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Pathological changes and their assessment in patients after cerebellar infarct

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Abstract

The cerebellum is a structure responsible for many important functions in human life. Cerebellar infarcts are very rare and account for a small percentage of all infarcts. Among other things, the influence of cerebellar infarct on imbalance, the ability to keep the body's centre of gravity in a balanced position, coordination, and the impact of an infarct on dysfunctions of muscle groups involved in gait were described. Following, it is explained what tests should be performed before presenting a treatment program for post-infarct complications. The conclusions emphasised the quickest possible assessment of cerebellar infarct-related disorders and the effectiveness of pharmacological or surgical treatment and intensive rehabilitation.

Key words: cerebellar infarct, balance, coordination, gait disturbance.

Introduction

Cerebellar infarcts are very rare and account for about 2-4% of all infarcts [1], of which 10% are haemorrhagic [2]. The cerebellum is a structure responsible for many important functions in human life. Its main role in motor skills is coordination of movements and maintaining balance. However, according to the latest research conducted by Krienen and Buckner in 2009 and Moore and her colleagues in 2017, the cerebellum, apart from activities related to movement, is also responsible for cognitive functions, which are used, among other things, to focus attention, communication, perception and emotional expression [3, 4].

The role of the cerebellum in balance and coordination

Thanks to its numerous afferent neural pathways, the cerebellum receives nerve impulses from all over the body. These are mainly impulses from receptors in muscles, tendons and joints which run along the pathways in the spinal cord, but can also come from the vestibular organ. Cerebellum is responsible for receiving information about the balance and position of the body in space. The received impulses are analysed by the cerebellum, and then information about them is sent through its efferent pathways, which run through the bridge and thalamic nuclei, to the motor cortex. This direction of impulses was confirmed, inter alia, by the study of Simona V. Gornati and colleagues, who verified it through electrical stimulation of various parts of the cerebellum [5]. By means of an electrophysiological examination, with an electron microscope, it was observed that the impulse initiated in a given region of the cerebellum gives a reaction in specific areas of the thalamic nuclei. The path of the nerve impulse could be observed using fluorescent agents. These agents reacted under the influence of an electric impulse causing them to glow. As a consequence, it was possible to determine the path of nerve impulses flow, depending on the place of initial stimulation [6, 7].

Balance

Balance is the ability to keep the body's centre of gravity in an equalised, stable position. It is divided into static equilibrium, characterised by maintaining an upright body position without any movement factors, and dynamic equilibrium, that is maintaining body posture during movement and under the influence of external forces. The equilibrium mechanism is maintained by human beings without their awareness [8, 9].

The main structure responsible for balance and its monitoring is the vestibular organ, which is located in the inner ear, otherwise known as the labyrinth or labyrinthus. The inner ear is a system of cavities and channels located in the petrous pyramid [5].

Human beings have 3 pairs of semi-circular canals which form pairs located in the same plane. On the other hand, the planes in which the canals are found remain perpendicular to each other. The cross-section of the canals is round and slightly flattened. Each canal makes about 2/3 of the circumference of a circle which is about 8 millimetres in diameter. Their lengths are 15-22 millimetres on average, and the diameter of the cross-sections is usually 3-5 millimetres [5].

Inside each canal, there are analogous to them semi-circular ducts: anterior, posterior and lateral. Each of them has an ostium in an utricle and an extension at the end called a membranous bulb equipped with a bubble comb. The bubble crest is a structure covered with sensory epithelium [10].

The sensory epithelium in the above structures has specialised ciliated cells which are covered with an otolithic membrane containing ear crystals. Between the cilia and the otolithic membrane there is a thin layer of the endothelium, and its movements are a stimulus perceived by the sensory hair cells of the epithelial layer. It causes depolarisation of the inside of the cell, which leads to sending an impulse from its base to the afferent neuron, and the strength of this impulse depends on the angle of the cilia [10].

The receptors of the maculae of the utricle and of the saccule react mainly to changes in linear acceleration both in the horizontal and vertical planes, but also to changes in the vector of gravity and centrifugal force. In contrast, the receptors of the cristae ampullaris of the semi-circular canals respond to the vector of the centripetal force of the rotational movement of the head or the whole body. One of their tasks is to stabilise the gaze at a stationary object while moving the head [10].

