

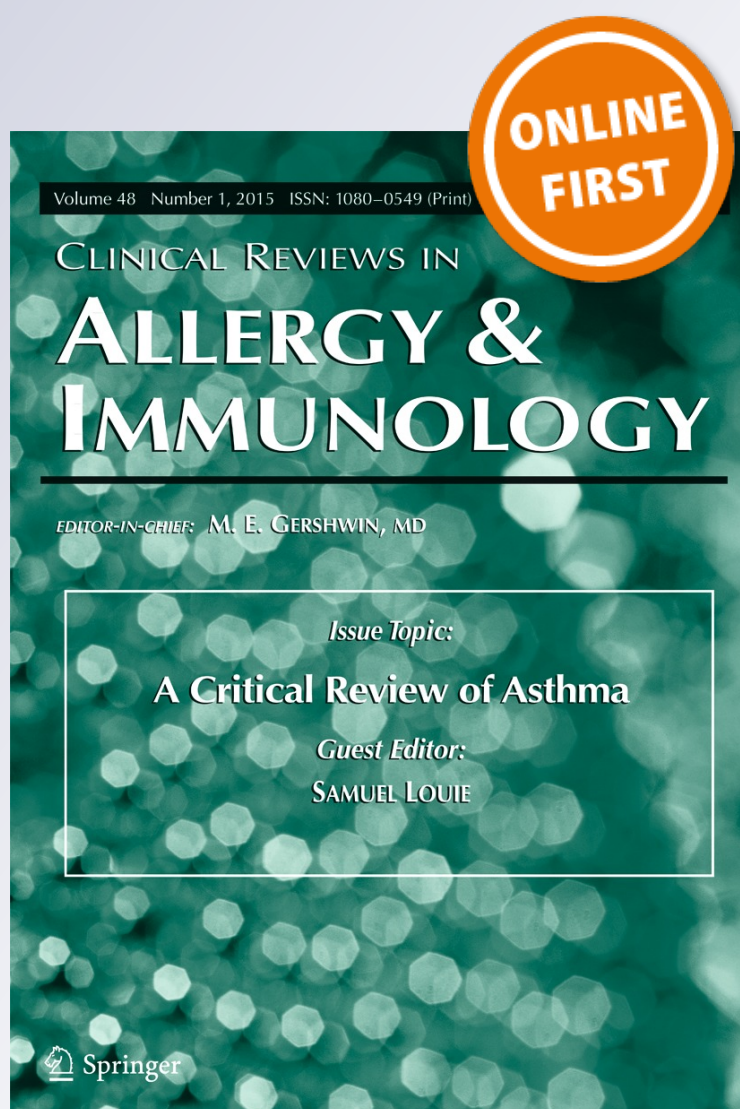
SCUBA Diving and Asthma: Clinical Recommendations and Safety

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SCUBA Diving and Asthma: Clinical Recommendations and Safety

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Abstract The objective of this article is to review the available studies regarding asthma and SCUBA (self-contained underwater breathing apparatus) diving. A literature search was conducted in MEDLINE to identify peer-reviewed articles related to asthma and SCUBA diving using the following keywords: asthma, allergy, and SCUBA diving. SCUBA diving is a popular sport with more than 9 million divers in the USA. SCUBA diving can be a dangerous sport. Bronchospasm can develop in asthmatic patients and cause airway obstruction. Airway obstruction may be localized to the distal airway which prevents gas elimination. Uncontrolled expansion of the distal airway may result in pulmonary barotrauma. There is also the risk of a gas embolism. Asthmatic divers can also aspirate seawater which may induce bronchospasm. Pollen contamination of their oxygen tank may exacerbate atopic asthma in patients. Diving may be hazardous to the lung function of patients with asthma. Despite the risks of SCUBA diving, many asthmatic individuals can dive without serious diving events. Diving evaluations for asthmatic patients have focused on a thorough patient history, spirometry, allergy testing, and bronchial challenges. For patients that wish to dive, their asthma should be well controlled without current chest symptoms. Patients should have a normal spirometry. Some diving societies recommend that an asthmatic patient should successfully pass a bronchial provocation challenge. Recommendations also state that exercise-, emotion-, and cold-induced asthmatics should not dive. Asthmatic patients requiring rescue medication within 48 h should not dive.

