the private party bears a significant amount of risk (Zere *et al.*, 2007). PPPs have significantly improved service delivery and infrastructure development in the healthcare industry, especially in developing nations (Bao *et al.*, 2018; Berezin *et al.*, 2018; Caballer-Tarazona and Vivas-Consuelo, 2016; Hrytsenko *et al.*, 2021).

The World Health Organization (WHO) defines health system strengthening (HSS) as a collection of programs intended to enhance health system operations, resulting in increased access, coverage, and effectiveness in the provision of healthcare (Berezin *et al.*, 2018; Giusti *et al.*, 2002; Powelson *et al.*, 2024). The participation of the private sector helps close the budget gap in healthcare systems, guaranteeing the effective provision of services (Al-Shareem *et al.*, 2015). These components are critical to improving health systems' overall performance, sustainability, and responsiveness, particularly in resource-limited settings (Yin, 2009).

Obstacles for financing biomedical projects

It is becoming apparent that the current financing systems around the world need significant reforms. Escalating health care costs, aging populations, the emergence of new chronic diseases and health conditions, and lack of resources have demonstrated the need to expand funding sources and explore alternatives to traditional health care financing. Total health care spending is growing across the globe. As countries continue to make advancements in medicine, populations grow older, and chronic diseases continue to flourish, the need for funds rises (Bujang, 2026; Cygańska *et al.*, 2023). The financial strain that rising healthcare costs place on people, governments, and healthcare systems raises concerns about the long-term viability of the present healthcare models (Bujang, 2026).

Financial sustainability represents a significant global challenge. In numerous regions, the costs associated with healthcare are escalating at a rate that surpasses economic growth, driven by the introduction of costly new treatments, elevated patient expectations, and shifts in demographics. Even affluent nations are encountering difficulties in maintaining balanced budgets while simultaneously enhancing the efficiency of healthcare services. Middle-income countries, in particular, are confronted with challenging decisions regarding investment priorities—whether to allocate resources towards primary care or to the development of expensive hospital infrastructure. Consequently, there is an increasing interest in value-based care models, which link expenditures to patient health outcomes rather than merely the volume of services rendered (Kibasi *et al.*, 2012).

In a bigger policy context, there is chronic underinvestment in healthcare and inefficiency in the healthcare system. There is an urgent need to establish an inclusive health financing approach that incorporates innovation in the private sector and other financing approaches. The need to enhance biomedical engineering by strengthening it with a proper financing model is hence necessary to enhance the outcomes in

healthcare and the realization of sustainable development objectives (Khan *et al.*, 2025).

CONFLICT OF INTEREST

The authors hereby declare that they have no conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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