Motor coordination

Motor coordination is of great importance in human life, and its impact on humans' functioning, along with the progress of civilization, continues to grow. It is related to new challenges brought by continuously more advanced elements and technologies of human activity. Coordination affects the economy of movement, increasing the effectiveness of the proper use of energy potential, the efficiency and aesthetics of movement activities. Motor coordination can also prevent accidents in complex everyday life situations by learning and improving motor skills, adapting them adequately to changing conditions. This mainly applies to the elderly and school-age children. The impact of motor coordination exercises on preventing falls for older people is confirmed by many studies. C. Sherrington and colleagues performed a meta-analysis of studies examining the effects of movement training, coordination and balance on the risk of falling. The 6-year studies between 2010 and 2016 were considered, including a total of 19,478 participants. A meta-analysis showed that exercise reduced the risk of falling by 21%, and if exercise lasted more than 3 hours a week, the risk of falling again was further decreased by up to 39% [11].

Dysfunction of the muscle groups involved in gait

Pathological gait is associated with abnormalities such as excessive, uncoordinated movement of individual parts of the body, mainly around the pelvis and lower limbs. In diseases such as cerebral stroke, there are disturbances in various muscles, which make the patient's gait more difficult, and its ergonomics and smoothness decrease. The most important abnormalities which deteriorate the quality of gait are dysfunctions of:

1) gluteus maximus - at the beginning of the support phase, immediately after the heel touches the ground, the patient's torso and pelvis suddenly retract, the hip joint moves forward, and during the middle period of the support phase, the lower limb in the knee is strongly extended,
2) gluteus medius - during the support phase, the pelvis descends on the healthy side, simultaneously moving laterally towards the patient's hip,
3) hip flexor muscles (iliopsoas, sartorius and rectus femoris) - cause a limp which begins at the end of the support phase and continues through the entire lunge phase on the side of the dysfunctional limb. This leads to a sudden projection of the torso and pelvis backwards when the toes are taken off the ground. If these muscles are not working properly, the hip moves forward, which is noticeable at the end of the lunge phase,
4) quadriceps femoris - its damage is particularly visible during fast walking, and with slow walking its dysfunction is almost imperceptible. Malfunction of the quadriceps leads to a sudden extension in the knee joint when the heel touches the ground. At the beginning of the support phase, the torso is tilted, the hip is forward and the thigh is retracted. The knee is kept extended and there is no cushioning when the knee is bent. The knee hyperextension usually occurs as a result of the thigh pressing against the knee. The dysfunction of the quadriceps causes hyperextension in the knee, and due to its ineffectiveness, there is no possibility of a quick forward projection of the lower leg,
5) triceps surae - its abnormality, during the support phase, causes the pelvis to fall on the dysfunctional side. This is particularly noticeable when lifting the foot off the ground. During the support phase, its lack of action also causes hyperextension in the knee joint,
6) foot flexor - causes the foot to drop during the lunge phase. It contributes to increased flexion in the hip and knee joints, and when the heel touches the ground, the foot slams [12].

Falls are common in patients with cerebellar ataxia. Fonteyn et al. [13] examined 113 patients after cerebellar infarct and found that 84% of patients fell at least once during the study. The traumatic consequences of falls increase with the number of incidents. Fall prevention is therefore essential. To this end, it is essential to raise the awareness of both patients and their families, friends and caretakers.

The role of the cerebellum in motor learning (including learning the posture) is now well established [14]. Before presenting a treatment program for post-cerebellar complications, an appropriate evaluation of the following is required:

- muscle tension,
- muscle strength,
- superficial sensation and bathyaesthesia,
- coordination,
- balance,
- gait.

Assessment of muscle tension

Muscle tension is a subjective assessment of the increasing resistance of given muscle groups during passive movement [15]. Any neurological disorders can lead to an increase in stiffness of muscles, joint capsules and ligaments. Incorrect range of motion makes it difficult and sometimes impossible to perform motor activities [16]. The modified Ashworth scale is used to assess the myotonus [17].

Examination and assessment of muscle strength

In the case of neurological abnormalities, the Barré manoeuvre is used to test the muscle strength of the upper limb. The patient flexes both upper limbs to 90 °, and the palms are facing forward, dorsally bent. Then, patients close their eyes to make control when their limb falls down difficult. Patients stay in this position for one minute. The weakened limb will drop, preceded by the downward slope of the hand. In turn, the Mingazzini test is used to assess the muscle strength of the lower extremities. The starting position for the patient is the supine position. While lying down, the lower limbs are elevated, bent at the hip and knee at 90 °. The weakened limb will fall down first. The Lovett scale is used to assess the strength of a particular muscle [18].

