Review articles

Rhinologic and oral-maxillofacial complications from scuba diving: a systematic review with recommendations

Devon M Livingstone, Beth Lange

Division of Otolaryngology – Head and Neck Surgery, Department of Surgery; University of Calgary, Calgary, Alberta, Canada

Corresponding author: *Devon Livingstone, Division of Otolaryngology – Head and Neck Surgery, Department of Surgery, University of Calgary, 7th floor, 4448 Front Street SE, Calgary, Alberta, Canada, T3M 1M4*

devonlivingstone@gmail.com

Key words

Dental; ENT; Rhinolog*; Barotrauma; Treatment; Review article

Abstract

(Livingstone DM, Lange B. Rhinologic and oral-maxillofacial complications from scuba diving: a systematic review with recommendations. Diving and Hyperbaric Medicine. 2018 June;48(2):79–83. doi: 10.28920/dhm48.2.79-83. PMID: 29888379.)

Rhinologic and oral maxillofacial complications from scuba diving are common, representing approximately 35% of head and neck pathology related to diving. We performed a systematic and comprehensive literature review on the pathophysiology, diagnosis, and treatment of rhinologic and oral maxillofacial pathology related to diving. This included complications due to sinus barotrauma, barodontalgia, odontocrexis, temporomandibular joint dysfunction, partially dentulous patients, and considerations for patients following major head and neck surgery. Of 113 papers accessed, 32 were included in the final synthesis. We created a succinct summary on each topic that should inform clinical decision making by otolaryngologists, dive medicine specialists and primary care providers when faced with pathology of these anatomic sub-sites.

Background

Scuba diving-related injuries in the head and neck are extremely common, and account for 80% of all diving injuries.[1] Approximately 35% of all dive-related head and neck complications occur in rhinologic and oral maxillofacial sub-sites.[2] Despite the prevalence and importance of injuries to these regions, it has been 25 years since the last comprehensive review of the topic.[3] Typically, dive injuries occur due to perturbations of normal physiology according to Boyle's Law, resulting in barotrauma, and Henry's Law, resulting in decompression sickness (DCS). The physics and implications of these laws are outlined in detail elsewhere.[4] The purpose of this report is to systematically review the published literature evaluating scuba diving physiology and complications related to rhinologic and oral maxillofacial sub-sites and provide a resource with evidence-based recommendations where possible.

Method

A systematic review of the literature was performed through a search of the following databases: Ovid/Medline, PubMed, EMBASE, UpToDate, Rubicon Repository, *Diving and Hyperbaric Medicine* publications, and the Cochrane Review Database up to September 2017. A screening literature search was used to identify all literature discussing scuba diving and any otolaryngology topics. Search terms included: "*SCUBA*" and/or "*diving*", and "*head and neck*", "*otolaryngolog**", "*otolog**" "*rhinolog**", "*sinus surgery*" or "*laryngolog**". Reference lists of identified publications were reviewed to ensure no relevant studies in this field were missed. 'Grey' literature, including the Diver's Alert Network online resources, was also queried for completeness. Inclusion criteria included any full text paper discussing scuba diving as it relates to rhinologic and oral maxillofacial anatomic subsites at any level of evidence (LOE). Exclusion criteria included papers that were not available in English or in an English translation.

The combined search resulted in a total of 398 abstracts to be reviewed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[5] Two-hundred-eighty-five abstracts were excluded due to duplications, leaving 113 abstracts to be reviewed. Nineteen abstracts were excluded, as they were not available full text or not available in English. Two were excluded because the topic did not include scuba diving. Sixty-nine were excluded as they solely discussed otology-related topics. This left a total of 23 articles that met the criteria of including both scuba diving and rhinology and oromaxillofacial topics. The works cited section of these articles were reviewed, in combination with discussion with experts in the field, and 12 additional studies were identified.

Results and discussion

A total of 32 articles were relevant to rhinologic and oromaxillofacial complications from diving, and were included in the study. There were no systematic reviews, metanalyses or randomised controlled trials found.

