Forensic medicine

Consultative problems in the cases of acoustic injuries caused by explosions, according to documented medical opinions on injuries sustained by Polish soldiers in Afghanistan

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Summary:

Introduction: The aim of the study was to analyse consultative problems in the cases of acoustic injuries caused by detonation of explosives or use of firearms and resulting in hearing loss detectable in audiometric tests.
Material and methods: The study was based on documented medical opinions released by Forensic Medicine Department, Medical University of Warsaw, and concerning injuries sustained by Polish soldiers serving in missions in Afghanistan. The expert's role was to indicate sustained injuries and provide their legal qualification.
Results: Consultative problems were reported for acoustic injuries due to the specificity of such cases. Sustained damage was related to permanent hearing loss in the high-frequency range confirmed in audiometric tests.
Conclusions: As Polish soldiers serve in military missions abroad, forensic medics often encounter problems releasing medical opinions on injuries sustained by the soldiers. It may be noticed, that changes in military equipment and warfare result in higher incidence of isolated hearing loss. At the same time, damage to the vestibulocochlear organ may limit the ability to continue military service and negatively affect the non-professional activities of the soldier.

Key words: acute acoustic trauma, barotrauma, hypoacusis, explosive detonation, forensic medical opinion.

1. Introduction

Nowadays, as Poland actively participates in military missions, Polish soldiers more frequently sustain injuries during warfare. They become victims of gunfire and explosives, which lead to injuries of various gravity, including damage to the middle and the inner ear.

In this paper, the authors will attempt to answer the question how to provide legal qualification

of middle- and inner-ear injuries caused by detonation of explosives and gunfire and leading to hearing loss, but also how these injuries may affect further professional and non-professional activities of the soldier.

Anatomical basis of sound reception

Sounds from the environment arrive at the outer ear in the form of acoustic waves and, thanks to the properly formed auricle, are concentrated in the external auditory meatus. At the bottom of the meatus, acoustic waves collide with the tympanic membrane and cause it to vibrate. Subsequently, tympanic membrane vibrations induce the motility of the ossicular chain in the middle ear (first the malleus, attached to the tympanic membrane, then the incus and the stapes) [1, 2]. The base of the last ossicle, the stapes, closes the vestibular window (previously denominated the oval window) and its movements are transferred to endolymph filling the membranous labyrinth [1, 2]. Within the latter, a wave induced in the liquid is propagated through the atrium, scala vestibuli and scala tympani and arrives at the secondary tympanic membrane covering the cochlear window (previously denominated the round window), which causes the membrane to deform. Finally, the movement of perilymph stimulates the hair cells in the organ of Corti (spiral organ). High-frequency sounds are received by hair cells localized within the basal part of the cochlear turn, whereas lower frequencies are detected in the apical part of the cochlear turn [1, 2].

Pathology of acoustic trauma and barotrauma

By analysing auditory system injuries diagnosed in the examined soldiers, we tried to specify the pathomechanism of those injuries. Damage to the vestibulocochlear organ in the examined group may appear as acoustic trauma, barotrauma and combined acoustic and pressure trauma.

Acoustic trauma

Acoustic injuries occur, when the auditory system is exposed to harmful noise. According to the time of exposure, the level of damaging factor and the rapidity of hearing damage, acoustic traumas may be divided into acute and chronic types [3, 4]:

- Acute acoustic trauma (AAT) is a rapid hearing loss caused by a short exposure to a high level of noise. It is induced by impulse noise produced by explosions, firearms or fireworks. In some cases, AAT may be caused by non-impulse noise, e.g. industrial noise, in particularly sensitive individuals [3, 4].
- Chronic acoustic trauma is a gradual, bilateral, advancing impairment of hearing due to long-term, often multi-year exposure to noise [3, 4].

Circulation disorders in the inner ear capillaries and decreased partial oxygen pressure in the inner ear liquids with cochlear ischaemia are indicated as the pathomechanism of acute acoustic trauma. What is important, in this type of injury damage to the organ of Corti and the basilar membrane occurs [5]. Hair cell damage within the basal part of the cochlear turn appears as isolated hypoacusis in the high-frequency range, characteristic of acute acoustic trauma, which is presented in Figure 1 [6].

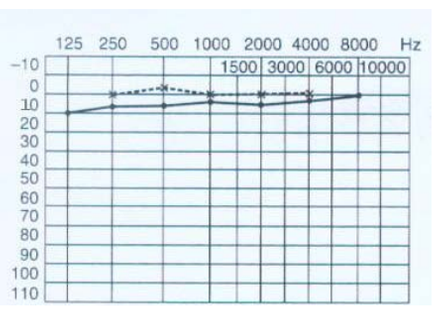

Figure 1: Pure-tone threshold audiometry - correct x-----x bone, •——• air [2].

