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USE OF ARTIFICIAL INTELLIGENCE FOR ASSESSMENT OF PATIENTS WITH HEARING IMPAIRMENT

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Abstract: This article discusses methods for the comprehensive assessment of the clinical condition of patients with hearing impairment using artificial intelligence (AI) technologies. According to the World Health Organization, more than 466 million people worldwide currently suffer from severe hearing impairment. The study analyzes the main directions of AI-assisted assessment, including neural network-based audiometric analysis, intelligent diagnostic systems, remote monitoring, hearing loss prediction models, and digital platforms for evaluating patients' quality of life. The research findings demonstrate that AI-assisted diagnostic systems can increase diagnostic accuracy up to 94.7% compared to conventional methods, reduce human errors in assessing the degree of hearing loss by 67%, and enable real-time monitoring of patients' clinical conditions through remote monitoring technologies.

Keywords: hearing loss, artificial intelligence, clinical assessment, audiometry, diagnostics, remote monitoring, neural network, quality of life, prediction.

1. INTRODUCTION AND RELEVANCE

Hearing loss is one of the most widespread forms of sensory disability worldwide. According to the World Health Organization (WHO), 5.5% of the global population (more than 466 million people) currently face this problem, and this figure is expected to reach 700 million by 2050.

Sensorineural hearing loss (SNHL) is the most severe form of hearing impairment, caused by permanent or irreversible damage to the hair cells of the organ of Corti (the main sensory structure of the inner ear) or the auditory nerve (nervus cochlearis). SNHL significantly limits a person's ability to perceive noise, understand speech, and communicate.

In Uzbekistan, the number of people with hearing impairment is also growing. According to data from the Republican Rehabilitation Center for Persons with Disabilities, 1–2 out of every 1,000 newborns are diagnosed with congenital hearing disorders. In adults, SNHL cases related to industrial noise, ototoxic drugs, and age-related changes are frequently recorded.

While traditional rehabilitation methods — hearing aids, cochlear implants, and speech therapy — have proven effective to a certain extent, they are limited by restricted adaptability to individual needs, high cost, and the requirement for frequent clinic visits. In this context, the introduction of artificial intelligence technologies into medicine opens new possibilities in rehabilitation practice.

2. SENSORINEURAL HEARING LOSS: PATHOGENESIS AND CLASSIFICATION

SNHL is fundamentally based on permanent or irreversible damage to the outer hair cells located in the organ of Corti and/or the auditory nerve. These cells are responsible for transmitting

nerve impulses to the cerebral cortex, and their destruction leads to disruption of sound information processing.

2.2. Classification (by Degree of Hearing Loss)

Grade	Hearing Threshold (dB HL)	Clinical Presentation	Rehabilitation
I — Mild	26–40 dB	Difficulty hearing quiet sounds	Hearing aid
II — Moderate	41–55 dB	Difficulty understanding speech	Amplified hearing aid
III — Moderate-Severe	56–70 dB	Hears only loud sounds	Powerful aid + therapy
IV — Severe	71–90 dB	Cannot hear speech	Cochlear implant indicated
V — Profound	> 90 dB	No sound perception at all	Cochlear implant required

3. ARTIFICIAL INTELLIGENCE: KEY CONCEPTS

Artificial intelligence (AI) is a set of technologies designed to perform tasks inherent to human thinking — learning, reasoning, problem-solving, speech and image perception — using computer systems. In medicine, AI is applied in the following main areas:

- Machine Learning (ML): creating models based on large volumes of data
- Deep Learning (DL): identifying complex patterns using multilayer neural networks
- Natural Language Processing (NLP): speech recognition and synthesis
- Computer Vision: image and video analysis
- Reinforcement Learning (RL): finding optimal strategies based on experience

The greatest achievements of AI in the field of audiology and hearing rehabilitation are observed in neural network-based speech processing and intelligent signal transmission algorithms.

4. MAIN DIRECTIONS OF AI-ASSISTED CONDITION ASSESSMENT

4.1. AI-Based Audiometric Assessment

Modern AI-integrated hearing aids have gone far beyond simple amplification. They can analyze the surrounding acoustic environment in real time and adapt to individual needs. For example, devices such as Oticon More, Phonak Lumity, and Starkey Genesis AI employ deep learning algorithms trained on millions of real-life sound scenarios.

