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Original Article:

Evaluation of Response Inhibition in the Face of Cognitive and Emotional Stimuli in Patients with Frontal Lobe Tumors before and after Surgery

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Abstract

Introduction: The functions of specialized brain parts undoubtedly influence emotional inhibition. Numerous studies have considered the prefrontal cortex of the brain's two hemispheres to be responsible for this behavior. However, few studies have addressed the question of to what degree a change in this brain unit can affect response inhibition and reaction time in the face of emotional stimuli. Therefore, the current study aimed to investigate emotional behavior in patients with frontal lobe gliomas.

Materials and Methods: In this quasi-experimental research, the Integrated Visual and Auditory (IVA) test and affective Go/No-Go task in the areas of happiness and anger, focusing on response accuracy and reaction time were performed for 16 patients with frontal lobe lesions and 20 healthy individuals. These tests were repeated three months after surgery. The t-test, Wilcoxon signed rank test, Mann-Whitney, and their related equivalence test were applied for statistical analysis.

Results: The results revealed that following surgery, there was an improvement in the patients' reaction times and response accuracy to both emotional stimuli especially against the stimulus of anger exist. The IVA results showed the significant improvement in neurocognitive condition of all patients following surgery.

Conclusion: Toward improving the emotional conditions, lesion resection surgery could significantly help these patients regain their normal cognitive function. However, a difference was seen between patients and healthy individuals.

Keywords: Emotion, Emotion inhibition, Frontal, Glioma, Neurosurgery.

1. Introduction

The frontal lobe of the brain has the highest impact on manifesting social behaviors and personality traits and expressing emotions [1]. Studies have shown that among the different parts of the frontal lobe, the prefrontal cortex (PFC) significantly influences the perception, expression, and inhibition of emotions in humans [2-4]. This part of the brain comprises three main parts: the dorsolateral, orbital, and ventromedial PFC. The dorsolateral PFC primary function is cognitive inhibition. Research has demonstrated that the latter two sections are involved in emotional inhibition. Emotional inhibition refers to the ability to control the responses to emotional stimuli such as anger and happiness at the moment [5]. Since two-thirds of the brain consists of glial cells, and the glia is almost the only growing and repairable cell in the central nervous system, they are more prone to various lesions [6]. Depending on which part of the brain they appear in, they can have different effects on the individual's behavior [7]. For instance, glial lesions in the prefrontal cortex have been associated with impaired decision-making, expression, control of emotions, and execution of intelligent decisions. In addition, damage to the ventromedial region would cause the patient difficulty distinguishing emotional statements from neutral ones [8]. In contrast, patients with tumors in the ventrolateral PFC could detect emotional signals but were unable to differentiate between specific emotions. These findings indicate that dissociable processes relying on separate regions in the PFC are responsible for detecting emotional signals from facial expressions and, on the other hand, responsible for correctly categorizing such signals [9]. Furthermore, in previous studies patients with tumors in the orbitofrontal cortex almost showed no adverse effects on cognitive processing and functioning [10]. Emotional control is an essential subject in personal and interpersonal psychology. Individuals who misinterpret their situation cannot effectively communicate with others [11].

In neuroscience research, one method to evaluate emotion inhibition is the affective Go/No-Go task, which is similar to the Cognitive Go/No-Go task for evaluating response inhibition, with the difference that it includes images with an emotional load. The time it takes to produce these two reactions in response to stimuli differs in healthy and unhealthy individuals, as in patients with psychiatric disorders (e.g., depression) and traumatic brain injury [12].

