Hyperbaric Oxygen Therapy in Acute Acoustic Trauma: A Rapid Systematic Review

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Abstract
In this rapid systematic review, we studied the clinical question, What is the effect of hyperbaric oxygen therapy on hearing thresholds in patients who suffered a recent acute acoustic trauma? After screening for eligible titles and abstracts and extracting duplicates, 6 original research papers could be found. The general methodology of the studies was weak and the differences between these studies were too profound to pool the data, especially because of heterogeneity in adjuvant therapies, follow-up, and treatment protocol. The mean dB of hearing recovery in these studies ranged from 17 to 47 dB in the groups treated with hyperbaric oxygen versus 5 to 46 dB in the groups who did not receive hyperbaric oxygen therapy. We conclude that the effect of hyperbaric oxygen therapy on hearing thresholds in patients with hearing loss caused by a recent acute acoustic trauma remains unclear. A well-designed randomized controlled trial with enough power is advised to answer this clinical question.

Keywords
acute acoustic trauma, hearing loss, hyperbaric oxygen therapy

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Introduction
Acute acoustic trauma (AAT) is defined as an acute impairment of hearing caused by sharp sounds. In addition to acute hearing impairment, AAT is characterized by the onset of tinnitus in the affected ear.1 One of the most common causes of AAT is shooting with firearms or the use of explosives near an unprotected ear. The prevalence of hearing disabilities caused by AAT is high in certain groups such as in the military; the US Veterans Administration notes that hearing loss and tinnitus are the most prevalent service-connected disabilities.2

The impact of high sound energy on the inner ear leads to a loss of function of the outer hair cells and may be associated with a loss of supporting Deiter’s cells. These damaged sensory cells are kept in a transitional phase over a period between regeneration and cell death. Theoretically, it is this transitional phase where therapy can make a difference.3 Since high intensity sounds reduce the oxygen tension within the cochlea, correlating with a decrease of hearing potentials, oxygen therapy theoretically reduces the hearing impairment caused by an AAT. Different authors found that oxygen applied under a hyperbaric condition can diffuse into the cochlea and recover hearing potentials in experimental animal studies.4,5

Clinical Question
What is the effect of HBO therapy on hearing thresholds in patients with hearing loss caused by a recent acute acoustic trauma?

Methods
We retrieved original study publications on the effect of HBO therapy on hearing loss in patients with AAT in PubMed, Embase, The Cochrane Library, and Web of Science (see Table 1 for the search strategy).

We screened retrieved titles and abstracts for potentially eligible citations and subsequently retrieved their full text for a more confined selection of eligible studies. We

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included original studies, including patients with hearing loss caused by an AAT that were treated with HBO therapy. We excluded articles not written in English, German, or Dutch; case reports; commentaries; reviews; animal studies; and studies concerning idiopathic sudden hearing loss. A related-articles search in PubMed and cross-reference checking were used to retrieve relevant articles missed and to identify additional useful search terms. Included studies were critically appraised for quality of their methods and reporting of results using the criteria shown in Table 2.

### Results

Our search yielded 99 publications in PubMed, 213 in Embase, 66 in The Cochrane Library, and 165 in Web of Science (search date: December 24, 2013) (Figure 1). Upon screening of titles and abstracts, 6 publications in PubMed, 5 in Embase, 2 in The Cochrane Library, and 3 in Web of Science were found to be eligible. After extracting duplicates, 6 unique records could be retrieved.1,3,5-8 The full text of these 6 selected publications was studied in terms of domain, determinant, and outcome and critically appraised according to the criteria presented in Table 2. Data could not be extracted from 3 studies; Demaertelaere and Van Opstal6 performed a case series, and as such, the results were not compared to results without HBO therapy.

Pilgramm5 did not give any numbers in the results section and did not respond when asked to provide them by email.

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Table 1. Search Strategy.

