

Dynamics of Audiological Disorders and Results of Treatment and Rehabilitation Measures for Patients in the Intermediate and Long-Term Periods of Isolated Craniocerebral Traumas

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Abstract: Traumatization of the population has become one of the main medical and social problems of industrially developed countries, requiring billions of funds for its solution, and has been characterized by a steady and widespread increase in injuries over recent decades. Scientific research dedicated to various aspects of craniocerebral trauma is relevant for all countries of the world due to its high prevalence, prevalence among affected working-age populations, persistent disability risks, and the pronounced medical and social consequences of this pathology. {Citation}

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Introduction

The epidemiological aspects of traumatic brain injury in various regions of the world have been extensively covered in many scientific works. When analyzing the data, significant fluctuations in the prevalence of these injuries are noticeable, ranging from 95 to 783 per 100,000 population.. According to the WHO report "Global Road Safety," approximately 1.35 million people die every year in road traffic accidents, and up to 50 million people sustain non-fatal injuries. Accidents are the eighth leading cause of death in all age groups, and the first among those aged 5 to 29. More than 90% of all deaths occur in low- and middle-income countries (27.5 and 14.4 cases per 100,000 population, respectively), while in high-income countries, the mortality rate is much lower (9.3 cases per 100,000 population). The contingent of injured patients in 50-80% of cases consists of young men of working age.

Among the causes of death, injuries are currently second only to oncological and cardiovascular diseases. Injuries are more common in people of working age (18-60 years) – 59.9% of cases, with 36.9% occurring in children and adolescents. Of the total number of injuries, 30–40% are isolated craniocerebral injuries. Modern concepts of craniocerebral trauma pathogenesis are based on the concept of primary mechanical damage and the subsequent cascade of secondary disorders, including cerebral hypoxia, ischemia, brain edema, microcirculatory disorders, inflammatory reactions, oxidative stress, and metabolic dysregulation. These mechanisms influence the overall neurological outcome and increase perceptions of post-traumatic hearing function disorders, as the auditory analyzer is sensitive to direct mechanical damage and

secondary vascular-metabolic influences.

In recent years, a number of studies have been conducted in the Republic of Uzbekistan aimed at improving the diagnosis and correction of hearing impairments. The features of auditory function in newborns with perinatal CNS damage, the surgical stage of cochlear implantation, speech audiometry in the Uzbek language, hearing screening in preschool age, as well as the features of the CNS course in twins were studied. However, the majority of works are devoted to non-traumatic hearing pathology, and post-traumatic hearing loss is insufficiently studied[1]. At the end of the 20th century, more than 80,000 Americans were hospitalized annually for traumatic brain injury (TBI) and were discharged home with trauma-related complications [2]. Currently, 5.3 million people in the United States are officially registered as disabled as a result of traumatic brain injury [3].

In the analysis of J.L. Steele et al., 34,878 adult patients with temporal bone fractures and hearing impairments were identified. Compared to individuals without such damage, they were significantly more likely to develop labyrinthitis - the relative risk (RR) was 3.56, facial nerve damage was 12.08, and liquorrhea was 40.71; the probability of subsequent cochlear implantation was 26.22 times higher. This transforms the fracture of the temporal bone into a marker of a structurally complex injury that requires prolonged otorhinolaryngological and surdological observation [4].

At the level of the inner ear, a complex of changes developing under the concept of cochlear contusion develops after a BMD. External and internal hair cells, a vascular band, a spiral ligament, spiral ganglion structures, and auditory nerve fibers may be involved in the pathological process [5].

Urbanization and industrialization have a direct impact on the increase in the number of personal vehicles among the population and the frequency of accidents, the occurrence of industrial emergencies, fires, domestic injuries, and military conflicts. In cities and large settlements, the majority of patients with combined injuries visit the emergency department in the evening, during non-working hours, and on weekends. T. Brinck et al. link these cases to the consumption of alcohol and other psychotropic substances in leisure time, which in most cases is the main cause of traffic and domestic injuries [6].

An important feature is the simultaneous involvement of the peripheral and central parts of the auditory system; depending on the direction and energy of the traumatic force, the damage can extend from the outer and middle ear to the receptor apparatus of the cochlea, the auditory nerve, brainstem nuclei, thalamocortical projections, and the auditory cortex. A significant decrease in quality of life or disability was observed in 2/3 of the treated patients due to combined injuries [7].