RHINOLOGIC PATHOLOGY AND COMPLICATIONS

Disorders of the nose and paranasal sinuses affect up to 18% of divers seeking outpatient ENT consultation.[6] Current evidence shows that chronic rhinosinusitis exists in greater frequency amongst divers, with one group finding an incidence of 11% among divers who presented for otolaryngological assessment.[6] However, study of 76 commercial divers did not show a correlation between radiographic sinus opacification and length of service,[7] albeit a finding of uncertain significance considering the poor sensitivity of plain film sinus radiography. Baseline paranasal sinus mucosa thickness may be greater among divers for uncertain reasons, even among those who have not experienced sinonasal barotrauma; for instance, mucosal hypertrophy was significantly more common among 79 recreational divers in comparison with case-matched controls (42% versus 23%).[8] This may represent thickening due to subclinical dysbaric stress placed on the sinus mucosa. Importantly, these divers were asymptomatic, despite the thickened mucosal lining, and the clinical significance of this finding is uncertain.[8]

Sinus barotrauma

Sinus barotrauma occurs in association with sinus outflow obstruction in the setting of rapidly changing ambient pressure. Sinus obstruction can occur due to many sinonasal pathologies but is most commonly related to acute or chronic rhinosinusitis. The first major series of sinus barotrauma from diving included 50 cases in an Australian Navy environment.[9] In this series of military divers, pain on descent was the predominant symptom in all cases, and in three-quarters of cases on ascent. Epistaxis was the second most common symptom occurring in over half the divers. There was also a strong association with middle ear barotrauma, which occurred in about half the cases.[9] Another series of 50 more severe cases in recreational divers, was self-selected owing to persistent symptoms after diving.[10] Four of these latter 50 divers experienced a dramatic popping sensation at depth, which may have represented haemorrhagic stripping of mucosa of the paranasal sinuses.[4]

The magnitude of barotrauma an individual will experience is related to the size of the sinus ostia, cavities and rate of ambient pressure change. When the sinus mucosal lining of a diver is subjected to a relative vacuum during descent, mucosal oedema, serosanguinous exudation and submucosal haematoma formation may occur.[4] Divers may experience pain, epistaxis and neuralgia within distribution of the maxillary division of the trigeminal nerve. Barotrauma may be limited to specific paranasal sinuses, resulting in a specific subset of symptoms. For example, isolated sphenoidal sinus barotrauma may present with retro-orbital/occipital pain with the absence of significant nasal secretions.[11] The optic nerve can also be affected; one diver experienced blindness due to compression of the optic nerve by a sphenoid sinus mucocoele.[12] Forced Valsalva at depth may also cause cranialisation of pus (and/or air) when diving with acute or chronic rhinosinusitis.[13] Barotraumatic orbital emphysema has been reported in breathhold and scuba divers, which likely tracked through an area of dehiscent *lamina papyracea*.[14,15] Thus, epidural abscess and empyema can occur, and these patients must be followed closely.

Sinus barotrauma may also occur on ascent. As gas expands within an obstructed sinus cavity, vascular compromise leading to mucosal necrosis, and sinus wall fracture leading to pneumocephalus, periorbital/orbital emphysema and meningitis may occur.[15,36] Ischaemic neuropraxia of the maxillary branch of the trigeminal nerve within the maxillary sinus[16] and of the posterior superior branch of the alveolar nerve may also occur, leading to numbness of the ipsilateral teeth, gums, and oral mucosa.[4] It is important to ask about any previous orbital or sinus trauma, in addition to symptoms of chronic rhinosinusitis, as any blocked sinus ostia could generate a closed cavity with potential for barotrauma.[17]

The most important method for prevention of paranasal sinus barotrauma in diving is abstention from diving during an upper respiratory infection, particularly sinusitis or rhinitis.[11] Topical or systemic vasoconstriction is typically contraindicated for 12 h before diving to prevent a rebound congestion and consequent barotrauma during the dive. Patients that present to an otolaryngologist for follow-up after suffering from sinus barotrauma should undergo a thorough endoscopic examination to rule out predisposing anatomic factors, such as septal deviation or nasal polyposis. Computer-aided tomography of the sinuses may be performed to establish persistent sinonasal disease after suffering barotrauma or to rule out pre-existing anatomic factors. Magnetic resonance imaging (MRI) using T1 and T2-weighted imaging can be useful to differentiate blood from mucosal thickening.[18] Endoscopic sinus surgery may be required in patients who have experienced recurrent sinus barotrauma or among those who remain symptomatic despite medical therapy.[19] Among the series of 50 Australian recreational divers published in 1994, six required operative intervention, "*such as sinus … and/or nasal surgery, often with excellent results*".[10]