The opinions or assertions herein are the private views of the authors and are not to be construed as reflecting the views of the Department of the Air Force or the Department of Defense.

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Introduction

SCUBA (self-contained underwater breathing apparatus) diving is an increasingly popular sport with more than 9 million divers in the USA completing more than 30 million dives per year. Certification for SCUBA diving can be obtained through diving certification organizations. These include the Professional Association of Diving Instructors (PADI) and SCUBA Schools International (SSI). This certification typically involves online classes, classroom instruction, pool practice, and open-water training. For patients with certain medical conditions including asthma, a medical clearance is required. Self-reporting is the only way to identify those patients with significant medical problems who want to participate in this sport.

SCUBA diving is not without risk. Decompression sickness (DCS) is one of the major threats. At 10 m in depth, oxygen volume is one half the volume at sea level (Boyle's law). The number of molecules of nitrogen and oxygen is doubled per liter of air due to the pressure/volume ratio (Dalton's law) [1]. Nitrogen is fat soluble and, with increased concentration, more nitrogen is stored in the soft tissues at depth. The large quantities of nitrogen that were stored during descent are then released in the form of nitrogen bubbles on rapid ascent as they exit the tissue [2]. Nitrogen bubbles can cause DCS as they enter various organs in the body. In addition to DCS, other risks of this adventurous sport include drowning, risk for nitrogen narcosis, and other common sports injuries [3]. Thus, conservative management of patients who have diseases that put them at increased risk has generally been advised. Asthma is one of these afflictions. This review will analyze the risks of SCUBA diving for the asthmatic patient. It will also focus on the evaluation and

recommendations for asthma patients to be able to successfully SCUBA dive.

Asthma and SCUBA Diving

There are specific risks for asthmatic divers, and some experts recommend that patients with asthma should not SCUBA dive [4]. Bronchospasm can develop in asthmatic patients rapidly and may cause airway obstruction underwater. Airway obstruction may be localized to the distal airway which prevents gas elimination. Uncontrolled expansion of the distal airway may result in pulmonary barotrauma and a gas embolism. Another risk for asthmatic divers is the possibility of microaspiration of seawater which may also cause bronchospasm.

A diving risk for atopic individuals is the possibility that their oxygen tank may be contaminated with pollen to which they are allergic. This pollen contamination may cause an asthmatic exacerbation. D'Amato et al. [5] described a 37-year-old man with rhinitis and asthma who was allergic to *Parietaria* pollen. He was an experienced diver and had good asthma control; however, on one dive, he developed a severe asthma attack while diving at 27 m. The patient had to resurface and was treated with a short-acting beta 2 agonist and an oral steroid. On further investigation, the authors found that this diver's tank had been filled with unfiltered air that had been contaminated with granules of *Parietaria* pollen. The authors warn of this possible allergen contamination risk and advise allergic asthmatic divers to ensure that the air in their tanks has been filtered to prevent the passage of respirable pollen grains. Astarita also reported a similar event with grass pollen allergy and alerted atopic diving patients to the potential risk of pollen allergens being entrapped in SCUBA tanks [6].

Diving may be detrimental to the lung function of patients with asthma. Ivkovic et al. [7] evaluated the pulmonary function of asthmatic divers versus non-asthmatic controls after a single pool dive of 5 m for 10 min. The study consisted of 22 asthmatic divers and 15 healthy divers. There were significant reductions in the forced expiratory volume in 1 s (FEV1), FEV1/forced vital capacity (FVC) ratio, and forced expiratory flows (FEF) in the asthma group after the dive as compared to the control group. The authors concluded that even a single dive of 5 m may impair the function of the small airways in asthmatic divers and caution should be advised for asthmatic divers.

There is also evidence that diving in general reduces an individual's lung function over time even if the individual has healthy lungs. Skogstad et al. [8] studied 77 healthy professional divers over a 6-year time period and compared their lung function with that of 64 healthy policemen. Pulmonary function tests were completed at 1-, 3-, and 6-year follow-up

time periods. The results demonstrated that the FVC, FEV1, maximal expiratory flow rates, and transfer factor for carbon monoxide were significantly reduced in divers over the follow-up period when compared with those of policemen. The authors concluded that diving performed over a 6-year time period contributes to a reduction in lung function.

