Publicación cuatrimestral del Hospital Universitario "General Calixto García" | Editorial de Ciencias Médicas

Archivos del Hospital Universitario "General Calixto García"

AÑO 2023
VOL. XI NO. 3
ISSN 2707-9120

Artículo de Investigación

Clinical and electroencephalographic evolution in patients with cerebral infarction subjected to saccadic eye movement exercises

Evolución clínica y electroencefalográfica en pacientes con infarto cerebral sometidos a ejercicios de movimientos oculares sacádicos

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Cómo citar este artículo

Martinez-Chile A, Esteban-Garcés E, Santos-Martínez Á, Belaunde-Clausell A, Machado-Curbelo C. Clinical and electroencephalographic evolution in patients with cerebral infarction subjected to saccadic eye movements exercises. Arch Hosp Univ “Gen Calixto García”. 2023;11(3):466-81. Acceso: 00/mes/2023. Disponible en: https://revcalixto.sld.cu/index.php/ahcg/article/view/1157

ABSTRACT

Introduction: Cerebrovascular disease is the first cause of adult disability. Rehabilitation with ocular exercises is useful in this group of patients.
Objective: To describe the neurological and electroencephalographic status before and after the performance eye exercises in patients with middle cerebral artery infarction.
Methods: An observational, analytical case-control study was carried out from January to December 2022 in 17 patients with cerebral infarction of the middle cerebral artery. The research consisted of two phases: clinical evaluation and electroencephalographic recording prior to exercise, and post-exercise electro-clinical reevaluation after three months. The variables evaluated were age, sex, smoking, arterial hypertension, diabetes mellitus, time since the occurrence of stroke, affected cerebral hemisphere, neurological status, cognitive impairment, Delta / Alpha Index, and Absolute Power Index.
Results: Male sex predominated (76.4 %). The mean age was 61.94 years. The main comorbidity was arterial hypertension (47.0 %). Also, 58.8% of patients had cerebral infarction in the right hemisphere. Patients with middle cerebral artery infarction who performed exercises with eye movements presented improvement according to NIHSS scale score, Mini-Mental State Examination score, and a decrease in the Delta / Alpha Index.
Conclusions: Rehabilitation with eye movement exercises in patients with cerebral infarction of the middle cerebral artery showed clinical and electroencephalographic improvement in relation to the control group.

Keywords: Cerebral infarction; eye movements; rehabilitation.

RESUMEN

Introducción: La enfermedad cerebrovascular es la primera causa de discapacidad en personas adultas. La rehabilitación con ejercicios oculares es de gran utilidad en este grupo de pacientes.
Objetivo: Describir el estado neurológico y electroencefalográfico antes y después de la realización de los ejercicios oculares, en pacientes con infarto de la arteria cerebral media.
Métodos: Se realizó un estudio observacional, analítico de casos y controles en el período de enero a diciembre de 2022, en 17 pacientes con infarto cerebral de la arteria cerebral media. La investigación

ISSN 2707-9120

quedó constituida en dos fases: evaluación clínica y registro electroencefalográfico previo a la realización de ejercicios y la reevaluación electroclínica posterior a los tres meses de ejectutados estos. Se evaluaron las variables edad, sexo, hábito de fumar, hipertensión arterial, diabetes mellitus, tiempo desde la ocurrencia del ictus, hemisferio cerebral afectado, estado neurológico, deterioro cognitivo, Índice Delta / Alfa, Índice de los Poderes absolutos.

Resultados: Predominó el sexo masculino (76,4 %). La media de edad fue de 61,94 años. La principal comorbilidad fue la hipertensión arterial (47,0 %). El 58,8 % de pacientes tuvo infarto cerebral en el hemisferio derecho. Presentaron mejoría, según la puntuación de la escala de NIHSS, de la miniprueba del estado mental y una disminución del Índice Delta / Alfa, a pacientes con infarto de la arteria cerebral media que realizaron ejercicios con movimientos oculares.

Conclusiones: La rehabilitación con ejercicios de movimientos oculares en pacientes con infarto cerebral de la arteria cerebral media mostró mejoría clínica y electroencefalográfica, en relación al grupo control.

