intrinsic or poorly controlled asthma or asthmatics with a reduced peak flow should not dive. Other conditions that should preclude diving include: recent spontaneous pneumothorax; bullous disease detected on chest x-ray; significant lung parenchymal or pleural scarring.

References

1 Neuman TS. Pulmonary fitness for diving. In *The Lung at Depth*. Lundgren CEG and Miller JN. Eds. New York: Marcel Dekker Inc. 1999; 73-90

2 UK Health and Safety Executive. *MA1, the Medical Examination and Assessment of Divers*. Glasgow: Health and Safety Executive, 1998

3 Bove AA. In *Fitness to Dive. 34th Undersea and Hyperbaric Medical Society Workshop.* Linaweaver PG and Vorosmarti J. Eds. Bethesda, Maryland: UHMS, 1987; 26-41

4 Liebow AA, Stark JE, Vogel J and Schaeffer KE. Intrapulmonary air trapping in submarine escape training casualties. *US Armed Forces Med J* 1959; 10: 265-289

5 Unsworth IP. Pulmonary barotrauma in a hyperbaric chamber. *Anaesthesia* 1973; 28: 675-678

6 Benton PJ, Pethybridge RJ and Francis TJR. A review of spirometry and UK submarine escape training tank incidents (1975 -1997) using objective diagnostic criteria. *Undersea Hyper Med* 1999; 26 (4): 213-217

7 Colebatch HJH, Smith MM and Ng CKY. Increased elastic recoil as a determinant of pulmonary barotrauma in divers. *Respir Physiol* 1976; 26: 55-64

8 Colebatch HJH and Ng CKY. Decreased pulmonary distensibility and pulmonary barotrauma in divers. *Respir Physiol* 1991; 86: 293-303

9 Calder IM. Autopsy and experimental observations on factors leading to barotrauma in man. *Undersea Biomed Res* 1985; 12 (2):165-182

10 Francis TJR and Denison DM. Pulmonary barotrauma. In *The Lung at Depth*. Lundgren CEG and Miller JN. Eds. New York: Marcel Dekker Inc. 1999; 295-374

11 Malhotra MS and Wright HC. The effects of a raised intrapulmonary pressure on the lungs of fresh unchilled cadavers. *J Pathol Bacteriol* 1961; 82: 198-202

12 Light RW. Pneumothorax. In *Textbook of respiratory medicine. 2nd Edition*. Murray JF and Nadel JA. Eds. Philadelphia: Saunders 1994; 2193-2210

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ASTHMA AND DIVING SCREENING PROTOCOLS

Cathy Meehan

Key Words

Asthma, diving medicals, fitness to dive.

Background

Ten to fifteen percent of children have some history of recurrent wheezing. It is estimated that 5 to 8% of adults are diagnosed as asthmatics. Asthma is an air trapping disease and the diving environment contains several potent triggers to asthma, such as exercise, inhalation of cold, dry air and also the possible inhalation of non-physiologically isotonic water which can be hypotonic fresh water or hypotonic salt water. There is no hard evidence that asthmatics are at greater risk of pulmonary barotrauma or death during diving. We know that some recreational divers who have asthma dive. They are often failed by the first diving doctor they consult but passed by the second because they suppress their asthma history.

Should asthmatics dive?

There is a divergence of opinion in the guidelines issued by authorities in different countries regarding fitness to dive. The UK recommendations for recreational divers can be briefly summarised as allergic or well controlled asthmatics may dive.[1] In America, as far as I am aware, there is no current agreed standard though active asthma is regarded as a contra-indication and provocation testing is regarded as a useful tool. In Australia there are various opinions. Carl Edmonds believes that asthmatics should not dive.[2] The Thoracic Society of Australia and New Zealand have published guidelines and there are Australian Standards for Recreational and Occupational Diving.[3-5]

Both Australian Standards state that any evidence of obstructive airways disease, such as current asthma, chronic bronchitis, allergic bronchospasm, shall automatically disqualify. In case of doubt, specialist medical opinion should be sought.