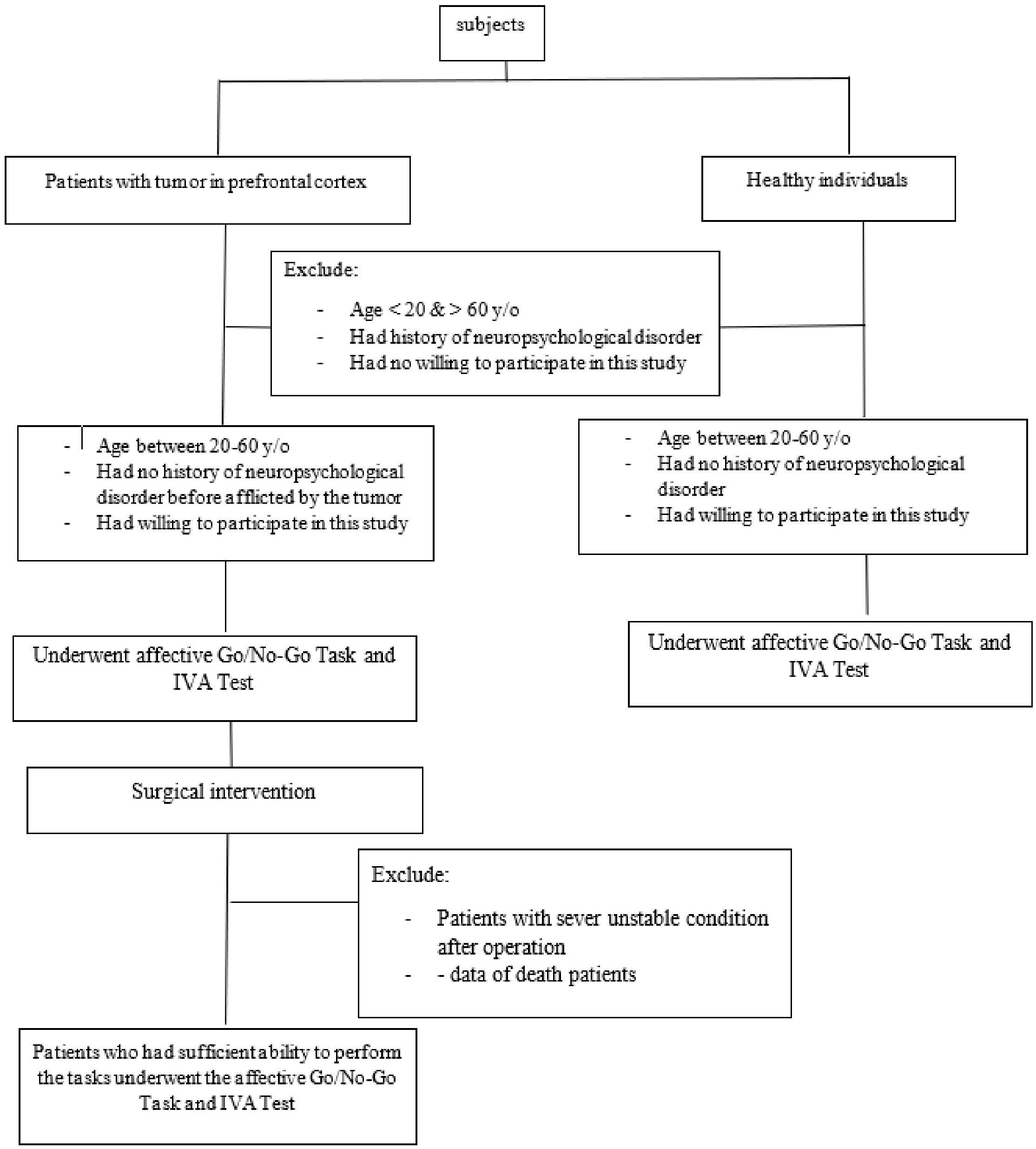
In a study on 41 young adults, Yu-Bin Shin et al. approcahed the affective (emotional) Go/No-Go task to identify the areas involved in emotional disorders caused by computer games. Reportedly, among the prefrontal, sensory-motor, parietal, occipital, insula, and striatum areas, involving the dorsolateral prefrontal cortex and the ventral striatum was only observed when performing high-demand tasks in the working memory [12]. Furthermore, it was only during high demand work that interaction between response inhibition and emotional states was observed in the dorsomedial prefrontal cortex. Therefore, a dysfunctional dorsomedial prefrontal cortex may mediate abnormal emotional effects on response inhibition in patients with internet gaming disorder (IGD) [13]. Egashira et al. used functional near-infrared spectroscopy (fNIRS) to measure oxygenated hemoglobin levels in the frontotemporal regions during the emotional Go/No-Go task in patients with schizophrenia. This study demonstrated that the dysfunction of the frontotemporal region is due to an interaction between the abnormal processing of facial expressions and negative valence and cognitive inhibition. Fishburn et al. have used fNIRS in 4-5-year-old children in the prefrontal region during the emotional Go/No-Go task. Reportedly, the emotional dimensions, only anger and frustration, predicted the process of prefrontal activation during emotional inhibition [14]. Moreover, Arbula's team studied the selective role of the prefrontal cortex in response suppression and reported that the left and right parts of the prefrontal cortex are the foundation of extensive cognitive-control processes, especially in response selection and target recognition [15]. Accordingly, Corell et al. proposed that successful inhibitory control is related to more than one distinct functional process, contributing to a better understanding of inhibitory disorders in various pathologies [16].