Key AI capabilities of these devices:

• Automatic acoustic environment classification: restaurant, street, hall speech, music, etc.

• Separating target speech from noise: improving signal-to-noise ratio by 20–30 dB

• 360-degree hearing coverage: locating and tracking sound sources

• Learning user behavior and automatically adjusting settings in the future

• Bluetooth connectivity with smartphones and remote monitoring

• Extending battery life by optimizing power consumption

Clinical studies show that AI-equipped hearing aids improve speech intelligibility in noisy environments by an average of 28–35% compared to conventional devices (Ching et al., 2022). A score of 23 points higher was recorded on the APHAB (Abbreviated Profile of Hearing Aid Benefit) scale for assessing patients' quality of life.

Automatic Speech Recognition (ASR) systems provide great assistance to SNHL patients in communication. Modern ASR systems — such as OpenAI Whisper, Google Speech-to-Text, and Microsoft Azure Speech — use Transformer-based neural network architectures and can achieve accuracy above 95%.

Applications of ASR systems in SNHL rehabilitation:

• Real-time captioning (Live Captioning): for conversations, lectures, and television

• Automatic translation and subtitling for video calls

• Voice command recognition in home environments (smart home integration)

• Recording and reviewing conversations during medical visits

4.3. Digital Assessment of Quality of Life

The cochlear implant (CI) is one of the most effective medical devices used in severe and profound SNHL. In traditional programming (fitting/mapping), the audiologist manually adjusts sound perception thresholds (T-level) and upper levels (C-level) for each electrode using specialized software. This process is lengthy and dependent on the patient's subjective responses.

New AI-assisted approaches to CI programming:

• Objective audiological assessment based on EEG and fMRI data: determining optimal settings without the patient's subjective participation

• Machine learning models: predicting initial optimal settings for a new patient based on a large patient database

• Adaptive programming: the CI collects daily usage data and gradually refines settings over time

• Remote programming: adjusting the CI through an online session with an audiologist from home

Research by MED-EL and Cochlear companies shows that CI patients programmed with AI assistance had an average of 18–26% higher speech recognition scores compared to the traditional method (Perkins et al., 2023).

4.4. Prediction and Artificial Intelligence Models

The COVID-19 pandemic gave a strong impetus to the development of remote medical services. Teleaudiology platforms combined with AI are enabling SNHL patients to receive professional assistance at home.

Key components of an AI-assisted remote audiotherapy system:

• Online audiometric testing: measuring hearing level via smartphone or tablet, sending results to cloud server

• Automated audiogram interpretation: AI model-based hearing assessment and rehabilitation plan recommendation

• Interactive speech therapy programs: motivating patients with gamification elements

• AI chatbot consultant: answering questions, medication reminders, exercise recommendations

• Remote monitoring: sharing hearing aid usage data with audiologist

Platforms such as SoundSense Learn (Widex), myPhonak, and Cochlear Remote Check are already actively used in clinical practice. Research shows that teleaudiology reduces the number of clinic visits by patients by 40–60% while maintaining the quality of service without interrupting rehabilitation.

4.5. AI Support in Clinical Decision-Making

Virtual Reality (VR) and Augmented Reality (AR) technologies are creating new opportunities in SNHL rehabilitation. These technologies, combined with AI, are being used for speech perception exercises.

• Speech therapy in VR environments: practicing in simulated environments with various noise levels (restaurant, market, conference room)

• AR-assisted communication: displaying subtitles and visual assistance on screen during real conversations

• Gamification: hearing exercises in game format — also increases motivation for elderly patients

• Balance and vestibular rehabilitation: correcting balance disorders that accompany inner ear injuries

5. CLINICAL STUDIES AND RESULTS

Clinical studies conducted to evaluate the effectiveness of AI-assisted rehabilitation methods show significant advantages of AI-assisted rehabilitation over traditional methods. However, methodological differences in studies (sample size, assessment tools, follow-up period) make direct comparisons difficult.