Assessing superficial sensation and bathyaesthesia

Disorders of superficial sensation and of bathyaesthesia are an important sign of disturbances in the peripheral and central nervous system. For this reason, there are abnormalities related to the perception of pain, temperature, as well as the feeling of touch and vibration [17]. When examining the surface sensation on the upper and lower extremities, the right and left sides should be compared. This applies particularly to the suspicion of unilateral sensory disturbance. The therapist should check the surface sensation by touching the patient's skin. The examination is best performed with the patient's eyes closed [15].

Bathyaestesia, or kinesthesis, is responsible for the feeling of the body in space both at rest and during movement. The correctness of the conducted examination of bathaesthesia depends on the cooperation of the therapist with the patient. The patient should describe the position of the limb and should independently perform the same movement as the passively guided movement of the limb on the opposite side. During the examination, the patients should perform all tasks with their eyes closed. Another form of examining bathyaesthesia is to describe the shape and size of an object which is given to the patient. Incorrect description of the object informs about a disturbance in bathyaesthesia. The feeling of vibration ought to be assessed as well. For this purpose, a tuning fork with a frequency of 128 Hz is used. After inducing vibrations, the forks should be placed close to structures such as the clavicle, kneecap or mastoid. In order to check whether the patient feels vibrations correctly, the forks without vibrations are also used [19].

Assessing coordination

Loss of mobility after an infarct is caused by a disorder of coordination, losing control over the movement performed. Ataxia, or incoherence of movement, results from disturbances within the structure of the cerebellum. Then there are problems with speed, range, direction and the force of the intended motion. For this reason, coordination training plays a key role in physiotherapeutic treatment [20].

One of the methods of assessing the upper limb coordination abnormalities is the finger-to-nose test, in turn, the heel-to-knee test used for the lower extremities. The patient, while sitting or lying down, is supposed to touch the tip of the nose with the index finger, with their eyes open and, subsequently, with their eyes closed [15].

Assessing the balance

In order to check the patient's balance, the Romberg test is used. Patients after a CVA and cerebellum infarct tend to fall over, therefore they should be secured during this attempt [15].

A more current method is to test the balance using a dynamic balance platform. At the same time, on such a platform, patients can practice their balance. The effects of such training were confirmed, inter alia, by a study by Janusz Maciaszek carried out in 2018, which consisted in checking the effectiveness of the balance platform in improving the balance [21].

Assessing the gait

One of the many methods of assessing the gait quality is the Timed Up & Go test. The patient sitting in the chair gets up and walks 3 meters, turns back, and then sits down on the chair again. At this time, the therapist measures how long it took for the patient to complete this task. A time longer than 20 seconds indicates a significant abnormality in the motor function and a much higher risk factor of falling [22].

Another option to evaluate the gait is a test performed on a dynamograph which can be used for both static and dynamic testing. Examination of the patient's gait consists in walking on it at least 6 times each way. The pressure forces exerted by the lower limbs while walking allow for visualisation, while the numerical data include: average stride length, foot spacing, pressure forces on individual parts of the foot and foot positioning [23]

Conclusions

Disorders following cerebellar infarct should be assessed as early as possible in terms of coordination, balance, sensation and gait. It is essential to monitor patient clinical progress and validate therapeutic efficacy in clinical trials. This evaluation may include specific as well as non-specific tools. Several treatment options are available, including pharmacological and surgical, and intensive rehabilitation.

The efficacy of pharmacological treatment is generally low and has been documented mainly for the oxitriptan/5-hydroxytriptophan serotonin precursor. In two randomised, controlled trials, placebo oxitriptan proved to be effective in controlling the kinetic and static cerebellar syndrome in Friedreich's ataxia [7, 10]. Research on amantadine has shown a significant improvement in gait and independence in daily activities (writing, getting dressed, etc.) - possibly through improved coordination [24–27].

A randomised study on 42 patients with degenerative cerebellar disease assessed the effects of an intensive program (11 hours per week for 6 weeks) consisting of physical therapy (balance exercises, gait training and muscle strengthening) and occupational therapy focused on balance and daily activities. Improvement on the SARA scale, walking speed and Functional Independence Index (FIM) was achieved after 6 weeks, and the effect was still present 24 weeks later [28].