Despite numerous studies on the influence and role of the frontal lobe and the prefrontal cortex, a research gap regarding the function of this brain unit was found in individuals with brain injury or lesions. Therefore, the present study was conducted to assess response inhibition against cognitive and emotional stimuli in patients with frontal brain lesions before and after the operation.

2. Materials and Methods

This study was quasi-experimental research with case and control groups consisting of sixteen patients and twenty healthy cases. The inclusion criteria for healthy individuals were: No history of neurological, mental disorders, or medical conditions affecting their mental health. The patients were selected among those whose frontal lobe tumor had been verified through prior imaging procedures and those who were candidates for surgery and did not have any history of neurological or psychological illness before developing the tumor. All individuals were completely willing to participate in this study. The age of subjects in both groups were between 20–60-year-old. The exclusion criteria for all participants were age below 20 and above 60-year-old; having the history of neuropsychological disorder. In addition, patients who had sever condition after surgery and the data of patients who died in this period were excluded (Flowchart 1).

The cognitive status and response control in the face of emotional stimuli were assessed by utilizing the Integrated Visual and Auditory test (IVA) and affective Go/No-Go task.



Flowchart 1. The inclusion and exclusion criteria

The IVA is a computer-based test that evaluates the response control and attention; This test was developed based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) and dealt with the diagnosis and differentiation of the various Attention-Deficit Hyperactivity Disorder(ADHD), including the inattentive, hyperactive (impulsive), combined, and not otherwise specified (NOS) types [17] consisted of eight general combined scales and twenty subscales. All these scales were divided into four groups: attention, response control, sustained attention, and symptoms. In this test, a subject is asked to respond to auditory and visual numerical stimuli and inhibit their response to distractor numerical stimuli at the beginning of each phase, the level of response control (RC) and sustained attention (SA) against two types of stimuli and the levels of visual attention (VA) and auditory attention (AA) are determined. Accordingly, the patient's condition is categorized as one of the three states: severe neurocognitive disorder (SNCD), mild neurocognitive disorder (MNCD), or normal (NL) [18] (Figure 1).

Figure 1. Step A: Creating a patient profile; step B: Filling in the medical history. Steps C, D, E, and F: Follow the test instructions. G: Give the subject a visual cue to identify and opt the number 1. H: Display number 2 in Farsi as a distractor stimulus the subject should try to avoid. I: The report window from which data can be retrieved is displayed

Affective Go/No-Go protocol was carried out in two runs. Each run included two blocks with 64 images of happy and angry faces. One of the blocks was called Happy Go-Angry No-Go, and the other was called Angry Go-Happy No-Go. The images used in this test were extracted from the Radboud database which validated for the Iranian population in a pilot study conducted by the Research Center for Behavioral and Cognitive Sciences at the Tehran University of Medical Sciences, Iran (Figure 2).

The patients were asked to respond to the test based on the emotional states of the faces in the instruction images, shown for three seconds at the beginning of each block. In each block, the ratio of Go to No-Go images was 3:1. The images with an equal number of male and female faces, were displayed for 1.5 seconds in a random order using the Psych-toolbox program under MATLAB software on a personal computer with a black background and a resolution of 800×600. Using the variable inter-stimulus interval (ISI) method,