Treatment of sinus barotrauma is based on the presenting symptoms. Medical therapy can include saline irrigations, use of decongestants, as well as topical and oral corticosteroids.[19] Intractable pain despite maximal medical therapy may require operative intervention, and should be guided by imaging and a thorough endoscopic in-office examination. Divers may return to diving within six weeks provided imaging demonstrates resolution of sinus opacification and any underlying predisposing factors have resolved (i.e., sinonasal polyposis, coexistent infection or inflammation).[15] These divers should test for pressure-induced headache in a swimming or dive pool at a depth of at least 3 m before resumption of diving activities.[15] Comorbid chronic rhinosinusitis should be treated by an experienced otolaryngologist to ensure maximal patency of sinus ostia, in order to prevent further episodes. Prevention remains the most important clinical consideration, and patients should endeavor to avoid smoking and other nasal irritants, adopt a feet-first position on descent, and utilize frequent and appropriate equalization techniques.[4] Patients presenting with sinus barotrauma will benefit from a thorough otologic assessment to rule out concurrent otologic complications, such as middle or inner ear barotrauma, which can be guided by information contained in a separate review.[20]

ORAL AND MAXILLOFACIAL PATHOLOGY AND COMPLICATIONS

Barodontalgia

Barodontalgia refers to dental pain due to fluctuations in ambient pressure. It has been reported in divers at depths of 10 m (202 kPa) or less.[21] This condition is the most common dental symptom experienced during a dive, with maxillary teeth more frequently involved than mandibular teeth.[22] A 2016 online survey of recreational divers reported that 41% of respondents had experienced dental symptoms at some point during dives.[22] Dry mouth is also extremely common both during and after diving, which may exacerbate pain due to caries.[23] Treatment is aimed at the underlying source of odontalgia, including removal of dental caries, diseased tooth pulp and dental extractions when appropriate. As noted previously, compression of the second branch of the trigeminal nerve from maxillary sinus pathology can also cause odontalgia when diving and should be included in a clinician's differential diagnosis.

Odontocrexis and dysbaric osteonecrosis

Odontocrexis refers to fracture of teeth during ascent or descent. Most often this occurs in teeth that have undergone dental restorations. Air may become trapped at the porcelain metal interface among patients undergoing endodontic procedures. Certain dental cements may also contain microbubbles, specifically crowns luted with zinc phosphate and glass ionomer cements, leading to decreased retentive strength.[37] These cements may undergo volumetric contraction and microleakage, though hyperbaric environments do not seem to promote dental alloy corrosion *in vitro*.[38] Resin cements are relatively unaffected by pressure changes and are advocated among those who undergo exposure to rapid fluctuations in pressure, including divers.[16,39] Repetitive diving may also affect retentive strength of dental adhesives; fibre reinforced composite cements have been shown to have higher strength in comparison with titanium and Zirconia-based cements following simulated dives.[39] Dissolved zinc ions can also be released from low gold content dental alloys in hyperbaric environments, with potential toxicity. High gold content dental alloys are thus advocated among high activity divers.[38] A 2014 survey of 520 Swiss divers and caisson workers demonstrated a prevalence of odontocrexis of 6.3%.[24] Gas emboli due to DCS can theoretically infarct the end arteries within mandible or maxilla causing dysbaric osteonecrosis, though no such cases have yet been reported.[16]

Temporomandibular joint (TMJ) dysfunction (TMD)

Diving regulator mouthpieces are typically silicone rubber and are held in place by a bite platform between incisor and canine occlusion. Typically, the mandible must be positioned anteriorly to properly position the regulator, leading to uneven loading of the TMJ.[16] The lip flanges of the mouthpiece may also cause local gingival irritation, apthous ulceration and trauma. Symptoms of TMD related to diving include pain and fatigue in the TMJ and muscles of mastication, TMJ crepitus or clicking, headache and tinnitus.

