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CHARACTERISTICS OF HEARING FUNCTION ALTERATIONS AND SURDOLOGICAL STRATEGIES IN PATIENTS SUFFERING FROM TYPE 2 DIABETES MELLITUS

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Abstract
This article is dedicated to the comprehensive investigation of the pathogenetic mechanisms, clinical manifestations, and diagnostic principles of sensorineural hearing loss that develops against the background of Type 2 Diabetes Mellitus (T2DM). Significant emphasis is placed on the profound impact of diabetic microangiopathy and neuropathy on the cochlear apparatus and central auditory pathways. Furthermore, the study meticulously examines the specific alterations observed in the results of pure-tone audiometry, speech audiometry, and tympanometry. The paper also provides a scientifically grounded analysis of the complexities involved in the hearing aid fitting and rehabilitation process (prosthetics) for this particular patient demographic, alongside advanced surdological strategies designed to overcome these clinical challenges.
Keywords: Type 2 diabetes mellitus, sensorineural hearing loss, cochleopathy, diabetic neuropathy, pure-tone audiometry, speech audiometry, tympanometry, hearing aid fitting.

Introduction

Type 2 diabetes mellitus (T2DM) represents a chronic endocrine disorder characterised by systemic vascular and nervous system impairment, whose complications exert a direct and profound influence on the overall quality of life of patients. Alongside traditional complications such as retinopathy and nephropathy, the detrimental impact of chronic hyperglycaemia on the auditory analyser has increasingly become a critical and pressing scientific issue in recent years [1]. Clinical evidence suggests that the metabolic disturbances inherent in T2DM initiate a cascade of degenerative changes within the delicate structures of the inner ear.

According to extensive epidemiological data, the prevalence of hearing loss—predominantly of the sensorineural type—is recorded at significantly higher rates among patients suffering from T2DM compared to the general population [2]. This heightened susceptibility is attributed to the synergistic effects of microvascular damage and metabolic neuropathy, which target the stria vascularis and the auditory nerve [3]. The progressive nature of this auditory decline often leads to communication barriers, social isolation, and cognitive decline if not addressed promptly.

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Within the contemporary practice of surdology, this clinical situation necessitates a more refined, nuanced, and systematic approach to both the diagnostic protocols and the subsequent hearing rehabilitation processes [4]. Understanding the specific patterns of frequency-specific hearing loss in diabetic patients is essential for accurate intervention [5]. Consequently, the integration of advanced audiological monitoring and personalised surdological strategies is imperative to mitigate the long-term sensory consequences of this systemic disease.

Materials and methods

1. Aetiopathogenesis of Diabetic Hearing Loss. The impairment of auditory function in Type 2 Diabetes Mellitus (T2DM) inherently possesses a polyaetiological character and is predominantly associated with the following two distinct pathological processes:

− Diabetic microangiopathy and cochleopathy: From an anatomical perspective, the inner ear lacks a collateral blood circulation system, rendering it exceptionally susceptible to ischaemia. Chronic hyperglycaemia consequently leads to the pronounced thickening of the basement membrane of the capillaries within the stria vascularis, alongside significant endothelial dysfunction. As a direct result of this pathophysiological cascade, the concentration of potassium ions in the endolymph is disrupted, which subsequently precipitates the metabolic starvation of the hair cells located within the organ of Corti and causes their gradual, irreversible necrosis.

− Diabetic neuropathy: The compounding effects of oxidative stress, the aberrant activation of the sorbitol pathway, and the advanced glycation end-products (AGEs) collectively lead to the demyelination of the auditory nerve (*Nervus vestibulocochlearis*) as well as the apoptosis of the spiral ganglion cells. This critical condition fundamentally disrupts the vital synchronicity of nerve impulse transmission to the central auditory analyser.

