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Analysis of Otologic Injuries Due to Blast Trauma by Handmade Explosives

Original Investigation

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Abstract

Objective: The aim of this study is to identify the otologic injuries due to handmade explosive-welded blast travma in the law enforcement officers during the combat operations in the curfew security region and to specify the disorders that Otolaryngology and Head Neck Surgery (OHNS) physicians can face during such operations.

Methods: Medical records of patients in law enforcement who were initially treated by OHNS physicians of Silopi State Hospital during combat operations, between December 14, 2015 and January 15, 2016 were reviewed. Twenty-five patients with otologic injuries due to blast trauma were included in the study. Trauma characteristics, physical examination findings, and beginning treatments were identified.

Results: Primary blast injury (PBI) was identified as the major disorder in all 24 cases. Tinnitus and hearing loss were the most frequent complaints. In physical examination, tympanic membrane perforations were found in four ears of three patients. Oral methylprednisolone in decreasing doses for 10 days was commenced as an initial treatment in patients with PBI. Secondary blast injury presented in the form of soft tissue damage in the auricular helix due to shrapnel pieces in one patient and a minor surgery was performed.

Conclusion: Otologic injuries due to blast trauma may often develop during this type of combat operations. Otologic symptoms should be checked, otoscopic examination should be performed, and patients should consult OHNS physicians as soon as possible after trauma.

Keywords: Blast trauma, hearing loss, tinnitus, tympanic membrane perforation

Introduction

Blast trauma is a complex type of physical trauma, which results from sudden and high-pressure changes during an explosion. A three-phase waveform with decreasing amplitude spreads outward from the site of explosion (Figure 1). In the first phase of this wave complex, which is called Friedlander curve, a shock irregularity develops, and subsequently, a positive pressure wave occurs that applies the pressure of hundreds to thousands of kilograms per square centimetre and lasts for 5-10 milliseconds. In the final phase, a negative pressure wave lasts for approximately 30 milliseconds and converts into atmospheric pressure (1, 2).

A positive wave phase can lead to many health problems due to its effects on organs that are sensitive to pressure. With the effect of pressure change, tympanic membrane perforations, pulmonary damages, air embolism, or internal organ ruptures can develop (3). Pressure of approximately 414-552 kPa is fatal to the human body (4). With the pressure increased up to 400 kPa, rupture can develop in the internal organs, such as the lungs and colon, and the tympanic membrane of an adult can be perforated at the pressure of 137 kPa (5). This specific structure of the tympanic membrane, which is sensitive to pressure changes, constitutes the basic mechanism of auditory and vestibular symptoms that frequently develop after blast trauma.

Otological damage is the most common organ injury after explosion (2). In association with inner ear damage due to positive and negative pressure waves, some problems, such as temporary or permanent threshold shifts, vertigo, and tinnitus, can be observed. The situation that develops with the effect of direct pressure is called primary blast injury (PBI) (6, 7). Tympanic membrane perforations or ossicular chain damage can occur in severe PBIs. Secondary blast injury (SBI) defines clinical

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states, such as external ear injury, tympanic membrane perforation, ossicular chain damage, or acquired cholesteatoma that develop due to foreign bodies, including dust, gunpowder, and shrapnel pieces, which spread around in explosion (1,6). In case of a primary or secondary injury, damage can occur in the external ear, tympanic membrane, middle ear, or inner ear.

In our study, otological injuries, which were not a part of multi-trauma and resulted from handmade, explosive-induced blast trauma were examined and discussed in light of literature. This was aimed to contribute to the experience of our colleagues by sharing findings developed in exceptional circumstances.

Methods

The study was started after receiving approval from the Ethics Committee of Fırat University Non-Invasive Clinical Research (Meeting no: 06, Decision no: 15). Law enforcement officers developing otological complaints after blast trauma during combat operations beginning from the curfew on December 14, 2015 until January 15, 2016 in Silopi, Şırnak, were identified. Their trauma characteristics, complaints, physical examination findings, initial treatments, and other hospital recordings were evaluated retrospectively. Because our hospital serves as a center providing primary emergency care and because there is no audiology laboratory, objective tests for evaluating auditory functions could not be applied. The auditory examinations of patients were evaluated only with 1024 Hz and 2048 Hz diapason tests. Personal identifying information of patients was de-identified, and the study was completed in accordance with basic ethical rules.

