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REVIEW

BALANCE DISORDERS AND DIABETES MELLITUS – GENERAL CONSIDERATIONS

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Abstract

The objective of this review is to summarize specialty literature data regarding the relation between balance disorders and diabetes mellitus, because balance disorders and vestibular dysfunctions are common complaints in ENT practice in Romania and these complaints seem to be more frequent in diabetic patients. We accessed electronic databases like PubMed, Scopus (Elsevier), Web of Science for research on this theme; clinical trials, specialty books and meta-analysis reports, pointing out plausible explanations for the association between balance disorders and diabetes mellitus. Because of decreased proprioception and vision, diabetic patients suffer more often from balance disorders than the rest of population and are at higher risk of falling. That seems to be the consequence of a combination between impaired proprioception, vision, and possible damage produced by long term hyperglycemia in the vestibular system according to some studies.

Key words: vestibular dysfunctions, balance, diabetes mellitus.

Résumé

Troubles de l'équilibre et diabète sucré – considérations générales

L'objectif de cet article est de résumer les données de la littérature de spécialité concernant la relation entre les troubles de l'équilibre et le diabète sucré, car les troubles de l'équilibre et les dysfonctions vestibulaires sont des plaintes fréquentes dans la pratique ORL en Roumanie. Nous avons accédé les bases de données électroniques comme PubMed, Scopus (Elsevier), Web of Science pour la recherche sur ce thème; des essais cliniques, des livres spécialisés et des rapports de méta-analyses, soulignant des explications plausibles portant sur l'association entre les troubles de l'équilibre et le diabète sucré en raison de la diminution de la proprioception et de la vision. Les patients diabétiques souffrent plus souvent de troubles de l'équilibre que le reste de la population et présentent un risque plus élevé de chute. Cela semble être la conséquence d'une combinaison entre la proprioception altérée, la vision, et les dommages possibles produits par une longue hyperglycémie thermique dans le système vestibulaire selon certaines études.

Mots-clés: dysfonctionnements vestibulaires, équilibre, diabète sucré.

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Introduction

This paper is a brief review of specialty literature data regarding the relation between balance disorders and diabetes mellitus. Control systems (reactive, anticipatory, sensory, dynamic, and limits of stability) and physiological systems (vestibular, visual, proprioceptive, muscle strength, and reaction time) contribute to the maintenance of balance[1]. The somatosensory system provides information about the position and motion of body's segments in relation to each other and the support surface by using proprioceptive and cutaneous inputs, the visual informs about the environment and body orientation, the vestibular system provides information about head position and spatial orientation[2].

Diabetic patients suffer more often from balance disorders than the rest of population and are at higher risk of falling. That seems to be the consequence of a combination between impaired proprioception, vision, and possible damage produced by long term hyperglycemia in the vestibular system according to some studies (a study on diabetic animals has shown that long-term hyperglycemia causes structural damage in the otolith organs of the vestibular system[2]).

General aspects

Everyday life challenges us to maintain equilibrium while standing, running, walking, stumbling or performing routine actions.

Balance is the maintenance or restoration of a person's center of mass within their limits of stability, meaning the area within the center of the mass can be moved safely without changing the base support[3]. The ability to maintain balance is a complex skill that requires the integration of multiple sensorimotor and cognitive processes[2].

Balance needs a complex integration of multiple inputs and includes maintenance of a specific postural alignment, facilitation of voluntary movement and reactions that recover equilibrium to external disturbances like slipping[4]. Postural behavior, includes postural orientation (the active alignment of the trunk and head with respect to gravity, support surfaces, the visual surround and internal references) and postural equilibrium (the coordination of movement strategies to stabilize the center of body mass during both self-initiated and externally triggered disturbances of stability)[5]. The somatosensory system provides information about the position and motion of body's segments in relation to each other and the support surface by using proprioceptive and cutaneous inputs, the visual informs about the environment and body orientation, the vestibular system provides information about head position and spatial orientation[2].