Another study was conducted to evaluate whether atopic subjects were at risk of developing airway hyperresponsiveness from SCUBA diving [9]. Fifteen atopic non-asthmatic patients and 15 controls underwent spirometry, skin prick testing for common environmental allergens, and methacholine challenges 24 h before and 20 min and 24 h after a standardized dive test, and after a hyperbaric chamber test. At the 20-min mark, the provocative dose of methacholine causing a 20 % fall of the FEV1 was significantly reduced in the atopic subjects. The authors concluded that SCUBA diving is associated with the development of early airway hyperreactivity in atopic patients.

Asthmatics may also be at greater risk of diving injuries. Weiss and Meter [10] described two asthmatic patients who experienced cerebral air emboli during SCUBA diving classes in a swimming pool. Despite shallow diving, these patients still experienced significant morbidity. The authors stated that asthma is a strong contraindication for diving.

A survey was performed to evaluate whether asthmatic divers were at higher risk for injuries. In this survey, there was a twofold increase in the risk of acute gas embolism in asthmatic divers [11]. Moon et al. described a 30-year-old male with mild asthma who reported only using his albuterol metered dose inhaler one to two times per month. This diver had two episodes of neurological decompression illness with a cerebral infarct during the course of six relatively low-risk dives [12]. Upon further evaluation, his FEV1 and FVC were found to be reduced and it was deemed that his low lung function contributed to his diving injuries.

Despite the risks of SCUBA diving, many asthmatic individuals are able to SCUBA dive without serious diving events or injuries. One study evaluated divers in Europe and asked specifically about asthma [13]. A survey was mailed out to SCUBA divers from Austria, Germany, and Switzerland. Two hundred and twenty-six male and 96 female divers completed the survey. Of the divers that responded, 8.7 % indicated that they had asthma and two thirds of these asthmatic divers complained of regular dyspnea. Of these asthmatic divers, only 42.2 % used medications to relieve or control their symptoms and only 27.3 % of these divers used their medications prophylactically before diving. These divers had logged 17,386 dives and reported no cases of serious diving injuries.

Physicians in Britain conducted a study to assess the risks of diving [13]. A questionnaire was completed by 104 divers aged 16–40 who had completed 12,000 dives. Of the respondents, 89 had asthma since childhood. No cases of pneumothorax or gas embolism had occurred among these asthma

divers; however, one diver had decompression sickness on two occasions. Ninety-six of these divers had taken beta 2 agonists before diving “just in case,” and 29 were taking prophylactic medications (17 inhaled steroids and 13 sodium cromoglycate).

Fitness-to-Dive Evaluations

Several studies have been conducted to assess SCUBA diving candidates for airway disease. These studies have focused on a thorough patient history, spirometry, the measurement of the fractional exhaled nitric oxide (FeNO), allergy testing, and bronchial challenges. Because airflow obstruction is a relative contraindication for diving, Weaver et al. [14] set out to evaluate prospective recreational divers for the prevalence of airflow obstruction. The evaluation included a respiratory disease questionnaire and spirometry. Of the 231 subjects who completed the questionnaire and spirometry, 10 % had mild, 1.7 % had moderate, and 0.4 % of these divers had severe airflow obstruction. There was an overall 12 % prevalence of airflow obstruction by spirometry. This study did not assess if these divers with obstruction were allowed to dive or if they had complications.

Another study evaluated professional SCUBA divers in Italy [15]. Seventy-four professional divers from the Italian National Fire Services Department were assessed with a questionnaire, spirometry, and a FeNO measurement. This study specifically focused on FeNO which is a measure of eosinophilic lung inflammation [16]. Ex-smokers in the study had significantly higher FeNO levels. A high FeNO can also be found with eosinophilic asthmatic patients [17]. The authors concluded that patients with a high FeNO (greater than 35 parts per billion) should be further evaluated to make sure they have no diving contraindications.

