Innovation and its Role in addressing Post-Stroke Depression

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Abstract: *Stroke is one of the leading causes of death and disability globally. According to the findings, there are 16 million strokes annually, with 6 million deaths and another 5.5 million left with significant disability with enormous health, social and economic impact worldwide. Depressions and symptoms associated with it can be severe and may lead to life-threatening issues, hence this study is undertaken with an aim to highlight its importance and how detrimental it can be when it has adverse effects on the lives of many. When it comes to the possible solutions, and in the current tech era innovation can play an imperative role in addressing post-stroke depression (PSD) by offering novel methods of prevention, diagnosis, treatment, and management. This study focused on depression and post-symptoms, and those issues can be mitigated to some extent while embracing innovation and leveraging available technologies. This study mainly focuses on how healthcare providers can enhance the prevention, detection, and treatment of post-stroke depression, ultimately improving the well-being and quality of life of stroke survivors by using different innovative sets of methods and reducing the cost of any health system. This study took the viewpoint of 50 individuals (both male and female) and analysis further confirmed the use of innovation was quite helpful, even when the majority of affected individuals were not able to see and reach the health professional in person, then innovation led measures helped to optimize depression self-management, accelerate social support, and strengthen connections between stroke survivors and health care provider. When we are moving towards innovation and new technologies are acting as the cornerstones in the health system, hence then such findings will help the system to facilitate the affected population in a far better and more promising way. From the SDGs perspective, enhanced scientific research and, use of the technological and existing capabilities in the health sector, especially pertaining to post-stress depression, with a prime focus on the encouraged innovation and sustainability will allow for the overall contribution and attainment of 2030 sustainable development goals.*

Keywords: Stroke, Innovation, Depression

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1. Introduction

The Development Agenda 2030, also known as the Sustainable Development Goals (SDGs) 2030, is now just a few years away. It is imperative that key decision-makers and influencers not only work towards achieving these goals but also ensure they deliver positive and meaningful outcomes for humanity. Among these goals is the commitment to ensure healthy lives and promote well-being for all, at all ages. Equal and equitable access to healthcare is a primary objective of the SDGs, and achieving this requires fostering innovation as a sustainable solution to address global health crises. According to the World Health Organization (WHO, 2023), an estimated 3.8% of the global population experiences depression, including 5% of adults (4% of men and 6% of women) and 5.7% of adults over 60 years old. This is particularly crucial for vulnerable populations, including those living below the poverty line or marginalized by societal pressures, which often lead to depression, anxiety, and other mental health challenges. These challenges frequently perpetuate a cycle of poverty, mental disorders, and lack of access to even basic healthcare, spanning generations.

Strokes, another major health challenge, result in a range of impairments, including sensory disturbances, motor limitations, cognitive impairments, and reduced capacity for self-care. They also often lead to diminished psychological well-being, reduced social interactions, and a decline in overall quality of life (Cheraghifard, 2021). Each year, approximately 16 million people suffer strokes globally, with 6 million fatalities and another 5.5 million left severely disabled. The psychological, social, and economic implications of strokes are profound, with annual direct costs per patient estimated at approximately $58,200 (Feigin et al., 2019). Depression and strokes are often interconnected, with both conditions linked to increased inflammatory activation of the immune system, compounding negative health outcomes (Liu et al., 2020). Approximately 280 million people worldwide suffer from depression, which is 50% more common among women than men. Among women, more than 10% of those who are pregnant or have recently given birth experience depression. Tragically, over 700,000 people die by suicide each year, making it the fourth leading cause of death among 15–29-year-olds.

Patients recovering from strokes frequently experience post-stroke depression (PSD), marked by symptoms such as mood disturbances, loss of focus, psychomotor agitation, feelings of worthlessness, sleep irregularities, weight changes, and even suicidal ideation. These symptoms can emerge as early as three months after a stroke and may persist throughout recovery (Robinson and Jorge, 2016). Research has also identified dysfunctions in glutamatergic neurotransmission as contributing to psychiatric conditions, including major depressive disorder (Ji et al., 2014).

