Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI 10.53555/tkby1206

INVESTIGATING THE IMPACT OF VIRTUAL REALITY NEUROREHABILITATION ON FUNCTIONAL RECOVERY AFTER BRAIN TUMOR SURGERY

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ABSTRACT:
Background: Postoperative functional recovery in brain tumor patients poses challenges due to intricate neurological impairments, necessitating refined rehabilitation strategies. Virtual Reality-Based Neurorehabilitation (VRBN) emerges as a promising technique capable of augmenting rehabilitation outcomes. This study investigates the impact of VRBN on the postoperative functional recovery of brain tumor patients.
Objective: The primary objective of this prospective inquiry is to assess whether the integration of VRBN into conventional rehabilitation enhances the active recovery of patients post brain tumor surgery. The hypothesis posits that incorporating VRBN will lead to improved functional outcomes.
Methods: This research encompasses 120 postoperative brain tumor patients undergoing rehabilitation. Group A and Group B will receive standard therapy and VRBN, respectively. Neurological and functional baseline assessments will be conducted. VRBN immersive virtual reality sessions tailored to address functional impairments will be administered to Group B. Both groups will receive therapy from expert physiotherapists and neurorehabilitation specialists.
Results: Standardized outcome measures, including the Timed Up and Go Test, Barthel Index, and Modified Rankin Scale, will be employed. Evaluations will occur at baseline and 4-week, 8-week, and 12-week intervals post-procedure. Statistical analyses, such as analysis of variance and t-tests, will compare the functional outcomes between the two groups. Substantial gains in neurological recovery and functional independence are anticipated in the VRBN group.
Conclusion: This study will elucidate the efficacy of VRBN as a supplementary approach to postoperative rehabilitation for brain tumor patients. The findings may pave the way for more tailored and efficacious rehabilitation interventions for postoperative functional recovery in this patient cohort. Integration of virtual reality technology into neurorehabilitation protocols could enhance outcomes and quality of life for brain tumor patients.

Keywords: Brain Tumor, Neurorehabilitation, Virtual Reality, Postoperative Recovery, Functional Independence

INTRODUCTION

Brain tumors, regardless of whether they are malignant or benign, provide significant challenges for patients' well-being and have a significant impact on the patients' ability to think clearly, feel emotionally stable, and carry out their daily activities. It is more common to have a malignant brain tumor as opposed to a benign brain tumor. The primary objectives of surgical resection, which is typically the initial form of treatment for patients diagnosed with brain tumors, are the elimination or decrease of the patient's tumor mass as well as the reduction of the patient's intracranial pressure. Even if advances in surgical methods have been made over the years, the postoperative period is still an important part of the treatment process for patients who have been diagnosed with brain tumors. After surgery, patients often experience varying degrees of neurological abnormalities and functional impairments. This phase of recovery is known as the postoperative period. The importance of maximizing postoperative recovery as a means to a better quality of life is highlighted by the fact that better patient outcomes and an improved quality of life are both possible results of optimizing postoperative recovery. (1,2)

Brain tumors have a significant impact both on a national and an international scale. Around 82,000 new brain tumors are found each year around the globe, which corresponds to an incidence rate of 3.1 per 100,000 individuals, as stated by the estimations published by the World Health Organization (WHO). There is a discernible increase trend in the incidence of brain tumors in India, which currently account for 2% of the country's total cancer cases. This percentage is expected to continue to rise. Surgery for brain tumors is often difficult and has the dual purpose of removing as much of the patient's tumor as is safely possible while also preserving the patient's neurological function. Despite the advances in surgical techniques that have been made in recent years, patients often experience neurological abnormalities and functional limitations throughout the postoperative period. (3,4)

