The Contribution of Imaging and Functional Diagnosis to the Rehabilitation of Patients with Stroke

PAUL LUCACI[1,2*], MARIUS NECULAES[2], DANISIA HABA[1]

[1] Grigore T. Popa University of Medicine and Pharmacy Iasi, 16 University Str., 700115, Iasi, Romania

[2] Alexandru Ioan Cuza University of Iasi, Faculty of Physical Education and Sport, 3 Toma Cozma Str., 700554, Iasi, Romania

The research conducted is based on the clinical evaluation through magnetic resonance and on functional testing using the stabilometric platform, of a sample of 23 subjects with a stroke ischemic localised in the area of the middle cerebral artery. With the help of magnetic resonance, the structural changes of the ischaemic focus were determined. At the same time, the evolution in time of the ischaemia and the alteration at the level of the ischaemic area were monitored. By using the stabilometric platform GPS 400, the distribution of the load at the level of the lower limbs was analysed, as well as barycentre variations. The results obtained after conducting the study highlight the high possibility of the functional re-education of the subjects when brain lesions do not extend and no complications arise, elements underlined by imaging exploration using magnetic resonance.

Keywords: rehabilitation, evaluation, ischaemia, magnetic resonance, stabilometry

Stroke represents an important problem of public health, and in the recent years the incidence of this disease increased dramatically, according to the statistics made worldwide [1,2]. The causes of this disease are mainly haemorrhagic and ischaemic, 85% f them being produced by cerebral ischaemic lesions and only 15% being determined by intracranial haemorrhages. As in case of other pathologies, stroke is the result of the interaction between genetic predisposition and the environmental factors [3]. Despite the years of clinical trials focusing on this phenomenon, stroke management remains suboptimal, though the clinical trials that tested the new treatments benefited from improvements over time, thus becoming ever more complex. Nowadays, a series of new promising treatments are part of ongoing trials, such as the latest neuroprotective compounds [4-7], hypothermia [8-10], oxygen therapy, brain stimulation and regenerative therapy.

Contemporary medicine is in the point of identifying therapies that may contribute decisively to the patients' rehabilitation, because thus far it has gone through a long period necessary for understanding this pathology. Specialists underpin that the close future has the potential of pointing out significant ways to optimise the management of stroke. The imagining investigation methods provide information regarding the type of brain lesion (ischaemia or haemorrhage) and other underlying causes for the onset of neuromotor deficit. At the same time, neuroimaging provides information about the status of the impaired brain tissue, which may help to decide on the type of therapeutic approach and to differentiate the irreversible damage from those with a chance to save the affected tissue. A structural lesion resulting from a stroke may perturb critically the complex balance of the excitatory and inhibitory influences within the motor network [11].

In the past years, successful treatment strategies have been discovered for the treatment of ischaemic stroke; they were found to be more effective when administered within the first hours from the onset of symptoms. Consequently, extremely fast diagnosis and initiation of treatment are essential in order to avoid severe disabilities or even death [12]. Modern imaging techniques are capable of determining diagnosis in a highly accurate manner, which leads to the possibility of starting treatment very soon, thus not missing the therapeutic window. All patients displaying specific symptoms must be examined with the help of computed tomography without contrast agent or of magnetic resonance [13].

Nuclear magnetic resonance provides the possibility of detecting the brain areas affected in a more precise way through the increased sensitivity of the tissue contrast, thus allowing to obtain detailed images at diverse levels. This technology provides new perspectives that may contribute to the improvement of the treatment of many patients [14]. The first images through nuclear magnetic resonance used in general for the identification of an ischaemic stroke are those on the weighted sequence T2 and DWI (diffusion-weighted imaging). Nuclear magnetic resonance provides better insight into the pathology of acute stroke that may lead to the improvement of the treatment applied [15].