Literature

1. Mazighi M., Amarenco P., Cerebellar infarcts, Cambridge: Cambridge University Press 2012, 469-479
2. Manto M., Cerebellar Disorders: A Practical Approach to Diagnosis and Management, Cambridge: Cambridge University Press 2010, 88-101
3. Krienen F., Buckner R., Segregated fronto-cerebellar circuits revealed by intrinsic functional connectivity, Cereb Cortex, 2009
4. Moore D. M., D'Mello A. M., McGrath L. M., Stoodley, C. J., The developmental relationship between specific cognitive domains and grey matter in the cerebellum, Developmental Cognitive Neuroscience, 2017

5. Bochenek A, Reicher M., Anatomia człowieka. Tom 5., PZWL Wydawnictwo Lekarskie Warszawa 2012
6. Gornati S. V., Schäfer C. B., Eelkman Rooda O. H. J., Nigg A. L., De Zeeuw C. I., Hoebeek F. E., Differentiating Cerebellar Impact on Thalamic Nuclei. Cell Reports, 2018; 23(9): 2690–2704
7. Vožeh F., Jan Evangelista Purkyně and the Cerebellum Then and Now. Physiological Research, Academy of Sciences of the Czech Republic, Praga 2015, 567 – 584
8. Gołąb B., Jędrzejewski K., Anatomia czynnościowa ośrodkowego układu nerwowego, PZWL Wydawnictwo Lekarskie, Warszawa 2009
9. Makowska I., Pierchała K., Niemczyk K., Rehabilitacja przedsionkowa w zawrotach głowy i zaburzeniach równowagi, Polski Przegląd Otorynolaryngologiczny 2014, 20–26
10. Kasperczyk T., Mucha D., Zarys kinezjologii An Outline of Kinesiology, Wydawnictwo JET, Kraków 2016
11. Sherrington C., Michaleff Z., Fairhall N., Paul S., Teidemann A., Whitney J., et al., Exercise to prevent falls in older adults: an updated systematic review and metaanalysis, British Journal of Sports Medicine 2017, 1750-1758
12. Milanowska K., Kinezyterapia, PZWL, Warszawa 2015
13. Fonteyn E. M., Schmitz-Hubsch T., Verstappen C. C., Baliko L., Bloem B. R., Boesch S., et al. Prospective analysis of falls in dominant ataxias. Eur Neurol 2013;69:53–7
14. Manto M. The cerebellum, cerebellar disorders, and cerebellar research–two centuries of discoveries. Cerebellum 2008;7:505–16
15. Kozubski W., Liberski P., Neurologia podręcznik dla studentów medycyny. Tom 2, Wydawnictwo Lekarskie PZWL Warszawa 2014
16. Lennon S., Ramdharry G., Verheyden G., Neurological Physiotherapy Pocketbook, Elsevier 2018
17. Kwolek A. Fizjoterapia w neurologii i neurochirurgii. Red. Warszawa: PZWL Wydawnictwo Lekarskie 2012
18. Hirose G., The Barrés test and Mingazzini test - Importance of the original paper by Giovanni Mingazzini, Rinsho Shinkeigaku 2015
19. Pogorzała A., Stryła W. Ćwiczenia propriocepcji w rehabilitacji, Wydawnictwo Lekarskie PZWL, Warszawa 2014
20. Stokes M., Stack E. Physical Management for Neurological Conditions, Churchill Livingstone 2011
21. Maciaszek J., Effects of Posturographic Platform Biofeedback Training on the Static and Dynamic Balance of Older Stroke Patients, Journal of Stroke and Cerebrovascular Diseases 2018
22. Szostek-Rogula S., Zamysłowska-Szmytke E. Przegląd skal i testów dla oceny + czynnościowej pacjenta z zawrotami głowy i zaburzeniami równowagi, Otorynolaryngologia, 2015
23. Jaszczur I., Koprowski P., Wrzosek Z., Próba stworzenia kryteriów oceny funkcji chodu z wykorzystaniem platformy PDM-S, Acta Bio-Optica et Informatica Medica, Inżynieria Biomedyczna 2013
24. Botez M. I., Botez-Marquard T., Elie R., Pedraza O. L., Goyette K., Lalonde R. Amantadine hydrochloride treatment in heredodegenerative ataxias: a double blind study. J Neurol Neurosurg Psychiatry 1996;61:259–64
25. Botez M. I., Young S. N., Botez T., Pedraza O. L. Treatment of heredodegenerative ataxias with amantadine hydrochloride. Can J Neurol Sci 1991;18:307–11
26. Botez M. I., Young S. N., Rotez T., Courchesne Y. Treatment of Friedreich's ataxia with amantadine. Neurology 1989;39:749–50
27. Peterson P. L., Saad J., Nigro M. A. The treatment of Friedreich's ataxia with amantadine hydrochloride. Neurology 1988;38:1478–80
28. Miyai I., Ito M., Hattori N., Mihara M., Hatakenaka M., Yagura H., et al. Cerebellar ataxia rehabilitation trial in degenerative cerebellar diseases. Neurorehabil Neural Repair 2012;26:515–22

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