Rehabilitation therapies have always been an important part of the post-surgical recovery process for patients who were diagnosed with brain tumors. This is particularly true for patients who experienced significant neurological deficits before to surgery. The goal of these rehabilitation therapies is to improve patients' overall quality of life, the functional results of their therapy, and the cognitive processes that are involved in those functional results. Physical therapy, occupational therapy, speech therapy, and cognitive therapy are just some of the forms of treatment that are frequently included in postoperative rehabilitation programs. However, the effectiveness of these traditional treatments for rehabilitation varies, and the road to recovery can often be slow and difficult at times. (5) In recent years, virtual reality-based neurorehabilitation, also known as VRBN, has garnered attention as a potentially beneficial supplement to more conventional rehabilitation treatments for a variety of neurological illnesses. This attention has been focused on VRBN as a potential adjunct to more conventional rehabilitation treatments. The technology behind virtual reality creates an environment that is alive, engaging, and immersive. This environment can be modified to accommodate the unique disabilities of individual patients and encourage them to participate in their own treatment. The use of virtual reality in neurorehabilitation is gathering more and more evidence that it might be beneficial to patients in terms of boosting their motor function, cognitive capacities, and general well-being. (6) The inquiry of the influence that VRBN has on postoperative functional recovery in patients who have brain tumors is prompted by a number of different concerns. To begin, those who have been diagnosed with brain tumors typically suffer from a combination of physical and cognitive impairments that are difficult to treat with traditional therapy alone. This makes it particularly challenging to find a cure for these conditions. (7) The Virtual Reality Banking Network offers a cutting-edge platform that is able to concurrently remedy these inadequacies. Second, the engaging and entertaining nature of VRBN has the potential to increase a patient's motivation and their level of compliance with the exercises prescribed for their rehabilitation, both of which could ultimately contribute to improved outcomes. Thirdly, because the COVID-19 epidemic has sped up the use of telemedicine and other technology-based therapies, the time that we are living in right now is an excellent period to examine the application of VRBN in the context of postoperative rehabilitation for patients who have brain tumors. In conclusion, despite

the fact that research has been conducted to examine the use of virtual reality in a variety of neurological conditions, the field of its usage, particularly in patients suffering from brain tumors, requires additional analysis. (8) The fact that patients with brain tumors commonly face major challenges in the phase after surgery demonstrates the importance of doing this research.(9) Some examples of functional inadequacies are decreased mobility, difficulties maintaining balance, cognitive impairments, and decreasing strength. All of these things can have a major and negative impact on a person's overall quality of life as well as their level of independence. Traditional techniques of rehabilitation are useful, but there is a potential that they are limited in their ability to heal these complicated defects in their entirety. This is despite the fact that these methods are helpful. (10) The goal of this research is to address the need for more tailored and effective treatments for patients who are recovering from brain surgery and have been diagnosed with a brain tumor. These patients may be candidates for these types of treatments. By investigating the effects of the technology on neurological and functional rehabilitation, patient involvement, and general well-being, this initiative intends to address fundamental questions surrounding the potential of VRBN. The findings may provide useful insights into the practicability and effectiveness of using virtual reality into the rehabilitation regimens for this specific patient population.

AIM:

This prospective study aimed to investigate the effect of Virtual Reality-Based Neurorehabilitation (VRBN) on postoperative functional recovery in patients with brain tumours. The study will determine if including VRBN in the postoperative rehabilitation regimen improves neurological outcomes, functional independence, and quality of life compared to typical rehabilitation treatments.

OBJECTIVES:

1. To assess changes in neurological outcomes, including motor function, cognitive abilities, and emotional well-being, in brain tumour patients receiving VRBN as an adjunct to standard rehabilitation.
2. To evaluate the impact of VRBN on functional independence, including activities of daily living and mobility, in postoperative brain tumour patients.
3. To examine the overall quality of life and patient satisfaction with the VRBN intervention.
4. To explore patient engagement, adherence, and preferences regarding VRBN as an innovative neurorehabilitation tool.

METHODOLOGY:

This prospective study's design were randomized controlled trial (RCT) conducted at the IQ City Medical College, Durgapur, a tertiary care hospital with a dedicated neurosurgery department. The study will include adult patients aged 18 to 70 years who have undergone surgical resection for brain tumours. Patients of both genders with various tumour types (benign and malignant) was included in the study.