Fatigue of the muscles of mastication is common during repetitive recreational diving due to the requirement for prolonged isometric contraction to retain the mouthpiece. MRI studies have demonstrated excessive retrodiscal stress within the TMJ using regulator mouthpieces, leading to worsened TMD.[25] Risk factors for TMD include female gender,[26] inexperience with diving,[27] whilst there is conflicting evidence as to whether cold-water or warm-water diving puts you at greater risk.[28,29] Bruxism also appears to be risk factor, and masticatory occlusal activity may be greater with softer mouthpieces.[26] Other risk factors include clenching, biting on the mouthpiece and a poor-quality mouthpiece.[29] Excessive occlusal pressure on a mouthpiece can also cause non-barotraumatic tooth fracture.[30] Exacerbation of pre-existing TMD is likely. Referred otalgia is common and should not be mistaken for otologic barotrauma.

Custom mouthpieces are recommended for divers with TMD to optimize underwater occlusal forces.[16] There seems to be no significant difference among currently available commercially produced mouthpieces among patients with TMD.[31] Mouthpiece design has been refined to the point that diving may simply be exacerbating pre-existing TMD, rather than causing new cases.[28] Current recommendations include a mouthpiece with an interdental bite platform with a thickness of less than 4 mm and a width less than 8 mm.[27] The interdental bite platform width also affects efficiency of air movement through the regulator, and should be considered in technical diving applications.[32] Cephalometric radiographs assessing jaw position is a useful adjunct in custom mouthpiece design.[33] Conservative treatment measures include a soft diet, massage and moist heat application during surface intervals between dives. Consideration can also be given to non-sedating oral muscle relaxants and anti-inflammatory medications.[27]

Edentulous/partially dentulous patients

Complete or partial, removable dentures can be a hazard in diving with conventional mouthpieces, though removal of dentures prior to diving is not necessarily required. There have been documented cases of fatal aspiration from a dislodged dental prosthesis during dives.[34] Custom mouthpieces can be fabricated to be retained by edentulous arches. Alternatively, patients may opt for meticulously maintained fixed prostheses or implants. Osseointegrated implants are solid and not at risk for pressure related damage.[16]

Head and neck surgery

Three patients were reported to have successfully returned to diving after extensive head and neck reconstructive surgery. Individual case-by-case assessment involving dive medicine and surgical consultation is essential in such circumstances.[35]

Conclusion

Scuba diving holds significant potential for complications affecting rhinologic and oral-maxillofacial anatomic sub sites. Otolaryngologists and dive medicine specialists should have a thorough understanding of the pathophysiology, treatment and fitness to dive implications of disorders of the head and neck as they relate to diving. The recommendations within this review should be considered in the context of each individual patient.

References

1 Klingmann C, Praetorius M, Baumann I, Plinkert PK. Barotrauma and decompression illness of the inner ear: 46 cases during treatment and follow-up. Otol Neurotol. 2007;28:447–54. doi: 10.1097/MAO.0b013e318030d356. PMID: 17417111.

2 Roydhouse N. 1001 disorders of the ear, nose and sinuses in scuba divers. Can J Appl Sport Sci. 1985;10:99–103. PMID: 4017159.

3 Roydhouse N. Underwater ear and nose care. Flagstaff AZ: Best Publishing Co; 1993. p. 116.

4 Edmonds CB, Bennett M, Lippmann J, Mitchell S, editors. Diving and subaquatic medicine, 5th ed. Florida: CRC Press; 2015. p. 865.

5 Foster RL. Reporting guidelines: CONSORT, PRISMA, and SQUIRE. J Spec Pediatr Nurs. 2012;17:1–2. doi: 10.1111/j.1744-6155.2011.00319.x. PMID: 22188266.