In case of a stroke, neurological deficits may be summarised after having identified all nervous, articular and muscular manifestations that may be included in the clinical diagnosis of patients. Several evaluation scales were developed to identify the severity of the sequelae installed post-stroke; they became valid instruments and reliable predictors of the outcomes of rehabilitation programs. Within functional evaluations, there is a focus on the quantitative evaluation of the quality of life of patients with disabilities post-stroke [16].

Stabilometry performs an objective evaluation of the posture and at the same time of the static and dynamic balance, thus allowing the quantification of the normal and pathological parameters, statistically validated, as indicators of body stability disorders.

Currently, research focuses on the discovery and implementation of new techniques and equipments for the complex and objective evaluation of body balance in the diverse pathologies. The new technologies of analysis by interpreting the stabilometric signals are applied successfully in neurological pathology and they represent means of monitoring the evolution of the rehabilitation of patients with disabilities. In order to increase the

* email: lucaciupaul@yahoo.com

productivity of this evaluation equipment, an international standardisation of stabilometry was proposed at several meetings of the International Society of Posture and Gait Research, in Bologna (2009), Akita (2013), Vancouver (2014) and in 2015 in Seville [17].

International studies determined optimal models for the healthcare of patients with a stroke, as the precocity of the institution of the rehabilitation treatment represents the key to success. Though there are doubts regarding the optimal window for initiating the rehabilitation therapy, the studies concerning the post-rehabilitation results demonstrated that the fast adherence of the rehabilitation programs leads to an improvement of the functional recovery and to the decrease in the duration of therapy [18].

Experimental part

Materials and methods

This research was conducted on a sample of 23 subjects with an ischaemic stroke, localised deeply or superficially at the level of the left or right middle cerebral artery (MCA) (6 subjects with ischaemic stroke in the superficial area of the right MCA, 2 subjects with ischaemic stroke in the deep area of the right MCA, 2 subjects with ischaemic stroke in the superficial area of the left MCA, 13 subjects with ischaemic stroke in the deep area of the left MCA). The subjects of the sample underwent imaging investigation through magnetic resonance in the subacute stage of stroke.

The imaging exploration protocol included the sequences specific to T1 (fig. 1.A), T2 (fig 1.B), FLAIR (fig. 1.C), diffusion (DWI, fig. 1.D), the apparent diffusion coefficient (ADC, fig. 1.E), on axial section.

The functional evaluation was conducted using the stabilometric platform GPS 400 through which we assessed the loading of the lower limbs, the variation and length of the barycentre curve. The loading of the lower limbs was shown in percentages, the speed of barycentre oscillations within the support polygon was measured in mm/s, while curve length in mm.

The testing method consisted in training the subjects and it involved asking them to stand with eyes open on the stabilometric platform with legs slightly apart, maintaining the position for 20 s [19].

The imaging evaluation and the functional evaluation were performed at the beginning of the study and after six months, a period during which the subjects benefited from medical rehabilitation programs.

The inclusion criteria concerned the type of stroke (ischemic), the lesion localisation (middle cerebral artery), limited function (the capacity to stand), the prescription and possibility of magnetic resonance imaging, the stage of stroke (subacute). The exclusion criteria concerned the biomechanical modifications of the leg and of Achilles' tendon, the severe gait impairment as a consequence of associated pathologies, the presence of vital risk.

Results and discussions

The research conducted has analysed the comparative results of the imaging and functional evaluation conducted at the initial testing and after six months of rehabilitation programs. The statistical analysis was performed using Statistics version 7.0, to highlight the differences from the initial testing to the final testing.

Following the magnetic resonance imaging evaluation, modifications were found (fig. 2), which were divided into two main categories (significant: reduced ischaemic focus compared to the initial evaluation, without lesion expansion and without the emergence of complications and insignificant: without modifications of ischaemia size and without the emergence of complications or of lesion expansion).

