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This paper is an edited transcript of Dr Veale's lecture, to which he has not objected.

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ASTHMATIC FITNESS TO SCUBA DIVE

Peter Chapman-Smith

New Zealanders enjoy their marine environment. With more trained scuba divers per capita than any other country, and many untrained ones too, diving is a major recreational sport as well as a means of food gathering for many. Sadly between 55 and 76 cases of significant diving illness are treated annually in NZ, with a steady trickle of fatalities annually. These occur more during summer with other deaths from snorkel or free diving.

Asthma occurs in about 10% of the general population and has been said to be associated with approximately 10% of scuba diving deaths in New Zealand and Australia between 1980 and 1987,[1] the actual cause of death often being unclear. But the more recent data certainly has much lower figures of association.

Conventional diving wisdom has declared that asthmatics should not scuba dive at all. The potential risk of barotrauma to the lung from inadequate emptying of the small airways and reduced lung compliance of ascending divers who suffer from asthma may well be unacceptable. The suggested increased risk of pulmonary barotrauma (PBT) on ascent for asthmatic divers is based on consideration of, reduced lung elasticity, greater residual volume, greater resistance to exhalation, variable expiratory time constants of exhalation from alveoli leading to small airway closure with air trapping (closing volumes exceeding functional residual capacity), while exertion, hyperventilation, breathing cold dry air, saline mist inhalation through a faulty regulator, anxiety, increased gas density, increased effort of breathing and wetsuit splinting of the chest (which can be claustrophobic) can all precipitate or worsen asthma. Pulmonary barotrauma is occasionally associated with lung cystic changes. There is a greater risk at shallow depths where the volume changes are larger and rapid ascents are more risky. It is clinical experience that many cases of PBT occur without obvious cause. The potential outcomes include pneumothorax, arterial gas embolism, or mediastinal emphysema. Fatal at worst, with minor to major long term disability at times. Recompression treatment can be difficult and may not be successful. Serious stuff from a leisure sport and quite reasonably diving physicians have taken a conservative view for decades. It is fair to say that there is little hard clinical data to support this advice, and to my knowledge no one has yet demonstrated by section at post mortem the actual pathology of such pulmonary barotrauma.

In the UK a more liberal view has embraced selective risk assessment, with low risk asthmatics allowed to dive if not suffering symptoms for 48 hours before diving.

And how long after wheezing does the label of "asthmatic" linger with one ? All that wheezes is not necessarily asthma. Certainly asthma may also be over diagnosed and over treated in general practice. Bronchial hyperreactivity is well accepted as an entity and of course many asthmatics ignore our advice and continue to dive anyway. Some do so for long periods and are apparently none the worse for it. However, some join the morbidity and mortality figures as well, the non-survivors are not present to put their case.

Prospective dive trainees ideally require a medical clearance from a diving physician. Purists suggest excluding all those with with a history of asthma in the preceeding 5 years, bronchodilator use within 5 years, expiratory rhonchi heard on auscultation, high pitched rhonchi on hyperventilation with the mouth open, high pitched rhonchi 5-10 minutes after exercise and poor respiratory function tests. These are discussed in Sandra Anderson's paper (pages 233-248). An asthma provocation test causing more than a 10% reduction in FEV_1 (a 20%

reduction would verify clinically significant asthma) has also been used to exclude people from diving. The diagnosis of asthma should be supported by a positive reaction to bronchodilator.

Respiratory fitness to allow scuba diving "safely" requires the ability to tolerate severe physical exertion, the ability to tolerate rapid changes in lung volumes and pressures, with equal compliance throughout the lung, no restriction of local airways, no cysts or fibrosis, no current use of bronchodilators (which can be arrhythmogenic and aminophylline is known to reduce the bubble filtration function of the lung) and normal airway resistance

Working in general practice, I have been doing bronchial challenge tests with hypertonic saline using the equipment described by Dr John Parker in the SPUMS Journal.[2] This technique involves the inhalation of 4.5% saline via an Omron NEU06 Model nebuliser with a suitably high output of approximately 1.5 ml per minute.

Subjects

Twenty three subjects were studied, 3 female and 20 male, between the ages of 13 and 51 years. Most were prospective scuba trainees, often referred,to confirm suggested diagnosis of asthma, by colleagues and instructors. Several active asthmatics on regular inhalational treatment were included for comparison.

In each case a medical and diving history was taken. An examination was undertaken to establish the diagnosis. After determining the need for a saline challenge I frequently tell these people that they should not be diving, but they insist on taking the test and some sail through with a negative result! Repeated baseline spirometry was done using a hand held Micro spirometer until reliable data for forced expiratory volume at one second (FEV_1), forced vital capacity (FVC) and peak flow were recorded, then the test was conducted over approximately 30 minutes. Further familiarisation with equipment such as the nebuliser preceded testing. A nose clip was not used.

A twenty percent drop from the base line FEV_1 was accepted as a positive test, or a failure for diving. This figure represented a significant level of reduction where the test would be considered positive and abandoned. Equipment for the treatment of provoked severe asthma was ready but in the twenty three cases the only one person needed treatment and three puffs on a Ventolin inhaler reversed the bronchospasm.

