EVIDENCE WORKSHEET
Guideline 9.3.5: Resuscitation of Divers who have used Compressed Gas

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Clinical question:

1. Does any intervention (I), compared to usual first-aid care (C) improve outcomes (O) for patients with a suspected diving related illness?(P)

Search Strategies:

A. The Cochrane Library (CDSR, CENTRAL, DARE)

1. ((diving medicine) OR (diving illness) OR (decompression sickness) OR (pulmonary barotrauma)).tw
2. Decompression sickness/exp
3. 1 OR 2
4. Emergency treatment / exp
5. 3 AND 4

B. MEDLINE (1950 – current)

1. exp decompression sickness
2. (decompression AND (sickness OR illness)).ti,ab
3. (diving and (emergenc$ or medicine)).ti,ab.
4. OR/1-3
5. exp emergency treatment
6. 4 AND 5

C. EMBASE

1. ‘decompression sickness’/exp OR ‘decompression sickness’ OR ‘lung barotrauma’/exp OR ‘lung barotrauma’ OR ‘diving’/exp
2. ‘emergency treatment’/exp OR ‘first aid’/exp OR ‘first aid’ OR ‘emergency patient’/exp
3. 1 AND 2

Databases / sources searched:

In addition to the electronic databases detailed above, backward and forward searching was undertaken in Scopus, hand-searching of reference lists of relevant articles, text-word based grey literature searches in Google Scholar and searches of Sydney University library for relevant books. A useful resource for diving medicine can be found at:
The Rubicon Research Repository (Diving Medicine Library)
http://archive.rubicon-foundation.org/dspace/index.jsp

Inclusion / exclusion criteria:

Due to the paucity of evidence available, any study (case-series, non-controlled cohorts, controlled studies, systematic reviews) examining interventions used in the first-aid or immediate emergency treatment of divers were retrieved for further review. Letters, editorials, individual case studies, papers not available in full or not available in English were excluded.

Search results: The combined searches outlined above yielded 35 studies, these papers were retrieved and assessed for inclusion as evidence.

Number of papers / studies meeting criteria for further review: 3

One LOE III-2 trial provided clinical evidence for the guideline. One further animal study and one computer modelling study (neither meeting the NHMRC criteria for classification as evidence for an intervention) were also used to support the guideline construction.

Level of Evidence	Definitions	Study
I	Evidence obtained from a systematic review of all relevant randomised controlled trials	
II	Evidence obtained from at least one properly designed randomised controlled trial	
III-1	Evidence obtained from well designed properly pseudo-randomised controlled trials (alternate allocation or other method)	
III-2	Evidence obtained from comparative studies with concurrent controls and allocation not randomised (cohort studies), case control studies, or interrupted time series with a control group	**Longphre et al 2007**
III-3	Evidence obtained from comparative studies with historical control, two or more single arm studies, or interrupted time series without a parallel control group	
IV	Evidence obtained from case series, either post-test or pre-test and post-test	
Extrapolated evidence	Animal, manikin etc	**Hyldegaard et al 1991** **Acott & Doolette 2002**

Methodological quality, levels of evidence & outcomes of studies examining the first aid management of the ill or injured diver		
Good The methodological quality of the study is high with the likelihood of any significant bias being minimal	**Fair** The methodological quality of the study is reasonable with the potential for significant bias being likely.	**Poor** The methodological quality of the study is weak possessing considerable and significant biases

1.Studies *supportive* of the use of oxygen for the first aid management of divers:

Good				Longphre 2007 E			
Fair							Acott & Doolette 2002 E Hyldegaard 1991 E
Poor							
	I	**II**	**III-1**	**III-2**	**III-3**	**IV**	**Extrapolated evidence**
	NH&MRC levels of evidence						

2.Studies with *neutral* findings for the use of oxygen for the first aid management of divers:

Good							
Fair							
Poor							
	I	**II**	**III-1**	**III-2**	**III-3**	**IV**	**Extrapolated evidence**
	NH&MRC levels of evidence						

3.Studies with *negative* findings for the use of oxygen for the first aid management of divers:

Good							
Fair							
Poor							
	I	**II**	**III-1**	**III-2**	**III-3**	**IV**	**Extrapolated evidence**
	NH&MRC levels of evidence						

Endpoints:

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = other endpoint

Class of recommendation:

Class A: The early and continued administration of high flow oxygen should be considered in any suspected diving accident victim. If resuscitation is required, the principles outlined in Guideline 8: Cardiopulmonary resuscitation should be followed.