Results

A total of 25 male patients who were exposed to, handmade explosive-induced blast trauma and had no history of a diagnosed otological disease were included in the study. Twenty-four patients had otological complaints that resulted from PBI, and one patient had tissue loss in an approximately 3-cm region in the upper part of the left auricular helix due to shrapnel pieces.

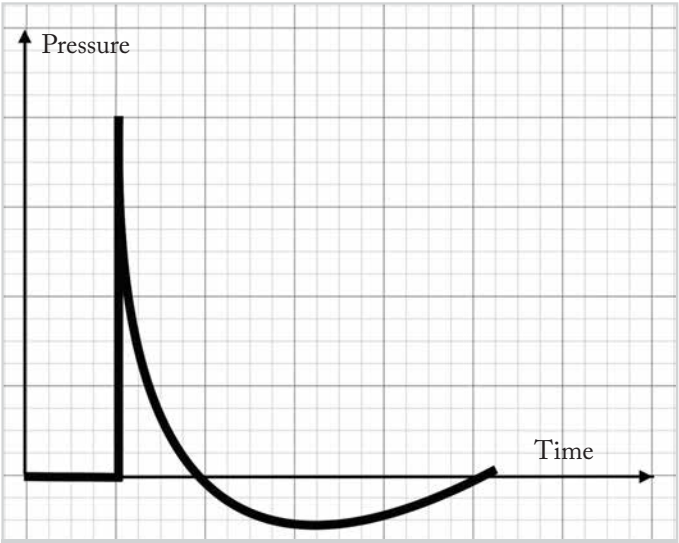

Figure 1. Friedlander curve

Twelve patients had tinnitus, seven had tinnitus with impaired hearing, two had impaired hearing, two had tinnitus with vertigo, and one had impaired hearing with vertigo. Otoscopic examinations revealed tympanic membrane perforation in four ears of three patients. The locations of the perforations in patients with unilateral tympanic membrane perforation were in inferior quadrant, whereas large central kidney-shaped perforations were observed in both ears of the patient with bilateral tympanic membrane perforation. The oto-endoscopic image of this patient is presented in Figure 2. In 1024 Hz and 2048 Hz diapason tests of three patients with tympanic membrane perforation, findings consistent with conductive hearing loss were found. While normal results were found at 1024 Hz in five of 22 patients without tympanic membrane perforation, findings consistent with sensorineural hearing loss were detected at 2048 Hz. Of the patients having sensorineural hearing loss, one had impaired hearing and vertigo; two had tinnitus and impaired hearing; and two had tinnitus and vertigo. One patient whose vestibular system examination revealed hearing loss and vertigo, had second-degree nystagmus with the fast phase beating towards the traumatic ear.

All patients having otological complaints were planned to be given 10-day oral 1 mg/kg corticotherapy due to possible high-frequency hearing loss (inner ear injury) that could not be detected through diapason tests, and the patients were referred to other hospitals for further audiological examinations. Pure-tone audiometry findings of a patient performed on the first day after trauma and on the fifth and tenth days of the treatment in different hospitals were drawn same as the original in a computer environment and presented in Figure 3. Tetanus vaccine was administered to the patient who developed tissue loss in the upper region of the left auricular helix, and the skin in the anterior and posterior auricular areas was primarily sutured to close the exposed cartilage. Oral antibiotic therapy was

Figure 2. Reniform tympanic membrane perforation in the left ear due to blast trauma