Palabras clave: Infarto cerebral; movimientos oculares; rehabilitación.

INTRODUCCIÓN

The concept of cerebrovascular disease (CVD) refers to any disorder in which an area of the brain is transiently or permanently affected by ischemia or hemorrhage, in which one or more cerebral blood vessels are affected due to a pathological process.[1]

Depending on its nature, cerebrovascular disease can present as ischemia or hemorrhage, with a proportion of about 85% and 15%, respectively.[1] cerebrovascular disease is one of the leading causes of death in the world population, the first cause of severe disability and the second cause of dementia after Alzheimer's disease.[2,3,4,5]

The problem of cerebrovascular disease is not only due to its high mortality, but also to the disability it usually leaves in patients who survive stroke. Worldwide, it is the seventh leading cause of years lost due to disability when all ages are analyzed.[6]

At present, there are well-defined electroencephalographic (EEG) criteria for the diagnosis of cerebral infarction and quantitative electroencephalogram (QEEG) measurements are used as a sensitive diagnostic tool, which are very useful in monitoring clinical evolution, response to any therapeutic intervention and as a predictive index for future clinical evolution and the appearance of sequelae.[7,8,9]

In patients with stroke in subacute and chronic stages, a great variety of rehabilitation methods and techniques are implemented with good results. A great difference is observed in patients who are not rehabilitated.[8] Recently, eye movement techniques have been implemented to rehabilitate different alterations of visual fields, campimetric defects, hemianopsias.[7,8]

The aim of this research is to describe the neurological and electroencephalographic status before and after the performance of eye exercises in patients with middle cerebral artery infarction.

METHODOLOGY

Study design and temporal and spatial context

An observational, analytical, case-control study was carried out in the neurology service of the Central Military Hospital "Dr. Carlos J. Finlay", from January to December 2022.

This research did not include clinical intervention in the patients. Medical records were used to obtain data on the primary and secondary variables defined in the study.

Selection criteria

Inclusion criteria: Age 45-85 years, attending neurology consultation during the study period, diagnosis of atherothrombotic cerebral infarction of the middle cerebral artery, diagnosis of cerebral infarction within three months and with intact visual field.

Exclusion criteria: Patients diagnosed with transient ischemic attack at admission, cerebral infarction of other locations, intraparenchymal or subarachnoid hemorrhage. Patients with diseases associated with a high degree of disability. Visual field alterations. Rankin scale between 0 and 1.[9] Patients who received anticoagulant treatment.

Study sample

The sample consisted of 31 subjects from the universe of patients treated for cerebral infarction in the period covered. The universe consisted of 480 subjects. Patients were selected by inclusion and exclusion criteria.

All patients with a diagnosis of cerebral vascular infarction of atherothrombotic etiology who received regular treatment for this entity and rehabilitation with saccadic eye movement exercises were considered. This group consisted of 17 subjects.

The control group consisted of 14 patients, matched in sex, age and topographically with cerebral infarction of the middle cerebral artery and who did not receive eye movement exercise strategies.

Variables analyzed

Age, sex, smoking, sedentary lifestyle, hypertension, type 2 diabetes mellitus, time since stroke, affected cerebral hemisphere, neurological status, cognitive impairment. Electroencephalographic variables: Delta / Alpha Index (IDA), Absolute Power Index (IPA).

The Delta / Alpha Index (IDA) was calculated from the formula:

ISSN 2707-9120

$$\mathbf{IDA} = \frac{\text{Delta spectral energy (1 to 3 Hz)}}{\text{Alpha spectral energy (8 to 13 Hz)}}$$

The Absolute Power Index (IPA) was calculated from the formula:

$$\mathbf{IPA} = \frac{\text{Delta spectral energy} + \text{Theta spectral energy}}{\text{Alpha spectral energy} + \text{Beta spectral energy}}$$

Assessment of neurological status (NS): according to the National Institutes of Health Stroke Scale (NIHSS) score. Less than 5 points: mild EN impairment. 5-9 points: moderate EN impairment. 10 points or more: severe EN impairment.[10]

The Folstein Mini-Mental State Examination (MMSE) was used to assess cognitive status.[11]

Rehabilitation using saccadic eye movements and electroencephalographic assessment

The program used for rehabilitation through saccadic eye movement exercise consisted of a white background and a black circle 3 cm in diameter in the lower left corner that moved in different directions on the screen when the computer screen was opened.[12] The patient had to follow the circle with his eyes every time it appeared only with his eyeballs, without moving his head. The execution of the program has 15 repetitions in 10 minutes, 3 times a day.