As illustrated in figure 2, the frequency of significant modifications has a value of 41.18% for the subjects with a stroke in the superficial area of the middle cerebral artery and a frequency of insignificant modifications accounting for 33.33%. In what regards the deep area of the middle cerebral artery at the final evaluation, the frequency of the decrease in the ischaemic focus was 58.82%, compared to the frequency of insignificant modifications (66.67%). The tissue modifications occurring in the acute stage of stroke - manifesting by inflammatory and oedematous responses - may reflect in the subsequent evolution of the ischaemic focus [20]. The size of ischaemic lesions has a crucial importance, thus influencing the evolution of recovery and of functional outcomes [21]. For the emergence of the ischaemic area atrophy, between 30 and 90 days are necessary, this period leading at the same time to an enlargement of the ventricle [22].

The preservation or decrease in the sizes as well as the lack of complications or expansion of the ischaemic focus favoured the rehabilitation process for the subjects, which

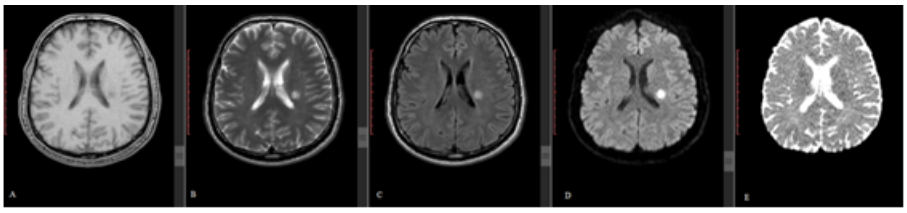

Fig. 1. Subacute ischaemic stroke, A (sequence T1), B (sequence T2), C (FLAIR), D (diffusion, DWI), E (apparent diffusion coefficient, ADC)

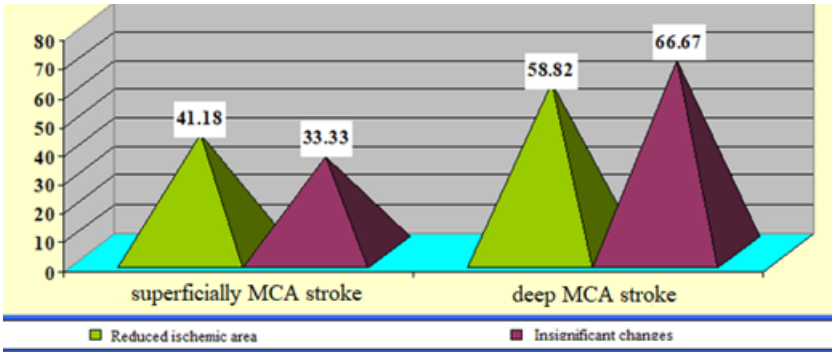

Fig.2. Frequency of significant and insignificant modifications by the localisation of stroke

reflected in the improvement of the functional parameters assessed using the stabilometric platform. figure 3 and figure 4 depict the graphic representation of average loading percentages of the lower limbs (healthy and plaegic) at the initial evaluation and at the final one, for the stroke in the superficial area (fig 3) and in the deep area (fig 4) of the middle cerebral artery.

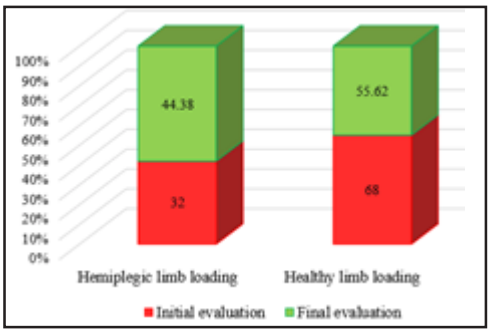

Fig 3. STROKE in the superficial area of the MCA, loading percentage for the lower limbs (healthy and plaegic)

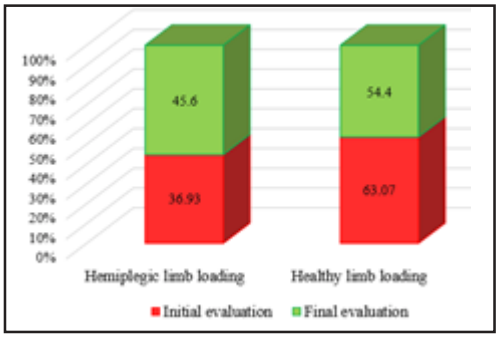

Fig 4. STROKE in the deep area of the MCA, loading percentage for the lower limbs (healthy and plaegic)