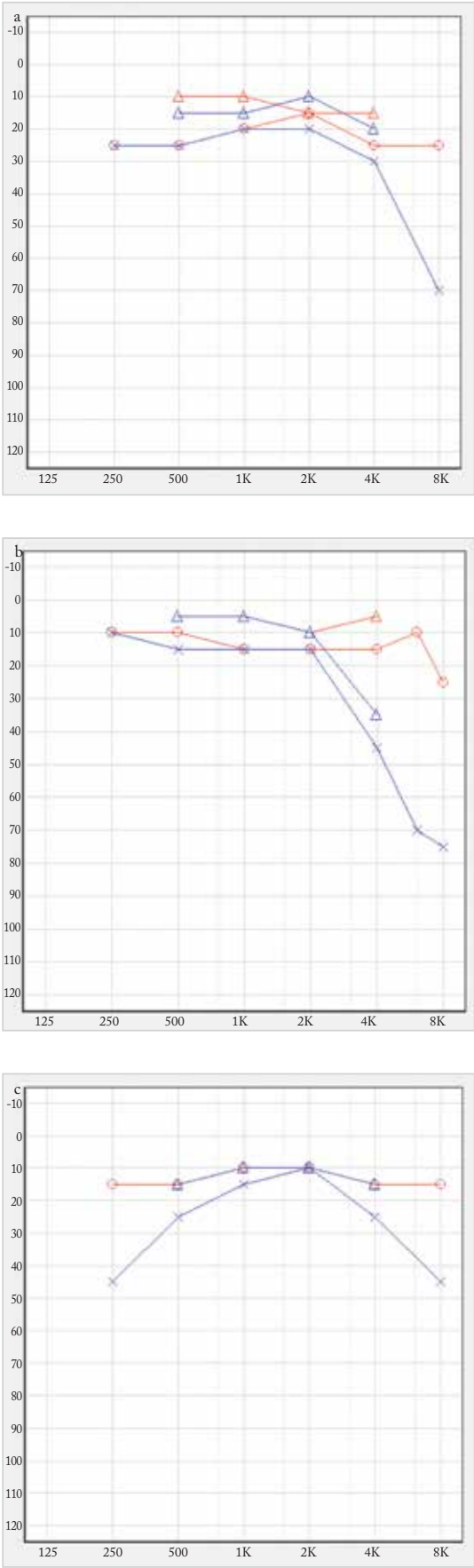

Figure 3. a-c. Pure-tone audiometry examinations of a patient experiencing hearing loss in the left ear due to blast trauma after trauma (a), on the fifth day of the treatment (b), and on the tenth day of the trauma (c)

Table 1. Patients' blast injury features, complaints, examination, and diapason test findings

	n/%
Blast injury	
Primary	24 (96)
Secondary	1 (4)
Complaints	
Tinnitus	12 (48)
Tinnitus + impaired hearing	7 (28)
Impaired hearing	2 (8)
Vertigo + tinnitus	2 (8)
Vertigo + impaired hearing	1 (4)
Auricular injury	1 (4)
Examination findings	
Intact tympanic membrane	22
Perforated tympanic membrane	3 (4 ears)
Tissue loss in the helix	1
1024 Hz Weber and Rinne tests	
Normal	22
Consistent with conductive hearing loss	3
2048 Hz Weber and Rinne tests	
Normal	17
Consistent with conductive hearing loss	3
Consistent with sensorineural hearing loss	5

planned for the patient. Data showing patients' injury features, complaints, examination, and diapason test findings are given in Table 1.

Discussion

The ear is the most commonly affected organ due to its pressure-sensitive structure after blast trauma (2, 3, 5). The extent of damage is in parallel with the severity of explosion and the distance to the site of explosion. In contrast, the symptoms are associated with the affected anatomic region (6-8). Injuries involving separate or multiple anatomic regions can be observed in the external ear, middle ear, and inner ear.

External ear damage due to blast trauma is nearly always observed after SBI. In our study, tissue loss involving the helix in a 3-cm region of the left auricle due to shrapnel pieces was found in a patient. The issues to be considered in such cases are rendering clean wound care, questioning the administration of tetanus vaccination, early appropriate closure of the wound and management of medical and surgical treatment.

Tympanic membrane injury is a condition that is commonly encountered after blast trauma. It can develop after PBI or SBI with the effect of direct pressure. Therefore, it should be known that inner ear damage could accompany conductive hearing loss in some cases (9). In a recently conducted study, it was hypoth-

esized that tympanic membrane perforation that could develop due to explosion could lead to deviations in the pressure wave, and it could form a protective mechanism over the inner ear. However, it was concluded in the study that there was no statistically significant difference between patients developing and those not developing tympanic membrane perforation in terms of inner ear damage (9).

Perforation is often wide in size. In a study, tympanic membrane perforation was frequently found to be total or near total (65%). It was accompanied by ossicular damage at the rate of 18% and by cholesteatoma at the rate of 9% (10). Cholesteatoma was attributed to the epithelial tissue implanted to the middle ear with the effect of explosion. These patients should firstly be followed with regard to spontaneous recovery. Spontaneous closure of the perforation was found to be associated with its size, and this rate was reported to vary between 38% and 74% (7, 11, 12). In literature, standard tympanoplasty and, if required, tympanoossiculoplasty are the treatment methods for tympanic membrane perforations that develop after blast trauma and do not heal in the follow-up. In patients undergoing surgery, the success rate of the graft after treatment is above 80% in many studies (7, 10, 11).

