

## Tympanoplasty after War Blast Lesions of the Eardrum: Retrospective Study

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**Aim.** To establish whether hearing loss after eardrum blast injury could be recovered by tympanoplasty performed immediately after injury and what material is the most suitable for eardrum closure.

**Methods.** Tympanoplasty was performed in 119 (a total of 181 injuries) out of 651 patients examined for blast injury of the ear between 1991 and 2000. The study included a total of 106 patients who underwent tympanoplasty: 51 patients with unilateral and 55 with bilateral blast eardrum rupture (a total of 161 injuries). Three different materials were used for eardrum rupture closure: temporal fascia in 81, perichondrium in 61, and heterograft in 19 cases. Injuries were divided in 4 groups, according to the time elapsed between the injury and tympanoplasty (0-20, 21-60, 61-180, and 181 days and more). Otomicroscopic finding, audiometry, and tympanometry were used for definitive evaluation of tympanoplasty outcome.

**Results.** Eardrum rupture was successfully closed with temporal fascia in 91%, perichondrium in 92%, and heterograft in 89% of the cases ( $p=0.429$ ). There were no statistically significant differences in either values of postoperative air-bone gap ( $p=0.210$ ) or in eardrum perforation closure rate ( $p=0.951$ ) with respect to the time period between the injury and tympanoplasty. Also, there was no correlation between the postoperative air-bone gap and the number of days elapsed between the rupture and tympanoplasty ( $r=-0.037$ ,  $p=0.641$ ).

**Conclusion.** Small ruptures of the eardrum should be left to heal spontaneously. The patients with subtotal and total rupture and rupture that did not heal spontaneously in three months should undergo tympanoplasty. Temporal fascia, perichondrium from tragus, and heterograft are equally acceptable materials for eardrum closure after blast injury.

**Key words:** *blast injuries; hearing loss, conductive; myringoplasty; tympanic membrane perforation; tympanoplasty*

Ear is extremely susceptible to air pressure wave, or blast, caused by explosion. Consequently, the lesions of the eardrum and internal ear are the most frequent of all blast injuries (1-4). In addition to eardrum lesion, the positive wave of air pressure causes a dislocation or interruption of the chain of auditory ossicles or the rupture of fenestrae, although less frequently (3,4). This positive wave of air pressure is followed by a prolonged but less intensive negative wave, affecting the ear to a considerably lesser extent (Friedlander's curve) (5-10). The strength of the positive wave depends on the strength of explosion and on the distance of the explosion site. Lesions are more severe if explosion occurs indoors, where the wave reflects from the walls. Eardrum rupture may occur at a pressure of not more than 35 kPa, and a pressure of 105 kPa causes rupture in 50% of eardrums in adults (5,6). A pressure required for lesions of the lungs and gastrointestinal system to occur is considerably higher, thus in patients with severe blast lesions of the respiratory or digestive systems a lesion of the eardrum should always be expected (10,11).

About 70-80% of all blast eardrum ruptures heal spontaneously, of which 40-50% within the first month, and the rest within the first two months from

the wounding (3,6,12). Spontaneous healing depends on the size and localization of the rupture. About 10% of the eardrum area is considered to heal spontaneously *per month*. However, if spontaneous healing does not begin within the first month, the epithelium on the lateral side of the eardrum will overgrow the rim of the rupture and then spontaneous healing will be very unlikely to occur (6). Eardrum particles torn by blast end up in the middle ear mucosa and at these sites cholesteatoma may form after spontaneous healing. The rims of the defect fold medially (3,13,14).

Surgical techniques used in the treatment of ruptured/blast eardrum include tympanoplasty and myringoplasty with perichondrium, temporal fascia, or a heterograft (10,15-17).

Some authors propose performing tympanoplasty and myringoplasty immediately after wound infliction (18), to prevent the penetration of infection into the middle ear through the auditory canal. Others suggest that the blast lesions of the eardrum should be left to heal spontaneously, and only ruptures that would not heal in several months and total ruptures, where spontaneous healing cannot be expected, should be closed surgically (3,5).