As time advances, isolated high-frequency hypoacusis may also cover other frequencies in a close range. Among the symptoms of acute acoustic trauma, typical sensorineural hearing loss isolated to high frequencies (usually at approx. 4000 Hz) may be accompanied by tympanic membrane rupture causing conductive hearing loss. Ear pain and tinnitus may also be observed. The above mentioned symptoms may recede naturally within several days, but usually permanent hearing loss occurs, which may aggravate with time [4].

Barotrauma

Barotrauma is caused by a shock wave, a rapid movement of air or liquid encountered by the tympanic membrane. It may be a consequence

of an explosion, increasing pressure gradient or a hit with an open hand near the auditory external foramen. [3, 4]

As a result of suffered barotrauma, both the middle ear and the inner ear may sustain damage including [3, 7]:

- Tympanic membrane rupture;
- Damage to the ossicular chain;
- Perilymph fistulas at the vestibular (oval) window and the cochlear (round) window with possible liquorrhoea;
- Damage to the organ of Corti and the basilar membrane.

Due to the fact, that in the case of barotrauma both the middle ear and the inner ear are subjected to injuries, both sensorineural and conductive hearing loss may occur, leading even to complete deafness. Moreover, symptoms such as balance impairment, vertigo and tinnitus may appear [3, 7].

Subjective and objective examinations used in the diagnostics of both acute acoustic trauma and barotrauma are listed in Table 1 and Table 2, respectively.

Table 1: Subjective tests.

- Acumetry – preliminarily differentiates sensorineural and conductive hypoacusis;

Tuning fork hearing test – preliminarily differentiates sensorineural and conductive hypoacusis;

- Audiometric tests:
  - Pure-tone threshold audiometry – determination of the type and the degree of hearing loss;
  - Pure-tone suprathreshold audiometry – localization of the sensorineural injury;
  - Verbal audiometry – assessment of the ability to understand speech.

Table 2: Subjective tests.

- Impedance audiometry;
- Otoacoustic emission;
- Electrophysiological audiometry.

Among the subjective examinations, the preliminary hearing test and the tuning fork hearing test as indicated by the Polish Society of Forensic Medicine and Criminology (PTMSiK) are of little or no use for forensic medical consultations. In the cases consulted by Forensic Medicine Department, Medical University of Warsaw, the released opinions were based on the available case documentation including the results of pure-tone threshold audiometry. Examples of the results of pure-tone threshold audiometry are presented in Fig. 1, 2, 3 and 4.

This examination method is used to determine the type and the degree of hearing loss. However, the method requires good cooperation between the examiner and the subject. Moreover, what is important in giving a medical opinion is that the subject may modify the results to some extent, for his/her own benefit, by aggravating the symptoms or dissimulating the present hearing loss. In order to avoid such situations, the most appropriate solution is conducting objective hearing examinations, which prevent the subject from manipulating the results.

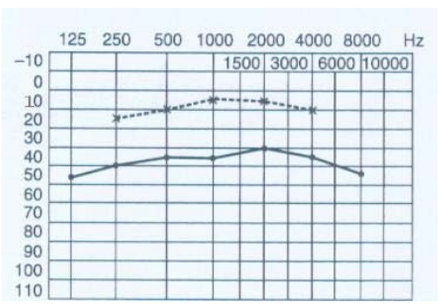

Figure 2: Pure-tone threshold audiometry – conductive hearing loss x-----x bone, •———• air [2].

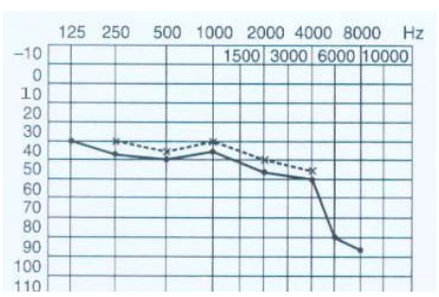

Figure 3: Pure-tone threshold audiometry- sensorineural hearing loss x-----x bone, •———• air [2].

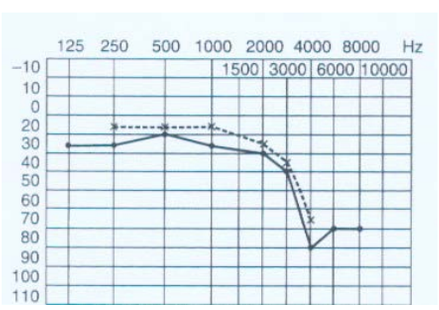

Figure 4: Pure-tone threshold audiometry - sensorineural hearing loss at approx. 4 MHz x-----x bone, •———• air [2].