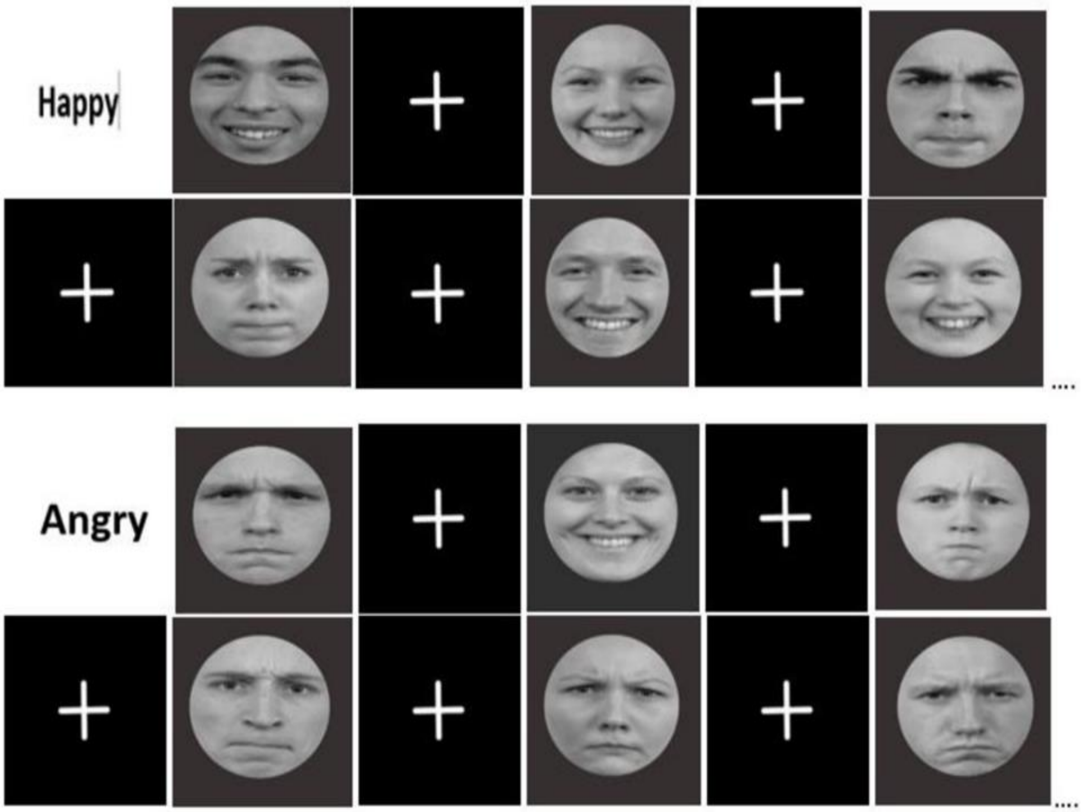


Figure 2. Visual contents of the go/no-go task. This graph shows a subset of the face Go/No-Go assessment. The images, ranging from "happy" to "angry," are randomly cycled. In the gap between them, a cross is displayed. By following the instruction at the beginning of each block, the patient can respond accurately and quickly with the desired emotion

a fixation cross was shown between the images for 1-2 seconds (1.5 sec on average) [19, 20].

Procedure

The subjects participated in the case group of this study were six men (37.5%) and ten women (62.5%) with an age range of 25-52 years (average of 39 years, standard deviation: 7.84) and twenty healthy individuals: Seven men (35%) and thirteen women (65%) with an age range of 22-54 years (average of 38 years, standard deviation: 7.41) were in the study as a control group. The number of women was greater than that of men in both groups.

Severe headaches, behavioral abnormalities (such as irritability), and in some cases, seizures prompted the patients to seek medical attention. During the medical visit, an initial assessment of the tumor using conventional magnetic resonance imaging (cMRI) revealed that the tumor was in the prefrontal region. As a result, surgical intervention was recommended and given the highest priority. Patients received analgesics or antiepileptic drugs if they suffered from headaches or seizures respectively. Nevertheless, they did not take any special treatment between tumor diagnosis and surgery. These patients were admitted to Imam Khomeini Hospital, Tehran, and prepared for lesion resection surgery through craniotomy, selected using convenience sampling.

Among the patients participating in this study, two (12.5%) had Anaplastic Astrocytoma Grade III, one (6.3%) had Anaplastic Oligoastrocytoma Grade III, one (6.3%) had Astrocytoma Grade II, one (6.3%) had Astrocytoma Grade III, one (6.3%) had breast metastasis, two (12.5%) had Diffuse Astrocytoma Grade II, three (18.8%) had glioblastoma multiform (GBM), and five (31.3%) had Oligodendroglioma Grade II. Their demographic data are presented in Table 1. In addition, the tumor was found in the right hemisphere in half of the patients, whereas it was found in the left hemisphere in the other half (Table 1).