Innovation and technology are revolutionizing the approach to addressing the multifaceted challenges of post-stroke depression (PSD) and its associated impacts. Advanced methodologies like machine learning are transforming how researchers explore the intricate connections between mood disorders and motor or cognitive dysfunctions in stroke survivors (Hama et al., 2020). Notably, researchers at Hiroshima University (2020) have employed artificial intelligence (AI) to pinpoint specific subtypes of post-stroke depression, paving the way for more precise and personalized treatment strategies. The effectiveness of these AI-driven diagnostic tools has been rigorously validated using performance metrics such as the receiver operating characteristic (ROC) curve, underscoring their reliability and accuracy.

In another groundbreaking development, the University of South Australia (2021) has introduced an innovative brain-based therapy that holds great promise for alleviating the symptoms of post-stroke depression. This therapeutic approach exemplifies how cutting-edge neuroscience can be leveraged to address complex mental health issues effectively.

The integration of such technological advancements into healthcare systems not only enhances patient outcomes but also contributes to significant cost reductions, particularly in areas like long-term care and mobility expenses. These innovations align with global efforts to achieve the Sustainable Development Goals (SDGs) by improving healthcare accessibility, reducing disparities, and promoting mental health equity on a global scale. By prioritizing and investing in innovation, we can reimagine stroke recovery and mental health care, transforming lives and fostering a more equitable healthcare landscape.

2. Innovation as a significant advancement

Practices and procedures for stroke rehabilitation have been evolved in recent years and science-backed and innovation-led ways to speed up recovery being adopted as an early screening mechanism for post-stroke depression, and the effect on functional outcomes and quality of life. The rapid changes around the world have made life faster, and so as our habits, which further leads to the change in human preferences. It is evident that approaches that were productive or acceptable at the end of the 20th century are increasingly less stimulating for today's patients, therefore, the medical world began to look for new solutions and new areas of activity, including virtual reality (Mazurek, 2019).

In the current tech-based era, post-stroke rehabilitation is more particularly open to different technological innovations supporting effective recovery, as stroke is considered to be one of the main causes of disability – For instance, Post-stroke rehabilitation reaching for virtual reality emphasises mainly therapies that improve motor function, such as through interactive video games with a focus on improving upper limb function, gait speed, balance (Laver, 2017). A systematic review conducted by Gao et al. (2021), confirms that virtual reality-based involvements used as adjunctive therapy have a positive impact on the treatment of mood disorders and depression in patients with chronic stroke, and training with virtual reality games in stroke patients may also improve psychological characteristics other than depression, such as interpersonal relationships (Song and Park, 2015).

The sudden emergence of a pandemic like COVID-19 a few years back has drawn attention to the side effects of being lonely, especially for those living alone already, which underscored the necessity to develop and implement new digital technologies in the care of acute and chronic patients (Iodice et. al, 2021). While considering the use of technology and its implications it is important to consider the targeted application of any adopted technologies, considering the factors such as age, gender, body mass, and cognitive status can influence their effectiveness, for instance, among healthy older adults, technological interventions might see a slightly reduced acceptability, attributed to higher dropout rates as compared to those who are technology driven and already familiar with the innovation and its perceived impact. Also, from the gender perspective, Eid et al. (2019) noted that there is a visible gender difference exists in depression-related gene expression, neuroplasticity, and immune signatures, which may lead to variations in the occurrence and pathobiology of the disease between men and women. Moreover, the presence of gender-specific variations in the pathophysiology of stroke, stresses the importance of integrating gender as a vital characteristic in formalising new clinical trials for developing personalized strategies in stroke prevention and treatment (Bushnell,

2018). This trend aligns with the growing focus on personalized and precise approaches in post-stroke therapy (Bonkhoff, 2022). Immersive virtual reality therapy, when used as an aide to post-stroke rehabilitation, seems to propose potential benefits, particularly for women exhibiting more pronounced symptoms of depression. Traditional methods might not yield the same efficacy among female patients as they do with their male counterparts (Rauwenhof, 2020). These variations could be rooted in the distinct ways depression manifests across genders, potentially due to a combination of biological, sociological, and psychological factors. Exploring innovative approaches, while being mindful of these differences, could pave the way for more tailored therapeutic strategies (Di Tella, 2021).

