

# Otorhinolaryngology and Diving— Part 2: Otorhinolaryngological Fitness for Compressed Gas Scuba Diving A Review

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**IMPORTANCE** Self-contained underwater breathing apparatus (scuba) diving has become increasingly popular with millions of people diving each year. Otorhinolaryngologists are often consulted either by patients or diving physicians regarding fitness to dive, and at present, the guidelines do not provide comprehensive information regarding the evaluation of this patient cohort. The aim of this review is to provide a comprehensive overview of existing otorhinolaryngological guidelines for fitness to dive recreationally.

**OBSERVATIONS** There is a paucity of guidelines for assessing otorhinolaryngological fitness to dive in the recreational diver. Comprehensive guidelines exist from US, European, and UK regulatory bodies regarding fitness for commercial diving; however, not all of these can be directly extrapolated to the recreational diver. There are also a variety of conditions that are not covered either by the existing fitness for recreational diving guidelines or the commercial regulatory bodies.

**CONCLUSIONS AND RELEVANCE** With the paucity of recreational fitness to dive guidelines we must draw on information from the commercial diving regulatory bodies. We have provided our own recommendations on the conditions that are not covered by either of the above, to provide otorhinolaryngologists with the information they require to assess fitness for recreational diving.

*JAMA Otolaryngol Head Neck Surg.* 2018;144(3):259-263. doi:10.1001/jamaoto.2017.2616  
Published online February 15, 2018.

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Self-contained underwater breathing apparatus (scuba) diving is an increasingly popular leisure activity both in the United States and abroad, with a 17.5 million-person increase in those accredited with the Professional Association of Diving Instructors from 1968 to 2008.<sup>1</sup> According to the Scuba Diving Participation Report 2014 (published by the US Sports and Fitness Industry Association), 3.1 million people in the United States participated in scuba diving once or more in 2013, which is a 14% increase over 2012. Otorhinolaryngological disorders are the main issues divers encounter, with 80% of adults<sup>2</sup> and 85% of juvenile divers (ages 6-17 years) having had an otorhinolaryngological complaint related to diving.<sup>3</sup> In view of these rising numbers, otorhinolaryngologists are often consulted either by patients or by diving physicians regarding fitness to dive, and at present there has not been a comprehensive review of the various guidelines since 2007.<sup>4</sup> The aim of this review is to provide a comprehensive overview of existing otorhinolaryngological guidelines for fitness to dive.

## Methods

We performed a systematic search with a focus on identifying articles relating to the otorhinolaryngological aspects of deep sea diving. The authors individually carried out an independent systematic literature search of all records in PubMed, Ovid MEDLINE, Ovid EMBASE, The Cochrane Library, and ClinicalTrials.gov from database inception until December 2016. Both “free-text term” and “MeSH term” searches were completed, using variations of the keywords “diving” and “otolaryngology” and in combination using Boolean operators. Only English-language articles were considered. The archives of major otorhinolaryngology and scuba diving journals were hand searched for recent or in-press articles that may have been missed by electronic searching. Each author’s search results were merged and duplicate citations discarded.

Table 1. Guidelines for Otorhinolaryngological Disorders and Commercial Diving

Otorhinolaryngological Disorder	Contraindications by HSE <sup>8</sup>	Contraindications by ADCI <sup>9</sup>	Contraindications by EDTC <sup>10</sup>
External ear canal	NA	NA	Any occlusion of the ear canal (eg, large exostosis)
Infective ear disorders	Active infection of external or middle ear	Otitis media	Complications of otitis media such as glue ear, deafness, perforation and persistent discharge are causes for rejection
Chronic ear disorders	Chronic ear canal or middle ear disease (eg, cholesteatoma)	Chronic serous otitis media	Chronic otitis media
Stapes surgery	Stapedectomy.	NA	Stapes surgery
Mastoid surgery	Mastoid surgery is not an absolute contraindication	NA	Atticotomy debar but a simple mastoidectomy does not
Tympanic membrane	Perforation of the tympanic membrane is a contraindication, but scarred tympanic membrane or healed perforations are not	Perforation of the tympanic membrane; Pressure Equalization Tubes in place	Healed or surgically repaired tympanic membrane are not a contraindication but the presence of attic or posterior marginal perforations of the drum indicate middle ear disease and contraindicate diving
Middle ear barotrauma	Only once signs and symptoms resolved	NA	NA
Inner ear	NA	Adequately repaired round window ruptures that have no significant residual deficits may be approved for diving	After successful repair of a round window rupture, the diver may resume diving
Hearing	Hearing that allows understanding of normal conversational voice	NA	Hearing should be of a level which permits normal conversation to be understood
Ménière disease or vestibular disease	Ménière disease	Ménière disease; Recurrent or persistent vertigo	Ménière disease