As shown in figures 3 and 4, the average weight distribution at the level of the lower limbs improved, but the values obtained were not statistically significant at the final evaluation (p 0.55; n=23). The initial mean for the plaegic lower limb in case of impaired superficial area of the MCA was 32%, and the final value reached a mean value of 44.38%. In what regards the impaired deep area of the MCA, the initial mean value was 36.93%, in the end reaching 45.6%. For the healthy lower limb, the mean values improved from the initial value of 68% to the final value of 55.62% for the superficial area of the MCA and from 63.07% initially, to 54.4% finally, for the deep area of the MCA.

The optimal loading of the lower limbs and especially of the plaegic lower limb (which tends to be reduced), represents an important component in preserving balance and orthostatism and in preventing the onset of equines foot, through the retraction of Achilles' tendon. The lack of plantar proprioception may be a cause of failing to attain this desideratum [23], the stimulation of plantar proprioceptors and the toning of muscles are the expertise area of physical therapists. In this respect, experts may also use vibrations in order to improve balance by reducing spasticity at the level of the flexing muscles of talocrural joint [24].

Figure 5 illustrates the mean values of the speed of barycentre oscillations within the support polygon for the patients with a stroke in the superficial and deep area of the middle cerebral artery. The average speed of oscillations was not significantly different from a statistical perspective by the localisation of stroke (p 0.30; n=23).

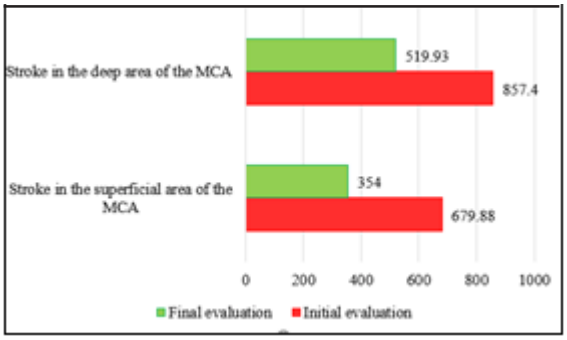

Fig 5. The speed of barycentre oscillations within the support polygon (mm/s)

As highlighted by figure 5, the speed of barycentre oscillations decreased from an initial average value of 857.5 mm/s for impaired deep area and a value of 679.88 mm/s for impaired superficial area to a mean final value of 519.93 mm/s for impaired deep area and 354 mm/s for the superficial area of the middle cerebral artery, respectively.

The decrease in the level of barycentre oscillations entails a better balance of the subjects. The improvement of this parameter may be the result of the exercises meant to stimulate the recovery and resposture responses, as well as of the exercises meant to tone the lower limbs and to stimulate plantar proprioception, activities that were guided and dosed by the intensity of misbalances identified on the stabilometric platform. In order to reduce postural oscillations, one must take into account the stabilisation of the pelvis and of the distal component of the plaegic lower limb [25], because in time, muscle strength and resistance decrease [26].

The values of curve length described by the barycentre for the subjects with a stroke in the superficial and deep area of the middle cerebral artery are illustrated in figure 6, the values obtained at the final evaluation were not statistically significant (p 0.06; n=23).

Figure 6 highlights the favourable evolution of barycentre curve length, from the initial mean value of 3.72 mm for impaired deep area and 2.85 mm for the superficial area to the final average value of 1.45 mm for the deep area and 1.21 for the superficial area of the middle cerebral artery, respectively. The improvement of this parameter reflects in the increase in step length and walking speed, which leads to the improvement of body balance, thus eliminating the fear of falling and the dizziness. The fear of falling is very common among individuals with disabilities post-stroke, as very few of them manage to stand without help after such a fall [27].