Reviewer's final comments and assessment of benefit / risk:

No high level clinical evidence exists supporting the use of any intervention specific to the immediate, on scene first aid management of an ill or injured diver. One good quality LOE III-2 retrospective chart review (Longphre 2007) (n=2231) found that the use of oxygen in the immediate management of diving injuries was associated with a reduction in the number of recompression treatments required and an increase in the relief or improvement of symptoms.
One small (n=18), fair quality comparative animal study (Hyldegaard 1991) reported that breathing either oxygen or heliox reduced the number and size of bubbles in spinal white matter more quickly than air.
One fair quality computer simulation study, modelling different resuscitation strategies on near-drowning in divers (Acott 2002) reported a reduction in risk of DCI if oxygen is used early in the resuscitation of diving accident patients.

Citation List:

Acott C, Doolette DJ. Simulation sof near-drowning and decompression sickness: a preliminary study. ***Sth Pac Underwater Med Soc J.*** **2002;32(1):35-40**
Theoretically near-drowning should decrease inert gas elimination from tissues by a reduction in cardiac output and increased intrapulmonary shunting. A delay in inert gas elimination may prolong tissue super-saturation and so increase the risk of decompression sickness (DCS). However, there are no data on inert gas elimination or the incidence of decompression sickness in near-drowned compressed air divers. Resuscitation might also retard inert gas elimination because of the adverse cardiovascular effects of intermittent positive pressure ventilation (IPPV) and positive end expiratory pressure (PEEP).
Decompression modelling using Linear-exponential kinetics of near-drowning scuba dive accident scenarios have shown an increased risk of DCS for no-stop dives to above the acceptable level of risk of 2.3% used the US Navy. Modelling of resuscitation following near-drowning demonstrated that there is no further increase in DCS risk provided the cardiac output was normal before IPPV and PEEP were instituted.
All compressed air divers who have near-drowned, except those who have a minimum disturbance of shunt and cardiac output, should be carefully assessed with regard to decompression risk and treated appropriately. Divers who have been resuscitated from a cardiac arrest or who are severely shocked at presentation should be recompressed because the risk of decompression sickness is increased to between 25 – 52%.
Extrapolated evidence from a computer simulated model of near-drowning diving scenarios. Reports increased risk of DCI in divers who have been resuscitated and decreased risk of DCI if oxygen is administered promptly.

Hyldegaard O, Moller M, Madsen J. Effect of He-O_2, O_2 and N_2O-O_2 breathing on injected bubbles in spinal white matter. ***Undersea Biomed Res.*** **1991;18(5-6):361-70**
Injected air bubbles in spinal white matter in the rat were studied at 1 bar after decompression from an exposure to air at 3.1 bar (absolute) for 4 hours. During air breathing all injected bubbles grew for the first two hours of the observation period. Thereafter 3 of the 9 bubbles began to shrink and one of them disappeared. During

breathing heliox (80:20) bubbles consistently shrank and disappeared from view. If the breathing gas was changed from heliox to N2O-O2 (80:20), while the bubbles still had an appreciable size, they started growing again. If the change to NO2-O2 was done after the bubbles disappeared from view, they did not reappear. During breathing of 100% oxygen, all bubbles initially grew. Subsequently they all shrank and disappeared at about the same time after gas shift, as during heliox breathing. The effect of heliox treatment on CNS decompression sickness is discussed.
Extrapolated evidence from a small (n=18) study of the effect of breathing either air, heliox or 100% oxygen on the rate of disappearance of bubbles injected in the spinal white matter of the rat. For air breathing, only 1/9 bubbles disappeared in 4h observation time, when the rats breathed heliox or 100% oxygen all 9 bubbles disappeared within 104 minutes. The generalisability of the study to DCI in humans is questionable, due to the small size and the use of a rat model.