The vestibular apparatus (the membranous labyrinth) includes three semicircular canals, the utricle, and the saccule and together with the cochlea is encased in the petrous portion of the temporal bone(the bony labyrinth)[6]. The sensory organs of the utricle and the saccule are the maculae (macula of the utricle lies mainly in the horizontal plane,macula of the saccule is located mainly in a vertical plane), specialized in detecting orientation of the head with respect to gravity (linear acceleration).The three semicircular ducts (anterior, posterior,and lateral / horizontal semicircular ducts) in each vestibular apparatus are arranged at right angles to one another so that they detect rotation/ angular acceleration in all three planes in space[6]. Each one of somatosensory, visual and vestibular system contributes to balance control explaining why balance is affected when one or more sensory inputs to the central nervous system is deficient[2].

Vertigo, dizziness and imbalance are frequent complaints in neurology and ENT practice in Romania and these complaints seem to be more frequent in diabetic patients.

Vertigo and dizziness cover a number of multi-sensory and sensorimotor syndromes of various etiologies and pathogeneses, that need an interdisciplinary approach[7]. Vestibular dysfunction increases significantly with age and it is higher among people with diabetes mellitus[8]. This is the conclusion of a study performed in US on patients over 40 years old, using data from the 2001-2004 National Health and Nutrition Examination Surveys. The study showed that 35.4% of US adults aged 40 years and older had vestibular dysfunction and that odds of vestibular dysfunction increased significantly with age and were 70.0% higher among people with diabetes mellitus[8]. The history of dizziness was determined using a balance questionnaire and vestibular function was measured by the modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces[8].

Diabetes mellitus is a group of metabolic diseases characterized by chronic hyperglycemia due to a deficiency of insulin action, which leads to abnormalities in almost the entire metabolic system, including carbohydrate, lipid and protein metabolism and causes susceptibility to specific complications[9]. The International Diabetes Federation estimated an overall prevalence of diabetes mellitus to be 366 million in 2011, and predicted a rise to 552 million by 2030[10].

The mechanism of diabetes mellitus includes insufficient insulin secretion and decreased insulin sensitivity in cells with insulin receptors[9]. There are

four groups of disorders related to diabetes mellitus: type 1 diabetes mellitus (insufficient insulin secretion, due to destruction of pancreatic β-cells), type 2 diabetes mellitus, characterized by combinations of decreased insulin secretion and decreased insulin sensitivity (insulin resistance); diabetes mellitus due to other specific mechanisms or diseases and gestational diabetes mellitus[9]. A greater prevalence of diabetes mellitus heightens the risk of vascular disease, which affects the microvasculature, arteries, and veins[11]. Microvascular disease is strongly associated with hyperglycemia and there are 3 major manifestations of micro-vascular disease: retinopathy, nephropathy, and neuropathy[11].

Retinopathy

In an analysis of the National Health and Nutrition Survey, the prevalence of retinopathy in the diabetic population was 28.5%, and 4.4% of the total had threatened loss of vision[12]. Retinopathy has two main types: nonproliferative and proliferative. In nonproliferative retinopathy, patients may develop small hemorrhages in the middle of the retina surrounded by hard lipid exudates and retinal edema may be present also[11]. Proliferative retinopathy is the development of neovascularization on the retina, which can be complicated by vitreous hemorrhage, retinal detachment and neovascular glaucoma, that can be associated with severe sight loss[13].

Neuropathy

The prevalence of neuropathy is estimated to be about 8% in newly diagnosed patients and greater than 50% in patients with long-standing disease[14]. There are two main types of diabetic neuropathies: sensorimotor (marked by pain, paresthesia and sensory loss) and autonomic neuropathies (associated with higher mortality, may have a role in myocardial infarction, malignant arrhythmia and sudden death)[14].

Diabetic neuropathy is usually a slowly progressive sensory predominant neuropathy. Patients initially experience sensory loss in the toes and feet that results from length-dependent dysfunction of nerve fibers[15]. Lack of sensitivity, or loss of nociception can lead to foot ulceration or injuries that can become infected and lead to amputation[16].