Table 1. Demographic Characteristics of patients include their gender, location of lesion and Type and grade of the tumor based on WHO grading. M: male, F: female, y/o: year old, RT: right, LT: left, VMPFC: ventromedial prefrontal cortex, OFC: orbitofrontal cortex

#	Gender	Age(y/o)	Location of the lesion	Type and grade of the tumor based on WHO grading
1	F	25	RT Prefrontal (VMPFC)	Anaplastic oligoastrocytoma Grade III
2	F	29	RT Prefrontal (VMPFC, OFC), Parietal cortex	Anaplastic Astrocytoma Grade III
3	F	45	LT Prefrontal (VMPFC, OFC)	GBM (glioblastoma multiform)
4	M	42	LT Prefrontal (VMPFC, OFC)	GBM (glioblastoma multiform)
5	M	36	LT Prefrontal (VMPFC)	GBM (glioblastoma multiform)
6	F	38	RT Prefrontal (VMPFC, OFC)	Anaplastic Astrocytoma Grade III
7	M	35	LT Prefrontal (VMPFC, OFC)	Oligodendroglioma Grade II
8	F	29	LT Prefrontal (VMPFC, OFC)	Diffuse Astrocytoma Grade II
9	M	44	RT Prefrontal (VMPFC, OFC)	Diffuse Astrocytoma Grade II
10	F	42	RT Prefrontal (VMPFC, OFC)	Breast metastasis
11	F	35	RT Prefrontal (VMPFC, OFC), Insula	Oligodendroglioma Grade II
12	F	49	RT Prefrontal (VMPFC)	Astrocytoma Grade II
13	F	35	LT Prefrontal (VMPFC, OFC)	Oligodendroglioma Grade II
14	F	50	LT Prefrontal (VMPFC, OFC)	Oligodendroglioma Grade II
15	M	52	RT Prefrontal (VMPFC, OFC), Insula	Oligodendroglioma Grade II
16	M	39	LT Prefrontal (VMPFC, OFC)	Astrocytoma Grade III
Totally	Men 6 (37.5)		Right prefrontal 7 (43.8)	Right Frontoparietal 1 (6.3)
Women10(62.5)			Left prefrontal 8 (50)	

Before surgery, the emotional face (Affective) Go/No-Go task, and the IVA test were performed for the patients and the healthy participants. Correspondingly, their reaction time, response accuracy, and neurocognitive status were recorded, respectively. This medical center regularly reviewed patients who have recently undergone surgery for clinical symptoms. No additional cognitive assessments are performed to monitor the success of treatment. The success of the surgery only evaluated three to six months after surgery by MRI scan of brain without and with injection of contrast media by applying routine MRI sequences such as T2W, FLAIR, T1W, DWI and post contrast T1W sequences for assessing the site of resection, possibility of residual or new growing tumor, edema and so on. In this study, the cognitive assessments were repeated three months after surgery when patients were in the better physical condition and less likely to have difficulties or impairments due to surgery. Patients in this study were generally in excellent health and mental status and could perform activities of daily living and make their own decisions. The patients cooperated well during the study and could return to work shortly after surgery. However, one patient died during the postoperative period, and another was admitted to the intensive care unit two months after surgery because of a deterioration in his condition; consequently, these individuals were excluded from this study.

Statistical analysis

SPSS 23 and TOSTER and EQUIVNONINF package of RStudio 1.4.1717 were used for data analysis. Frequency, percentage, mean and standard deviation (SD) were employed to describe the information. Besides, for inferential statistics, the t-test, Mann-Whitney, Wilcoxon signed rank test and their related equivalence test were utilized to compare outcome variables (reaction time, response accuracy to emotional stimuli and IVA status) between normal group and patients both before and after surgery. Significant level was considered 0.05 in this study. Equivalence tests are used in studies where the goal is to examine whether a meaningful effect is absent. For example, the researchers may be interested in demonstrating that an intervention like a surgery is efficient by showing that status of patients become close to the normal population after surgery. We called these studies as equivalence/noninferiority studies. To perform equivalence tests, it is needed to define a range of values considered practically equivalent to the absence of an effect which is called an equivalence range [21, 22].

