Middle ear barotrauma in a tourist-oriented, condensed open-water diver certification course: incidence and effect of language of instruction

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Abstract

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Introduction: In Professional Association of Diving Instructors (PADI) Open Water Diver certification courses that cater to tourists, instruction is often condensed and potentially delivered in a language that is not the candidate's native language.

Objective: To assess the incidence of middle ear barotrauma (MEBt) in open-water diver candidates during a condensed four-day certification course, and to determine if language of instruction affects the incidence of MEBt in these divers.

Method: The ears of participating diving candidates were assessed prior to commencing any in-water compression. Tympanic membranes (TM) were assessed and graded for MEBt after the confined and open-water training sessions. Tympanometry was performed if the candidate had no movement of their TM during Valsalva. Photographs were taken with a digital otoscope.

Results: Sixty-seven candidates participated in the study. Forty-eight had MEBt at some time during their course. MEBt was not associated with instruction in non-native language (adjusted odds ratio = 0.82; 95% confidence intervals 0.21–3.91). There was also no significant association between the severity of MEBt and language of instruction.

Conclusion: Open-water diver candidates have a high incidence of MEBt. Education in non-native language does not affect the overall incidence of MEBt.

Key words

Barotrauma; middle ear; risk factors; instruction – diving; training; education

Introduction

The Professional Association of Diving Instructors (PADI) Open Water Diver course typically consists of classroom instruction, five confined-water sessions, and four open-water dives often spread over weeks. Candidates must learn the laws of physics that are important for divers, including Boyle's law. One practical implication of this law is the need for divers to 'equalize' the middle-ear air space as they descend, using various methods.

Ear pain and middle ear barotrauma (MEBt) are common in divers.[1,2] Open-water diver candidates may be at a greater risk of this as they are simultaneously learning how to equalize their ears, breathe through a regulator, adjust their buoyancy, clear their mask and perform other essential tasks required of a diver. This multi-tasking may overwhelm the diving candidate so that they equalize their ears late or not at all. It has been reported that the inability to equalize the middle ear is the most common reason for diving candidates to quit their training.[3]

Some PADI open-water diver certification courses cater specifically to tourists. In these circumstances, instruction is often condensed and potentially delivered in a language that is not the candidate's native language. Few studies have looked at the incidence of MEBt in diving candidates completing open water diver courses,[4] and no study has examined the role of language of instruction. This prospective, observational study was performed to assess the incidence of MEBt in open-water diver candidates during a condensed, four-day Open Water Diver course and to determine whether language of instruction affects the incidence of MEBt in these divers.

Methods

Ethical approval for this study was granted by the Human Research Ethics Committee of the Townsville Hospital and Health Service (HREC/12/QTHS/7). The study was conducted at a training centre in Cairns, Queensland, Australia, certifying approximately 3,600 divers each year. Cairns is the most common departure point for diving along Australia's Great Barrier Reef (GBR). The GBR is a chain of reefs, islands and coral cays, extending 2,300 kilometre along Australian's north-east coast. Instruction is offered in English, German and Japanese; however, students may be tourists who primarily speak other languages, and some German and Japanese tourists choose to attend English language classes due to their greater availability. Approximately half of the 21,000 open-water diver certificates issued each year by PADI Australia are issued in Queensland (Nimb H, personal communication, 2014).

Open-water diver candidates were approached to participate in the study. All subjects were determined fit to dive by either completing a diver's medical questionnaire or by passing a dive medical (Australian Standard 4005.1) prior to their first confined-water session. The exclusion criteria were children, if no parent was available to give consent, and non-English speaking candidates with no interpreter available. All participants were given a study information sheet and informed consent was obtained.

Table 1
Incidence of middle ear barotrauma after each water session by language of instruction; there were no statistically significant differences at any stage; * one subject withdrew before the final open-water dive

Instruction in:	1st pool	2nd pool	1st open-water	Last open-water	Any
Native language (n = 42)	12	20	21	25*	31
Non-native language (n = 25)	4	8	10	17	17

The courses evaluated in this study were completed over four days. All of the instruction was delivered by certified instructors. Classroom instruction occurred at the training centre. The five confined-water dives were performed during two pool sessions in 4-metre-deep, heated training pools. Open-water dives were performed from live-aboard dive boats in warm, tropical waters with candidates wearing thin wetsuits for warmth or stinger suits for protection; no gloves or hoods were worn.

Investigators accompanied the candidates and instructors during the confined and open-water dives. Baseline data, including age, gender and BMI, were collected prospectively using pre-formatted data forms. Candidates were asked if they were smokers, had any medical or previous ear, nose or throat (ENT) problems, were using any medications or had any allergies, including environmental. Time since their last flight was recorded along with previous scuba experience. Instructor-to-student ratio, candidate's native language and language of diving instruction were also documented.