<table>
<thead>
<tr>
<th>Database</th>
<th>Search</th>
<th>No. of Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embase</td>
<td>‘hyperbaric’ OR hyperbaric:ab,ti AND (‘hearing’/exp OR ‘hearing loss’/exp OR ‘acoustic trauma’/exp OR hearing:ab,ti)</td>
<td>213</td>
</tr>
<tr>
<td>The Cochrane Library</td>
<td>hyperbaric AND (hearing OR “hearing loss” OR “acoustic trauma”)</td>
<td>66</td>
</tr>
<tr>
<td>Web of Science</td>
<td>TS=hyperbaric AND (TS=hearing OR TS=hearing loss OR TS=acoustic trauma)</td>
<td>165</td>
</tr>
</tbody>
</table>

Table 2. Assessment of Studies on the Effect of Hyperbaric Oxygen (HBO) Therapy on Hearing Loss in Patients with Acute Acoustic Trauma.\(^a\)

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Follow-Up, d</th>
<th>HBO Protocol, Bar/Min</th>
<th>HBO Cycles, Mean, d</th>
<th>Study Type</th>
<th>Moment</th>
<th>Start</th>
<th>Therapy</th>
<th>DOM</th>
<th>DET</th>
<th>OUT</th>
<th>FRP</th>
<th>BD</th>
<th>STP</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ylikoski et al(^1)</td>
<td>60</td>
<td>7-15</td>
<td>2.4/90</td>
<td>6.1</td>
<td>CC</td>
<td>&lt; 48 h</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Pilgramm and Schumann(^3)</td>
<td>122</td>
<td>42</td>
<td>2.8/60</td>
<td>10</td>
<td>RCT</td>
<td>&lt; 48 h</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Demaertelaere and Van Opstal(^6)</td>
<td>56</td>
<td>NS</td>
<td>3.0/60</td>
<td>10</td>
<td>CS</td>
<td>&lt; 6 d</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Lafère et al(^7)</td>
<td>68</td>
<td>10</td>
<td>2.5/70(^c)</td>
<td>10</td>
<td>CC</td>
<td>&lt; 43 h</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Pilgramm(^5)</td>
<td>NS</td>
<td>42</td>
<td>NS</td>
<td>NS</td>
<td>RCT</td>
<td>&lt; 48 h</td>
<td>●</td>
<td>●</td>
<td>NS</td>
<td>NS</td>
<td>○</td>
<td>NS</td>
<td>○</td>
<td>NS</td>
<td>○</td>
</tr>
<tr>
<td>Vavrina and Muller(^8)</td>
<td>78</td>
<td>6.5</td>
<td>1.4-2.2/60</td>
<td>7.2</td>
<td>CC</td>
<td>&lt; 15 h</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
</tbody>
</table>

Abbreviations: BD, blinding; CC, case control; CD, completeness of data does not exceed 20%; CS, case series; DET, determinant (HBO therapy); DOM, domain; FRP, formal randomization procedure; NS, not specified; OUT, outcome (percentage of hearing recovery in the high frequencies); RCT, randomized controlled trial; STP, standardization of treatment protocol.

\(^a\) * = accurate; ○ = not accurate.

\(^b\) 7 days or until end of military service.

\(^c\) 1 to 2 times per day.

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![Flowchart](oto.sagepub.com)
Vavrina and Muller gave only an average for hearing improvement per frequency, although hearing loss caused by AAT and possible improvement are considered to affect the higher frequencies. These data could, however, not be extracted. Therefore, 3 studies could be used to assess the effect of HBO therapy on hearing loss in patients with AAT (Table 3). The mean dB of hearing recovery in these studies ranged from 17 to 47 dB in the groups treated with HBO versus 5 to 46 dB in the groups who did not receive HBO therapy. It is unfortunate that the differences between these studies were too profound to pool the data, especially because of heterogeneity in adjuvant therapies, follow-up, and treatment protocol (Table 3). Moreover, the data from Pilgramm and Schumann are not absolute data but are read from the figures given.

These limitations taken into account, 1 study showed a statistically significant effect, 1 study showed only a small effect, and 1 study showed no effect while claiming otherwise (Table 3).

### Discussion

We have reported the first systematic overview on the effect of HBO therapy on hearing thresholds in patients with hearing loss caused by a recent AAT. Although a recent Cochrane report on the effect of HBO therapy on sudden deafness showed a positive effect with uncertainty regarding the clinical relevancy, we found that the current evidence concerning the effect of HBO therapy on hearing thresholds in patients who suffered a recent AAT is still weak.