6 Klingmann C, Praetorius M, Baumann I, Plinkert PK. Otorhinolaryngologic disorders and diving accidents: an analysis of 306 divers. Eur Arch Otorhinolaryngol. 2007;264:1243–51. doi: 10.1007/s00405-007-0353-6. PMID: 17639445.

7 Taniewski M, Graczyk M, Laba L. Mucous membrane of the nose and paranasal sinuses in professional divers. Bull Inst Marit Trop Med Gdynia. 1979;30:237–44. PMID: 548146.

8 Sonmez G, Uzun G, Mutluoglu M, Toklu AS, Mutlu H, Ay H, et al. Paranasal sinus mucosal hypertrophy in experienced divers. Aviat Space Environ Med. 2011;82:992–4. PMID: 21961405.

9 Fagan P, McKenzie B, Edmonds C. Sinus barotrauma in divers. Ann Otol Rhinol Laryngol. 1976;85(1 Pt 1):61–4. PMID: 1078539.

10 Edmonds C. Sinus barotrauma: a bigger picture. SPUMS Journal. 1994;24:13–9.

11 Bourolias C, Gkotsis A. Sphenoid sinus barotrauma after free diving. Am J Otolaryngol. 2011;32:159–61. doi: 10.1016/j.amjoto.2009.10.005. PMID: 20022669.

12 Mowatt L, Foster T. Sphenoidal sinus mucocele presenting with acute visual loss in a scuba diver. BMJ Case Rep. 2013 Aug 20;2013. Epub 2013/08/22. doi: 10.1136/bcr-2013-010309. ; PMCID: PMC3761784.

13 Parell GJ, Becker GD. Neurological consequences of scuba diving with chronic sinusitis. Laryngoscope. 2000;110:1358–60. doi: 10.1097/00005537-200008000-00026. PMID: 10942141.

14 Bolognini A, Delehaye E, Cau M, Cosso L. Barotraumatic orbital emphysema of rhinogenic origin in a breath-hold diver: a case report. Undersea Hyperb Med. 2008;35:163–7. PMID: 18619111.

15 Becker GD, Parell GJ. Barotrauma of the ears and sinuses after scuba diving. Eur Arch Otorhinolaryngol. 2001;258:159–63. PMID: 11407445.

16 Brandt MT. Oral and maxillofacial aspects of diving medicine. Mil Med. 2004;169:137–41. PMID: 15040636.

17 Chua DY, Lo S. Orbital fracture in a professional diver: issues and management. J Maxillofac Oral Surg. 2015;14(Suppl 1):81–3. Epub 2015/04/04. doi: 10.1007/s12663-011-0315-9. PMID: 25838675. PMCID: PMC4379266.

18 Zimmerman RA, Bilaniuk LT, Hackney DB, Goldberg HI, Grossman RI. Paranasal sinus hemorrhage: evaluation with MR imaging. Radiology. 1987;162:499–503. doi: 10.1148/radiology.162.2.3797665. PMID: 3797665.

19 Skevas T, Baumann I, Bruckner T, Clifton N, Plinkert PK, Klingmann C. Medical and surgical treatment in divers with chronic rhinosinusitis and paranasal sinus barotrauma. Eur Arch Otorhinolaryngol. 2012;269:853–60. doi: 10.1007/s00405-011-1742-4. PMID: 21901337.

20 Livingstone DM, Smith KA, Lange B. Scuba diving and otology: a systematic review with recommendations on diagnosis, treatment and post-operative care. Diving Hyperb Med. 2017;47:97–109. doi: 10.28920/dhm48.2.97-109. PMID: 28641322.

21 Lyons KM, Rodda JC, Hood JA. Barodontalgia: a review, and the influence of simulated diving on microleakage and on the retention of full cast crowns. Mil Med. 1999;164:221–7. PMID: 10091498.

22 Ranna V, Malmstrom H, Yunker M, Feng C, Gajendra S. Prevalence of dental problems in recreational SCUBA divers: a pilot survey. Br Dent J. 2016;221:577–81. Epub 2016/11/05. doi: 10.1038/sj.bdj.2016.825. PMID: 27811894.