We tested different materials to determine which one is the most suitable for eardrum closure after blast injury. Also, we wanted to establish what would be the best time to perform tympanoplasty after blast injury to maximally preserve hearing. The number of blast ear injuries during 1991-1995 war in Croatia enabled us to test, on a large sample, whether the time elapsed between injury and tympanoplasty influenced the success rate of tympanoplasty.

**Patients and Methods**

From the beginning of the war in Croatia in 1991 until the end of 2000, we treated 651 patients for blast injury of the ear, out of whom 403 had bilateral ear injury. Out of the total of 1,054 ear blast injuries, 444 (42%) were injuries with mixed hearing loss, 493 (47%) with pure sensorineural hearing loss, and 117 (11%) with pure conductive hearing loss without internal ear damage. Patients who had had different ear problems (chronic otitis, hypoacusis, or previous ear surgery) before the blast injury were not regarded as having the blast injury.

Of the total of 561 cases with conductive hearing loss (444 mixed hearing loss and 117 pure conductive hearing loss), 549 were eardrum ruptures, 9 were eardrum ruptures with dislocation or interruption of the chain of auditory ossicles, and 3 were hematotympanum.

Tympanoplasty was performed in 172 out of 549 cases with eardrum rupture without dislocation or interruption of the ossicles chain (Fig. 1), and was not performed in cases of small eardrum defect (up to 50% of eardrum), because spontaneous healing was expected.

Our study included 106 patients with a total of 161 eardrum ruptures. Tympanoplasty was performed unilaterally in 51 and bilaterally in 55 of them. Inclusion criteria were injuries with

eardrum rupture, patients with regular postoperative clinical and audiological follow-up, and patients with follow-up time longer than 2 years. Exclusion criteria were injuries with dislocation or interruption of the chain of auditory ossicles and injuries with hematotympanum. There were 105 men and 1 woman, aged 18-54 years (mean 28.1 ± 7.2 years). The right ear was injured in 82 (51%) cases and left in 79 (49%) cases. All patients received 500-mg amoxicillin (Amoxil, Pliva, Zagreb, Croatia) 3 times a day, for 5 days, as postoperative antibiotic prophylaxis.

Suppuration after injury was observed in 21 (13%) out of 161 injuries. After the cessation of suppuration, at least one month had been allowed to elapse before the surgery was performed in these patients.

To close the eardrum rupture we used temporal fascia in 81 cases (50%), perichondrium from the tragus in 61 cases (38%), and heterograft (absorbable dura mater substitution from bovine collagen; Lyoplant, B. Braun Surgical GmbH, Melsungen, Germany) in 19 cases (12%).

Median number of days between the injury and tympanoplasty was 79 (range, 4 days to 5 years, 7 months, and 12 days). According to the number of days elapsed between the injury and the surgery, we divided all injuries in 4 groups: 0-20 days, 21-60 days (when spontaneous healing is finished in most injuries), 61-180 days (spontaneous healing must be finished in all injuries), and 181 days and more (Fig. 2) (3,6,13).

Otomicroscopy and audiometry were performed 2, 6, 12, and 24 months after the surgery. We used the last audiometry result as definitive. Tympanometry was performed in all patients to confirm the closure of eardrum rupture.

All statistical analyses (descriptive statistic, Kruskal-Wallis test, Spearman's Correlation) were made in SPSS for Windows Version 8.0 computer program (19). P-values lower than 0.05 were considered statistically significant.