The Thoracic Society of ANZ states that the student should fail if there is a history of asthma or use of bronchodilators within the last 5 years.[3] If there have been no symptoms for 5 years and there is evidence of bronchial hyper-responsiveness after provocation testing they fail. A 20% fall in FEV_1 is usually needed to fail. Edmonds et al. consider that a greater than 10% reduction in FEV_1 after both histamine and hypertonic saline is a fail.[2] I recently surveyed some diving specialists in Australia through the ANZ HMG chat line. I want to thank everyone who replied

very much. I found that there was a range of opinions from a slight variation of the Thoracic Society Guidelines to entering into a formal contract of risk assessment and informed consent with the student who wanted to dive regardless of occasional mild symptoms.

It is well known that prospective divers, who are very keen to dive, often go off and just not put their history of asthma on the form. Screening procedures are available from various centres, the waiting periods are from one day up to 10 days. Some centres require visits to more than one location to get the screening done. Hypertonic saline challenge was done by all the centres I checked on and some added exercise challenge but not all of them.

So who has the final say? Is it the diving doctor or the diver's physician? The dive instructor or the training agency? They both like to have a say sometimes. Or is it the informed diver or the student diver?

Bronchial challenge testing

Bronchial challenge tests have been shown to be useful in the identification of persons who would be at risk from acute airway narrowing during the activities associated with diving. Traditionally pharmacological agents, such as histamine or methacholine, have been used. But hypertonic saline seems more appropriate when assessing divers. Strenuous exercise, when an increased rate of respiration causes water loss which may also act as a hypertonic stimulus, can induce asthma.

What is the most appropriate challenge test for would be divers? What is the degree of responsiveness that can be accepted? How does this actually relate to the diver risk? And can the screening procedure be simplified so that the student diver can continue with the training without major disruption to their timetable?

In 1995 Dr Graham Simpson, a respiratory specialist in Cairns, and I did a study of the incidence of bronchial hyper-responsiveness in a group of experienced recreational scuba divers.[6] Our objectives were to study the incidence of hyper-responsiveness in experienced scuba divers, some of whom had obtained their diving qualifications before rigid medical criteria applied to diving candidates. Each diver was given a pharmacological challenger, histamine, and was also challenged with hypertonic saline. The subjects were all volunteer divers recruited from a local dive club and a local dive school and they all signed an "informed consent" form. The protocol was approved by the hospital Ethics Review Committee.

Hypertonic saline challenge was performed by me and was followed by documenting any response to a bronchodilator. The histamine challenge was performed by Dr Simpson in his rooms and at least 72 hours separated the two challenges. The results were totally confidential and each individual diver was given an opportunity to discuss his or her results and any possible implications with regard to their continued diving. Confidentiality was particularly important because some of the divers were actually occupational as well as recreational divers.

For the hypertonic challenge, I used a small hand held ultrasonic nebuliser and complied with the standards and protocol used by Royal Adelaide Hospital Respiratory Unit. The protocol is measuring the FEV_1 at increasing times after inhalation of hypertonic saline using a minimum of 15 ml of hypertonic saline. Histamine provocation tests were done using the rapid hand operated technique with a Diviblis hand-held nebuliser. There were 50 divers who had a total of 70,000 dives between them. The average age was 37. Fifty two percent of the volunteers were occupational divers and 48% were recreational. Seventy six percent were male and 24% female. Forty six percent were smokers and 54% non-smokers. Most of the occupational divers were smoker.

These divers had very few problems associated with their 70,000 dives. Four, all occupational divers, had suffered salt water aspiration. Three had a history of decompression illness. One had experienced shortness of breath and wheeze. One gave a history of muscle strain underwater. And one had actually become wheezy after diving.

Six of the 50 divers gave a past history of asthma and 5 of these had experienced symptoms within the last 5 years. Four had actually suffered symptoms within a month and of these, 3 were on regular medication and one was on intermittent therapy. Four of the 6 with a history of asthma had smoked in the past and one had abnormal baseline function test.

Divers with a history of asthma

Of the divers who gave a history of asthma some were on quite a lot of medication and had quite regular symptoms and the others had very intermittent symptoms and one had not had symptoms since childhood.

Results of bronchial challenge testing

Table 1, reprinted from our 1995 paper, summarises the falls in FEV_1 after hypertonic saline or histamine.[6] We took the highest fall after both tests. Fifteen (30%) of the divers had a fall of greater than 10%, which is Carl Edmonds' standard. Six (6) of the divers had a fall of greater than 15% while only two (4%) had a fall of greater than 20%, which is the Thoracic Society's recommended level.