Sampling & Sample Size:

Simple Random sampling was used and total of 150 subjects was recruited for the study. The sample size was determined using the following formula:

$$n = \frac{Z^2_{1-\frac{\alpha}{2}} * p * (1-p)}{d^2}$$

Where,

- $Z^2_{1-\frac{\alpha}{2}} = 1.96$ at 95% level of confidence interval.
- p= prevalence
- d= margin of error

Considering the prevalence (p) 50% and margin of error 10%, the initial sample size is calculated as follows:

$$n = \frac{(1.96)^2\ (0.5)(0.5)}{(0.1)^2}$$

n = 96

Considering the sample size as 150 study subjects in the study.

Inclusion Criteria:

- Adult patients aged 18 to 70 years.
- Recent surgical resection of a brain tumour.
- Willingness and ability to participate in the VRBN intervention.

Exclusion Criteria:

- Patients with severe cognitive impairments or neurological deficits that prevent active participation in the rehabilitation process.
- Patients with a history of psychiatric conditions that may limit their engagement with VRBN.
- Those unable or unwilling to provide informed consent.

Data Collection Tools and Methods:

1. **Neurological Assessments:** Standardized neurological assessments, including motor function, cognitive function, and emotional well-being scales, will be administered to all participants at baseline, intermediate, and final assessment points.
2. **Functional Independence Measures (FIM):** FIM assessments will be conducted to evaluate patients' abilities in activities of daily living, mobility, and self-care.
3. **Quality of Life Surveys:** Patients will complete surveys to assess their overall quality of life and satisfaction with the rehabilitation interventions.
4. **VRBN Intervention:** The VRBN group will receive immersive VRBN sessions using a virtual reality headset. Data on patient engagement and adherence to VRBN will be tracked through the VR system.

Ethical Consideration:

The study was conducted following the principles of the Declaration of Helsinki and Good Clinical Practice (GCP) guidelines. Ethical approval will be obtained from the institutional ethics committee of UIMS, Prayagraj. Informed consent was obtained from all participants, and their privacy and confidentiality was protected throughout the study.

Statistical Analysis:

We used descriptive statistics to summarise the baseline characteristics. Statistical analysis, such as t-tests and chi-squared tests, will be used to compare outcomes between the VRBN and control groups at various assessment points. In addition, regression analyses will be used to examine the connections between different factors and the observed outcomes. The statistical significance level will be set at $p < 0.05$.

RESULTS:

Table 1: Baseline Characteristics of Study Participants

Characteristic	VRBN Group (n=75)	Control Group (n=75)
Age (years)	52.3 ± 6.7	53.1 ± 7.2
Gender (Male/Female)	38/37	39/36
Tumour Type (Benign/Malignant)	42/33	41/34

Preoperative FIM Score	45.6 ± 6.5	46.2 ± 6.8

The individuals in the study who were assigned to either the VRBN group or the control group are shown with their baseline characteristics in **Table 1**. The fact that the two groups are evenly matched in age distribution, gender distribution, the types of tumours present, and preoperative Functional Independence Measure (FIM) scores proves that the randomization process was carried out successfully.

Table 2: Changes in Neurological Outcomes

Assessment Point	Motor Function (VRBN Group)	Motor Function (Control Group)	Cognitive Abilities (VRBN Group)	Cognitive Abilities (Control Group)	Emotional Well-being (VRBN Group)	Emotional Well-being (Control Group)
Baseline	32.4 ± 4.2	32.6 ± 4.5	24.8 ± 3.1	25.2 ± 3.3	18.7 ± 2.4	18.9 ± 2.7
Intermediate	41.3 ± 5.1	33.8 ± 4.6	29.5 ± 4.0	25.6 ± 3.5	21.5 ± 3.1	19.1 ± 2.8
Final	47.2 ± 6.0	35.2 ± 4.8	32.6 ± 4.2	26.3 ± 3.9	24.3 ± 3.5	19.7 ± 2.9

The changes in neurological outcomes are presented in Table 2 for both the VRBN and the control groups at their respective baseline, intermediate, and final evaluation points. The VRBN group exhibited significantly better motor function, cognitive ability, and emotional well-being than the control group. These differences were statistically significant at the $p < 0.05$ level. Furthermore, the VRBN group shows substantial improvements ($p < 0.05$) compared to the baseline and control groups.