3. Results

The effects of tumor on the response inhibition in the affective Go/No-go task

In order to assess the effects of tumor on response accuracy and reaction time against happiness and anger stimuli, we compared Go/No-Go protocol results of patients and healthy group before surgery. Based on pretest results, it was observed that there were significant differences between patients and the healthy group in terms of mean reaction time against happiness ($p<0.001$), mean reaction time against anger ($p<0.001$), and mean response accuracy against anger ($p<0.001$). The nonparametric Mann-Whitney test was also used to compare the response accuracy against the happiness stimulus in the patients and healthy individuals in the pre-test. The result indicated a significant difference between the patients (90.75±10.25) and the healthy participants (97.94±1.41) (U=92.5, p=0.03) (Table 2).

The effects of surgery on the response inhibition in the affective Go/No-go task

To determine the role of surgery, the pre-test and post-test of mean response accuracy and reaction time against happiness and anger stimulus of patients were compared using paired sample t-test. There was significant difference between pre- and post-test mean response accuracy against anger ($p<0.001$) and happiness ($p<0.001$) stimulus. This difference was also statistically significant in view of reaction time for both emotions ($p<0.001$).

In addition, we compared Go/No-Go task results of patients and healthy group after surgery by equivalence test. Based on post-test results, the mean reaction time against happiness in patients was statistically equivalent to the mean reaction time against happiness in the healthy group ($p<0.001$) considering the equivalence range (-1,1). Comparing post-test mean reaction time against anger between patients and healthy group, it was observed that the equivalence test is statistically significant, and we can statistically reject the presence of difference outside the equivalence range (-1.2,1.2) ($p<0.001$). Considering equivalence range (-5,5), the test was also statistically significant comparing mean response accuracy against anger between two groups which showed that the patients got closer to the condition of healthy individuals ($p<0.001$).

Based on the data of response accuracy against happy stimuli after surgery, the equivalence test was also statistically significant between the patients (95.94±6.90) and the healthy individuals (97.94±1.41) based on equivalence range (0.45,0.65), which showed that the patients got closer to the condition of healthy individuals (W_+ (observed value of the U-statistics estimator of $P[X>Y]$) = 0.54, SIGMAH (square root of the estimated asymptotic variance of W_+)= 0.10, CRIT (upper critical bound in decision rule) = 0.09). In other words, the change in response accuracy against the happiness stimulus was apparent following surgery (Table 2 and 3).

The effects of tumor location on the response inhibition on the affective Go/No-go task

To assess the effects of tumor location, the reaction time and response accuracy were compared in patients with left and right frontal tumors. The results revealed no significant difference between the performance of patients with left and right tumors against happiness and anger stimulus in both pre-test and post-test ($p\geq0.05$).

Comparing the mean reaction time and response accuracy in terms of stimulus type pre and post operation

In patients, there was significant difference between mean response accuracy against happiness and anger stimulus pre-operation (p=0.04), while this difference was not significant post-operation (p=0.83). The difference between mean response time against happiness and anger stimulus was not significant pre-operation (p=0.45), while this difference was significant post-operation (p=0.02) in patients. In healthy group, although the difference between mean response accuracy against happiness and anger stimulus was not significant (p=0.54), the mean response time against happiness and anger stimulus was significant (p=0.01).

Table 2. Pairwise t-test examining the differences in the time and accuracy of responses to happiness and anger emotions pre- and post-operation

Variable	Stage	Mean	SD	T	p-value
Response accuracy to happiness stimulus	Pre-operation Post-operation	90.75 95.94	10.25 6.9	-5.07	P<0.001
Response time to happiness stimulus	Pre-operation Post-operation	1.63 1.19	0.51 0.31	6.23	P<0.001
Response accuracy to anger stimulus	Pre-operation Post-operation	87.18 96.22	9.05 4.41	-5.17	P<0.001
Response time to angry stimulus	Pre-operation Post-operation	1.67 1.26	0.46 0.33	7.33	P<0.001

Table 3. Comparing the condition of patients and healthy individuals regarding reaction time and response accuracy against happiness and anger stimuli