Abbreviations: ADCI, Association of Diving Contractors International; EDTC, European Diving Technology Committee; HSE, Health and Safety Executive; NA, not applicable.

## Results

Reviewing the literature, there is a paucity of guidelines for the otorhinolaryngological contraindications to recreational diving. Various institutions around the world offer fitness-to-dive medical examinations; however, for otorhinolaryngology it seems that a lot is left to the discretion of the examiner, and there is little consensus. The UK Diving Medical Committee (UKDMC),<sup>5</sup> who advise the British Sub-Aqua Club; the Professional Association of Diving Instructors (PADI)<sup>6</sup>; and the South Pacific Underwater Medicine Society (SPUMS)<sup>7</sup> offer some advice for clinicians assessing the recreational diver. While both UKDMC and PADI recommend a self-reported questionnaire with positive answers prompting referral to a diving physician, the SPUMS have adopted a mandatory medical examination by an accredited diving physician. Three major institutions, the Health and Safety Authority in the United Kingdom, the European Diving Technology Committee (EDTC), and the Association of Diving Contractors International (ADCI) all have their own individual guidelines for commercial diving.

The guidelines of the Health and Safety Executive (HSE) apply to all recreational diving projects within the 12-mile limit of territorial waters adjacent to Great Britain and applies to diving projects where: (1) at least 1 person taking part in the project is employed or self-employed and at work; (2) the equipment and techniques are confined to free swimming using scuba; and (3) the purpose of the project is recreational diving (ie, diving carried out by a person for recreational purposes while not at work).

Table 1 outlines the various nuances to each of these guidelines. The most interesting variation surrounds stapes and mastoid surgery. While the HSE and EDTC report that a stapedectomy is a contraindication to commercial diving, the ADCI make no comment. Interestingly in a study by House et al<sup>11</sup> no increase in ad-

verse events was found in patients who dive poststapedectomy provided that adequate eustachian tube function has been established. Both the HSE and the EDTC caution diving following mastoidectomy. The EDTC are quite prescriptive allowing diving following a simple mastoidectomy but not following atticotomy. Again, in this instance, the ADCI do not report on mastoid surgery.

### Diving Eligibility With Otological Conditions

As evident from Table 1 and 2, otological conditions and diving eligibility with such conditions have been relatively well covered by current guidelines. Past surgical history of a stapedectomy, or a canal wall down mastoidectomy; active Ménière disease, or other vertiginous conditions; and a perforation of the tympanic membrane are frequently considered contraindications for diving. However, a previous atticotomy does not debar from diving. As described above, one study<sup>4</sup> contradicts the guidelines and has shown that stapedectomy does not appear to increase the risk of inner ear barotrauma in scuba divers, and if adequate eustachian tube function has been established, it may be performed safely.

There is no formal guidance pertaining to diving following a tympanoplasty. The physician's guide to diving medicine<sup>12</sup> states that as long as the eustachian tube is normal, the repaired tympanum should withstand the normal forces of diving. This is further supported by a study by Velepich et al<sup>13</sup> that demonstrated that from a cohort of 20 patients with palisade tympanoplasty, the 3 who dived preoperatively returned to diving 6 months postoperatively without complications. Eustachian tube dysfunction can cause the diver significant difficulties if it does not resolve with conservative medical management. The standard surgical management involves a myringotomy and insertion of a grommet; however, these can be considered a contraindication to diving. A recent systematic review<sup>14</sup> has shown the efficacy and safety of eustachian tube balloon tuboplasty for the treatment of eustachian tube dysfunction and the tech-

Table 2. Recommendations for Otorhinolaryngological Disorders and Recreational Diving