A Neuronic device was used for the electroencephalographic evaluation. A selection was made of windows in the quantitative electroencephalogram recording that were free of artifacts and epileptiform activity. Quantitative analysis was performed with the Neuronic 6 software from the Fourier coefficient, determining the spectral energy by the classical frequency bands with the eyes closed condition.(11) In addition, the mathematical statistical programming program MATLAB 7.5 was used to calculate the quantitative electroencephalogram indices.[11]

Procedure for the collection of information and statistical analysis

Primary information was obtained from the review of medical records. The information obtained was entered into an SPSS 20.0 database.

In the statistical analysis, absolute and relative frequencies were used as summary measures. For each variable recorded, it was verified that there were no extreme, inconsistent or missing values.

A non-parametric test for dependent variables (Wilcoxon $p < 0.05$) was calculated for the pre- and post-exercise intra-group analysis of the Qquantitative electroencephalogram indices studied and the clinical scales studied.

To study the relationship between changes in the quantitative electroencephalogram indices and the clinical scales evaluated, the Spearman correlation coefficient ($r= -1$ and 1) was calculated ($p < 0.05$).

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To differentiate between the group of patients with eye movements and the control group of quantitative electroencephalogram measures and clinical scales, the differences (post values - pre values) of the IDA, IPR, NIHSS and MME were used as measures. For this purpose a Mann-Whitney test was applied ($p < 0.05$).

Ethical aspects

The medical equipment used for the electrophysiological recordings complied with the international safety standards related to this technology and are endorsed by the National Center of Medical Equipment of Cuba. The principle of confidentiality of the information was respected. The aspects of the Helsinki declaration for research on human beings were respected. The research was approved by the Scientific Council and the Research Ethics Committee of the institution where it was performed.

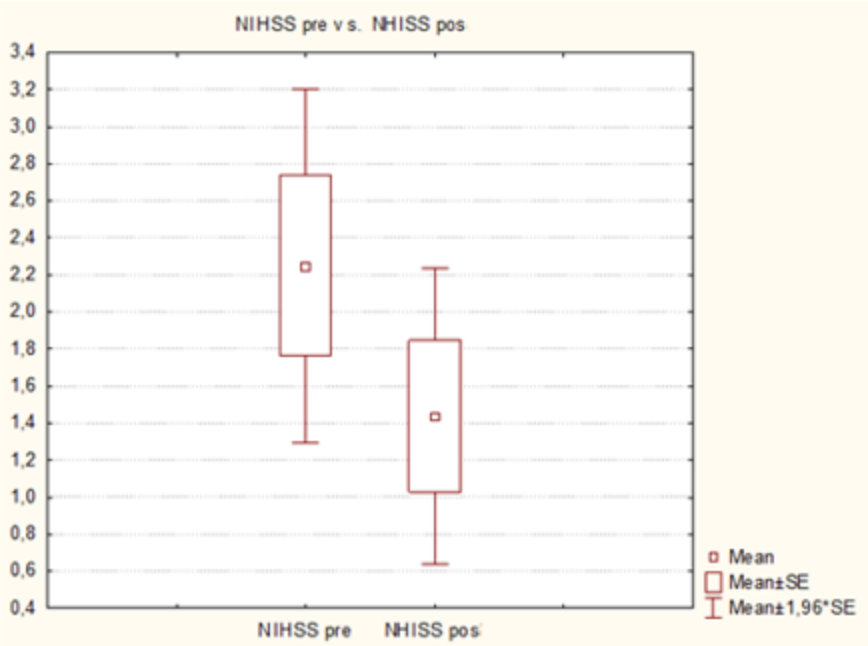
RESULTS

Male sex predominated (76.4 %). The age range was 45 to 85 years for a mean of 61.94 years. The main comorbidity was arterial hypertension (47.0 %), followed by type two diabetes mellitus (35.7 %). Sedentary lifestyle prevailed in 82.3 %, smoking in 70.5 %.