Purpose of the study

dynamics of audiological disorders and results of treatment and rehabilitation measures for patients in the intermediate and long-term periods of isolated craniocerebral traumas

Materials and Methods

To meet the objectives of this study and accomplish the assigned tasks, an additional 258 patients with chronic inflammatory bowel disease (CIBD), aged 18-69, who presented to and were hospitalized at the Khorezm branch of the Republican Research Centre of Emergency Medicine (RRCEM) between 2023 and 2025 were enrolled. These patients were conditionally assigned to and studied as Group 3.

The mean age of the patients was 41.8 ± 6.4 years; the cohort comprised 144 men and 114 women. The mean age was 44.2 ± 4.8 years for men and 35.1 ± 3.7 years for women. No statistically significant gender-based difference was observed in the incidence of CIBD ($\chi^2=3.49$; $p=0.062$).

Results

Research at this stage was conducted in the intermediate period—in Groups I and II, 3.04 ± 0.25 months after the injury, and in Group III, 4.56 ± 0.62 months after the injury. These intervals were selected in accordance with the generally accepted classification and the established duration of this period for various degrees of BMD severity [8].

By the intermediate period, the severity of neurological complaints significantly decreased, but the degree of their regression depended on the severity of the MCI experienced. In Group II patients, periodic headaches persisted in 18 (10.11%) patients, while in Group III, they persisted in 10 (29.41%) patients; i.e., after severe ISMT, residual cephalgia was noted almost 3 times more frequently than after moderate trauma; the difference between Groups II and III was statistically significant ($p=0.003$) [9].

Most patients attributed headache episodes to changes in meteorological conditions, atmospheric pressure fluctuations, as well as physical or emotional stress.

In the intermediate period of ISMT, a trend toward a decrease in the frequency and intensity of subjective audiological symptoms depending on the severity of the injury persisted in all groups. The minimum manifestations were noted in Group I, and the maximum ones in Group III [10].

Subjective hearing loss by the end of the acute period was noted in 34 (73.91%) patients in Group I, 145 (81.46%) patients in Group II, and 31 (91.18%) patients in Group III. In the intermediate period, the frequency of this complaint decreased to 30 (65.22%), 138 (77.53%) and 29 (85.29%) patients, respectively. Statistically significant intragroup dynamics were established in Group II ($p<0.05$), while in Groups I and III, the decrease in complaint frequency was characterized by a trend.

During intergroup comparison in the intermediate period, the difference between Groups I and II did not reach statistical significance ($p_1=0.085$), while subjective hearing loss in Group III persisted statistically significantly more frequently than in Group I ($p_2=0.044$). The difference between Groups II and III was statistically insignificant ($p_3=0.311$), i.e., a gradual decrease in the frequency of complaints regarding hearing loss was identified; however, after severe MCI, this symptom persisted in the vast majority of patients [11].

In Group I, the frequency of subjective hearing fluctuations decreased from 2 (4.35%) to 1 (2.17%) cases, in Group II from 18 (10.11%) to 13 (7.30%), and in Group III from 7 (20.59%) to 6 (17.65%) without statistical significance of intragroup dynamics. In the intermediate period, the difference between Groups I and II was also statistically insignificant ($p_1=0.328$), while in Group III, this symptom was statistically significantly more frequently noted compared to Group I ($p_2=0.047$), without statistical significance compared to Groups II and III, with a tendency toward a higher frequency of this symptom after severe MCI ($p_3=0.071$).

In Group I, the incidence of tinnitus decreased from 11 (23.91%) to 8 (17.39%), in Group II from 78 (43.82%) to 68 (38.20%), and in Group III from 25 (73.53%) to 22 (64.71%) patients, with statistical significance of changes relative to the end of the acute period in Group II ($p<0.05$) and statistically significant intragroup dynamics of symptom regression in Groups I and III [12].

In the intermediate period, tinnitus persisted in 17.39% of Group I patients, 38.20% of Group II patients, and 64.71% of Group III representatives, forming a distinct gradient of $I < II < III$. The incidence of tinnitus in Group II was statistically significantly higher than in Group I ($p_1=0.008$), in Group III significantly higher than in Group I ($p_2<0.001$), and also higher than in Group II ($p_3=0.004$).

Tinnitus was one of the most stable subjective manifestations of post-traumatic hearing dysfunction, and the likelihood of its persistence in the intermediate period increased significantly as the severity of the ISMS increased.