Innovations continue to progress and are offering new hope and improved results for patients dealing with stroke and depression. Combining innovations for stroke and depression, and how much assistance can help in improving the recovery process of the patients, a few benefits in terms of post-stroke rehabilitation and mental health could be through:

i. **Integrated Online Telehealth Platforms:** Possibilities of offering both physical and mental health services through comprehensive care for stroke survivors experiencing depression – such as by adopting virtual physical therapy sessions along with psychological support and counselling.

ii. **Multidisciplinary Rehabilitation Programs:** Combining physical, occupational, and psychological therapies in a synchronised approach to enhance the overall recovery – Intervention may include group therapy sessions (including online consultation and sessions) to address the emotional and psychological aspects of stroke recovery.

iii. **Mindfulness and Stress Reduction Technologies:** Softwares, apps and devices that promote and teach mindfulness and stress reduction techniques, are particularly useful for stroke survivors dealing with depression – Such online or virtual tools can improve mental well-being and support the overall rehabilitation process.

3. Methodology

To evaluate the execution and usage of the innovation in the PSD, and to further comprehend what worked and what did not, how and why, a mixed quantitative (Questionnaire distributed among the patients) and qualitative approach (Through routine observations taken by the health carers during the admission of any patients) was used, for patients to produce their preferences. With regards to the intervention itself, assessment of depressive symptoms and other secondary outcomes were measured and analysed using direct observations. At the end of the intervention, a questionnaire and a semi-structured interview guide were collected having information and perspective about the participants. Prior consent was taken from the respondent and confidentiality was ensured during this whole process. The questionnaire was divided into four sections: Demographics; Understanding of Post-Stroke Depression; Role of Innovation; Effectiveness of Innovations; and Future Directions. Data was gathered, processed, and analysed after receiving completed questionnaires and requested information from the participants. Confidentiality was ensured from an ethical perspective as well, to protect the privacy of the respondents as well as the health career and system associated with it. Moreover, considering the health conditions and sensitivity participants shared their honest and accurate information when they were assured that their data would remain confidential, and this trust was essential for obtaining informed consent. A systematic and ethical approach was adopted to meet the research goals and to cover this important area of health and well-being from different aspects.

Participants

Sixty-one patients with the symptoms of PSD were approached out of which a total of fifty responses were received or completed with the response rate of 81.96%, and analysis was performed on this set of groups. As stated above both quantitative and qualitative approach was used to notice the use of innovation and the level of acceptance in the patients when it comes to overcoming the PSD. The age range was controlled because studies by other researchers confirm that the mental health of stroke survivors differs between young adults and the elderly. Further, considering depression as a common state, hence, all age groups were focused, starting from the minimum age of 18 and above, because young adults on average, may have significantly higher depressive symptom scores (Lyu et. Al, 2020).

4. Analysis

4.1 Demographics
4.1.1 Gender
Observation: 44% male, 56% female respondents.
Analysis: Women are more represented, possibly reflecting the higher prevalence of stress-related diseases among women. Factors such as hormonal, psychological, and social dynamics might contribute. Tailored healthcare strategies are critical for addressing these disparities, including interventions aimed at women's unique stress management needs.

4.1.2 Age Group
Observation: Mean age = 39.8 years, SD = 15.34 years, with most respondents in the 45–54 range.
Analysis: A broad age range reflects inclusivity in the sample. The clustering around the late 30s and 40s suggests a focus on middle-aged individuals, often a critical period for stress and health challenges. Tailored age-specific interventions are necessary, addressing both youthful stressors (e.g., career pressure) and aging-related challenges (e.g., chronic diseases).

4.1.3 Education
Observation: Secondary/higher education predominant (46%), followed by lower secondary (28%).
Analysis: Education influences stress coping skills. Higher educational attainment often correlates with better stress management due to increased access to resources, awareness, and problem-solving abilities.

4.1.4 Employment Status
Observation: Retired (40%), unemployed (34%), employed (26%).
Analysis: Employment status significantly impacts stress levels. Retirees may experience relief from work stress but face other challenges like health concerns or financial insecurity. Unemployment can exacerbate stress due to economic pressure, while employment-related stress affects some workers.