The mean time of evolution after cerebral infarction was 31.5 days. The 58.8 % of patients had cerebral infarction in the right hemisphere.

Patients with cerebral infarction who performed saccadic eye movements presented at 3 months a significant improvement in language and in the motor sphere expressed in a significant decrease in the NIHSS scale (Fig. 1).

ISSN 2707-9120



(p = 0,010316)

Fig. 1. Comparison of the NIHSS scale before and after rehabilitation with saccadic eye movement exercises.

In both groups of patients studied with cerebral infarction, there was an increase in the Mini-Mental State Examination values, where there was an improvement in cognitive skills in all patients. However, the improvement in this area was significant in patients who performed exercises with saccadic eye movements (Fig. 2).

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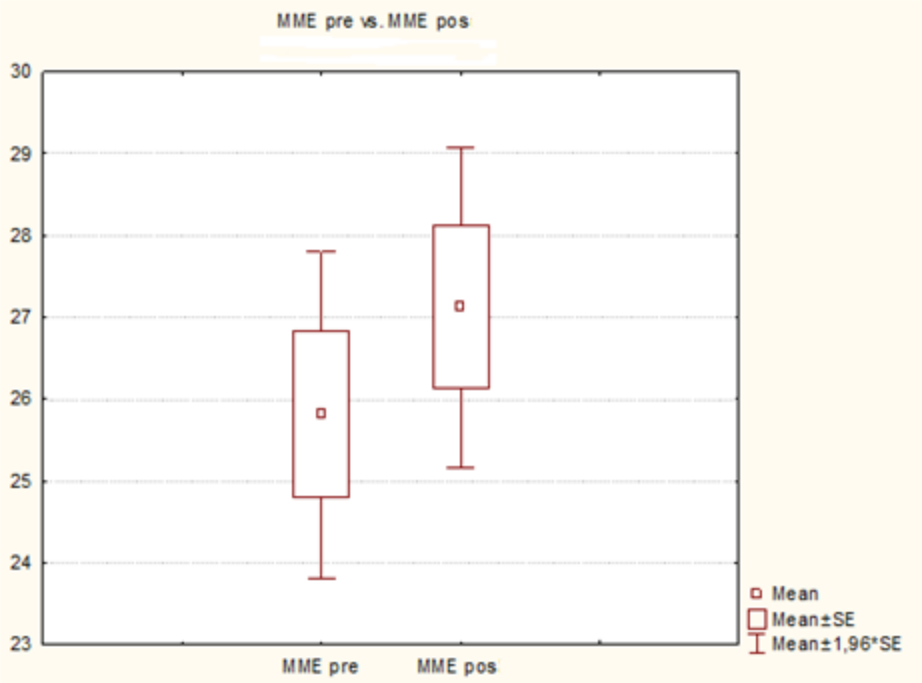


(p = 0,001475)

Fig. 2. Comparison of the MMSE scale before and after rehabilitation with saccadic eye movement exercises.

The indices calculated in the quantitative electroencephalogram study showed a significant decrease in IDA in the group of patients who performed the saccadic eye exercises. This result denotes an overall increase in the spectral power of the alpha activity and a decrease in the spectral power in the delta activity of the electroencephalographic as seen in the topographic maps of the absolute delta and alpha powers, as well as the topographic map of the IDA (Fig. 3 and Fig. 4).