Otorhinolaryngological Disorder	UKDMC	PADI	SPUMS
General	NA	Significant obstruction of the external auditory canal (RR); history of significant cold injury to pinna (RR); Eustachian tube dysfunction (RR)	Check eustachian tube clinically, tympanometry if necessary; sinusitis, catarrh, cleft palate and allergies may increase risk of barotrauma
Middle ear barotrauma	NA	NA	Observe clinically if tympanic membranes are mobile; tympanometry if they are not
Infection	NA	Recurrent otitis externa (RR); recurrent otitis media or sinusitis (RR).	Chronic outer or middle ear discharge may indicate increased risk of barotrauma
Ménière and other vertiginous conditions	NA	History of vestibular decompression sickness (SR)	If abnormal audio or labyrinthine function, refer to a diving specialist
Hearing	Audiogram if hearing loss suspected or as a baseline; hearing loss not a contraindication to diving	Significant conductive or sensorineural hearing impairment (RR)	Audiogram if hearing loss suspected or as a baseline; hearing loss not a contraindication to diving
Tympanic membrane	NA	Open tympanic membrane perforation (SR); history of tympanic membrane perforation (RR); monomeric tympanic membrane (SR)	NA
Previous otorhinolaryngological surgery	NA	History of tympanoplasty (RR); tube myringotomy (SR); history of mastoidectomy (RR); history of stapedectomy (SR); history of ossicular chain surgery (SR); history of inner ear surgery (SR)	NA
Facial nerve	NA	Facial nerve paralysis not associated with barotrauma (RR); facial nerve paralysis secondary to barotrauma (SR)	NA
Inner ear	NA	History of round window rupture (RR); inner ear disease other than presbycusis (SR)	NA
Larynx and airway	NA	Uncorrected upper airway obstruction (SR); laryngectomy or status postpartial laryngectomy (SR); tracheostomy (SR); uncorrected laryngocele (SR)	NA

Abbreviations: PADI, Professional Association of Diving Instructors; RR, relative risk; SPUMS, South Pacific Underwater Medicine Society; SR, severe risk; UKDMC, UK Diving Medical Committee.

nology has been approved by the US Food and Drug Administration for use in 2016.<sup>15</sup>

Hearing loss is a contraindication for commercial diving if hearing is not at a level that permits normal conversation to be understood. There is no guidance regarding hearing loss in the recreational diving population; however, we would propose that those with unilateral deafness should be counseled regarding the possibility of contralateral hearing loss following their dive and, thus, subsequent deafness. Any inner ear pathology should be thoroughly investigated prior to diving as further damage to the ear could result in deafness. Furthermore, certain inner ear pathologies causing hearing impairment may also render the diver prone to vertigo.

For rhinological and laryngological conditions, and for individuals with a history of head and neck cancer, there is a paucity of evidence for diving eligibility, and as such we have proffered recommendations based on expert opinion.

### Diving Eligibility With Rhinological Conditions Deviation of the Nasal Septum

Significant septal deviation that occludes drainage pathways of the paranasal sinuses predisposes to sinus barotrauma.<sup>16</sup> In such cases, septal surgery may be considered after medical treatment.

### Rhinitis, Rhinosinusitis, and Other Chronic Inflammatory Conditions of the Nose

Significant rhinitis causes obstruction of the drainage pathways and the eustachian tube orifices and predisposes to sinus and middle ear baro-

trauma. Treatment of allergic rhinitis should follow international guidelines.<sup>17</sup> The aim should be to control the symptoms with allergen avoidance (eg, diving at sites with no exposure to an airborne allergen) and by topical treatments only, as there are not enough data on the sedating effects of antihistamines under hyperbaric conditions to deem them safe for diving. If symptoms are well controlled with topical treatment only, a trial dive with an experienced diver is advisable. During an episode of acute viral rhinitis and acute sinusitis, diving is contraindicated and appropriate treatment should be commenced. Once resolution has occurred and the nose is clear, the individual can dive. For patients with chronic rhinosinusitis with and without nasal polyps, medical treatment is usually commenced and, if unsuccessful, patients may undergo sinus surgery. After endoscopic sinus surgery, a review by a diving medicine specialist is recommended, as adhesions and recurrence of symptoms at this stage are not uncommon. If an individual is cleared at this stage, a trial dive with an experienced diver is advisable.