Diabetic neuropathy is associated with vascular and nonvascular abnormalities. Basement membrane thickening, pericyte loss and decreased capillary blood flow to C fibers, give an explanation for attenuated perfusion of the nerves leading to endoneurial hypoxia[17]. The neuropathy is characterized by axonal thickening and eventual loss of neurons. It is generally believed that oxidative stress is the key pathological process inducing nerve damage in diabetes [18]. Oxidative stress, possibly triggered by vascular abnormalities and associated microangiopathy in the nerve, is a key pathological process inducing nerve damage in diabetes[14,8]. Apart from strict glycaemic control, no further therapeutic approach exists in the prevention of this phenomenon[14].

Diabetes mellitus and dizziness

Patients with diabetes mellitus are at a higher risk of falls because of a combination of risk factors including sensory loss and impaired proprioception and spinal reflexes[19].

Loss of light touch, visual acuity, contrast sensitivity, and depth perception may increase both the risk and the recurrence of falls in people with diabetes[13,20]. People with diabetes, neuropathy and retinopathy have significant physical limitations because of decreased proprioception and vision[13,20].

There are studies in specialty literature that reinforce the idea that subtle declines in sensory functions (somatosensory, visual and vestibular), metabolic muscle function and executive functions, found in diabetes mellitus, may contribute to increased fall risk in older adults with type 2 diabetes[2]. An example is a prospective cohort study published in 2013, tested 199 older than 60 years adults and followed them12 months. The participants underwent some tests (Gait, balance, grip strength, and cognitive status). The conclusion was that adults with type 2 diabetes mellitus are at increased risk of falling even after controlling for poor balance, possibly due to taking more medication, poorer walking performance and reduced cognitive functioning. The authors proposed tailored preventive programs including systematic medication reviews, specific balance exercises and cognitive training that might be beneficial in reducing fall risk in older adults suffering from diabetes.[21]

Timar and al assessed the presence and severity of balance impairment in diabetic patients by using the Berg Balance Scale, Single leg stand test, Timed-up and go test and Fall Efficacy Scale—International questionnaire and reported a significant association between diabetic neuropathy and balance impairment and indirectly with the risk of falls in patients with type 2 diabetes[16]. Also a strong correlation between the severity of diabetic neuropathy and the balance impairment's degree was found, concluding that if impairments are diagnosed, these patients should be included in a rehabilitation program (physiotherapy and kinesiotherapy), aiming to improve their balance and walking stability[16].

Another study, published in 2015, compared balance of diabetic patients with/ without neuropathy and nondiabetic patients during the dynamic daily activities of walking on level ground and stair negotiation[22]. Balance was assessed by measuring the separation between the body center of mass and center of pressure during level walking, stair ascent, and stair descent. The authors found higher medial-lateral separations in patients with diabetic neuropathy which requires greater muscular demands to control posture explaining the tendency to fall of these patients[22].

The presence and severity of diabetic peripheral neuropathy correlates to increase postural instability. People with diabetic peripheral neuropathy have a larger range of sway in the anterior-posterior and medial-lateral directions and a higher sway speed than people matched for age and serving as controls[23].

„The Influence of diabetic peripheral neuropathy on local postural muscle and central sensory feedback balance control" was the subject of a recent study that showed that diabetes mellitus neuropathy affects the amount of body sway in short time-intervals which suggests a compromised local-control balance behavior when comparing with healthy controls[24]. This could be related to inability of lower extremity and postural muscles to provide sufficient activity level and joint stiffness in patients with DPN.

Anderson et al reported 17% and 14% less strength in ankle flexor and extensor muscles of patients with diabetic neuropathy[25]. Muscle strength is important for short time-interval balance control by setting an activity level in postural muscles based on muscle loading. Also deterioration of reflexive responses of lower extremity muscles, compromised spindle sensation of muscles in diabetic neuropathy and sensory performance of postural muscles lead to impaired local-control balance behaviors during upright standing[24].