Longphre JM, Denoble PJ, Moon RE, Vann RD, Freiberger JJ. First aid normobaric oxygen for the treatment of recreational diving injuries. *Undersea Hyperbaric Med.* 2007;34(1):43-9
INTRODUCTION: First aid oxygen (FAO_2) has been widely used as an emergency treatment for diving injuries, but there are few studies supporting its efficacy. METHODS: 2,231 sequential diving injury reports collected by the Divers Alert Network (DAN) Injury database from 1998 to 2003 were examined. RESULTS: 47% (1,045) of cases received FAO_2. The median time to FAO_2 treatment after surfacing was four hours and after symptom onset was 2.2 hours. Persistent complete relief (14%) or improvement (51%) was seen with FAO_2 alone (65% overall response; n = 330). After one recompression treatment 67% of FAO_2 patients reported complete relief compared to 58% of the no FAO_2 group (OR = 1.5, 95% CI = 1.2 -1.8). FAO_2 given at any time after surfacing significantly reduced the odds of multiple recompression treatments (OR = 0.83, 0.70-0.98). When FAO_2 was given within 4 hours of surfacing, the OR decreased to 0.50 (0.36-0.69) yielding a number needed to treat of 6. Case severity affected urgency of FAO_2 treatment. Individuals with more prominent symptoms received prompt treatment. Cardiopulmonary, skin, and serious neurological symptoms had shorter delays to FAO_2 ($p < 0.001$). CONCLUSIONS: FAO_2 increased recompression efficacy and decreased the number of recompression treatments required if given within four hours after surfacing.
LOE *III-2 retrospective chart review of 2231 diving injury reports from the Diver's Alert Network. Outcomes were compared between the cases that received any first aid inhaled oxygen therapy and those cases who did not receive oxygen. Patients who received oxygen were more likely to gain symptomatic relief from recompression treatment than those who did not receive oxygen, independent of the time to the initiation of oxygen therapy. Authors reported that patients with more severe symptoms were significantly more likely to receive oxygen therapy, but do not report the results of their stratified analysis, potentially leading to considerable bias.*

Review papers

Lippmann J. First aid oxygen administration for divers. ***South Pacific Underwater Med J.*** **2003;33(4):192-8**

Hypoxia in divers can result from a variety of causes, including decompression illness (DCI). The benefits of oxygen first aid in DCI are increased de-nitrogenation and improved oxygenation, and the sooner oxygen is provided the better the outcome. When oxygen is provided prior to recompression, symptoms may be relieved earlier, and there is a slightly lower chance of post-treatment residua. Despite this, DAN America data indicate that only 30 to 40% of injured divers receive oxygen. This provides an ongoing challenge for the diving community. There is a plethora of oxygen equipment available and careful consideration needs to be given when selecting appropriate equipment to manage a dive accident. Such equipment needs to easily provide high oxygen concentrations to responsive or unresponsive, breathing or non-breathing victims. The wide range of available devices all have advantages and disadvantages that need to be weighed against the required outcome. Important considerations include the oxygen concentrations that can be provided; the ease of use; the amount of training and practice required and the number of operators needed to use the device effectively.

Lynch JH, Bove AA. Diving Medicine: A Review of Current Evidence. ***J Am Board Fam Med.*** **2009: 22(4);399-407**

Recreational scuba diving is a growing sport worldwide, with an estimated 4 million sport divers in the United States alone. Because divers may seek medical care for a disorder acquired in a remote location, physicians everywhere should be familiar with the physiology, injury patterns, and treatment of injuries and illnesses unique to the underwater environment. Failure to properly recognize, diagnose, and appropriately treat some diving injuries can have catastrophic results. In addition, recreational dive certification organizations require physical examinations for medical clearance to dive. This article will review both common and potentially life-threatening conditions associated with diving and will review current evidence behind fitness to dive considerations for elderly divers and those with common medical conditions.

DeGorordo A, Vallejo-Manzur F, Chanin K, Varon J, Diving emergencies. ***Resuscitation*** **2003: 59(2);171-80**

Self-Contained Underwater Breathing Apparatus (SCUBA) diving popularity is increasing tremendously, reaching a total of 9 million people in the US during 2001, and 50,000 in the UK in 1985. Over the past 10 years, new advances, equipment improvements, and improved diver education have made SCUBA diving safer and more enjoyable. Most diving injuries are related to the behaviour of the gases and pressure changes during descent and ascent. The four main pathologies in diving medicine include: barotrauma (sinus, otic, and pulmonary); decompression illness (DCI); pulmonary edema and pharmacological; and toxic effects of increased partial pressures of gases. The clinical manifestations of a diving injury may be seen during a dive or up to 24 h after it. Physicians living far away from diving places are not excluded from the possibility of encountering diver-injured patients and therefore need to be aware of these injuries. This article reviews some of the principles of diving and pathophysiology of diving injuries as well as the acute treatment, and further management of these patients.