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Identifying eustachian tube dysfunction prior to hyperbaric oxygen therapy: Who is at risk for intolerance?☆

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ABSTRACT

Purpose: Determine whether specific risk factors, symptoms and clinical examination findings are associated with hyperbaric oxygen therapy (HBOT) intolerance and subsequent tympanotomy tube placement.
Materials and methods: A retrospective case series with chart review was conducted from 2007 to 2016 of patients undergoing HBOT clearance at a tertiary care university hospital in an urban city. Eighty-one (n = 81) patient charts were reviewed for risk factors, symptoms and clinical examination findings related to HBOT eustachian tube dysfunction and middle ear barotrauma. Relative risk was calculated for each variable to determine risk for HBOT intolerance and need for tympanotomy tube placement. Risk factor, symptom, physical examination and HBOT complication-susceptibility scores were calculated for each patient.
Results: Mean risk factor, clinical and HBOT complication-susceptibility scores were significantly higher in patients who did not tolerate HBOT compared to patients who tolerated HBOT. Patients reporting a history of otitis media, tinnitus, and prior ear surgery were at a higher risk for HBOT intolerance. Patients reporting a history of pressure intolerance and prior ear surgery were more likely to undergo tympanotomy tube placement. Patients noted to have otologic findings prior to HBOT were at a higher risk for both HBOT intolerance and tympanotomy tube placement.
Conclusions: A thorough otolaryngological evaluation can potentially predict and identify patients at risk for HBOT intolerance and tympanotomy tube placement.

1. Introduction

Hyperbaric oxygen therapy (HBOT) is a common treatment modality used for various medical conditions such as chronic infections, non-healing wounds and ulcers, acute carbon monoxide poisoning, cystitis and many other indications [1]. HBOT is safe and tolerated well, but it is associated with side effects [2–3]. One commonly encountered side effect is middle ear barotrauma (MEB) with an incidence ranging from 2 to 82% due to eustachian tube dysfunction (ETD) [2–8]. This develops due to the patient's inability to equalize middle ear pressure, usually during the compression phase of therapy [3,7–8]. It has been shown that with continued therapy after development of intolerance to HBOT, up to 69% of patients will redemonstrate signs of middle or inner ear barotrauma [6,8–9].

When these side effects develop during the course of treatment, otolaryngologists are often consulted. Normally, therapy has to be postponed or abandoned due to the side effects of HBOT until the conditions are treated. Delays in HBOT caused by ETD occur in approximately 10–40% of patients [6,10]. Topical and systemic decongestants are a treatment option for patients with intolerance to HBOT [2,9,11]. Educating patients on auto-insufflation techniques such as Valsalva and Toynbee maneuvers before the first session has also been shown to reduce the risk of barotrauma during HBOT [13]. However, myringotomy with tube placement is the standard treatment to prevent MEB associated with ETD [11–12]. Myringotomy with tube placement for patients with severe symptoms is required in 2–30% of patients undergoing HBOT [5–6,11,14].

Current standard pre-HBOT assessment involves a baseline otoscopic examination usually performed by hyperbaric staff. Otoscopy is repeated for patients who have difficulty equalizing middle ear pressure, intolerance to HBOT and subsequent development of MEB related to ETD [15]. The results of these examinations are used to develop a treatment plan for the patient which may include an otolaryngology

Abbreviations: HBOT, hyperbaric oxygen therapy; MEB, middle ear barotrauma; ETD, eustachian tube dysfunction; *P*, *P*-value.

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consult. Various classification methods have been used when conducting an otoscopic examination. The initial TEED classification has been modified over the years, and the other versions of the criteria are used more commonly [15–16]. The modified TEED classification system is graded in increasing severity from Grade 0 to 5, with 0 being a normal appearing tympanic membrane and 5 being perforation of the tympanic membrane [15,17]. The drawback of the TEED criteria is inter-observer variability. The O'Neill grading system attempts to remove inter-observer variability. The O'Neill grading system uses photographic images of the tympanic membrane, which allow for more consistent documentation from one examiner to the next. The O'Neill grading system is graded in increasing severity from Grade 0 to 2. Grade 0 is ETD while Grade 1 and 2 is varying barotrauma [15].

Prospective identification of patients at risk for otic barotrauma has been discussed in the literature. The various physical examination methods proposed for identification of barotrauma are otoscopic inspection, ETD evaluation using the Bluestone method, and tympanometry [11]. Each of these modalities has its own limitations. Clinical ETD evaluation requires a patient who is awake and cooperative. It also is not predictive prior to the patient's first session [6]. Risk factors that have been reported for MEB due to HBOT are age >60 or <16, female gender, prior history of ETD, first HBOT session, radiation-related injuries to the head and neck and presence of an artificial airway [4–5,7,14,18–20]. Unconscious patients and infants are also susceptible due to a compromised ability to equalize middle ear pressure [11]. Studies have shown that patients with an artificial airway are at a 94% risk for middle ear complications, with 61% receiving tympanotomy tube placement [14]. Allergic rhinitis, nasal congestion, inferior turbinate hypertrophy, deviated nasal septum, otitis media and ear pain have also been associated with middle ear barotrauma [21,22].