Inhalation testing was with the trigger demand flow provision of nebulised 4.5% saline. Sequential challenges lasting 30, 60, 120, 240 and 480 seconds were given with 3 minute breaks between. During these breaks, spirometry was performed at 30, 60 and 120 seconds. When the FEV_1 fell 20%, a positive result, the test was stopped but spirometry at 60 second intervals was continued until recovery was evident.

Asthma history

Sixteen had been diagnosed with asthma under the age of 10 years. Four since the age of 20. The last episode of asthma was less than 5 years ago for 21, less than 3 years for 16, and for 11 was less than 12 months. 11 had a history of allergic rhinitis. Twelve had exercise induced asthma while 13 had URTI induced asthma.

Asthma medications

Seven had no medications for the treatment of bronchospasm. Six were prescribed prophylactic steroid inhalers. One had been on prednisolone when aged 12, 2 years before being tested (Case 17). Thirteen used bronchodilator inhalers irregularly. Four were using them regularly (Cases15, 16, 21 and 23). One of these had been treated for status asthmaticus 18 years before, had been on prednisolone on about 3 occasions, admitted to wheeze on exertion even in the water, is bilaterally deaf, suffers from intermittent depression, has patchy sensory loss of the lower limbs and perineum, and has been an instructor for years (Case 23). Another was a very heavy smoker (Case 16).

A third was a tourist, whom I advised to not dive, but who intended to proceed anyway despite the risks. She was on regular treatment for asthma (Case 21) and had a negative test.

Dive experience

Thirteen were experienced snorkel divers. Sixteen had not dived on scuba. 5 had scuba dived on less than 4 occasions. 2 had active asthma but had scuba dived often (Case 15 for over 2 years and Case 23 for over 30 years).

Examination findings

Nineteen were entirely normal while four had a wheeze (Cases 10, 16, 20 and 23). Two wheezers had negative provocation tests (Cases 10 and 20). One of these had had a heart transplant, smoked and was functionally normal with unremarkable spirometry (Case 10).

Peak flows at the start were notable in that one was 66%, failing the test (Case 23), 2 were less than 75% with neither failing (Cases 9 and 12) and 18 were better than 80%. Initial FVC recordings were close to that predicted and often better as were initial FEV_1.

Cough and wheeze during testing

Ten were noted to cough, complain of chest tightness or have an audible wheeze during the test. Three of these had positive test outcomes (Cases 2, 16 and 23). It is quite clear that many people with normal lung function devlop a cough during this test.

Outcomes

Four were positive, that is dropping 20% from the baseline FEV_1 (Cases 2, 15, 16 and 23). All those who failed had had symptoms of asthma within the previous month. Case 2 was allergic to cats and horses only and admitted to no other triggers, so presumably truly allergic asthma. The last attack of asthma was three week before the test which was rapidly positive. Case 15, on regular asthma treatment, had dived frequently for 2 years without apparent problems. He had a positive challenge despite being on regular inhaled steroids. Case 16, with a 38 year-pack history of smoking, had chronic obstructive airway disesase (COAD) and responded with wheezing to all the usual asthma triggers. He was very keen to go diving but failed rapidly with a positive challenge. Case 23 had longstanding atopic asthma and his history has been described. In recent years he has been well controlled and has had few problems.

Nineteen tests were negative. Seven of the negative challenges had had symptomatic asthma in the last 12 months. All 7 teenagers in this study had negative challenges. One 14 year old girl had been on oral steroids for asthma 2 years previously and responded with wheeze to all the triggers. Symptom free for 12 months, she was on no regular treatment and surprisingly had a negative challenge (Case 17). A man aged 22 years had had a heart transplant in the UK and been pronounced fit to dive 4 months before at the Great Ormond St Hospital in London. He had a positive family history of asthma, smoked, only wheezed with colds and had a negative challenge result (Case 10).

Twelve subjects admitted to exercise induced wheeze all with negative challenges except for Case 23 (see above) and Cases 15 and 16, who smoked. All three on history and examination alone would normally have been excluded from diving.

Discussion

Exercise induced asthma seems to be caused by osmotic changes in the airways rather than a temperature effect. Water loss per se may be the key stimulus. Swimming hard in a 1 knot current is not unusual and increases the work and volume of breathing. A clinical observation of rhonchi on auscultation (especially after hyperventilation) or a progressive drop in spirometry after exercise would confirm the likely diagnosis of asthma.

Inhalation testing standardisation demands a consideration of nebuliser output, particle size, method of inspiration, airway calibre, drug usage, recent viral infection, exposure to irritants or allergens and individual characteristics. The solution used is critical and either hypo or hypertonic saline solutions are reliable. The equipment must be thoroughly rinsed after use or corrosion will occur. Non-asthmatic subjects do not suffer a 20% or greater drop in FEV_1. Inhaled temperature between 22° and 35° C. seems to not make any difference. Solutions need to be sterile and any bronchoconstriction caused can usually be readily reversed. Lung irritant receptors may be directly stimulated by the altered osmolar solutions inhaled, with subsequent mast cell release of histamine in the bronchial mucosa.

