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Main Article

Does the slow compression technique of hyperbaric oxygen therapy decrease the incidence of middle-ear barotrauma?

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Abstract

Objective: To note the incidence of middle-ear barotrauma following standard and slow compression during hyperbaric oxygen therapy (HBOT). The standards used were: (1) less than 40 per cent of the cohort should develop barotraumas, and (2) the incidence of barotrauma following the slow technique should be less than that caused by the standard technique.

Design: Prospective clinical audit.

Material and methods: Forty-two consecutive patients who received either standard compression or slow compression HBOT were included. Pre- and post-treatment otoscopy (graded according to a modified Teed's scale), tympanometry, audiometry and subjective ear complaints were compared between the groups and also compared with the set standard.

Results: Significantly less middle-ear barotrauma was noted when using the slow compression technique compared with the standard compression technique ($p < 0.05$). The incidence of barotrauma when using standard compression failed to meet the set standard of less than 40 per cent.

Conclusion: The slow compression method of HBOT proved to be both safe and superior to the standard compression technique.

Key words: Hyperbaric Oxygenation; Barotrauma; Middle Ear

Introduction

Hyperbaric oxygen therapy (HBOT) is an important adjunct in the management of acute and chronic oxygen deficiency conditions in which the local oxygen tension is below that optimal for healing. This therapy stimulates fibroblast proliferation and differentiation, increases collagen formation and cross-linking, augments neovascularization, and stimulates leukocyte microbial killing. Hyperoxygenation also improves preservation of energy metabolism and reduction of oedema.[1] Hyperbaric oxygen is administered in either a multiplace or a monoplace hyperbaric chamber.

The primary effect of hyperbaric oxygen (HBO) is to increase tissue oxygenation (PO_2 of up to 250–500 mmHg at 2.4 atmospheric pressure) from a normal PO_2 of 30–50 mmHg in healthy tissue or 5–20 mmHg in irradiated tissue.[2]

Middle-ear barotrauma is the most common side effect of HBOT. The incidence of barotrauma ranged from 5 to 40 per cent in various studies.[1–3] Air in the middle ear normally communicates with the atmosphere through the eustachian tube, the function of which is to maintain equality of air pressure on each side of the tympanic membrane. If the eustachian tube is unable to equalize pressure then barotrauma can affect the ears during the compression stage of HBOT. Excessive gas pressure or volume may result in mechanical tissue disruption, while decreased gas pressure or volume may result in vascular engorgement, haemorrhage and mucosal oedema. These may lead to retraction, haemorrhage and even perforation of the tympanic membrane. Symptomatically, the patient may experience discomfort, pain, hearing loss or bleeding from the ear.

Wallace Teed (a US submariner during the Second World War) described the original classification for the severity of middle-ear barotrauma. This widely used Teed score was a rating scale (graded zero to four) for barotrauma associated with submarine escape training.[4] The score was later modified to include a grade five.[5] The modified Teed's grading was used in this audit, as shown in Table I.

Various methods have been proposed to reduce the incidence of middle-ear barotraumas during HBOT. They include: (1) preventing the middle ear from becoming a closed cavity by keeping the

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TABLE I
MODIFIED TEED'S SCORE GRADING

Grade	Symptoms & signs
0	Symptoms with no otological signs
1	Diffuse redness and retraction of tympanic membrane
2	Grade 1 plus slight haemorrhage within tympanic membrane
3	Grade 1 plus gross haemorrhage within tympanic membrane
4	Dark and slightly bulging tympanic membrane due to free blood in the middle ear; a fluid level might be present
5	Free haemorrhage into middle ear, with tympanic membrane perforation; blood may be seen outside or within the external auditory canal

eustachian tube open, using the Valsalva manoeuvre, Frenzel manoeuvre, yawning, swallowing or movement of the jaw from side to side (local or systemic decongestants may also be beneficial);[6,7] and (2) altering the mode of HBOT by slowing the rate of compression used (initial pilot studies of this modification have confirmed the benefits of slow compression in reducing the incidence of middle-ear barotrauma).[8]

The standard used for this clinical audit was that the incidence of barotrauma should be less than or equal to 40 per cent. In addition, the incidence of barotrauma should be less in the slow compression technique compared with the standard compression technique.

Materials and methods

This multidisciplinary, prospective audit was conducted from September 2003 to October 2004. Consecutive patients requiring HBOT for chronic medical conditions were included. Patients with previous otological problems and patients needing grommet insertion prior to HBO therapy were excluded.

The hyperbaric team administered HBO therapy under the supervision of the physician in charge and strictly followed departmental protocols (which adhered to the European code of good practice in HBOT) (see Table II).[9]

TABLE II
HBO TECHNIQUE SPECIFICATIONS

Parameter	Standard compression	Slow compression
Pressure	2.4 ATA	2.4 ATA
Pressure increase (min)	5	13
Descent rate (m/min)	2.8	1.1
Pressure decrease (min)	5	10
Ascent rate (m/min)	1.57	1.57
Total time elapsed	1 hr 55 mins	2 hr 8 mins

HBOT = hyperbaric oxygen therapy; ATA = absolute atmosphere

Patient monitoring

At the enrolment visit (day zero), all patients were examined by an ENT physician. This included a clinical history, otoscopic examination, evaluation of autoinflation, tympanometry and audiometry. The patients who were found to have severe equalization problems underwent grommet insertion prior to HBO therapy, and therefore were excluded from the study.