The candidates were assessed for MEBt prior to the first pool session, after each of the two pool sessions and after the first and last open-water certification dives. Candidates were questioned about any difficulties equalizing or ear pain. Examination of the tympanic membrane (TM) was conducted using a Welch Allyn Digital MacroView® otoscope immediately after completion of the pool sessions and within one hour of completion of the open-water dives. Digital photos were taken of those TMs that were abnormal. Movement of the TM with Valsalva was documented and any candidate whose TM was not seen to move had tympanometry performed (MicroTymp3®, Welch Allyn Inc, Skaneateles Falls, NY, USA). When necessary, cerumen was gently removed with a disposable Jobson-Horne probe to allow for visualization of the TM. Grading of MEBt was done using the Edmonds grading scale of 0 to 5.[5] Figure 1 provides recent example photographs of each grade. The digital images of the abnormal TMs were reviewed by a senior physician (DFB) for accuracy of grading. When a student experienced symptoms but the view of the TM was obscured, the student was considered to have MEBt of unknown grade. All collected data were de-identified and entered into a pre-formatted Excel spreadsheet. These data were subsequently exported into Stata Statistical Software: Release 11 (StataCorp. 2009. College Station, Tx: StataCorp LP) for analysis.

ANALYSIS

The objectives of this analysis were to determine the incidence of MEBt in open-water diving candidates completing a condensed course, and to assess the influence of language of instruction on the incidence of MEBt in these candidates. Using Fisher's Exact Test (FET), the incidence of MEBt was compared at each stage of the course among candidates instructed in either their native or non-native language. To account for potential covariates and confounders, we also conducted logistic regression for MEBt including language of instruction, participant age and gender, previous scuba experience, time since last flight, and instructor-to-student ratio in the model. We compared the grade of MEBt among subjects instructed in their native and non-native language using Wilcoxon Rank Sum Test. Finally, to differentiate clinically significant from clinically insignificant MEBt, we evaluated the incidence of grade 2 or greater MEBt (the level at which diving and hyperbaric physicians would advise divers to refrain from further dives) at each stage of the course, again using FET. In all analyses, $P < 0.05$ was considered statistically significant.

Results

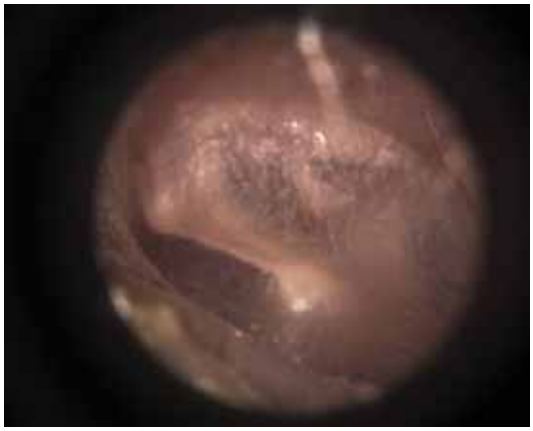
Sixty-seven dive candidates participated in the study, 37 male and 30 female. Mean age was 26.7 (standard deviation, SD 8.6) years; 29.4 (9.6) years in the native language group (n = 42) and 22.2 (3.4) years in the non-native language group (n = 25; $P < 0.001$). One candidate withdrew (for unrelated reasons) prior to the final open-water dive. Twenty-seven had previous scuba experience, including *Discover Scuba Diving*; 21 in the native language group and six in the non-native language group (P = 0.043). English was not the native language of 38 of the students, and 25 of the students received instruction in a language other than their native language. There were 10 candidates whose TM did not move with Valsalva; all 10 had a normal tympanogram.

Forty-eight of the 67 candidates had MEBt at some time during the course. There were no associations between MEBt and gender (P = 0.296), scuba experience (P = 0.599), inability to Valsalva (P = 0.260), previous ENT problems (P = 0.357), allergies (P = 0.551) or instructor-to-student ratio (P = 0.064). Table 1 shows the incidence of MEBt for each water session by language of instruction. There was no significant association between language of instruction and incidence of