2. Specific Audiological Diagnostic Indicators. The comprehensive assessment of diabetic hearing loss unequivocally requires a multifaceted and systematic approach:

− Pure-tone audiometry: The observed alterations frequently exhibit a bilateral and symmetrical character, wherein the pathology initially manifests as a marked reduction in auditory sensitivity within the high-frequency range (specifically between 4000 and 8000 Hz). As the clinical duration of the disease progresses, the pathological process eventually encroaches upon and affects the vital speech frequencies.

− Speech audiometry: Neuropathy developing against the background of T2DM prominently exhibits the classic clinical signs of retrocochlear pathology. Although the pure-tone hearing threshold may remain relatively preserved in these patients, a precipitous decline is consistently observed in both speech comprehension and phonemic differentiation (speech discrimination score). Notably, the cognitive task of identifying and distinguishing words becomes exceptionally challenging in the presence of competing background noise.

− Tympanometry and impedancemetry: The physiological function of the middle ear is typically preserved within normal parameters (characterised by a Type "A" tympanogram). Nevertheless, the meticulous examination of the acoustic reflex can facilitate the detection of latent or subclinical neuropathy: this is clinically documented by the abnormal prolongation of the reflex's latent period or its rapid pathological decay.

3. Hearing Aid Fitting and Surdological Strategies. The clinical practice of selecting and intricately fitting hearing aids for patients diagnosed with T2DM (and, in particular, the systematic development of targeted surdological rehabilitation strategies) is invariably accompanied by a series of highly specific clinical challenges:

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− Narrowed dynamic range and recruitment phenomenon: Consequent to the structural damage inflicted upon the outer hair cells, patients frequently experience a rapid, subjective escalation in perceived sound loudness. This specific audiological anomaly necessitates extreme precision and utmost caution during the calibration and programming of the hearing device.
− Central processing dysfunction: Owing to the profound impairment of central auditory information processing, the mere acoustic amplification of sound generally fails to yield the anticipated therapeutic outcomes for the patient.
The most appropriate and evidence-based surdological strategies to be actively implemented include the following:
− Wide Dynamic Range Compression (WDRC): The strategic utilisation of wide dynamic range compression necessitates highly refined and meticulously calibrated adjustments. This sophisticated technological approach ensures the adequate amplification of weak speech signals while simultaneously preventing loud acoustic stimuli from exceeding the patient's Uncomfortable Loudness Level (UCL).
− Noise blocking and directionality: In order to significantly enhance speech intelligibility and overall auditory comprehension, the mandatory activation of adaptive directional microphones coupled with highly advanced noise reduction algorithms is an absolute clinical prerequisite.
− Principle of binaural fitting: To optimally support and maximise neuronal synchronisation, and to ensure the comprehensive and accurate processing of auditory information at the critical level of the brainstem, an exclusive and steadfast adherence to a binaural (bilateral) fitting strategy is strongly recommended.

Conclusion

The impairment of auditory function that develops against the background of Type 2 Diabetes Mellitus (T2DM) is not merely a conventional age-related physiological alteration, such as presbycusis. Instead, it constitutes a highly complex cochleopathy that intrinsically involves a multitude of profound metabolic, microvascular, and neuropathic mechanisms. The systematic implementation of comprehensive audiological examinations—specifically encompassing pure-tone audiometry, speech audiometry, and impedancemetry—provides a critical diagnostic advantage, thereby facilitating the early and precise detection of these underlying pathological alterations before significant sensory deterioration occurs. Furthermore, within the specialised clinical practice of surdological rehabilitation and the meticulous fitting of hearing aids for this specific patient demographic, it is imperative for clinicians to take into profound consideration the patients' inherent difficulties in speech comprehension alongside the challenging recruitment phenomenon. Consequently, the strategic application of specialised wide dynamic range compression parameters and steadfast adherence to binaural fitting (prosthetic) strategies hold decisive clinical importance. These targeted audiological interventions are ultimately essential for ensuring the successful social adaptation, preserving communicative competence, and substantially elevating the overall quality of life for patients suffering from diabetic hearing loss.

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