We would suggest that active chronic inflammatory and granulomatous conditions of the nose, such as granulomatosis with polyangiitis (Wegener granulomatosis), and others are contraindications to diving, not only in view of the potential complications described above, but also owing to the multiorgan involvement, especially of the respiratory tract.

### History of Basal Skull Fractures and Cerebrospinal Fluid Leaks

Patients with a history of frontal or lateral skull base fractures are at increased risk of pneumocephalus during ascent (phase of

decompression) when expanding air may track through fracture lines and dehiscence of the bones in the course of sinus barotrauma and introduce bacteria into the cerebrospinal fluid. In the absence of clear rhinorrhea and more than 3 months after the repair of a cerebrospinal fluid leak, a computed tomography scan of the skull base should be performed and  $\beta$ -2-transferrin tested to rule out a covert cerebrospinal fluid leak. If the computed tomography confirms the adequacy of the repair, clear paranasal sinuses and drainage pathways and  $\beta$ -2-transferrin levels are negative, an individual may be eligible to dive; however, we would suggest a supervised test dive in the first instance.

### Diving Eligibility With Laryngological Conditions

Any condition causing an incompetent larynx is a contraindication to diving, as is the presence of a tracheostomy or a previous laryngectomy. The following conditions shall be discussed in detail:

#### Acute Laryngitis

Upper respiratory tract infections, namely laryngitis, predispose divers to laryngospasm. In addition, pharyngitis and tonsillitis are known causes of eustachian tube dysfunction<sup>18</sup> and as such can cause difficulty with middle ear pressure equalization. Presence of symptoms of an upper airway infection precludes from diving and diving should only be resumed until voluntary middle ear ventilation is achieved with Valsalva maneuvers.

#### Laryngocele

A laryngocele is a rare, benign dilatation of the laryngeal saccule, traditionally observed in glass blowers. A laryngocele is a contraindication until corrected surgically, as outlined by the HSE.<sup>19</sup>

#### Inflammatory Conditions of the Larynx

A variety of inflammatory diseases have been known to affect the larynx. Relapsing polychondritis, a disease most commonly associated with bilateral auricular chondritis, can manifest in the laryngeal, tracheal and bronchial cartilages. Common laryngotracheal symptoms and signs include cough, dyspnea, wheeze, hoarseness, and stridor.<sup>20</sup> Over time, the recurrent inflammation can result in laryngomalacia or permanent laryngeal stenosis with inspiratory dyspnea.

Laryngeal sarcoidosis is a rare phenomenon with an estimated incidence of between 1% to 5% of those patients diagnosed with sarcoidosis. It has similar laryngeal presenting symptoms to relapsing polychondritis and stridor with airway obstruction requiring a tracheostomy has been previously described.<sup>21</sup>

Systemic lupus erythematosus is a systemic inflammatory disorder that may have upper airway symptoms in up to 30% of cases.<sup>22</sup> However, laryngeal involvement is rare. Patients with involvement of the larynx may develop diffuse laryngeal edema, vocal cord paralysis, and ultimately upper airway obstruction.<sup>23</sup>

Rheumatoid arthritis is the most common autoimmune disorder affecting 2% to 3% of the population.<sup>24</sup> While commonly thought of as a disease of the small joints of the hands, it can affect the synovial cricoarytenoid joints, causing eventual fixation of the joint with adduction of the cords and a narrowed airway.<sup>19</sup>

Scleroderma is a disease characterized by multisystem inflammation and progressive fibrosis.<sup>16</sup> If it manifests in the larynx, it can have a wide variety of presentations from progressive hoarseness and dyspnea to sudden onset airway obstruction. Pulmonary fibrosis that of-

ten occurs in this condition can predispose to pulmonary barotrauma and arterial gas embolism during ascent.

While all the above inflammatory diseases have laryngeal manifestations, they occur rarely. If the respiratory tract is affected, we would suggest that they can be considered an absolute contraindication to diving. Furthermore, given that many of these conditions commonly have systemic manifestations, many of the extralaryngeal manifestations, such as joint or eye disease, could preclude any diving activity.<sup>16</sup> Even in inactive or successfully treated disease, any upper airway symptoms in this patient cohort need careful investigation prior to undertaking any diving activity.