Badier et al. [18] undertook a study evaluating SCUBA diving candidates with bronchial challenges in order to identify those patients who may be at risk for bronchospasm and pulmonary barotrauma. They performed carbachol bronchial challenges in 76 patients with asthma, a history of asthma, or allergic rhinitis. Nearly half of the subjects (47 %) had bronchial hyperresponsiveness, and it was most frequent in the patients with asthma. Interestingly, there was a fairly high prevalence of bronchial hyperresponsiveness in the allergic rhinitis group.

Meehan et al. compared a questionnaire and a medical interview-based approach for fitness-to-dive evaluations in 1000 SCUBA diving students [19]. The authors found that a face-to-face medical interview was superior for identifying individuals who are at risk while diving when compared with a questionnaire.

Pulmonary dysanapsis can be confused with obstructive airway disease. Ong et al. [20] evaluated several patients with

pulmonary dysanapsis which is defined as having a normal FEV1 but a disproportionately large lung capacity or FVC. The patients that were evaluated were initially felt to have asthma or some type of obstructive airway disease. However, upon further evaluation which included a lack of reversibility with albuterol, a negative hypertonic saline challenge, and a lack of reported asthma symptoms, these patients were assessed to not have asthma and were cleared to SCUBA dive.

Recommendations from Diving Agencies

There are published recommendations regarding SCUBA diving and asthma among the different agencies of Australia, the UK, and the USA. In Australia, the South Pacific Underwater Medicine Society recommends that asthmatics who wish to dive should have no current chest symptoms and good lung function on spirometry. They should also be able to successfully complete bronchial provocation testing with exercise, dry air (hyperpnea), or hypertonic saline (no greater than a 15 % reduction of the FEV1). If the asthmatic patient cannot pass the bronchial challenge, then SCUBA diving is not recommended [21]. Figure 1 shows an algorithm developed by the South Pacific Underwater Medicine Society for the evaluation of the asthma patient to SCUBA dive [22].

The UK Sports Diving Medical Committee (UKSDMC) recommendations state that asthmatics may dive if they have allergic asthma but not if they have cold-, exercise-, or emotion-induced asthma. The UKSDMC recommends that all asthmatics should be managed in accordance with guidelines from the British Thoracic Society. In addition, the recommendations state that only well-controlled asthmatics may dive and asthmatic patients should not dive if they have needed a therapeutic bronchodilator in the last 48 h. The UKSDMC recommendations do discuss an exercise bronchial challenge and mention that a beta 2 agonist may be taken prediving as a preventive but not to relieve bronchospasm at the time of diving [13].

The Undersea and Hyperbaric Medical Society in the USA recommends that exercise- and cold-induced asthmatics should not dive. Additionally, their recommendations state that asthmatics requiring rescue medication should not dive. If a patient has mild to moderate asthma with normal screening spirometry, then he/she can be considered a candidate for diving. Also, if a patient suffers from an asthma attack, the individual should not dive until their airway function on spirometry returns to normal. An exercise challenge may be performed [23].

To summarize, most of the diving agencies agree with the following evaluation: a thorough history, spirometry, and an exercise challenge. Indirect bronchial challenges with dry air, saline, or mannitol are recommended by the South Pacific Underwater Medicine Society; however, these tests are not