A 20% fall in FEV_1 is considered a positive response, correlating well with the reduction in flow rates in the middle half of the vital capacity. 80% of asthmatics will respond to a cumulative dose of 10 ml or less of either water or 4.5% saline. 40% respond to 2 ml or less. Droplets of hypertonic saline undergo hygroscopic growth in the airways and cross membrane ion fluxes may well be altered. A direct action on bronchial smooth muscle or on afferent vagal nerves is postulated. Although very specific as a test stimulus to detect moderate and severe hyperresponsiveness, hypertonic saline is less sensitive than methacholine and histamine.

Non-isotonic aerosols induce changes in lung function reflected in FEV_1 estimation. The maximum response is usually seen within 60 seconds of a challenge, those patients with an initial FEV_1 of less than 80% of predicted value can be expected to respond to less than 2 ml of inspired saline.

On my figures I cannot agree with the suggestion that we should exclude anybody with a history of asthma in the last three to five years. A saline provocation test is needed. However active ongoing asthma is a clear absolute indication of unsuitability to dive. Saline provocation is cheap, reproducible, safe, quick to do, and if inducing asthma makes an explanation of diving unfitness easier. The similarity to the inhaled mist through a regulator is readily understood. False positive results are virtually unknown, asthmatics with symptoms having a correlation of virtually 1, that is a high reliability and sensitivity. A positive result correlates highly with exercise induced asthma.

To pronounce fitness for diving in prospective dive trainees is an outdated concept. Informed consent is the current approach promoted in Australasia. A wide general awareness now exists amongst general practitioners who perform most dive medical screening in New Zealand that

active asthma is a contraindication. Determining the need for ongoing treatment or prevention of asthma should be reassessed from time to time and the diagnosis of hyperresponsive airways (or bronchial hyperreactivity) needs to be remembered more often.

There are grey areas in the consideration for diving fitness. One active asthmatic has clearly not escaped injury, but continued (and thoroughly enjoyed) diving for years. Is there a case for allowing diving occasionally if one has excellent lung function tests but takes a prophylactic inhaled steroid? (Budesonide especially appears very effective.) If one only wheezes and gets asthma after a specific allergen challenge (such as riding horses) should this exclude the individual from ever scuba diving? Is exercise induced asthma the main diagnosis of exclusion? How many divers have asthma and ignore conventional wisdom? I believe we should be studying that group in much more depth.

A five year asthma free period seems unreasonable for adolescents who often outgrow the disease. Active asthma in the last month appears to be a useful marker. Those with significant asthma still fail the provocation test despite being on regular inhalational treatment. As the actual risks and consequences of pulmonary barotrauma in asthmatics are in fact not well described, perhaps they can be ignored in those who pass a saline challenge. The paucity of clinical data is notable, but ignoring the theoretical risks and consequences of pulmonary barotrauma seems unwise. Guidelines for examining doctors should perhaps urge dividing trivial from more serious asthma. A continuum of risk exists, and perhaps an informed consent approach could be adopted allowing some recreational diving to a wider public. Certainly this would be welcomed by many in the dive industry, but the safety of this advice is ill defined at present.

Questions

Mike Davis, Christchurch

I was not quite clear what your advice was to asthmatics, with a positive history and on medication, who had a negative challenge test with regard to their diving.

Chapman-Smith

The reason it is not clear is I did not mention it. I thought it would be interesting to discuss, rather than say what I had done. In fact I suggested to those who had a negative test that they could do a dive course, after adequate discussion of the risks of barotrauma, which is a dilemma because a number of those people I would never, before doing the test, have suggested they should dive. So I have changed my advice to patients on the basis of this test .

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LUNG FUNCTION AND BRONCHIAL PROVOCATION TESTS FOR INTENDING DIVERS WITH A HISTORY OF ASTHMA

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(presented by Sandra Anderson)

Abstract

With our experience over 7-10 years in assessing intending divers with a past history of asthma we have concluded that full spirometric tests, bronchial provocation and response to bronchodilator should be performed, together with measurements of functional residual capacity and residual volume, if possible. This combination of tests to assess risk has arisen over time and in consultation with our referring medical practitioners. The choice of bronchial provocation test (pharmacological or physical) may present some difficulty. The use of dry air hyperpnea and hypertonic saline have the advantage of being familiar and relevant to the intending diver and having a high specificity for asthma. The use of pharmacological challenges, while well accepted by the medical community, are less acceptable for the intending diver as the stimulus is not relevant to diving. Further, the low specificity for identifying current asthma may lead to the unnecessary exclusion of some persons with otherwise normal lung function. Occasionally a response to a pharmacological agent is negative but the airway response to dry air challenge positive.

Asthma is an inflammatory disease of the airways that can vary widely in severity over a life-time. In assessing 180 adults with a past history of asthma we have found that 50% had no evidence of the disease and had normal lung function and no bronchial hyperresponsiveness. Others who had been symptom free for some years, had abnormal lung function and/or were hyperresponsive. We