2. Material and methods

The study was conducted based on several series of documented medical opinions released by Forensic Medicine Department, Medical University of Warsaw in 2010 and 2011, concerning 18 Polish soldiers serving in military missions in Afghanistan. Among the consulted cases, 12 soldiers sustained injuries from detonation of explosives, whereas 5 soldiers did not experience any type of injuries.

In three analysed cases, the soldiers died of lesions caused by explosive detonations, among whom two died at the site of explosion and one died after long-term hospitalization. It is not known whether hearing loss occurred in those three cases. In other six cases, damage to the auditory system was reported and in three of them hearing loss was accompanied by other injuries regarding e.g. the back and the lower limbs. In the two remaining cases, no hearing loss was reported, yet one of the soldiers suffered from lower limb and head injuries.

Apart from the cases described above, reported was a single case of a soldier, who sustained upper limb injuries including damage to nerve and vessel trunks while being under attack by long-range gunfire.

3. Results

In the cases of hearing loss consulted by Forensic Medicine Department, Medical University of Warsaw, the results of pure-tone threshold audiometry were available, both obtained soon after the injury (within a few days) and derived from 2-3 control tests conducted after several weeks or months of the injury.

Among the six discussed cases of soldiers with hearing loss, the following characteristics were observed:

- two cases of bilateral hearing loss accompanied by inner ear problems, including vestibular disorders (Fig. 5);
- two cases of bilateral hearing loss with no symptoms of inner ear disorders;
- two cases of unilateral hearing loss (Fig. 6).

Among all consulted cases, only in one case the soldier was explicitly reported to have been wearing protective earmuffs at the moment of explosion (which occurred within a close range) and this fact prevented him from sustaining hearing loss.

Considering the circumstances of the occurrence of damage to the auditory system, i.e. detonation of explosives in close proximity, two mechanisms of injury should be taken into consideration. Apart from acute acoustic trauma, components of barotrauma may also be expected. Nevertheless, we are unable to clearly assess the extent, to which barotrauma is responsible for the sustained damage. Assessment difficulties originate from the fact, that the hearing loss determined in audiometric tests may be a result of either acute acoustic trauma

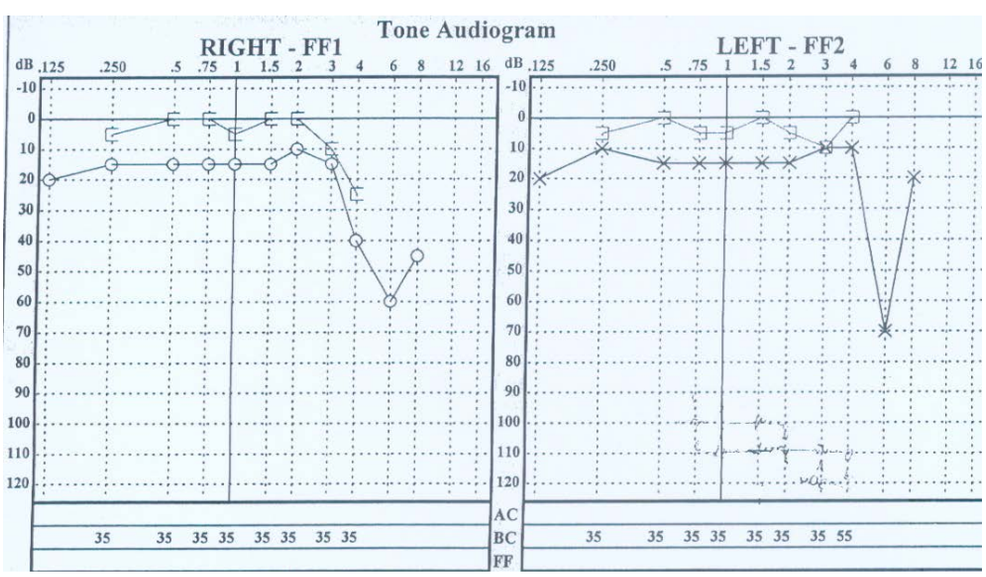

Figure 5: PTA of one of the soldiers – bilateral sensorineural hearing loss at approx. 6 kHz.