In Group I, the frequency of subjective decrease in speech readability decreased from 3 (6.52%) to 2 (4.35%) patients, in Group II from 32 (17.98%) to 30 (16.85%) patients, and in Group III from 16 (47.06%) to 14 (41.18%) examined patients without statistical significance of decrease in frequency relative to the end of the acute period.

In the intermediate period, impaired speech intelligibility was noted in 4.35% of patients in Group I, 16.85% in Group II, and 41.18% in Group III. The differences were statistically significant between groups I and II ($p=0.031$), between groups I and III ($p_2<0.001$), and between groups II and III ($p_3=0.001$).

Thus, the impairment of speech perception in the intermediate period was determined by the magnitude of peripheral hearing deficit and the persisting impairment of central processing of acoustic information.

Thus, in the intermediate period of ISMT, the regression of subjective audiological manifestations was of varying severity, with maximum positive dynamics observed in Groups I and II, while in Group III, the highest frequency of hearing loss, tinnitus, hearing fluctuations, and speech intelligibility impairments persisted most frequently, forming a stable intensity of post-traumatic hearing dysfunction $I < II < III$ and its persistence in the intermediate period, which aligns with the research findings.

By the end of the acute period, persistent intensive tinnitus was identified in 1 (2.17%) patient in Group I, 22 (12.36%) patients in Group II, and 11 (32.35%) patients in Group III. In the intermediate period, this noise variant was no longer recorded in Group I; in Group II, its frequency decreased to 16 (8.99%), and in Group III, to 8 (23.53%). In Group II, the decrease was statistically significant relative to the end of the acute period ($p<0.05$).

Despite the positive dynamics, a clear gradient in the frequency of persistent intensive tinnitus was maintained by the intermediate period depending on the severity of the ISMT; the differences were statistically significant between Groups I and II ($p_1=0.049$), Groups I and III ($p_2<0.001$), and Groups II and III ($p_3=0.027$).

A different dynamic was observed regarding periodic low-intensity noise. Its share in Group I decreased slightly from 15.22 to 13.04%, while in Group II it increased from 17.42 to 20.22%, and in Group III from 17.65 to 23.53%. Intergroup differences in the intermediate period did not reach statistical significance ($p>0.05$).

Increasing the proportion of periodic low-intensity noise in groups II and III should not be considered a deterioration of the condition. On the contrary, it reflected the redistribution of a portion of patients from the category of persistent intensive tinnitus to a less severe, periodic variant against the background of a general decrease in tinnitus frequency [13].

The frequency of noise, which occurred primarily during BP elevation, was relatively low in all groups. In the intermediate period, the indicator was 2.17% in Group I, 4.49% in Group II, and 5.88% in Group III, with no statistically significant intergroup differences; this variant of subjective noise did not possess a pronounced discriminatory capacity regarding the severity of ISMT.

The uncertain sensation of "noise in the head" also showed a downward trend: its frequency decreased from 4.35 to 2.17% in Group I, from 8.43 to 4.49% in Group II, and from 14.71 to 11.76% in Group III. In Group II, the decrease reached a statistically significant level ($p<0.05$). Despite the numerically higher frequency of this symptom after severe ISMT, intergroup differences did not reach statistical significance by the intermediate period, which was also related to the limited volume of Group III.

When analyzing the acoustic characteristics of tinnitus in all groups, descriptions such as "roar," "wind noise," or "turned off television" were most frequently preserved. Their frequency decreased from 13.04 to 10.87% in Group I, from 24.72 to 21.91% in Group II, and from 35.29 to

29.41% in Group III. In the intermediate period, this variant was statistically significantly more frequently recorded in Group III compared to Group I ($p=0.036$), while differences in Groups I–II and II–III did not reach a statistically significant level.

The remaining acoustic variants of subjective noise were significantly less common. The frequency of sensations such as "waterfall," "sea surge," and "forest noise" was 4.35; 5.62 and 11.76%, "whistle," "bell," and "cricket" – 2.17; 6.18 and 11.76%. Although the quantitative high-frequency characteristics of tinnitus were more frequently preserved in severe MCI, no statistically significant intergroup differences were identified for individual acoustic descriptions, i.e., the acoustic phenotype of subjective noise itself characterized the severity of the injury significantly weaker than the persistence and severity of tinnitus.