Currently there are no objective criteria which can effectively predict and identify which patients scheduled to undergo HBOT will have MEB due to ETD. In addition, there is no consensus on the use of various treatment modalities (i.e. topical decongestants, systemic decongestants, tympanotomy tubes). Studies have investigated the use of these treatment modalities after patients have developed intolerance to HBOT. However, data on the use of these treatments prior to the initiation of HBOT have not been published. The primary goal of this study was to identify patients at risk for developing HBOT intolerance using a thorough otolaryngological history and physical examination with emphasis on sinonasal and otologic processes.

2. Materials and methods

After institutional review board approval, a retrospective case series with chart review was conducted at our institution. Charts were reviewed of patients being evaluated by our otolaryngology service for HBOT clearance from 2007 through 2016. A multidisciplinary team approach to HBOT had been created between the primary wound care teams (either vascular surgery or podiatric surgery) and the consultants needed for HBOT clearance (otolaryngology, ophthalmology and radiation oncology). To our knowledge, an otolaryngology consultation was not requested for every patient undergoing HBOT. However, of the patients who were evaluated by our department, the consultation was completed prior to their first hyperbaric session. In our department, consultation involved screening patients being considered for HBOT to assess risk factors, symptoms, and clinical signs of ETD and subsequent MEB. The only exclusion criteria were incomplete consultation in patients refusing evaluation, and patients who had tympanotomy tubes at the time of evaluation. After exclusion criteria, a total of eighty-one (n = 81) patients were identified.

Based on the existing literature as well as the clinical experiences of the otolaryngology staff, a focused history and physical examination was completed for each patient encounter. The patients were asked about their past medical history including a history of pressure intolerance (i.e. on an airplane or deep sea diving), rhinitis (i.e. history of nasal obstruction or congestion treated with intranasal or oral therapy), ear infections (as an adult or child), hearing loss, vertigo, tinnitus, ear trauma and previous ear surgery (i.e. myringotomy, tympanoplasty with or without mastoidectomy) as well as allergies, social history and family history. A comprehensive review of otolaryngological symptoms prior to HBOT included aural fullness, otalgia and nasal congestion, among others. The physical examination included a head and neck examination, basic otoscopic examination (non-microscopic), anterior rhinoscopy, and oropharyngeal examination. Specific pertinent physical examination findings were noted, including monomeric tympanic membrane, tympanosclerosis, tympanic membrane retraction and turbinate hypertrophy. The number of patients for each finding collected was noted as a frequency and percentage of the total population.

Patients were cleared by our otolaryngology team for HBOT if they were not having symptoms of ETD during the evaluation. Prior to HBOT, no patients evaluated had symptoms of ETD and were therefore cleared for therapy. For patients experiencing ETD after the institution of HBOT, our team recommended 2 sprays of intranasal oxymetazoline in each nasal cavity prior to their next hyperbaric treatment. When decongestant therapy was unsuccessful after one session, tympanotomy tube placement was offered as definitive treatment. All patients requiring decongestant therapy and/or tympanotomy tube placement were classified as not tolerating HBOT. Intolerance to HBOT was defined by a patient experiencing unrelenting otalgia and/or fullness with subjective hearing loss during or after a hyperbaric session. The session number during which the patients began not to tolerate HBOT was recorded.

Each aspect of the patient's history and physical examination was noted to have or not have each specific finding (Fig. 1). The presence of a particular finding was denoted as a score = 1, and its absence as a score = 0 using a standard checklist for each item. A risk factor score was calculated based upon the sum of having a history of pressure intolerance, rhinitis, ear infections, tinnitus, hearing loss, vertigo, ear trauma and ear surgery (possible score range 0–8). A total symptom score was calculated based upon the sum of having ear (otalgia or aural fullness) and sinonasal (nasal congestion) symptoms prior to HBOT (possible score range 0–3). A total physical examination score was calculated based upon the sum of having ear (monomeric tympanic membrane, tympanic membrane retraction and tympanosclerosis) and sinonasal (turbinate hypertrophy) examination findings prior to HBOT (possible score range 0–4). The risk factor, total symptom and total physical examination scores were added together to produce a HBOT complication-susceptibility score (possible score range 0–15). This novel scoring system was developed by the author (J.C.).

Relative risk was used to determine whether each variable influenced risk for HBOT intolerance and tympanotomy tube placement. Relative risk was not calculated for a history of vertigo and ear trauma due to only one patient having a positive history of each. Independent *t*-test was used to compare the mean risk factor, symptom, physical examination, and total HBOT complication-susceptibility scores in those who tolerated and did not tolerate HBOT. Analysis of variance was conducted to compare the mean risk factor, symptom, physical examination and HBOT complication-susceptibility scores of those who tolerated HBOT versus those who improved with oxymetazoline versus those who did not improve with oxymetazoline and required tympanotomy tubes. Chi-square test of independence was used to determine the relationship between each variable and ETD improvement with oxymetazoline. A multivariate analysis was performed to determine whether age, gender, or race influenced risk of HBOT intolerance. The significance level was set at a *P*-value (*P*) less than or equal to 0.05.

3. Results

Our total study population consisted of eighty-one (n = 81) patients who were evaluated by our department prior to starting HBOT (Table 1). The mean age of our cohort was 59 years. Of the total study population, 55 (67.9%) were male and 50 (61.7%) were African

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