TABLE 1

RESPONSES OF 50 EXPERIENCED DIVERS TO BRONCHIAL PROVOCATION TESTING WITH HISTAMINE (47) AND SALINE (50)

Fall in FEV_1	Histamine	Saline	Responding to either
Less than 10%	32	32	27 (54%)
10% to 14%	10	13	15 (30%)
15% to 19%	3	4	6 (12%)
20% or greater	2	1	2 (4%)
Totals	**47**	**50**	**50 (100%)**

Of the 50 divers, 11 had abnormal, baseline, respiratory function testing. Four more had a history of wheeze within the last 5 years and eight others had a fall in FEV1 of 10% or greater after challenge with histamine or hypertonic saline. Using the strictest criteria 23 (46%) of these experienced divers would have been excluded from diving. Using the most lenient criteria 2 (4%) would have been excluded for failing due to 20% drop after provocation testing. We concluded that further evaluation of criteria for assessment of pulmonary medical fitness to dive was necessary and that a 10% fall was far too stringent. Other conclusions were that the clinical history was a good indicator of increased potential risk and that abnormal lung function appeared to increase the potential risk.

In our survey divers with a history of asthma who were well maintained on medication had a reduced response to provocation testing and passed the provocation test. What are the implications that this has on asthma and diving.

I have performed a retrospective analysis of the bronchial provocation testing that I had done when assessing fitness to dive in diving students with a history of asthma or wheeze. They all passed a diving medical in all other aspects of health. There were 50 challenges with histamine before 1994. After that I used hypertonic saline and I have done over 100 hypertonic saline challenge tests. In the last few years, I have been adding an exercise challenge. Unfortunately, because the others were filed separately, I was only able to go through the 23 that have been done this year.

The 50 histamine challenges of prospective divers who had a history of asthma were done quite a long time ago and 17 (34%) failed at a 10% reduction. In the end only 11 (22%) of the students failed. Only nine (18%) dropped by 20% but two others started to wheeze and so were failed. In the joint study 15 divers (30%) failed at a 10% reduction, about the same proportion as with the trainee divers.

Twenty three people had both a hypertonic saline challenge and an exercise challenge this year. In Fiji in 2000 David Elliott suggested that I could break new ground by testing for both to see how well they compared. My protocol is to exercise the students using the British Army step test for 6 minutes. It is done in an air conditioned office, which has dry and cool air. One minute after finishing the exercise FEV_1 was tested and then was repeated after 5 minutes. After the 5 minutes the hypertonic saline challenge was started. The end result is probably a combination of both tests. This was done purely to enable the test to be carried out on the one day.

After exercise the FEV_1 was unchanged after 5 minutes in 22 (96%) of the subjects. Only one (4%) of the 23 had dropped by more than 16%. But at the end of the hypertonic saline challenge 8 (35%) of the students had a significant drop and were excluded from diving.

The overall outcomes were that similar percentage of student divers and experienced divers had a 10% fall in FEV_1 after provocation testing. Seventeen (34%) of the students had hyper-responsiveness after histamine but only nine (18%) after hypertonic saline. Of those who had hypertonic saline after exercise 8 (35%) had a positive response but the numbers are small so I am not sure if that is significant. It would be useful to compare the response after exercise challenge to the response after hypertonic saline if these can be carried out on separate days. Simon Mitchell tells me that he does this but if they have a positive response to exercise he does not do a hypertonic saline challenge on the second day. And so his results cannot be compared with mine.

There needs to be a standardised protocol for exercise challenge testing. Do we need to look at air temperature, the humidity and what is the appropriate activity? We need an internationally recognised consensus of the medical opinions of what criteria determined respiratory fitness to dive.

References

1 Francis TJR. Pulmonary fitness to dive. *SPUMS J 2001*; 31 (4): 221-226

2 Edmonds C, Lowry C and Pennefather J. *Diving and Subaquatic Medicine. 3rd Edition*. Oxford: Butterworth-Heinemann, 1992; 461-476

3 Jenkins C, Anderson SD, Wong R and Veale A. Compressed air diving and respiratory disease. *Med J Aust* 1993; 158: 275-279

4 *Training and certification of recreational divers. Part 1: Minimum entry-level scuba diving. AS 4005.1 - 1992* Sydney: Standards Australia, 1992

5 *Occupational diving operations. Part 1: Standard operational practice. AS/NZS 2299. 1:1999.* Sydney: Standards Australia, 1999

6 Simpson G and Meehan C. Prevalence of bronchial hyper responsiveness in a group of experienced scuba divers. *SPUMS J* 1995; 25 (4): 249-253

The above is an edited version of the transcript of the recording of Dr Meehan's paper presented in Madang.