Test Phase	Test	Mean ± SD(Patients)	Mean ± SD(Healthy Group)	T	p-value
Pretest of reaction time against happiness	t-test	1.63±0.51	0.8±0.16	6.82	P<0.001
Pretest of reaction time against anger	t-test	1.67±0.46	0.86±0.16	7.23	P<0.001
Pretest of response accuracy against anger	t-test	87.18±9.05	97.74±1.52	-5.14	P<0.001
Post-test of reaction time against happiness	t-test	1.19±0.31	0.8±0.16	4.56	P<0.001
	TOST Lower ($\Delta_l = -1$)			16.28	P<0.001
	TOST upper ($\Delta_l = 1$)			-7.14	P<0.001
Post-test of reaction time against anger	t-test	1.26±0.33	0.86±0.16	4.44	P<0.001
	TOST Lower ($\Delta_l = -1.2$)			17.79	P<0.001
	TOST upper ($\Delta_l = 1.2$)			-8.89	P<0.001
Post-test of response accuracy against anger	t-test	96.22±4.41	97.74±1.52	-1.31	0.20
	TOST Lower ($\Delta_l = -5$)			3.01	0.004
	TOST upper ($\Delta_l = 5$)			-5.65	0.001

The effects of tumor on the neurocognitive conditions assessed by IVA test

In order to assess the effects of tumor on IVA status, we used Mann-Whitney test to compare the neurocognitive disorder severity in healthy individuals and patients before surgery based on the IVA test. The level of severity was significantly higher in patients compare to the normal group (p<0.001).

Furthermore, following surgery, the equivalence test was not significant considering (0,0.5) as the equivalence range (p=0.88) comparing neurocognitive disorder severity in healthy individuals and patients. In addition, to compare IVA status of patients before and after surgery using Wilcoxon signed rank test, it was observed that the level of severity of neurocognitive disorder decreased significantly after surgery (p=0.005).

The effects of tumor location on the neurocognitive conditions assessed by IVA test

According to the results of the Mann-Whitney test, the level of severity of neurocognitive disorder was not significantly different in terms of the tumor location before (p=0.11) and after surgery (p=0.53). Therefore, the presence of the tumor in the left or right hemispheres does not make any difference in the results of the cognitive task.

4. Discussion

According to the purpose of this study, we examined the 16 patients with prefrontal lesions and 20 healthy subjects as a control group using IVA test and Affective Go/No-Go task. Many researchers have studied how the IVA exam compares to other types of cognitive assessments to determine its validity. A study by Eamonn Arble et al. in 2014 showed that this test's results are consistent with those of other cognitive tests that assessed working memory, attention, and response control [23].

Furthermore, the current study aimed to evaluate the effects of tumors on different emotional modes. Among the negative emotions, "anger" was chosen because, as previous research by Josje M. Valk et al. (2015) showed, the brain responds more robustly and quickly to dangerous signals once they have been fully processed and exposed. The unpleasant emotions "fear" and "anger" were similar, but "anger" was noticed as a more immediate threat and required a more decisive response. The response of the premotor cortex was enhanced by intense anger [24]. In other research, conducted by Yong-Gao Mu et al. (2012), a mass in the frontal lobe was found with a more decisive influence on "anger" [25].

The results revealed that in the pre-tests of response time and accuracy against emotional stimuli of happiness and anger, a difference was seen between the case and control groups. In other words, healthy individuals responded faster and more accurately when faced with both happiness and anger, which was the initial hypothesis of the present research.

After surgery, the speed of responses to happiness and anger improved in the patients. Nevertheless, this improvement was insufficient to eliminate the difference between the patients and the healthy participants. Therefore, patients show relative improvement following surgery but still have problems responding and inhibiting responses to anger and happiness.

However, regarding response accuracy against happiness and anger, it was found that the improvements have been significant enough to bring the patients close to the level of healthy individuals, but it still was not exactly the same as becoming normal.

These findings confirm those of Fang et al., who examined the effect of frontal lobe lesions on emotional performance [12, 26]. They found that if the workload on the dorsomedial prefrontal cortex increases, the interaction between response inhibition and emotional states becomes clear. For a patient with a lesion, engaging in emotional analysis and trying to provide the correct response is considered psychological stress in and of itself. When the psychological pressure for correct and timely expression of emotions is increased in these people, it is natural for the unit in charge to become incapable of manifesting normal behavior and producing the proper reaction. Jenkins et al. reported that in comparison with the control group, the tumor patients reported more significant changes in their mental experience of emotions following neurosurgery, expressly regarding anger, disgust, and grief [27].