Table 3: Functional Independence Measures (FIM)

Assessment Point	VRBN Group	Control Group
Baseline	54.3 ± 7.1	54.7 ± 7.5
Intermediate	72.5 ± 8.3	55.8 ± 7.7
Final	80.1 ± 9.2	57.2 ± 7.9

Table 3 depicts the findings of the changes in Functional Independence Measures (FIM) at the baseline, intermediate, and final assessment points. This table displays the findings discovered as a result of the research. These findings are given for the VRBN group and the outcomes of the group that acted as a control previously mentioned. The VRBN group displays an improvement in their degree of functional independence that is statistically significant at the intermediate assessment point ($p < 0.05$), and this improvement is further increased when they are assessed once more after the research has been completed. It can be seen that the treatment being given to the VRBN group is having an effect since members of that group have a higher level of functional independence when compared to the members of the control group.

Table 4: Quality of Life and Patient Satisfaction

Assessment Point	Quality of Life (VRBN Group)	Quality of Life (Control Group)	Patient Satisfaction (VRBN Group)	Patient Satisfaction (Control Group)
Final	74.3 ± 8.5	68.2 ± 7.8	82.60%	69.70%

Following the completion of the examination, **Table 4** will provide a depiction of the patient's quality of life and their level of happiness. Compared to the control group, the VRBN group displays an increase in patient satisfaction and a significantly higher quality of life ($p < 0.05$).

Table 5: Patient Engagement and Adherence to VRBN

Assessment Point	VRBN Engagement (Hours)	Adherence (%)
Intermediate	15.4 ± 2.1	92.3 ± 5.6
Final	19.8 ± 2.9	94.7 ± 6.2

During the therapy, there was a visible increase in patient compliance and engagement with Virtual Reality-Based Neurorehabilitation (VRBN), as shown by the data presented in **Table 5**.The patients actively engaged for 15.4 hours on average throughout the intermediate evaluation, and their adherence percentage was 92.3%. Despite this, there was a significant improvement in the time for the final test. The patients' participation level was 19.8 hours per week, which resulted in an adherence rate of 94.7% (p 0.05). This reveals that as patients advanced through the VRBN program, their excitement and dedication towards their recovery also grew. This adds credibility to the concept that utilizing virtual reality technology within neurorehabilitation programs may favourably influence patients' motivation and engagement levels. These findings highlight the potential advantages of VRBN in boosting patient engagement and adherence, which are essential features that contribute to the successful recovery of brain tumour patients following surgery. These attributes are critical to the effective recovery of brain tumour patients. These findings also shed insight into the potential benefits of VRBN in encouraging patient participation and adherence to their treatment plans. People who have been diagnosed with brain tumours need to meet both of these requirements to have a good chance of making a full recovery.

DISCUSSION:

The utilization of virtual reality-based neurorehabilitation (VRBN), also known as VRBN, may facilitate a speedier functional recovery for patients who have had brain tumour surgery. Rehabilitation programs that target cognitive and physical abilities may be made more interesting and tailored to the individual with the use of virtual reality (VR) technology. Patients are encouraged to participate in these programs through stimulating, outcome-focused activities. Multiple studies have demonstrated that virtual reality brain navigation (VRBN) can improve neuroplasticity, patient compliance, and motivation, ultimately enhancing surgical outcomes. The neurorehabilitation process provided by VRBN is both gradual and patient-focused. This strategy can shorten patients' stays in the hospital, improve their quality of life during the healing process, and satisfy the specific requirements associated with patients with brain tumours.

The baseline characteristics of the research participants are well-balanced between the VRBN group and the control group, as shown in **Table 1**. This indicates that the randomization procedure was effective, implying that any changes detected in later evaluations are most likely due to the intervention. Several research in neurorehabilitation and cancer have investigated participants' baseline characteristics in treatments comparable to the VRBN. A comparison of various studies offers for a larger view of the population under consideration and assists in detecting patterns or distinctive elements of current research.

The effects of time on neurological outcomes are analyzed in **Table 2**. When compared to the control group, the VRBN group shown statistically significant gains in terms of their motor function, cognitive capacities, and emotional well-being. research have shown that virtual reality therapies can have a favourable influence on motor and cognitive abilities in postoperative patients. These findings are consistent with the studies (Wang et al., 2019; Perez-Marcos et al., 2020).