ISSN 2707-9120

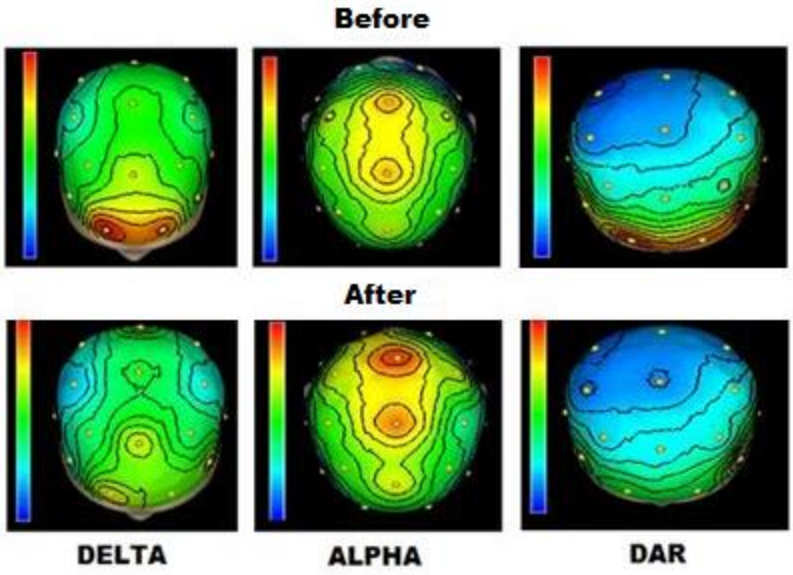


Fig. 3. Electroencephalographic study before and after the use of saccadic eye movements.

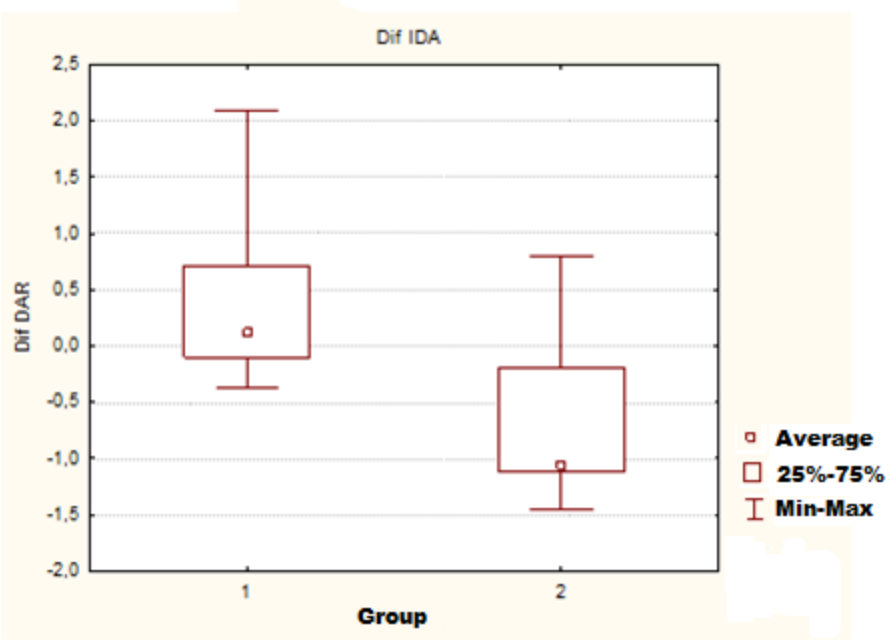
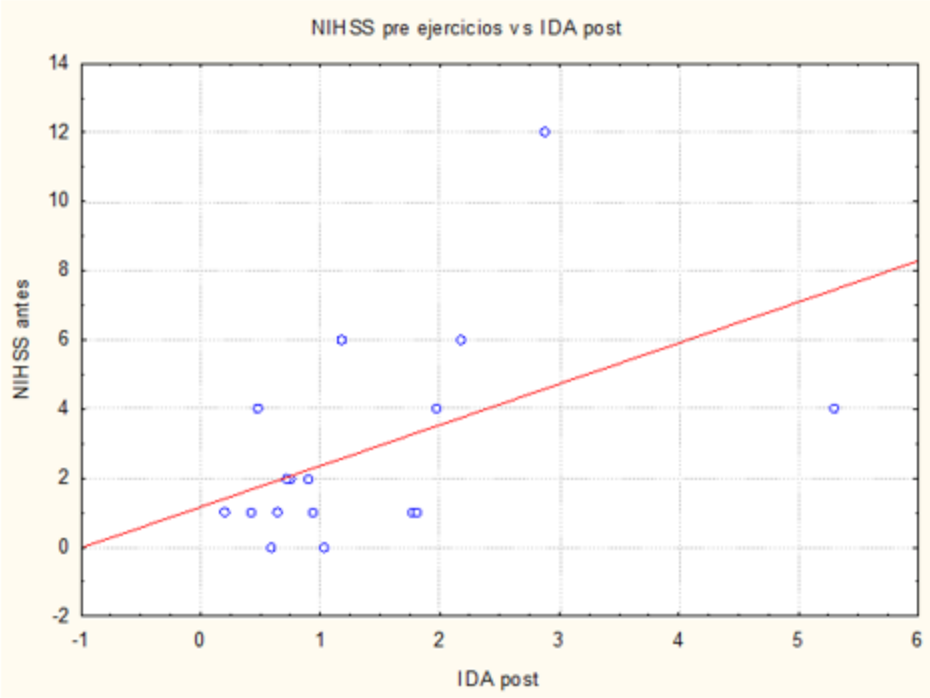