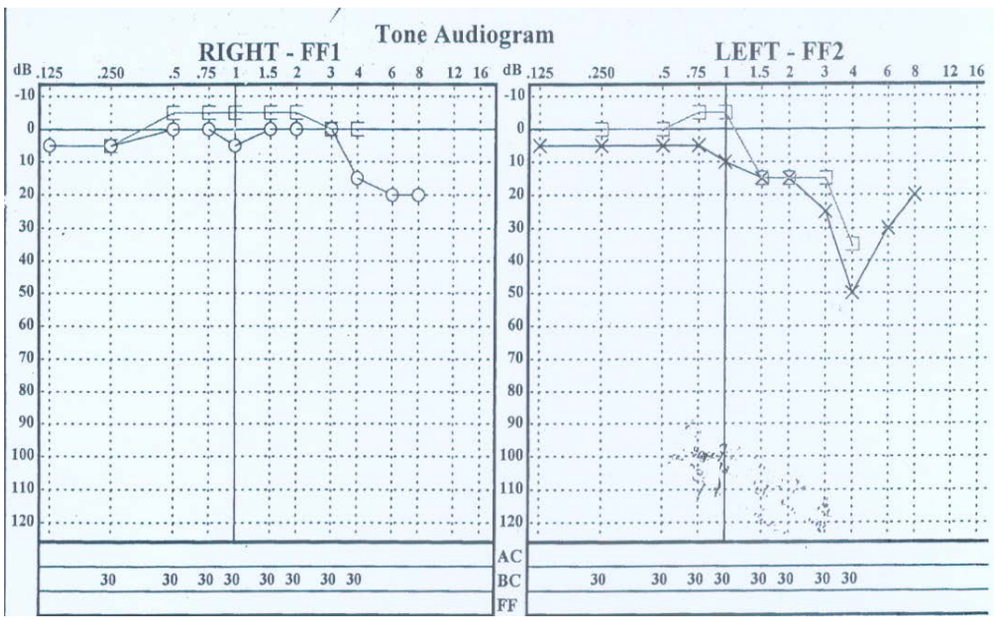

Figure 6: PTA of one of the soldiers – left-sided sensorineural hearing loss at approx. 4 kHz.

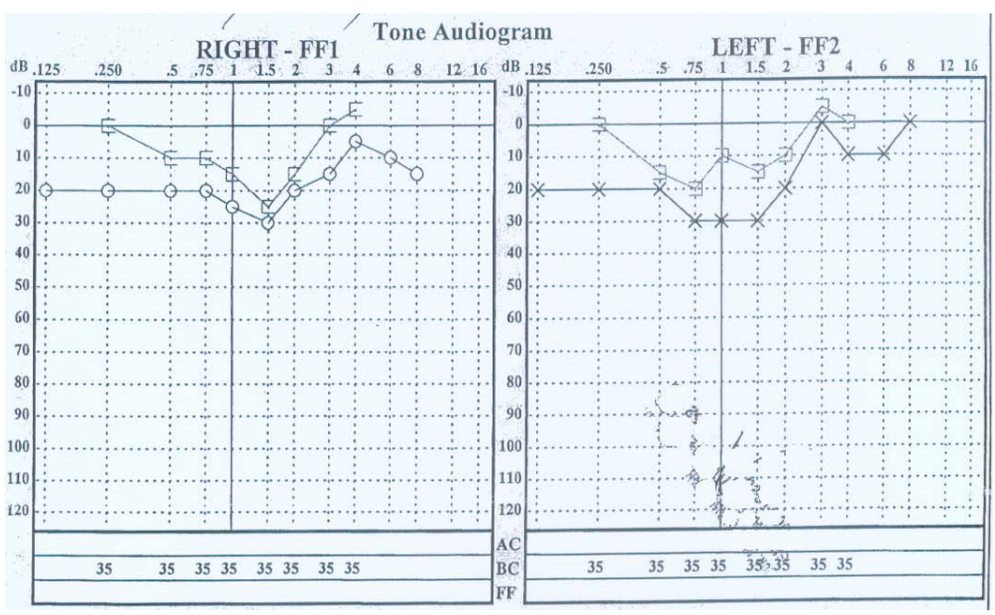

Figure 7: PTA of one of the soldiers – mild bilateral hearing loss, unusual for AAT.

or barotrauma. At the same time, no middle ear damage was reported in the discussed cases.

In the cases of hearing loss consulted by Forensic Medicine Department, Medical University of Warsaw, several consultative problems were encountered. Even though permanent hearing loss likely to undergo progression was reported, there were no cases of complete deafness. Moreover, in the cases of isolated hearing loss in the high-frequency range, the ability to hear may be regarded as socially efficient. People suffering from this condition may be disoriented by not being able to understand their interlocutor in certain situations (e.g. large and loud gatherings), but in comfortable conditions (speaking to one person in a quiet room) they are able communicate [8]. Considering the above fact in the consulted cases, impairment of the auditory system lasting over 7 days according to Art. 157.1 of the Polish Penal Code was reported.