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LUNG FUNCTION TESTING TO DETECT ASTHMA IN RECREATIONAL DIVERS

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Key Words

Asthma, exercise, histamine, hypertonic saline, lung function testing, methacholine.

Introduction

Current Australian recommendations suggest that those with active asthma should not dive, nor should those with previous symptoms of asthma and current bronchial hyper-reactivity.[1,2] These recommendations are not universal and a number of countries suggest that individuals with well-controlled asthma may dive. Recently the British Sub-Aqua Club (BSAC) and other organisations have introduced guidelines which allow those with mild and well-controlled asthma to dive, with the intention of monitoring this policy in terms of safety.[3] Undoubtedly, some divers from these countries will be visiting Australasia and will be diving. In addition, many Australian recreational divers have asthma.[4] This paper will briefly discuss some of the issues surrounding asthma and diving, and will summarise the methods of diagnosing current asthma. The issues that give rise to concern have been described in previous issues of this journal and elsewhere are several-fold and can be summarised in terms of:[5-8]

1 the hypothetical increased risk of barotrauma;
2 the risk of salt-water aspiration or nebulisation and subsequent bronchospasm;
3 exercise-induced asthma;
4 poorly controlled asthma leading to difficulties either while submerged, or while swimming at the surface.

The risk of pulmonary barotrauma is considered to be increased in asthma as there is the potential for small airways to be either constricted by smooth muscle over-activity or by mucous plugs. This could occur while at increased barometric pressure and so fail to allow this portion of the lung to equilibrate on ascent, leading to overpressure and pulmonary rupture, with subsequent pneumothorax or pneumomediastinum. The available data in man are very much lacking, despite this making sound physiological sense. Colebatch et al. showed that in those submariners who developed pneumothoraces on ascent, the problem was associated with abnormal elastic properties of the lung, rather than an obstructive pattern in their lung function, although those with frank airway obstruction had been screened out of this group.[9] James Francis reported at the 2001 SPUMS Scientific Meeting, that the data from the Royal Navy would suggest that a restrictive pattern was associated with pneumothoraces, rather than any evidence of obstruction.[10] Also reported at the same meeting were data from our own research in those with a heavy smoking history who underwent hyperbaric oxygen therapy. While the degree of airway obstruction was mild, there was clear evidence of air-trapping at baseline which did not increase after hyperbaric therapy, and the residual volume did not change. The likelihood of air-trapping in association with airway obstruction and hyperbaric conditions remains to be proved.

Salt water aspiration is probably not uncommon in any diving population and regulators may allow a mist of sea-water to be nebulised into the airway. This hypertonic solution could cause airway narrowing in a susceptible individual, particularly those with unstable asthma. It would therefore seem logical that those with a significant response to a challenge of hypertonic saline should at least be aware of the increased risks of diving, if not advised not to dive at all. Again, the data suggesting that this is the correct advice are minimal.

Exercise-induced asthma is associated with airway cooling and drying. Cold dry air is a bronchoprovocant for some asthmatic individuals, and can be associated with exercise-induced asthma. The logical advice again is that if there is evidence of bronchoconstriction during or after strenuous exercise, then diving should be avoided, particularly as the compressed air will be cold and have a low humidity, thus making bronchoconstriction likely. In addition, if a vigorous swim against a strong current is required to return to the surface or to the boat is required, this too may provoke exercise-induced asthma.

An additional, but largely unsubstantiated risk which is oft quoted is that the use of bronchodilators could lead to increased systemic gas emboli.[11] These experiments were performed in dogs which were given aminophylline, and the normal filtering of bubbles by the lung as blood passed through the pulmonary circulation was considered to be reduced. These results have not been demonstrated in man. Thus, in theory, the use of bronchodilators in asthma could be disadvantageous if shown to increase the passage of bubbles into the systemic circulation.