Patients were seen immediately by the ENT surgeons if they developed any problems during the procedure. Otherwise, they were followed up in the ENT department after completion of their HBOT. Audiometry and tympanogram were repeated at each ENT visit. A single examiner graded the otoscopic findings. Patients with equalization problems were advised to perform Valsalva and Toynbee's manoeuvre and given decongestant nasal drops (ephedrine 1 per cent). Patients with persistent equalization problems for more than two HBOT sessions were reassessed by the ENT physician and pressure equalizing tubes were inserted when required to relieve the symptoms.

Statistical analysis

We used the paired *t*-test to compare the symptom score, otoscopy findings and number of grommet insertions in each group. The *p* value for statistical significance was set at <0.05 (see Table V).

Results

Forty-two patients were enrolled in the audit, all of whom completed their course of HBOT. The distribution of baseline characteristics was similar in the two groups, as shown in Table III. There was no significant difference in indications for HBOT between the two groups, as shown in Table IV. None of the patients in either group had osteoradionecrosis of the mastoid bone.

In the standard compression technique group, 11 patients (52.3 per cent) experienced problems in equalizing their middle-ear pressures and showed otoscopic signs of barotrauma ranging from Teed's scale grades one to three. Grommets were inserted to relieve equalization problems in 10 patients (48 per cent).

In the slow compression technique group, the incidence of equalization problems was reduced to six patients (28.5 per cent), who on otoscopy showed barotrauma ranging from Teed's scale grades one to two. Insertion of grommets was required in three patients (14.2 per cent). Table V compares the outcomes in the two groups.

Discussion

Hyperbaric oxygen therapy is administered by having the patient breathe oxygen under pressures higher than one absolute atmosphere (ATA), within a purpose-built chamber. Only a limited

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TABLE III

BASELINE PATIENT CHARACTERISTICS

	Combined sample ($n = 42$)	Standard compression ($n = 21$)	Slow compression ($n = 21$)
Male:female	22:20	12:9	10:11
Mean age (years)(SD)	53.16 (14.63)	53.76 (13.22)	52.6 (16.04)
Nasal allergy	10	5	7
Smokers	13	6	7
Peri-HBOT nasal decongestant	42	21	21

SD = standard deviation; HBOT = hyperbaric oxygen therapy

TABLE IV

HBO INDICATIONS IN THE TWO GROUPS

Condition	Standard compression (n)	Slow compression (n)
Osteoradionecrosis	15	6
Soft tissue radionecrosis	2	5
Osteomyelitis	2	7
Non-healing skin ulcer	1	2
Radiation-induced neuropathy	1	1

HBOT = hyperbaric oxygen therapy

TABLE V

PATIENT OUTCOMES IN THE TWO GROUPS

	Standard compression	Slow compression	p
Equalization problems	11	6	0.02
Teed gr 0	10	15	0.02
Teed gr 1	1	3	0.16
Teed gr 2	8	3	0.02
Teed gr 3	2	0	0.16
Teed gr 4	0	0	0
Teed gr 5	0	0	0
Total Teed's score	11	6	0.02
Grommet insertion	10	3	0.005

Teed's scores were established on otoscopy. gr = grade

amount of oxygen is dissolved in the blood at normal atmospheric pressure, but, under hyperbaric conditions, it is possible to dissolve sufficient oxygen to meet the usual requirements of the body. Both the increased concentration and the partial pressure of oxygen during HBOT result in greater tissue oxygenation, providing proven and not so proven benefits in a wide variety of clinical conditions.

Middle-ear barotrauma is recognized as the most common complication of HBOT. This could happen to any patient and, depending on its severity, may prevent completion of HBOT. The resultant morbidity must also be treated, depending on the severity of the middle-ear barotrauma. The ability to autoinflate the eustachian tube may reduce the incidence of barotrauma.[10] Numerous hyperbaric incident monitoring studies have suggested the following factors as contributing to middle-ear barotrauma development: concurrent upper respiratory infection; communication problems; inadequate instructions and stoic patients (JT Vrabec, personal communication, 2001). In this audit, all patients were able to autoinflate; autoinflation was therefore not a confounding factor. We used Teed's scale of otoscopic examination, as previous studies have noted that it is the most reliable test to assess middle-ear barotrauma.[4,11] Millar has proposed a new 'T-S-I' scoring system, taking into account the appearance of the tympanic membrane, the symptom score and the impact score (I Millar, personal communication, 2001).

In our audit, the number of patients undergoing standard HBOT who required grommet insertion was similar to that found in other studies. However, the incidence of middle-ear barotrauma in this group was higher than the set standard for this audit. On the contrary, the incidence of barotrauma in patients undergoing slow compression HBOT was less than the set standard for this audit, indicating its superiority over the standard HBOT procedure.

Conclusion

This audit compared the incidence and severity of middle-ear barotrauma suffered by patients undergoing standard and slow compression HBOT techniques, and results suggest a significant reduction in barotrauma when using slow compression HBOT. The cost implications of running HBOT for longer periods could be offset by the benefits of reducing the incidence of middle-ear barotrauma and its implications. This audit result suggests the need for well designed, properly randomized trials to assess the benefits of slow compression HBOT.

- **Middle-ear barotrauma is the most common side effect of hyperbaric oxygen treatment**
- **This audit shows that the incidence of middle-ear barotrauma was significantly less following slow compression compared with standard compression therapy**
- **The outcomes of this audit suggest the need for clinical trials to obtain better evidence on the benefits of slow compression**

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