Fig. 4. Differences in IDA modifications before and after the study.

Patients who performed saccadic eye exercises started the study with a more deteriorated clinical condition. They were those who subsequently had higher IDA scores, i.e., they presented higher Delta activity and less Alpha activity (Fig. 5).

ISSN 2707-9120



(p = 0,025559)

Fig. 5. Correlation between pre-exercise NIHSS and post-exercise ocular ADI in patients with cerebral infarction.

DISCUSIÓN

In the group of patients with cerebral infarction of the middle cerebral artery who received neurorehabilitation, including the technique with saccadic eye movement exercises for three months, a significant clinical improvement was obtained, especially in the motor sphere. Both results were evident in the modifications of the NIHSS scale.[10]

A study is reviewed in which patients with acute cerebral infarction underwent saccadic eye movement techniques with the aim of improving their motor skills. There are others in which the use of eye movements to rehabilitate patients with cerebral infarction who have had eye movement disorders has been evaluated.[11,13] In these studies, there was a satisfactory change in this type of visual sequelae.

A 2019 study including ten patients with right middle cerebral artery infarction rehabilitated a unilateral hemineglect, due to a non-total and non-proportional direct hemiparesis of the left side, by means of eye exercises. The hemianopsias improved in 100 % of the cases of those who presented it, as well as the paresis of the affected limbs without specifying the percentage of improvement since it was not the

objective of their work, but the improvement of the neglect was not significant.[14] This group of researchers did not apply the NIHSS scale in their study, but they clearly obtained promising results in the motor sphere of their patients by means of saccadic type movements, very similar to those of this study.[14]

There are other investigations in which the NIHSS has been used as a clinical evaluation scale in patients with acute middle cerebral artery infarction who are undergoing rehabilitation and who have used other techniques, mainly physical exercise, where very positive results expressed in the NIHSS have been achieved.[14,15] Although it would not be valid to compare these studies directly with this one, it can be affirmed that in the subjects of this research there was a clinical improvement superior to the control cases that only performed physical exercises in their rehabilitation. This could be justified by the eye movements as an alternative rehabilitative therapy, the only difference between both groups.[13]

It is known that using saccadic eye movements to rehabilitate these patients activates cortical areas related to eye movements and others not so closely related.[16,17] In a German study using functional magnetic resonance imaging of eight patients with posterior cerebral artery infarction and different forms of hemianopsia as sequelae, saccadic exercises were prescribed 90 minutes a day for two months. Subsequent re- evaluation of these patients showed that 100 % had improved visuo-perceptual skills during activities of daily living. Before performing the exercises, only areas of the occipital cortex were activated; eight weeks after the exercises with saccadic movements, activations of the extrastriate cortex of that hemisphere and peristriate of the hemisphere contralateral to the lesion were found, as well as in all areas related to oculomotor function, including frontal areas.[14,15,16]

Motor commands for saccades are generated at multiple levels of the neuroaxis: the frontal eye field, the supplementary eye field, and the prefrontal and dorsolateral cortex and posterior parietal region of the eyes (all areas supplied by the middle cerebral artery) send commands to the superior colliculi, which then project them to the brainstem saccade center.[17,18]

The brainstem generators guarantee an optimal signal to ensure a fast speed of saccadic movements, while the neural integrator, which integrates the saccade pulse, facilitates a stable gaze fixation support. This explains how patients with middle cerebral artery infarction could improve with eye movement exercises.[19,20]