4.1.5 Marital Status
Observation: Married (48%), widowed (42%), single (10%).
Analysis: Marital status can influence stress-related outcomes, with married individuals possibly benefiting from emotional and social support, whereas widows may face increased stress due to bereavement and isolation.

4.1.6 Disability

Observation: 12% of respondents have a disability, with 66% of these being post-stroke disabilities.

Analysis: Disability, especially post-stroke, is deeply intertwined with stress-related conditions. Addressing both the physical and psychological aspects through holistic care models is essential for improved outcomes.

4.2 Understanding of Post-Stroke Depression (PSD)
4.2.1 Familiarity with PSD

Observation: 90% familiar, 8% unfamiliar, 2% never heard.

Analysis: High awareness is crucial for early detection and management. Familiarity enhances patient outcomes by reducing delays in care and promoting holistic recovery strategies.

4.2.2 Effectiveness of Conventional Treatments

Observation: 52% rate conventional treatments as very effective, 34% as somewhat effective, 10% as ineffective.

Analysis: Conventional approaches like psychotherapy and medication are valued but require customization for optimal results. Patient adherence and personalization are critical for success.

4.2.3 Received Expected Care for PSD

Observation: 90% agreed they received expected care.

Analysis: This highlights the importance of comprehensive care models, ensuring access to physical and psychological support systems for managing PSD effectively.

4.3 Role of Innovation in PSD Treatment
4.3.1 Innovative Solutions Utilized

Observation: Tools like telemedicine, psychological therapy apps, and wearable devices were highlighted.

Analysis: Innovations expand treatment options by improving accessibility and personalization. These tools can bridge gaps in care, especially for remote or underserved populations.

4.3.2 Importance of New Technology Integration

Observation: 68% believe technology integration is important.

Analysis: Technological advancements can complement traditional methods, offering better monitoring, real-time support, and tailored interventions.

4.4 Effectiveness of Innovations
4.4.1 Effectiveness Ratings

Observation: 38% rated innovative approaches as very effective, while 20% found them ineffective.

Analysis: While innovations are promising, their effectiveness depends on user-friendliness, accessibility, and patient adherence. Further research and refinement are needed to enhance their impact.

4.4.2 Challenges in Implementing Innovations

Observation: Major barriers include cost (24%), resistance to change (26%), and technological barriers (18%).

Analysis: Addressing these challenges requires public awareness campaigns, training programs, and subsidized access. Policies to reduce the digital divide and promote technological adoption are critical. (For summary and comparative - Annex I)

5. Actionable Strategies

5.1 Demographics-Based Interventions

5.1.1 Gender-Specific Approaches

Action: Develop women-focused health programs, addressing biological and social stress factors. For men, design strategies to improve engagement in mental health support systems, given their potential underrepresentation in such studies.

Implementation: Organize community workshops focusing on stress management tailored to gender-specific challenges. Partner with women's health organizations to enhance outreach.

5.1.2 Age-Specific Interventions

Action: Implement age-targeted support programs. For younger adults, focus on stress due to career and education pressures. For middle-aged and older adults, address chronic diseases and financial stress.

Implementation: Establish online forums and counseling services segmented by age groups. Introduce technology literacy programs for older adults to increase adoption of innovative tools.

5.1.3 Education-Driven Coping Mechanisms

Action: Provide stress management education programs targeting those with lower secondary education. Include practical resources like budgeting tools, community support, and mental health resources.

Implementation: Partner with local schools and community centers to create awareness campaigns on stress coping mechanisms.

5.1.4 Marital and Employment Status Support

Action: Create peer support groups for widows and retirees. Offer job counseling and upskilling programs for unemployed individuals to mitigate financial and social stressors.

Implementation: Collaborate with NGOs and employment agencies to provide resources tailored to employment or relationship status.

5.1.5 Disability-Specific Care

Action: Establish dedicated rehabilitation programs for individuals with post-stroke disabilities. Include psychological support for stress management.

Implementation: Use telehealth platforms to connect disabled individuals with specialized therapists. Develop financial aid programs for rehabilitation costs.