Figure 1

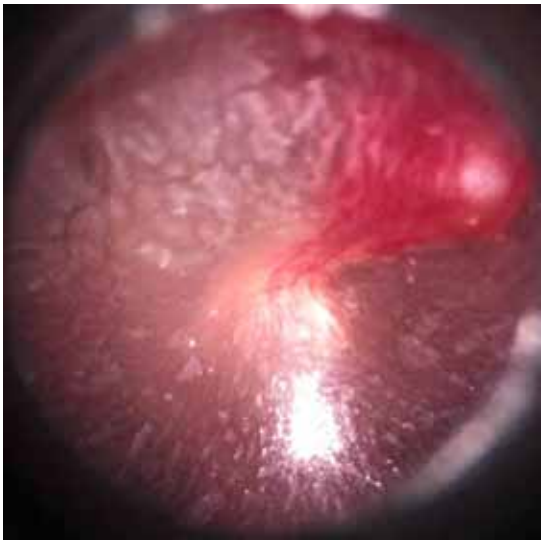
Grades of tympanic membrane barotrauma seen in this study (except for the grade 5 photo) as defined by Edmonds[5]

Grade 0: symptoms with no signs

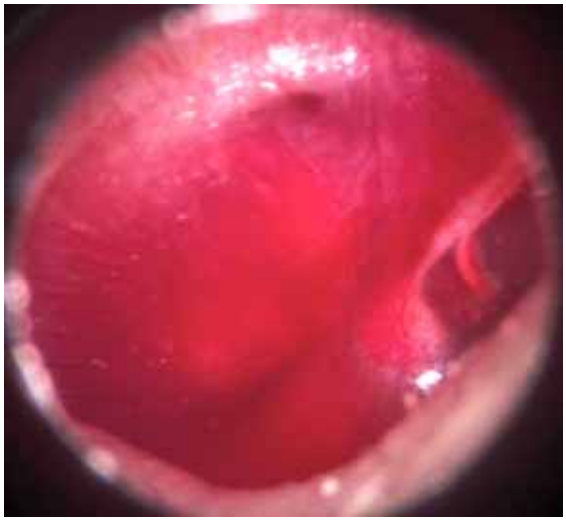


Grade 1: injection of the tympanic membrane (TM)

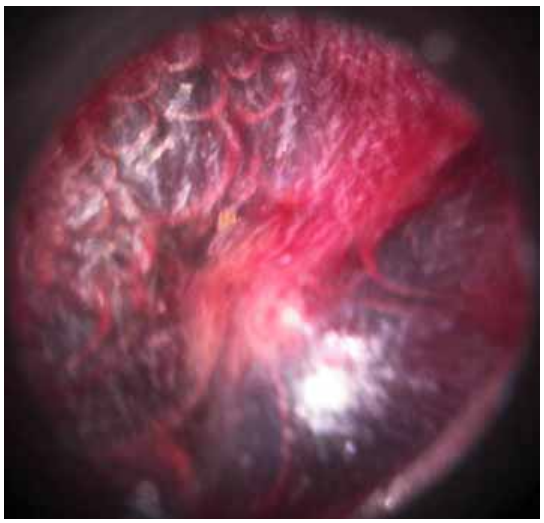
Grade 2: injection of the TM plus slight haemorrhage within the substance of the TM



Grade 3: gross haemorrhage within the substance of the TM



Grade 4: free blood in the middle ear, as evidenced by blueness and bulging



Grade 5: perforation of the TM

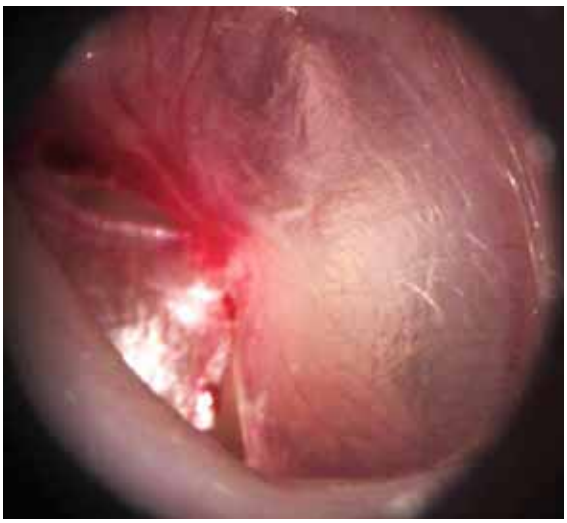


Table 2
Grade of MEBt in relation to language of instruction, median (inter-quartile range); there were no statistically significant differences between the two groups

	Grade of MEBt	
	Native language	Non-native language
1st pool session	1 (1–1)	1.5 (1–2)
2nd pool session	1 (1–1.5)	1.5 (1–3)
1st open-water dive	1 (1–2)	1 (1–3)
Last open-water dive	1 (1–2)	1 (1–2)

MEBt. Indeed, subjects instructed in a language other than their native language had lower rates of MEBt than students who were instructed in their native language ($P = 0.780$).