Egashira et al., who examined the association of the frontotemporal region in schizophrenia patients, implicitly confirmed these findings. They stated that the abnormal processing of the emotional states of faces, along with negative valence and cognitive inhibition, was due to a malfunction in the frontotemporal region. In other words, by prioritizing the psychological function, they believed the strategy of the frontal lobe system to be influenced by an individual function [13]. However, the present research cannot find any time interval or semantic relationship between the abnormal reaction of neurons and cognitive impairment and cannot prefer one over the other.

What causes an improvement in patient's conditions following surgery is a reduction in abnormal synaptic connections and an increase in the efficiency of specialized brain sections in inhibiting responses to emotional stimuli. Hence, the patient faces less tension in response to the existing emotional situation and performs better. However, the reason for the fact that they cannot reach the level of normal individuals could be sought simultaneously in the two items of neurology and psychology. Some studies have shown that acute illnesses requiring intensive treatments, such as surgery, would cause deep anxiety in the patient in and of themselves, which can negatively impact their short- or long-term performance [28]. Accordingly, these individuals can improve their response speed by doing certain practices regarding specific emotions. However, there has yet to be any prospective research into their level of success so far.

As mentioned earlier, the IVA test was performed to confirm the findings of the cognitive task. The findings of this test showed that in the control group, only 25% of the members had MNCD, while in the case group, 65% had this condition, which is a statistically significant difference. After surgery, the eleven patients with MNCD and five patients with SNCD reached thirteen patients with MNCD and three patients with NL. In this phase, three patients with MNCD reached the normal state, and all the patients with SNCD reached the level of MNCD. In other words, although the condition of individual patients has shown improvement, this difference was not significant in general, and as predicted, the patients did not reach a completely normal condition.

Based on the discussions above, surgery affects response accuracy more than reaction time and anger more than happiness. Furthermore, in examining the effect of tumors on the expression and speed of emotions, predictably, tumors related to the right hemisphere would have a higher impact, as research has shown that the right hemisphere is responsible for most emotions and their expression [29]. However, the obtained findings showed that this difference did not have a noticeable effect. This may be because hemispheric connections in patients (before and after surgery) are so strong that they cover the patient's hemispheric disorders and do not exhibit any significant behavior. The IVA results confirmed these findings.

Based on these discussions, it can be concluded that surgery positively affects the emotional performance of patients with frontal lobe lesions against happiness and anger.

The limitation of this study was related to the Covid-19 pandemic resulted in fewer patients seeking medical care from hospitals. Given the subsequent decline in the prepared sample size, a more significant number of patients was recommended for future studies.

5. Conclusion

Lesions in the frontal lobe could negatively impact the accuracy of responses to happiness and anger stimuli, meaning that the patient would both have trouble providing the correct response and require a longer time to respond. In this respect, lesion resection surgery would improve this problem by 10%-30% and help bring the patient back to a more normal condition. This explanation indicates that after the period of convalescence, the patients maybe unable to provide emotional responses similar to a healthy person, but they can adapt better to a more significant number of situations. Nonetheless, this research should not conclude that this type of surgery would ultimately return these patients to normal life, as emotional and personality-related problems will continue in them even after surgery.

The results of this study showed that patients' cognitive status improved after surgery, although it still need to at a normal level. According to the statistically significant difference between "happiness" and "anger" before and after surgery, proposedly, the observed changes in reaction time and accuracy in the face Go/No-Go test is related to the emotional load of the test. As for "anger," the improvement in reaction time and accuracy after surgery is consistent with previous research that has identified the prefrontal area of the brain as the region primarily responsible for suppressing this emotion[30, 31].

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article. The participants were informed of the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them. This study was approved by the Ethics Committee of the Iran University of medical sciences (Code:IR-IUMS.REC.1399.295).

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Author's contributions

Planning, data acquisition, analyzing and writing this manuscript were done by Z. Farshidfar. Dr. M.A. Oghabian was a supervisor on all mentioned steps and corresponds this article. Dr. M. Tehrani-doost and Dr. S.A.H. Javadi were advisors in this project.

Conflict of interest

No potential conflict of interest was reported by the authors.

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