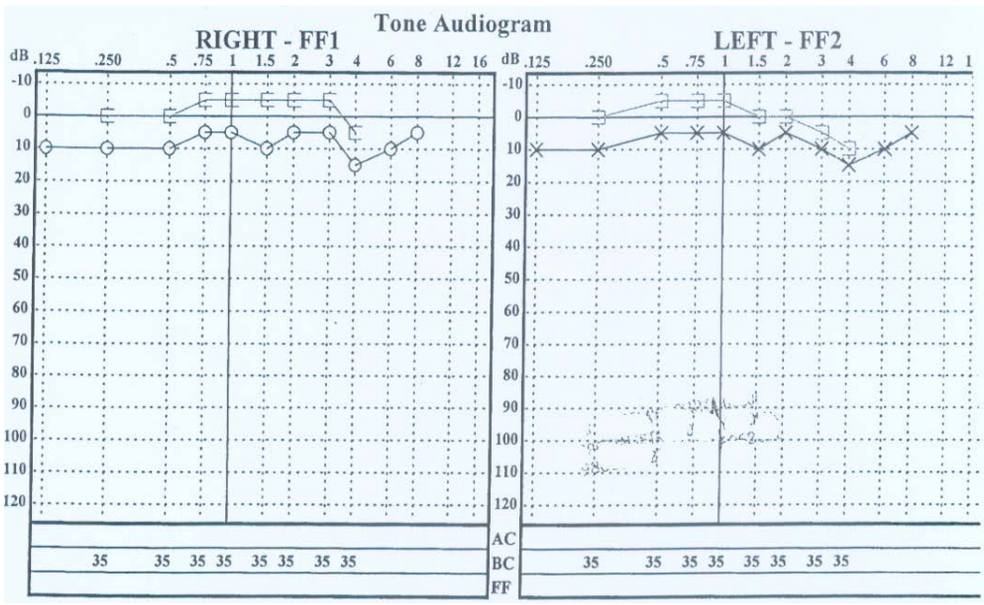

Figure 8: PTA of one of the soldiers – correct.

4. Discussion

The problem of hearing loss in people exposed to impulse noise may be found in the literature. Many of the described cases concern soldiers, who were exposed to gunfire during their military service (including both practice and combat shooting), explosive detonations and other types of noise derived from military equipment [8, 9, 10, 11]. Both bilateral and unilateral hearing loss were reported, but unilateral injuries were attributed by some researchers to the shooting position [12, 13]. In the cases consulted by Forensic Medicine Department, Medical University of Warsaw, either unilateral or bilateral hearing loss were observed, although the conditions were caused exclusively by explosive detonations and not by using firearms. Some authors emphasize the fact, that besides obvious symptoms of acute hearing loss, such as hypoacusis, special attention needs to be given to such vestibular disorders as vertigo, balance impairment and nystagmus [11]. Symptoms of vestibular disorders also occurred in two cases consulted by Forensic Medicine Department.

Nonetheless, soldiers are not the only group descri-bed in the context of acute acoustic trauma. Studies of other social groups using firearms may be found in the literature. Those are e.g. police officers and hunters [14] or people accidentally witnessing gunfire [15]. There are also reports of hearing loss as a consequence of explosive detonations in large gatherings [16].

In the cases reported in the literature, injury circumstances, symptoms, diagnostics and treatment were taken into consideration. The need of acute acoustic trauma prevention by using earplugs or earmuffs was also indicated. Yet, the problem of legal qualification of the reported damage to the auditory system remained unsolved.

As Polish soldiers serve in military missions abroad and civilian prosecutors are obliged to investigate warfare injuries and deaths, forensic medics face the problem of providing opinions on injuries, which are less frequent among civilians, but are characteristic of military activities. Moreover, there are no straightforward guidelines for the consultancy of permanent functional impairment of the vestibulocochlear organ. Providing a proper opinion requires considering many variables, such as the permanence of damage, its range and effect on further functioning of the victim.

5. Conclusions

1) Due to warfare changes, cases of isolated injuries to the vestibulocochlear organ with no other health damage may occur more frequently.

2) Isolated sensorineural hypoacusis in the high-frequency range may affect proper military service.

3) Isolated sensorineural hypoacusis affects the non-professional activities of the soldier.

4) Despite many reports on acoustic traumas in the literature, there are no straightforward guidelines for the consultancy of permanent, isolated sensorineural hypoacusis in the high-frequency range.

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