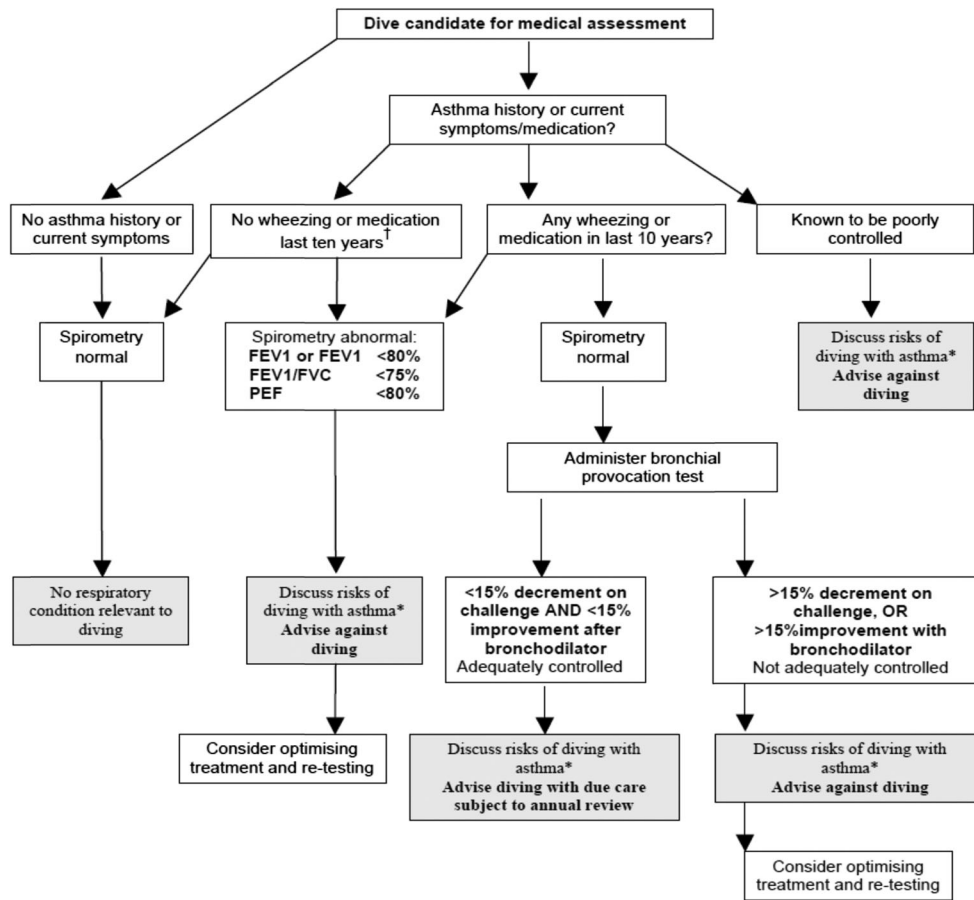


Fig. 1 SCUBA diving evaluation for asthmatic patients from the South Pacific Underwater Medicine Society

recommended by the Undersea and Hyperbaric Medical Society because these tests are not sufficiently standardized to be interpreted in the context of SCUBA diving [23]. A summary of the recommendations are shown in Table 1.

Management

For physicians who evaluate asthmatic patients for clearance to SCUBA dive, there are useful published guidelines. First,

Table 1 Recommendations from diving agencies

SCUBA diving recommendations for asthmatic patients
A thorough history and physical examination by a trained physician
The patient's asthma should be well controlled (no current chest symptoms)
Normal spirometry: FEV1≥80 %, FEV1/FVC≥75 %
Successful completion of a bronchial provocation challenge (exercise, dry air hyperpnea, mannitol, or hypertonic saline)
Cold-, exercise-, or emotion-induced asthmatic patients should not dive
Asthmatics requiring rescue medication within 48 h should not dive

severe asthmatic patients should not dive [24] and only well-controlled asthmatics should be considered for clearance to dive. Asthmatic patients should not dive within 48 h of having chest symptoms and needing to use a rescue bronchodilator. A beta agonist can be used as a pre-dive preventive medication, but the asthmatic SCUBA diver should not be experiencing any active chest symptoms [25]. All asthmatic divers should have an annual review of their fitness for diving [22]. Peak flow measurements should be followed for asthmatic divers especially during diving season. A fall of 10 % or more in the peak flow measurement should exclude diving for the asthmatic patient. The asthmatic diver should not SCUBA dive again until his peak flow measurement is within 10 % of the best values. This should occur at least 48 h prior to the dive [25]. Physicians should provide the SCUBA candidate with carefully documented guidelines [22]. Physicians should not sign a note stating that diving “is safe” for the individual. Recreational diving is a risky sport, and a brief note summarizing the patient's medical condition and risk education and their acceptance of that risk is more appropriate [26]. Physicians should not limit the asthmatic diver to shallow water as barotrauma is more likely to occur closer to the surface than in deeper water [27, 28].

Conclusion

Recreational SCUBA diving is a dangerous sport with many risks. Patients with medical conditions may be more at risk for diving injuries. Asthma is one of the medical conditions that must be carefully evaluated prior to SCUBA diving. The evaluation of a potential asthma diving candidate includes a thorough history, spirometry, and possible exercise or indirect pulmonary challenge. In general, asthmatic patients with normal lung function and well-controlled asthma should be able to successfully SCUBA dive.

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