The optimal weight distribution at the level of the lower limbs and the capacity of maintaining balance stance should be trained by integrating daily movements of patients, because it is necessary to make certain postural adjustments that are not possible to make but during such movements [28].

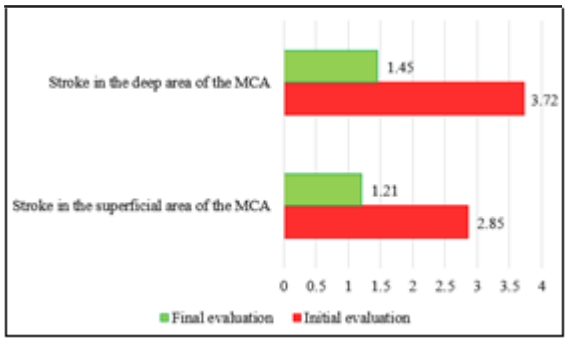

Fig. 6 The length of the barycentre curve (mm).

As clearly shown in figures 3-6, the balance of patients improved after six months of rehabilitation programs, the loading at the level of the plaegic lower limb improved for the subjects who had suffered a stroke in the deep area and in the superficial area of the middle cerebral artery. The researches conducted confirm that balance re-education is also necessary and useful in the chronic stage of rehabilitation. This is possible through activities entailing barycentre oscillation motions within various types of exercises [29]. The movements and activities entailing the modification of the barycentre may also be performed with the help of stabilometric platforms leading to the optimisation of balance [30]. For the improvement of swing and of the biomechanical gait parameters, the treadmill may also be used, with the possibility of re-educating the transfer of barycentre outside the support polygon, an essential factor in order to attain this objective being gait intensity [31]. Nowadays, the robotic gait and balance re-education methods available to patients with a stroke have improved considerably; studies have underlined that they may be useful in improving motor performances [32].

Conclusions

Imaging and functional diagnosis have a significant contribution to the development, monitoring and improvement of medical rehabilitation programs for patients with a stroke. Stabilometric evaluation may represent an important factor in choosing the right exercises in order to improve weight distribution at the level of the lower limbs as well as to optimise the parameters of gait and of the static and dynamic balance. The imaging re-evaluation through magnetic resonance helps to orient the rehabilitation process, thus highlighting the rehabilitation possibilities and limitations of an individual by the lesion localisation, by the size of the ischaemic focus and by the presence or absence of complications.