In our study, tympanic membrane perforation was found in four ears of three patients. The sites of tympanic membrane perforations of two patients with unilateral perforation were similarly limited to the inferior quadrant. These patients were referred to further centers for audiological examinations on their initials days, but they voluntarily did not leave the district for 3 weeks to attend the continuing combat operations, and their perforations healed with atrophic areas in this period. Another patient had reniform perforations in both ears, and similarly, he did not leave the district for 3 weeks, either. His tympanic membrane perforations did not heal during the follow-up. With the end of combat operations, these cases were referred to further health centers and some were lost to follow-up.

Inner ear damage is another frequently encountered condition after blast trauma, and its most common symptoms are tinnitus and hearing loss (1, 2, 7). In an animal model designed on PBI, it was found that auditory brain stem responses and otoacoustic emissions were impaired due to pressure. In the evaluation of histopathologic results of the same study, development of loss was detected particularly in the outer hair cells in the basal turn of the cochlea, spiral ganglion cells, and afferent nerve cell synapses (6). This indicates an audiological configuration that can be confused with acoustic trauma. However, while continuous or intermittent exposure to loud sound is observed in acoustic trauma, blast trauma includes a single and sudden high-pressure exposure (1). The exposure to blast trauma in indoor places and close distance to the site of explosion particularly increases the risk of sensorineural hearing loss (8). After blast trauma, vestibular symptoms can be observed more rarely, but the reason for that is often head trauma and perilymph fistula or superior semicircular canal dehiscence and should be remembered in cases having valid peripheral vertigo (7-9).

In our study, the most frequent symptoms due to inner ear damage were found to be tinnitus followed by impaired hearing. The diapason tests revealed unilateral sensorineural hearing loss in five of the patients, but these findings could not be confirmed through pure-tone audiometry tests that would be simultaneously performed with the examination. As a treatment principle, all patients having tinnitus and/or impaired hearing were prescribed 1 mg/kg oral corticotherapy and were referred to further health centers.

We could not present the results of audiological examinations, which was a limitation of the study, since the study center was a primary care emergency service and an audiology laboratory was not available. In a literature review, we noticed that almost all studies in our references were performed in hospitals providing tertiary healthcare services. Therefore, we hope that the bigger centers, which serve as region hospitals, will publish results that are more objective in the near future. Another limitation is that otological symptoms could not be investigated, and examinations could not always be performed in patients who were followed up by different departments due to severe trauma or who were rapidly referred. In a literature review, some studies investigated that tympanic membrane perforation could be used as a marker for predicting visceral damages in patients with multiple traumas because of tympanic membrane's sensitivity to pressure (5, 13). In a study, it was specified that 50% of patients with lung injury did not have tympanic membrane perforation; therefore, it was not considered as a reliable marker. In another study, the sensitivity and specificity of tympanic membrane perforation for identifying visceral injuries were reported to be approximately 50% and 87%, respectively (5, 13). These studies show that each patient exposed to blast trauma should definitely be evaluated by an otorhinolaryngology and head-neck surgery physician during emergency intervention or later, and further examinations should be performed in symptomatic patients.

In Turkey, the number of cases exposed to blast trauma is high because of frequent terrorist attacks. These patients are often followed for injuries that can be mortal, and they cannot be evaluated for otological disorders with high morbidity rates. The absence of a national study on ear injuries due to blast trauma in literature can be considered as an indicator of this fact. Although this study has some limitations in terms of objective data, it can be regarded as a step for drawing attention to this specific situation and guiding the physicians of otorhinolaryngology and head-neck surgery working in regions under high risk.

Conclusions

Ear injuries frequently develop after blast trauma, and recent terrorist attacks in Turkey increase the importance of this fact. All cases experiencing blast trauma should definitely be evaluated by otorhinolaryngology and head-neck surgery specialists; their treatments should be initiated urgently, and their audiological examinations should be performed at the earliest. Additionally, more extensive studies, including objective data of these cases, are needed for expanding the national literature and increasing knowledge and experience of physicians in the related area.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Fırat University Non-Invasive Human Research.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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