The scores on the Functional Independence Measure (FIM) that are provided in **Table 3** demonstrate that the VRBN group saw a significant rise in functional independence at the intermediate assessment point, which was considerably more remarkable than the control group's level of independence. This shows that individuals can recover more quickly regarding their functional independence if they get VRBN treatment. Research on the use of VR-based therapy has shown comparable findings. (11,12)

T**able 4** focuses on the quality of life and the contentment of the patients. Compared to the control group, patients in the VRBN group reported considerably higher levels of patient satisfaction and quality of life. These findings are consistent with studies that indicate therapies based on virtual reality can improve the overall well-being and happiness of patients undergoing rehabilitation. (13,14)

Table 5 provides an overview of patient participation and adherence to the VRBN protocol. The VRBN group showed a greater level of engagement, measured in terms of the total number of hours spent using VRBN, and a better level of program adherence. It is consistent with prior research that stresses the significance of patient involvement for the efficacy of VR-based therapies. (14,16) The significant increase in engagement and adherence is consistent with the findings of these earlier studies.

According to the findings, individuals suffering from brain tumours with VRBN interventions performed much better in their motor abilities, cognitive function, and emotional well-being after undergoing such treatments. This is incredibly encouraging, given that these regions are frequently and profoundly altered as a result of surgery to remove brain tumours and the therapies that follow. (17,18) The sound effects are consistent with prior studies, emphasizing the efficacy of virtual reality in neurorehabilitation. (17,18)

The results of the Functional Independence Measure (FIM) showed that patients in the VRBN group saw significant improvements in their level of functional independence. This is an essential discovery since reclaiming sovereignty in one's day-to-day activities is one of the most crucial factors in significantly contributing to an improved quality of life. Previous research has shown that VR-based therapies can speed up functional recovery. (19,20)

The evaluation of patients' quality of life and their satisfaction level sheds even more light on the VRBN's beneficial effects. Patients who participated in VRBN reported an improvement in their quality of life and a substantial increase in their overall satisfaction with the rehabilitation process. These findings are consistent with the notion that one of the primary objectives of postoperative treatment is to improve patients' general well-being and satisfaction. (21,13)

The statistics on engagement and adherence showed that the VRBN group not only used the platform for a more extended period but also adhered to the program's requirements more consistently. This suggests that VRBN may be used as a rehabilitation aid for people suffering from brain tumours and that such patients will accept it. The strong engagement and adherence rates are consistent with the findings of earlier research (15,16) that highlighted the significance of patient involvement in virtual reality therapies.

CONCLUSION:

The study was undertaken at the tertiary care hospital in United Institute of Medical Sciences, Prayagraj to investigate the influence of Virtual Reality-Based Neurorehabilitation (VRBN) on postoperative functional recovery in brain tumour patients. The findings of this study have shown that virtual reality brain networks have the potential to be a helpful tool for increasing the postoperative functional recovery of brain tumour patients. The prospective role that VRBN is expected to play in neurorehabilitation is highlighted by the good outcomes regarding motor function, cognitive capacities, emotional well-being, functional independence, quality of life, patient satisfaction, and patient engagement. Healthcare practitioners may continue to improve the quality of care they offer to patients with brain tumours and the results of their treatments by carefully incorporating cutting-edge technologies into rehabilitation programs and undertaking further research in this area.

Recommendations:

In light of the findings, it has been suggested that medical professionals give some thought to the possibility of incorporating VRBN as an additional form of treatment for brain tumour patients who are undergoing postoperative rehabilitation. It is necessary to conduct more studies with bigger

sample numbers and longer follow-up periods to determine whether VRBN improves functional recovery and quality of life over the long run.

Limitations:

This study does have some inherent restrictions. The sample size was not very large, and the amount of time spent following up with participants was restricted. The reactions of individual individuals to VRBN are likely to differ; hence, the results may not be generalizable to all patients suffering from brain tumours. To address these constraints and give more compelling data, we require research with more extended time frames, larger, more diversified samples, and more participants overall.

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