References

1.KIM A.S., JOHNSTON S.C., Circulation, **124** no.3, 2011, p.314-323.
2.HO E., CHEUNG SHC., DENTON M., KIM BDH., STEPHENSON F, CHING J., BOYLE K., LYEO S., SALBACH N.M., Top Stroke Rehabil., **15**, 2018, p.1-7.
3.GROSU, C., MASTALERU, A., COSTAN, V.V., NITA, O., LEON, CONSTANTIN, M.M., Rev. Chim (Bucharest), **69**, no.11, 2018, p. 3068-3071.
4.GINSBERG M. D., Neuropharmacology, **55**, 2008, p.363-389.
5.SAHOTA P., SAVITZ S. I., Neurotherapeutics, **8**, 2011, p.434-451.
6.MINNERUP J., SUTHERLAND B. A., BUCHAN A. M., KLEINSCHNITZ C., Int J Mol Sci, **13**, 2012, p.11753-11772.
7.SUTHERLAND B. A., MINNERUP J., BALAMI J. S., ARBA F., BUCHAN A. M., KLEINSCHNITZ C., Int J Stroke, **7**, 2012, p.407-418.
8.FROEHLER M. T., OVBIAGELE B., Expert Rev Cardiovasc Ther, **8**, 2010, p.593-603.
9.CAMPOS F., BLANCO M., BARRAL D., AGULLA J., RAMOS-CABRER P., CASTILLO, J., Neurochem Int, **60**, 2012, p.495-505.
10.YENARY M. A., HAN, H. S., Nat Rev Neurosci, **13**, 2012, p.267-278.
11.GREFKES C., FINK G.R., Brain, **136**, no.5, 2011, p.1264-1276.
12.POWERS W. J., DERDEYN C. P., BILLER J., COFFEY C. S., HOH B. L., JAUCH E. C., JOHNSTON K.C., JOHNSTON S.C., KHALESSI A.A., KIDWELL C.S., MESCHIA J.F., OVBIAGELE B,, YAVAGAL D. R., Stroke, **46**, no.10, 2015, p.3020–3035.
13.YEW K.S., CHENG E.M., Am Fam Physician, **91**, no.8, 2015, p.528-36.
14.BAERT A.L., SARTOR K., Springer, 2006, p. 17.
15.KUMMER V.R., BACK T., Springer, 2006, p. 26.
16.TAYLOR-ROWAN M., WILSON A., DAWSON, J., QUINN, T. J., Front Neurol. **26**, no.9, 2018, p.191.
17.YAMAMOTO M., ISHIKAWA K., AOKI M., MIZUTA K., ITO Y., ASAI M., SHOJAKU H., YAMANAKA T., FUJIMOTO C., MUROFUSHI T., YOSHIDA T., Auris Nasus Larynx. **45**, no.2, 2018, p.201-206.
18.MEYER M. J., TEASELL R., KELLOWAY L., MEYER S. B., WILLEMS D., O'CALLAGHAN, C., Disabil Rehabil. **40**, no.26, 2018, p.3120-3126.
19.NECULAES, M., BOTEZ, P., Sp Soc, **11**, no 2, 2011, p. 206-221.
20.HEISS W., ZARO WEBER O., J Nucl Med. **58**, no.2, 2016, p.187-193.
21.YAMAGUCHI S., HORIE N., MORIKAWA M., TATEISHI Y., HIU T., MOROFUJI Y., IZUMO T., HAYASHI K., MATSUO T., PLoS One, **13**, no.4, 2018, e0195554.
22.TIPIRNENI-SAJJA A., CHRISTENSEN S., STRAKA M., INOUE M., LANSBERG M.G., MLYNASH M., BAMMER R., PARSONS M.W., DONNAN G.A., DAVIS S.M., ALBERS G.W., J Cereb Blood Flow Metab. **37**, no.8, 2016, p.3077-3084.
23.PARSONS S.L., MANSFIELD A., INNESS E.L., PATTERSON K.K., Top Stroke Rehabil. **23**, no.5, 2016, p.326-32.
24.KARIMI-AHMADABADI A., NAGHDI S., ANSARI N.N., FAKHARI Z., KHALIFELOO M., J Bodyw Mov Ther. **22**, no.2, 2018, p.242-246.
25.LOPES P. G., LOPES J. A. F., BRITO C. M., ALFIERI F. M., RIZZO BATTISTELLA L., Biomed Res Int. 2015, 716042.
26.PIZZIGALLI L., MICHELETTI CREMASCO M., MULASSO A., RAINOLDI A., J Bodyw Mov Ther. **20**, no.2, 2016, p.409-17.
27.SHOVLIN E., KUNKEL D., Disabil Rehabil. **40**, no.26, 2017, p.3191-3197.
28.CARR H.J., SHEPERD B.R., Butterworth Heineman, 2004, p. 80.
29.VAN DUIJNHOVEN H.J., HEEREN A., PETERS M.A., VEERBEEK J.M., KWAKKEL G., GEURTS A.C., WEERDESTEYN V., Stroke. **47**, no.10, 2016, p.2603-10.
30.TSAKLIS P.V., GROOTEN W.J., FRANZEN E., Top Stroke Rehabil. **19**, no.1, 2012, p.23-31.
31.TALLY Z., BOETEFUER L,, KAUK C., PEREZ G., SCHRAND L., HODER J., Top Stroke Rehabil. **24**, no7, 2017, p.539-546.
32.ZHANG X., YUE Z., WANG J., Behav Neurol. 2017, 3731802.

Manuscript received: 18.12.2018