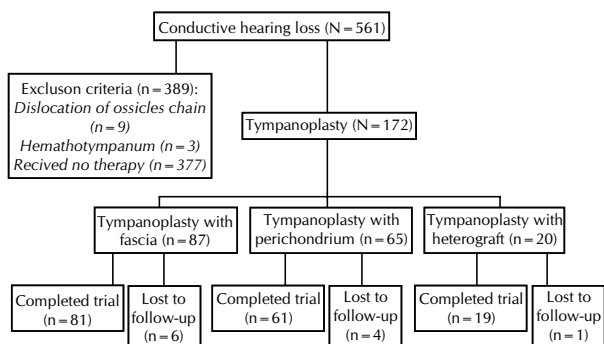
**Results**

*Descriptive Statistics*

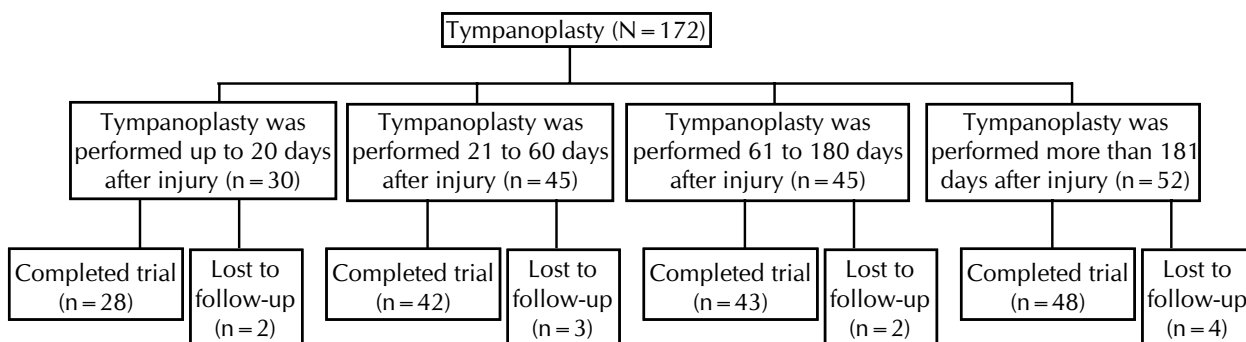
In the blast lesion of the eardrum, conduction hearing loss was not always present in all the frequencies. Low frequencies of < 1,000 Hz were affected in 80-86%, and frequencies of 2,000-6,000 Hz in 97-99% of the cases (Fig. 3). High frequencies were more severely damaged than low frequencies (Fig. 4).

*Tympanoplasty Success According to the Material Used*

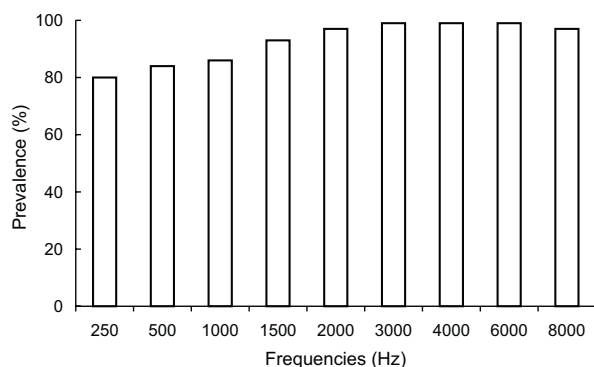
After tympanoplasty with any of the three materials (temporal fascia, perichondrium, or heterograft), eardrum rupture closure was successful in 89-92% of eardrums. There was no significant difference in the values of postoperative air-bone gap (conductive component of hearing loss) among the patient groups analyzed according to the used material (Table 1).



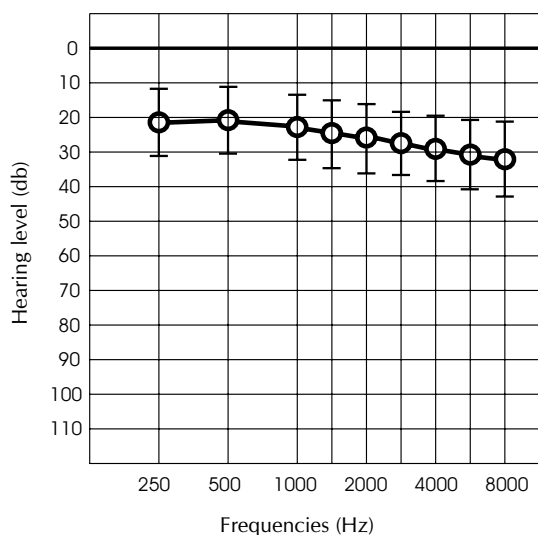
**Figure 1.** Study profile. Injuries are distributed in three groups according to the materials used for tympanic membrane rupture closure (temporal fascia, perichondrium from tragus, heterograft).



**Figure 2.** Profile of the patients with tympanoplasty, according to the time elapsed between injury and tympanoplasty.



**Figure 3.** Prevalence of conductive hearing loss on different frequencies after blast injury of the eardrum in the patients with tympanic membrane rupture without dislocation of ossicle chain (n = 549).