#### Vocal Cord Palsy

Unilateral, well-compensated vocal cord palsy may not preclude an individual from diving, as long as the airway is not significantly impaired and pulmonary function tests and stress electrocardiography are normal. Bilateral vocal cord palsy is a contraindication to diving.

#### Stenosis of the Upper Respiratory Tract

A significant stenosis of the upper respiratory tract, such as subglottic stenosis, is a contraindication until corrected surgically in view of the increased risk of pulmonary barotrauma on ascent.

#### Laryngopharyngeal Reflux

There is little literature on the risks of laryngopharyngeal reflux during diving, and it is not generally listed in lists of diving risks. However, a recent case report<sup>25</sup> forensically associated the death of a scuba diver with an episode of vomitus, and McMullan<sup>26</sup> includes severe gastroesophageal reflux disease in her pre-dive evaluation. Gastric barotrauma on ascent can occur, although this is extremely rare.

### Diving Eligibility With Head and Neck Cancer

Regardless of the location of cancer of the upper aerodigestive tract, the tumors themselves and surgical treatment or other treatment effects distort the normal anatomy of the airway. Due to angiogenesis, the vasculature is often friable and located close to the surface. Patients presenting with head and neck cancers often have comorbidities, with both smoking and alcohol being major risk factors for the disease.<sup>27</sup> In light of these reasons, we would suggest that diving should be deferred until after treatment with a thorough diving medicine review required following recovery.

Radiation therapy is a cornerstone in the treatment of head and neck cancer.<sup>28</sup> However, this therapy is not devoid of adverse effects. Strategies have been developed to avoid vital organs such as the brain, eyes, and pituitary gland, but no such strategies exist for preventing damage to the middle ear.<sup>29</sup> Edema following radiotherapy has been shown to cause transient eustachian tube dysfunction and otitis media. If a patient was generally fit after head and neck cancer treatment, we would suggest review by an otolaryngologist to exclude middle ear pathology that would impair the patient from equalizing their middle ear pressures and preclude them from diving. Moreover, late effects from radiotherapy can lead to significant edema and fibrosis of the airway, and some chemotherapeutic agents can cause pulmonary fibrosis. All these factors need to be taken into account for consideration of whether an individual is eligible for diving or not.

## Conclusions

Otorhinolaryngological conditions and complications caused by diving are very common, and comprehensive knowledge about the different conditions and their differential diagnoses are a cornerstone for appropriate management. This review provides an overview of the guidelines on fitness to dive with otorhinolaryngological condi-

tions from various societies and regulatory bodies, discussing the issues pertinent to return to diving after middle ear and inner ear barotrauma.

The review allows the reader to compare these guidelines and displaying that they are relatively uniform. Conditions that are not covered by any of the guidelines, namely the rhinological, laryngological, and head and neck cancer related, are discussed separately with recommendations suggested by the authors.

### ARTICLE INFORMATION

**Accepted for Publication:** October 8, 2017.

**Published Online:** February 15, 2018.  
doi:10.1001/jamaoto.2017.2616

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**Author Contributions:** Drs Lechner and Sutton had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Drs Lund and Rubin are joint last authors.

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**Obtained funding:** Lechner, Sutton, Fishman, Masterson, Rubin.

**Administrative, technical, or material support:** Lechner, Sutton, Fishman, Masterson, Rubin.

**Study supervision:** Lechner, Sutton, Fishman, Moon, Lund, Rubin.

**Conflict of Interest Disclosures:** All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

**Additional Contributions:** We would like to thank Carl Edmonds, MD, of the Diving Medical Centre and Royal Australian Navy School of Underwater Medicine (Sydney, Australia) for his invaluable advice and comments on this article; and Dr Lechner would like to personally thank Pieter Bothma, MBChB, Medical Director of the London Hyperbaric Unit (London, England), as well as Adel Taher, MD, Medical Director of the Hyperbaric Center (Sharm-el-Sheikh, Egypt), for their training and mentorship in diving and hyperbaric medicine. They were not compensated for their contributions.

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