5.2 Improving Awareness and Familiarity with PSD

5.2.1 Awareness Campaigns

Action: Run community-driven awareness campaigns on the importance of recognizing and addressing post-stroke depression (PSD).

Implementation: Use social media, healthcare settings, and local events to disseminate educational content. Engage local influencers and survivors to share their stories.

5.2.2 Healthcare Provider Training

Action: Train healthcare providers in PSD early diagnosis and holistic care approaches.

Implementation: Partner with medical institutions to conduct regular workshops and certification programs focusing on PSD awareness and treatment.

5.2.3 Accessible Information

Action: Create multilingual resources for PSD information to reach diverse populations.

Implementation: Develop brochures, videos, and apps in multiple languages to cater to varied demographics.

5.3 Leveraging Innovations in PSD Treatment
5.3.1 Promoting Telemedicine and Digital Tools

Action: Expand access to telemedicine platforms, mobile apps, and wearables for PSD monitoring and therapy.

Implementation: Partner with tech companies to subsidize tools for underserved communities. Offer free trials to increase adoption.

5.3.2 Integration of Technology in Care Models

Action: Incorporate technology like AI-based mental health monitoring and virtual reality (VR) therapies into PSD treatment. AI tools can monitor and analyze behavioral, physiological, and psychological data to provide continuous and personalized mental health support.

Implementation: Pilot test these technologies in hospitals and clinics, providing feedback loops for further refinement. By incorporating AI and VR into post-stroke depression care, we can enhance early detection, personalize treatment, and improve overall recovery, paving the way for a more resilient and engaged patient journey.

5.3.3 Education on Innovation Use

Action: Educate both patients and caregivers on how to use innovative tools effectively.

Implementation: Organize community training sessions. Offer simplified tutorials within apps and devices.

5.4 Addressing Challenges in Innovation Adoption
5.4.1 Reducing Costs

Action: Advocate for insurance coverage of innovative PSD treatments, such as telemedicine consultations and wearable devices.

Implementation: Engage policymakers and healthcare insurers to include these options in coverage plans.

5.4.2 Overcoming Resistance to Change

Action: Provide trial periods for innovative tools to build trust and comfort.

Implementation: Work with communities to introduce these tools in a phased approach, using testimonials from early adopters to build confidence.

5.4.3 Technological and Training Barriers

Action: Bridge the digital divide by offering devices and internet access to low-income populations. Train healthcare providers and caregivers in using these technologies.

Implementation: Partner with governmental and non-governmental organizations for funding and distribution.

5.4.4 Awareness for Stakeholders
Action: Conduct awareness campaigns targeting both patients and healthcare providers about the benefits of innovative approaches.
Implementation: Publish case studies demonstrating success stories of using these innovations for PSD treatment.

5.5 Monitoring and Continuous Improvement
5.5.1 Feedback Mechanisms
Action: Establish mechanisms to collect patient and caregiver feedback on the effectiveness of treatments and innovations.
Implementation: Use surveys, focus groups, and app-based feedback systems to gather insights.

5.5.2 Ongoing Research
Action: Fund research into the long-term efficacy of innovative PSD treatments.
Implementation: Collaborate with universities and research institutes to track patient outcomes over time.

These strategies aim to address the demographic diversity, improve PSD awareness, leverage innovative tools, and tackle adoption challenges while ensuring ongoing refinement based on feedback.

6. Limitations

When focusing on the role of innovation in addressing post-stroke depression (PSD), several limitations need to be taken into consideration. The field of innovation in mental health, particularly in the context of PSD, still has some gaps in research, including the limited studies or data available on specific types of innovations (e.g., technological interventions, novel therapies) or insufficient exploration of their long-term effectiveness and impact on PSD. Moreover, even if innovation shows promise in clinical trials, its successful translation into routine clinical practice may be hindered by barriers such as cost, accessibility, healthcare provider training, and patient acceptance. Also, many studies on innovative treatments for PSD may focus on short-term outcomes (e.g., symptom reduction), while long-term effects on quality of life, functional recovery, and recurrence rates remain unclear.