**Figure 4.** Mean curve with standard deviation of air-bone gap after blast injury of eardrum in the patients with tympanic membrane rupture without dislocation of ossicles chain (n = 549).

*Tympanoplasty Success Rate According to the Time Elapsed between Injury and Tympanoplasty*

The rate of successful closure of eardrum rupture was between 89.3% and 93.0% in all four groups of injuries. There was no significant difference in postoperative air-bone gap (T=4.523, p=0.210, Kruskal-Wallis test) (Table 2).

The postoperative air-bone gap and the number of days elapsed between the wound infliction and tympanoplasty did not correlate either (Spearman's Correlation Coefficient r=-0.037; p=0.641).

**Discussion**

In contrast to other authors (3,5-6,10,12,16), who used only temporal fascia and perichondrium from the tragus for the eardrum closure, we have also used a heterograft, with the same success rate. For all

**Table 1.** Success rate of tympanoplasty and postoperative air-bone gap (mean ± SD) according to the material used for reparation of the injured eardrums (n = 161)

Grafting material	Success rate	Postoperative air-bone gap (dB) <sup>a</sup>
Fascia	74/81 (91%)	5.3 ± 4.9
Perichondrium	56/61 (92%)	5.5 ± 4.3
Heterograft	17/19 (89%)	6.7 ± 7.3

<sup>a</sup>Kruskal-Wallis test = 1.694; p=0.429.

**Table 2.** Success rate of tympanoplasty and postoperative air-bone gap (mean ± SD) according to the number of days between the injury and the tympanoplasty (n = 161)

No. of days between injury and tympanoplasty	Success rate	Postoperative air-bone gap (dB) <sup>a</sup>
0-20	25/28 (89%)	6.4 ± 4.2
21-60	38/42 (90%)	5.3 ± 5.5
61-180	40/43 (93%)	4.9 ± 2.4
>180	44/48 (92%)	5.9 ± 6.6

<sup>a</sup>Kruskal-Wallis test = 4.523, p=0.210.

three materials used, the success rate was 89-92%. Our results showed no difference in the eardrum closure success rate or in the postoperative air-bone gap values among the three patient groups analyzed according to the materials used. All three materials – temporal fascia, perichondrium from the tragus, and heterograft – can be successfully used for the eardrum closure after blast injury.

Comparing the success of the tympanoplasty performed at different times after blast injury, we found no significant difference among the groups. Also, there was no correlation between the time that passed from the injury to the tympanoplasty and the success of the operation measured by the air-bone gap in the post-operative audiogram. Since the probability of spontaneous healing of the large ruptures of the eardrum is very low, the postponement of the tympanoplasty increases the possibility of ear inflammation (18). Therefore, tympanoplasty should be performed without delay on all total and subtotal tympanic membrane perforations. Our results suggested that the success of the tympanoplasty remains the same, even if the surgery is performed six months or more after the blast injury. This finding implies that we can wait for the spontaneous healing for a long period of time, except in the cases of total and subtotal perforations and spontaneous healing failure.

Air blast may induce eardrum rupture, internal ear lesion, or both. In this study, conductive hearing loss was almost exclusively caused by the eardrum rupture (97.9%). The chain of auditory ossicles was interrupted in 9 cases (1.6%), which was less than in another study (10). We also had three cases of hemothympanum, which other authors usually do not describe (3,11).

Our results showed that the conduction hearing loss caused by the blast injury of the eardrum involves high frequencies more frequently, usually those between 2 and 6 kHz. Unlike the conductive hearing loss due to the eardrum defect in chronic otitis, the conductive hearing loss due to the blast injury more severely affects high frequencies than the low ones, even up to 11 dB on average.

Although it included large number of patients, our study would have carried more weight if it had been prospective and the patients randomized. However, that could not have been done because in 1991 all hospitals worked under unfavorable war conditions (20) and had to take care of many wounded as quickly as possible, which is also the reason why the material for tympanoplasty depended mainly on the free choice of the surgeon in each particular case.

In conclusion, total and subtotal eardrum ruptures should be operatively treated because they will not heal spontaneously and can be complicated with ear infection. Tympanoplasty of smaller eardrum perforations that did not heal spontaneously can be performed at any time after injury with the same success, regardless of the material used for eardrum rupture closure.

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