The strength of our study was that we described the results of HBO therapy in a well-described group of only patients with a recent AAT, thereby minimizing the risk of a possible dilution of the effect caused by different domains studied.

However, some aspects need consideration when interpreting our findings and the findings of the studies found. First, the general methodology of the studies found was weak. Most were not randomized, thereby causing a risk of bias due to selection or confounding by indication (ie, there may be an unequal distribution of prognostic factors between the treatment groups). This is especially not preferable since hearing loss caused by AAT improves partly spontaneously because of a temporary threshold shift and improvement in time.

Second, the studies were difficult to compare: HBO treatment protocols and follow-up differed to a great extent and results were not presented in the same manner. Moreover, some studies summed the results for all or a part of the frequencies together, thereby showing a statistical effect, without a thought for the clinical relevancy. Other studies described a significant effect without presenting the data. Because of these methodological flaws, pooling of the study results was not feasible.

Third, it remains uncertain what the clinical significance is of the studies that did report a significant effect of HBO therapy on hearing improvement in patients with AAT. The highest effect reported was 15 dB additional improvement in the HBO treated group, but other studies did not find any additional effect.

Fourth, follow-up was generally short in the studies found (42 days maximum). Pilgramm and Schumann claim a persistent effect after 42 days. When found effective, it would be important to know whether HBO therapy facilitates the improvement of hearing in the short term and if this effect is still present in the long run.

Fifth, another effect of AAT is the development of tinnitus. Only 3 of our selected studies reported on tinnitus: Vavrina and Muller did not find a significant difference, whereas Ylikoski et al described the presence of tinnitus at the end of the study in 5% in the HBO treated group and in 18% of the patients not treated with HBO. In the study by Pilgramm and Schumann, these numbers were 6% versus 17%, respectively. This indicates a potential positive effect on the presence of tinnitus in the long term, but more research is needed.

Sixth, side effects were mostly not mentioned in the studies found but are most important when the effect of a therapy is questionable. In general, HBO therapy has few side

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Comparison</th>
<th>Hearing Improvement on HPTA, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ylikoski et al</td>
<td>60</td>
<td>HBOT vs NBOT (90 min 100% O₂ twice daily)</td>
<td>25.7 vs 21</td>
</tr>
<tr>
<td>Pilgramm and Schumann</td>
<td>122</td>
<td>4 groups: 1) dextran + sorbitol IV 2) 1 + betahistine 3) 1 + HBO2 4) 2 + HBO2</td>
<td>46 vs 32 vs 47 vs 43a</td>
</tr>
<tr>
<td>Lafère et al</td>
<td>68</td>
<td>3 groups: 1) prednisone po + piracetam po 2) HBOT + prednisone IV + piracetam IV 3) HBOT + prednisone po + piracetam</td>
<td>5.58 vs 20.62 vs 17</td>
</tr>
</tbody>
</table>

Abbreviations: HBOT, hyperbaric oxygen therapy; HPTA, 4-6-8 kHz high tone average; NBOT, normobaric oxygen therapy. HPTA was read from the figures.
effects. However, HBO therapy can have a few major side effects (pulmonary barotrauma, acute neurological toxicity, and seizure) and minor side effects (visual disturbance, barotrauma of middle ear, lungs, and sinuses). In their study, Pilgramm and Schumann described 1 patient with barosinusitis and 1 patient with oxygen intoxication (2 out of 62 patients), and Vavrina and Muller described no serious side effects, without further specification. The recent Cochrane review on hyperbaric oxygen for idiopathic sudden sensorineural hearing loss did not find more articles with a good description of side effects.

**Conclusion**

In conclusion, the clinical effect of HBO therapy on hearing thresholds in patients who suffered a recent AAT remains unclear. The contrary results of the reported studies found justify a well-designed randomized controlled trial on the true effect of HBO therapy in patients who suffered a recent acute acoustic trauma.

**Author Contributions**

Erwin L. van der Veen, design, acquisition, analysis, and interpretation of the data and drafting, final approval, and agreement to be accountable for all aspects of the work; Rob A. van Hulst, design and revision, final approval, and agreement to be accountable for all aspects of the work; J. Alexander de Ru, design and revision, final approval, and agreement to be accountable for all aspects of the work.

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**References**