Discussion
Technology plays an essential role in addressing and minimizing the impact of post-stroke depression by enabling early detection, modified involvements, and improved support systems for stroke survivors. For example, by leveraging telemedicine, AI, VR therapy, and assistive technologies, healthcare providers can provide inclusive care that improves mental health results and improves the overall well-being of persons recovering from stroke. Machine Learning Models can analyze patterns in speech, activity, and vital signs to detect early signs of depression or cognitive decline in stroke patients. Also, Natural language processing (NLP) algorithms analyze tone, sentiment, and language use to gauge mood and offer tailored support. AI systems can alert healthcare providers to significant changes in patients' mental health, enabling timely interventions. These systems can integrate with electronic health records (EHRs) to streamline care. VR can create immersive and controlled environments to improve mental well-being and support rehabilitation. VR can simulate calming environments (e.g.,

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beaches, forests) to reduce anxiety and stress in PSD patients. Guided mindfulness or relaxation sessions within VR can teach coping mechanisms. VR-based physical therapy motivates patients with engaging exercises, indirectly reducing depressive symptoms by promoting physical activity and social interaction. Virtual platforms allow patients to interact with peers, family, or therapists in a virtual setting, combating feelings of isolation.

However, it is important to steer the ethical challenges and ensure that technological solutions are cohesive into inclusive, patient-focused care models to enhance overall effectiveness. Stroke survivors often face challenges with daily activities due to physical and cognitive impairments. Assistive technologies, such as smart home devices and mobility aids, can enhance independence and quality of life. These technologies can automate routine tasks, provide reminders for medication adherence, and improve communication with caregivers, reducing the stress and frustration that may contribute to PSD. Hence, addressing and minimizing the impact of post-stroke depression (PSD) through technology involves a multifaceted approach that integrates various technological advancements and strategies.

7. Conclusion

Innovations have become an integral part of the treatment for post-stress disorders (PSDs), playing a vital role in improving recovery outcomes for individuals. By offering a variety of approaches, these innovations address multiple aspects of PSDs, providing tailored solutions that meet the specific needs of patients. Whether through pharmacological interventions to alleviate symptoms, technological advancements to enhance therapy accessibility, rehabilitation programs to facilitate recovery, or strengthening social support networks, these innovations collectively enhance the effectiveness of PSD treatments.

The continuous development of new tools and technologies is expanding the range of treatment options available for PSDs. From digital platforms to artificial intelligence (AI) and virtual reality (VR) systems, these tools provide opportunities for more personalized, efficient, and engaging care. They not only help in reducing the burden on healthcare systems but also create more accessible solutions for those who might otherwise struggle to receive timely treatment. The ability to customize treatment plans based on a patient's specific needs and preferences allows for more effective management of stress-related disorders.

Despite the undeniable benefits, the integration of innovative technologies into PSD treatment faces challenges. One of the main hurdles is the acceptance of these technologies by both patients and healthcare providers, often due to concerns about privacy, effectiveness, or the perceived complexity of these tools. Overcoming these challenges requires a holistic approach that incorporates medical, psychological, and social perspectives. It's essential to ensure that innovations are inclusive, considering factors such as access to technology, mobility issues, or sensory impairments, so that no patient is excluded from the benefits of technological advancements.

A comprehensive approach that combines traditional in-person therapy with advanced technologies like AI and VR can significantly enhance the patient's experience. AI can monitor patients' progress over time, identifying early signs of distress or relapse and ensuring continuous adaptation of treatment plans. VR offers immersive therapy sessions, which can help patients confront and process traumatic memories in a controlled, safe environment. Together, these tools support a more resilient recovery journey, making therapy more engaging, personalized, and effective.

In conclusion, integrating innovations into the treatment of PSDs has the potential to revolutionize mental healthcare. By combining technology with traditional therapeutic methods, offering more personalized and accessible care, and ensuring inclusivity, these innovations pave the way for improved recovery outcomes. However, to fully realize their potential, it is crucial to address the challenges of technology acceptance and ensure that advancements are implemented with sensitivity to diverse patient needs. With continued research, development, and thoughtful integration, the future of PSD treatment holds immense promise, offering hope for a more engaged, supportive, and effective recovery process for individuals facing post-stress disorders.

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