In the intermediate period, grade I tinnitus according to A.P. Velitsky's classification was identified in 7 (15.22%) patients in Group I, 42 (23.60%) in Group II, and 7 (20.59%) in Group III; furthermore, differences between groups did not reach a statistically significant level, and the increase in the share of grade I in Groups II and III was a consequence of the transition of a portion of patients from more severe categories to lighter ones.

Conversely, there were pronounced intergroup differences in grade II tinnitus. In Group I, its frequency decreased from 6.52 to 2.17%, in Group II from 18.54 to 12.92%, and in Group III from 41.18 to 35.29%. In Group II, the decrease was statistically significant relative to the end of the acute period ($p<0.05$). In the intermediate period, the second degree of tinnitus was statistically significantly more frequent in Group II compared to Group I ($p=0.043$), in Group III compared to Group I ($p<0.001$), and in Group III compared to Group II ($p=0.002$) [14].

Grade III tinnitus by the intermediate period was absent in Group I, remaining in 3 (1.69%) patients in Group II and 3 (8.82%) patients in Group III. The difference between groups II and III was statistically significant ($p=0.037$). When comparing groups I and III, statistical significance was not achieved ($p=0.073$), despite a noticeable absolute difference, which was explained by the small number of patients with grade III tinnitus.

If we combine the most clinically significant II–III degrees of tinnitus, the differences become even more evident: in the intermediate period, they were identified in 1 out of 46 (2.17%) patients in Group I, 26 out of 178 (14.61%) patients in Group II, and 15 out of 34 (44.12%) patients in Group III. Pronounced tinnitus persisted in approximately every seventh patient after moderate BMD and in almost every second patient after severe trauma; differences in I–II and especially in I–III and II–III were statistically significant.

Overall, the structure of tinnitus degrees in the intermediate period differed statistically significantly between the three groups ($\chi^2\approx 31.6$; $df=6$; $p<0.001$ when analyzing the categories "no tinnitus/I/II/III degree"). Similarly, the overall structure of tinnitus differed in intensity and persistence ($\chi^2\approx 24.7$; $df=8$; $p\approx 0.002$).

In the intermediate period, the overall prevalence of tinnitus decreased and the intensity of persistent noise simultaneously decreased, which is most pronounced in mild MCI and minimal after severe trauma, which may subsequently serve as promising clinical markers of unfavorable functional restoration of the auditory system.

By the intermediate period of ISMT, further normalization of the otoscopic picture was observed in all three groups; however, the severity of residual regression depended on the severity of the injury sustained. The proportion of patients without visible pathological changes in the tympanic membrane increased in Group I from 97.83 to 100.00%, or 2.17%, in Group II from 84.83 to 94.94%, or 10.11%, and in Group III from 70.59 to 85.29%, or 14.70%. Differences between groups I and II did not reach statistical significance ($p=0.210$), while a statistically significant difference persisted between groups I and III ($p=0.012$). The difference between groups II and III was borderline ($p=0.054$) [15].

The frequency of tympanic membrane vessel injections in Group I decreased from 2.17 to 0%, in Group II from 8.43 to 2.81%, and in Group III from 17.65 to 8.82%, with a decrease of 2.17%, 5.62%, and 8.83% respectively. In relative terms, vascular injection completely regressed in Group I, decreasing by 66.7% from the baseline frequency in Group II and by 50.0% in Group III without statistical significance of intergroup differences in the intermediate period ($p_1=0.586$, $p_2=0.073$, and $p_3=0.119$).

In Group I, the dullness of the tympanic membrane and the shortening of the light cone completely regressed from 2.17 to 0%. In Group II, the frequency decreased from 7.30 to 2.25%, by 5.05%, and in Group III, from 14.71 to 8.82%, by 5.89%. In the intermediate period, tympanic opacity persisted approximately 3.9 times more frequently in Group III patients compared to Group II without statistical significance of intergroup differences ($p_1=0.584$; $p_2=0.073$; $p_3=0.084$).

Conclusion

In the intermediate period, against the background of a decrease in tonal thresholds and a decrease in hearing loss severity, a slight decrease in the proportion of patients with sharply pronounced FUNG and a corresponding increase in the frequency of low and intermediate SISI values were observed. A high SISI index of 70–100% was maintained in nearly three-quarters of patients with post-traumatic CNS, indicating incomplete restoration of cochlear function and resistance to the receptor component of auditory analyzer damage after IPMT.

In the intermediate period, the further dynamics of tympanometric indicators were significantly less pronounced than the dynamics of AR characteristics, due to the almost complete restoration of middle ear function by the end of the acute period.

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