In logistic regression modelling for MEBt, including language of instruction and various potential covariates and confounders, there remained no significant association between language of instruction and MEBt (adjusted odds ratio = 0.82; 95% confidence intervals: 0.21–3.91). There was also no association between any of the potential explanatory and/or confounding variables and MEBt. Neither were there any statistically significant associations between the severity (grade) of MEBt and language of instruction (Table 2). When dichotomizing MEBt severity as grade < 2 or grade ≥ 2 there remained no statistically significant association. Two subjects had MEBt of unknown grade in one ear, one after the first and one after the second open-water dive.

Discussion

Ear problems are common in divers.[1–3,7] Otoscopic changes have been reported in 71.5%[7] to 100%[3] of ears in experienced divers after repetitive diving. In one survey, 52% of divers stated they had experienced ear 'squeeze' on at least one occasion.[7] Divers often seek medical advice for equalization difficulties encountered during confined water training,[2] and these difficulties can lead to open-water dive candidates not completing their diving certification.[9]

While the rates of MEBt at various stages of this four-day course are seemingly high, they are consistent with the previous literature, in which the reported incidence of MEBt in diving candidates ranged between 41% and 48% after confined-water sessions,[4,10,11] and up to 66%[12] after the first open-water session. While we do not have an extended-course control group for direct comparison, it does not appear that a condensed course increases the risk of MEBt.

About a third of the divers studied were instructed in a language other than their native language. The PADI open-water dive manual is an essential component of the candidate's education. Whilst this manual is available in 23 languages, most dive centres realistically cannot have instructors speaking all 23 languages. Completing the Open Water Diver course in their non-native language did not increase the incidence or severity of MEBt in the divers we studied, which is consistent with research from traditional education settings that has explored such things as students learning a second language[13] or the effect of non-native, English-speaking university teaching assistants on student mastery of content.[14,15] In those studies, minimal[14] to no decrease[15] in student performance was found when the teaching assistant did not speak the students' native language.

There were some associations between demographic characteristics and language of instruction that might have confounding effects in our data. Candidates instructed in a language other than their native language were younger, less likely to be female, and less likely to have prior scuba experience. However, in the logistic regression for MEBt that included these variables, there remained no significant association between language of instruction and MEBt.

Although this was not a focus of our study, we do note that despite the high incidence of MEBt, this did not prevent any candidate in this cohort from successfully becoming a certified Open Water Diver.

Limitations

Most Open Water Diver candidates in our study were tourists and, therefore, we were unable to follow the divers after the three-day, live-aboard dive trip. However, some candidates developed signs or symptoms of MEBt in the day following the course, their first day of diving as a certified diver. Documentation of these later equalizing difficulties was not done, though there appeared to be no increased incidence in candidates instructed in a language other than their native language.

Although we know that 25 candidates were instructed in a language other than their native language, we do not know whether these students accessed the PADI manual or additional educational materials (e.g., via the internet) in their native language. This may have influenced the incidence of MEBt in the non-native language group. We also did not assess English proficiency in the non-native language group; it is common in many countries for people to have a good working knowledge of English. These potentially mitigating factors, however, are not unique to our study population and would likely be equally present and equally effective at minimizing the effects on non-native language instruction in other settings.

Other than language of instruction, this study was not designed to elicit the predictors of or contributors to MEBt. As smoking, ENT pathology, medications and allergies were not incidentally associated with language of instruction in our sample, they were not included in our logistic regression modelling. That does not suggest that those variables

are not associated with MEBt; rather, only that, in this sample, those variables did not confound the relationship between language of instruction and MEBt. Previous scuba experience was more common among students instructed in their native language and, therefore, was included in our logistic regression. Although there was no association between MEBt and scuba experience, the small sample size likely limited the ability to detect such an association.

Finally, this analysis is a sub-analysis of a larger on-going trial exploring MEBt in open-water diver candidates. That larger study was not designed to specifically explore the effects of language of instruction, so there might be other explanatory or confounding variables that were not collected or evaluated. This study has a small sample size which does limit its statistical power. However, the raw rate of MEBt was lower in candidates who were instructed in a language other than their native language; a larger study would have to both strengthen and reverse the observed association between language of instruction and MEBt to achieve clinically meaningful significance.

Conclusion

Open Water Diver candidates instructed in a condensed, four-day course had a high incidence of MEBt, but it did not appear to be higher than the incidence of MEBt reported in previous studies. Training in a candidate's non-native language did not appear to increase the overall incidence or severity of MEBt.

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