23 Yousef MK, Ibrahim M, Assiri A, Hakeem A. The prevalence of oro-facial barotrauma among scuba divers. Diving Hyperb Med. 2015;45:181–3. PMID: 26415069.

24 Zanotta C, Dagassan-Berndt D, Nussberger P, Waltimo T, Filippi A. Barodontalgias, dental and orofacial barotraumas:

a survey in Swiss divers and caisson workers. Swiss Dent J. 2014;124:510–9. PMID: 24853026.

25 Balestra C, Germonpré P, Marroni A, Snoeck T. Scuba diving can induce stress of the temporomandibular joint leading to headache. Br J Sports Med. 2004;38:102. PMID: 14751960. PMCID: PMC1724751.

26 Koob A, Ohlmann B, Gabbert O, Klingmann C, Rammelsberg P, Schmitter M. Temporomandibular disorders in association with scuba diving. Clin J Sport Med. 2005;15:359–63. PMID: 16162996.

27 Ozturk O, Tek M, Seven H. Temporomandibular disorders in scuba divers-an increased risk during diving certification training. J Craniofac Surg. 2012;23:1825–9. doi: 10.1097/SCS.0b013e3182710577. PMID: 23147349.

28 Aldridge RD, Fenlon MR. Prevalence of temporomandibular dysfunction in a group of scuba divers. Br J Sports Med. 2004;38:69–73. PMID: 14751950. PMCID: PMC1724734.

29 Lobbezoo F, van Wijk AJ, Klingler MC, Ruiz Vicente E, van Dijk CJ, Eijkman MA. Predictors for the development of temporomandibular disorders in scuba divers. J Oral Rehabil. 2014;41:573–80. Epub 2014/04/29. doi: 10.1111/joor.12178. PMID: 24766672.

30 Gunepin M, Zadik Y, Derache F, Dychter L. Non-barotraumatic tooth fracture during scuba diving. Aviat Space Environ Med. 2013;84:630–2. Epub 2013/06/12. PMID: 23745293.

31 Hobson RS. Temporomandibular dysfunction syndrome associated with scuba diving mouthpieces. Br J Sports Med. 1991;25:49–51. PMID: 1913032. PMCID: PMC1478804.

32 Hobson RS. Airway efficiency during the use of SCUBA diving mouthpieces. Br J Sports Med. 1996;30:145–7. PMID: 8799600. PMCID: PMC1332379.

33 Hobson RS, Newton JP. Dental evaluation of scuba diving mouthpieces using a subject assessment index and radiological analysis of jaw position. Br J Sports Med. 2001;35:84–8. PMID: 11273967. PMCID: PMC1724303.

34 Stein WE. Diving and dentistry. Northwest Dent. 1991;70:21–3. PMID: 1815192.

35 Thiele OC, Knape U, Mischkowski RA, Kreppel M, Rothamel D, Zoller JE. Scuba diving after extensive head and neck reconstructive surgery: is it possible? J Craniofac Surg. 2016;27:e225–7. Epub 2016/03/12. doi: 10.1097/SCS.0000000000002331. PMID: 26967102.

36 Tseng W, Lee H, Kang B. Periorbital emphysema after a wet chamber dive. Diving Hyperb Med. 2017;47:198–200. PMID: 28868601.

37 Gulve M, Gulve N, Shinde R, Kolhe S. The effect of environmental pressure changes on the retentive strength of cements for orthodontic bands. Diving Hyperb Med. 2012;42:78–81. PMID: 22828814.

38 Mehl C, Heblich F, Lenz R, Ludwig K, Kern M. The influence of hyperbaric environment and increased oxygen partial pressure on the corrosion of gental alloys. Diving Hyperb Med. 2011;41:151–5. PMID: 21948501.

39 Mitov G, Draenert F, Schumann P, Sotzer M, von See C. The influence of pressure changes on the retentive force and coronal microleakage of different types of posts in endodontically treated teeth during simulated dives. Diving Hyperb Med. 2016;46:247–52. PMID: 27966204.

Conflicts of interest and funding: nil

Submitted: 19 December 2017; revised 01 and 31 March 2018
Accepted: 28 April 2018