These aforementioned areas, all involved in the performance of eye movements and saccadic movement areas, are in turn the ones that are most stimulated by the passive movements of the extremities that are suggested and are part of the mechanisms of recovery of the patients' muscle strength. Although these mechanisms are not well defined, there is another series of events that would partially explain this process, among which are the ipsilateral axons coming from the undamaged cortical areas, perilesional organization, the recovery of the damaged pyramidal pathway, and the contribution made by the supplementary motor area.[20, 21]

When a brain lesion occurs, a series of changes occur in the neighboring regions that can take place from the first minutes to several months later. For more than half a century many theories or possible mechanisms have been invoked, but the main fact is that when a lesion occurs, modifications occur

throughout the perilesional territory at the level of the synaptic connections, which leads to a reorganization at the level of the cortical areas. This special characteristic of plasticity at the level of the horizontal synaptic connections of the cortex makes it possible to restructure the cortical map, and that other regions can acquire the functions that the injured area used to perform.[22] This phenomenon can be reinforced by using different rehabilitation techniques.[23]

In the group of patients in the study, they also presented improvement in cognitive function through the Mini-Mental State Examination score. Neither has this scale been evaluated in Cuba in patients with cerebral infarction who use saccadic eye movements as therapy. There are studies that evaluate individualized rehabilitation in stroke patients.[23] The studies that use this scale do so for cognitive impairment or dementia, which is not the case here. The results of this research assert that eye movements in the study patients have a propensity to improve cognitively.[23,24]

In the aforementioned study where the electroencephalographic evaluation is evaluated in the studies that used eye movements in patients with cerebral infarction, and in others the IDA has been widely used to evaluate changes in brain electrical activity in patients with stroke at any stage who are being rehabilitated.[13,18,19] A study was carried out in Australia in 2007, in 13 patients with a stroke of different topographies, between 2 and 30 days of evolution, using the NIHSS scale and IDA measurements in the QEEG; also, the average age of their patients ranged between 61 and 66 years, and they were able to verify that at 30 days, the NIHSS scale and the delta alpha index had experienced a direct relationship, as the NIHSS scale decreased, the delta alpha index decreased, thus proving that both parameters are strongly related.[13,23]

In this study, when comparing the group of patients who performed saccadic eye movement exercises with the control group that did not perform them, it was noted in the latter that the improvement was not significant, even in the latter, delta and beta type alterations persisted, with less organization of the alpha and maintaining the bihemispheric asymmetry. The decrease of the IDA is directly related to a clinical improvement of the patients. This parameter of QEEG has a great prognostic value and is useful to evaluate rehabilitation in different acquired brain lesions, especially in cerebral infarction.[13,23,24] Increased alpha activity in QEEG after cerebral infarction is an electrical marker of neuronal survival and decreased delta activity suggests a decrease in the area of cortical deafferentation or the area of neuronal injury.[13]

In this study, the patients who performed the saccadic movement exercises not only obtained an improvement in the NIHSS scale but also had an ostensible improvement of the IDA in the QEEG compared to the control group. There was a reduction in spectral power in the delta and an increase in the grouped alpha, which speaks in favor of a greater neuronal survival in these patients, which helps to explain the better functionability they obtained.[25]

There was no direct correlation between clinical and electroencephalographic variables in either of the two groups studied, only a positive correlation was obtained between pre- exercise NIHSS and post-exercise ADI. From the neurological and neurophysiological point of view, it is not known to what extent this could be useful. It is interpreted that patients with worse NIHSS scores before eye exercises were those who obtained less improvement in ADI. Likewise, there are studies where it is known that different

QEEG index variables correlate with clinical scales, especially the NIHSS scale and the IDA. These indexes serve as prognostic factors for the clinical evolution of these patients.[26,27]

It is concluded that patients with cerebral infarction of the middle cerebral artery, rehabilitated by means of eye movement exercises, have clinical and electroencephalographic qualitative improvement compared to the control group.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

Authors' contribution

ISSN 2707-9120

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Financing

The authors did not receive funding for the development of this research.

Received: 21/10/2023.
Approved: 05/12/2023.