Central nervous system (the spinal cord, the brain), takes part in controlling posture and diabetic neuropathy involves beside the peripheral nervous system, the central nervous system too[26]. Long-term hyperglycemia has been documented to result in complications of mitochrondrial dysfunction, accumulation of plaque (amyloid precursor protein), and oxidative and proinflammatory stress on brain tissue[2].

Considering the relation between the central nervous system and coordination of posture and movement control, one can expect impaired balance in central nervous system damage[26].

Comparison of balance ability between patients with type 2 diabetes with and without peripheral neuropathy was the subject of a study published in 2014, on 60 patients divided into healthy, diabetic with and diabetic without neuropathy patients. Assessment of sensory impairment, motor impairment and functional limitation were obtained by using the Balance Master system. The results showed that balance stability related to functional limitations in specific movements decreased more significantly in diabetic patients with peripheral neuropathy than in diabetic patients without peripheral neuropathy or in normal subjects and also showed significantly worse dynamic balance control in diabetic patients without peripheral neuropathy than in normal subjects[27].

Vestibular impaired function

The vestibular system senses angular and linear acceleration of the head in three dimensions and is responsible for generating vestibulo-ocular and vestibulo-spinal reflexes that stabilize the visual image on the retina and adjust posture, during head movement[28]. Recent research in animals and humans showed that the vestibular system has also a role in cognitive processes such as memory, spatial navigation and bodily self-consciousness[28].

Degerman et al used immunohistochemistry to demonstrate that the insulin receptor, insulin receptor substrate 1, protein kinase B and insulin-sensitive glucose transporter are expressed in the sensory epithelium of the human saccule, which also exhibits expression of a calcium-sensitive cAMP/cGMP phosphodiesterase 1C and the vasopressin type 2 receptor[29]. The expression of these proteins in the saccule could have a role in the observed link between diabetes and balance/hearing disorders[29]. The signaling pathways, can be affected by increased glycemia and insulin resistance impairing the inner ear function[23]. Long-term hyperglycemia causes inflammation and reduced sensitivity of the highly active metabolic vasculature in the inner ear. Studies on diabetic animals have shown that long-term hyperglycemia causes structural damage in the otolith organs of the vestibular system[2]. Hypofunction of the otolith organs and semicircular canals may cause people with diabetes to have impaired gaze stability and decreased sensory feedback from the peripheral vestibular organs. BPPV also may be more frequent in people with diabetes[23].

Klagenberg et al analyzed vestibulocochlear manifestations in patients with type I diabetes mellitus and reported that vestibular system dysfunction was seen more often than auditory dysfunction (60% versus 30%), indicating that metabolic disturbances may affect the homeostasis of the vestibular organ more quickly than of the cochlea[30].

A small study published in „Clinical Diabetes" in 2014, on 37 diabetic patients who complained of dizziness, loss of balance, or falling, used quantitative

dynamic platform posturography to demonstrate that the majority of patients failed to maintain balance in vestibular-related conditions and had normal equilibrium scores in conditions relying on somatosensory input[31].Those results imply that regardless of the presence of peripheral neuropathy, vestibular dysfunction should be immediately considered because balance is maintained by compensatory visual and vestibular input despite the presence of neuropathy[31].

Considering the multifactorial causes of balance disorders in diabetic patients discussed above, the treatments can be focused on a functional level to reduce the impact of the impairment and facilitate function or on a physiological level to improve a sensorimotor system (balance and strength retraining, vestibular rehabilitation)[1].

Conclusions

Diabetic patients suffer more often from balance disorders than the rest of population and are at higher risk of falling. That seems to be the consequence of a combination between impaired proprioception, vision, and possible damage produced by long term hyperglycemia in the vestibular system according to some studies. Knowing the mechanisms involved in the equilibrium disorders encountered in diabetes mellitus one facilitates the management of this pathology for ENT practitioners.

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