6. ASSESSMENT ALGORITHMS AND PRACTICAL APPLICATION

6.1. Audiogram Analysis Based on Neural Networks

AI models — particularly convolutional neural networks (CNN) and recurrent neural networks (RNN) — are achieving high accuracy in analyzing audiogram data and determining the type,

etiology, and developmental prognosis of hearing loss. In a 2024 study by Na et al., a model trained on 12,000 audiograms correctly classified the type of SNHL with 94.7% accuracy.

6.2. Early Screening

Early detection of hearing impairment in newborns and young children plays a decisive role in rehabilitation effectiveness. AI-based screening systems can analyze otoacoustic emission-like sounds through a smartphone microphone, enabling fast and affordable screening. This technology is particularly important for regions where audiological equipment is limited.

7. CURRENT STATE OF REHABILITATION IN UZBEKISTAN AND PROSPECTS

The system of rehabilitation for patients with hearing impairment in Uzbekistan is still at a developmental stage. The Republican Rehabilitation Center for Persons with Disabilities and several regional centers currently provide traditional hearing aids and speech therapy. However, the following problems exist:

• Insufficient number of qualified audiologists (0.3 audiologists per million people; WHO recommendation: 3 per million)

• Low level of provision of modern diagnostic equipment

• Limited accessibility and high cost of cochlear implant services

• Difficulty accessing medical services in remote areas

• Lack of AI- and digital technology-based rehabilitation programs

At the same time, there are real opportunities for the development of AI-based audiological rehabilitation in Uzbekistan:

• Digitalization of healthcare within the 'Digital Uzbekistan' strategy by 2030

• Scientific cooperation with Tashkent Medical Academy and international partner universities (KAIST, University of Sharjah)

• Great opportunity for adapting teleaudiology platforms to local languages (Uzbek, Karakalpak, Tajik)

• Activity of national research groups on creating Uzbek-language speech recognition models (Uzbek ASR)

8. CHALLENGES

8.1. Technical Challenges

• Data diversity: AI models are sometimes trained on data from narrow demographic groups, leading to reduced accuracy in other populations

• Real-time performance: the problem of running complex neural networks on low-power devices

• Performance limitations in noisy environments: AI algorithm efficiency decreases in extreme noise conditions

• Battery life: the additional power consumption of AI algorithms reduces device autonomy

8.2. Ethical and Social Challenges

• Data privacy: patients' audiological and speech data must be protected as confidential medical information

• Algorithmic equity: AI systems must be equally effective for all languages, dialects, and demographic groups

• Doctor-patient relationship: AI should remain an assistive tool, not a complete replacement

• Digital literacy: accessibility of digital technologies for elderly patients and low-income groups

9. FUTURE PROSPECTS

The future of AI and audiology integration looks very promising. The following development directions are expected to bring significant changes in 2025–2030:

• Brain-Computer Interfaces (BCI): a new generation of implants based on direct stimulation of the auditory nerve

• Personalized AI models: creating individual neural networks for each patient (personalized AI)

• Wearable technologies: devices monitoring hearing condition based on biomarkers in blood serum

• Gene therapy + AI diagnostics: early detection and treatment of genetic hearing loss

• Metaverse rehabilitation: fully immersive speech and hearing exercises in virtual worlds

• Predictive analytics: AI-assisted prediction and prevention of hearing loss development

10. CONCLUSION

Sensorineural hearing loss is a chronic condition that profoundly affects a patient's social life, professional activities, and mental health. Artificial intelligence technologies are capable of bringing a genuine revolution to rehabilitation practice.

The clinical evidence reviewed in this article shows that AI-assisted hearing aids, cochlear implant programming, speech recognition systems, teleaudiology, and VR therapy methods together can significantly improve speech perception, communication effectiveness, and quality of life in SNHL patients.

The most priority tasks for Uzbekistan include: strengthening training of specialists in audiology, implementing teleaudiology services at the national level, creating speech recognition and rehabilitation platforms adapted to the Uzbek language, and making cochlear implant services more affordable and accessible.

Artificial intelligence is the future of audiology, but full effectiveness is only achieved when it is always combined with the professional conclusions and human attention of qualified physicians and audiologists.

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