CG020 Diving Emergencies

<table>
<tr><th colspan="3">1a. Key Recommendations for operational use</th></tr>
<tr><td>1</td><td>Give Surface Oxygen</td><td>• Give continuous high flow oxygen by trauma mask IRRESPECTIVE OF S_PO_2.
• Improvement or resolution of signs and symptoms of decompression illness (DCI) whilst receiving oxygen does not preclude the need for hyperbaric treatment.</td></tr>
<tr><td>2</td><td>Recompression & Hyperbaric Oxygen</td><td>• Rapid transport to an NHS Scotland approved hyperbaric chamber is required for severe DCI or arterial gas embolism.</td></tr>
<tr><td>3</td><td>Other interventions</td><td>• Prolonged immersion: ensure horizontal extrication to avoid cardiovascular collapse.
• C-spine: unlikely to be a concern unless history of injury under, or whilst exiting, water. Neurological signs/symptoms are common in DCI.
• Lay flat: to limit cephalad migration of bubbles.
• Rehydrate: aim for one litre of fluid, oral or IV (two if prolonged transfer to definitive care):
- hypovolaemia is due to capillary leak (bubble injury), cold, immersion diuresis and pre-existing or exercise-related dehydration.
- rehydration aids dispersal of micro-bubbles and may improve outcome.
• Hypothermia: treat conventionally.</td></tr>
<tr><td>4</td><td>Information required</td><td>• History of incident dive:
- which breathing gas and any problems with supply; total dive time; maximum dive depth; dive profile (e.g. reverse; “sawtooth”); missed decompression/safety stops; uncontrolled ascent; buoyancy / equipment issues; other difficulties.
• Diving activity on incident and preceding days (surface intervals).
• Dive Computer (worn like a watch or connected to cylinder) and Dive Log should travel with diver for later interrogation.
• Photographs: consider taking photographs of any rash on the patient’s own telephone.
• Status of diving “buddies”.</td></tr>
<tr><td rowspan="5">5</td><td rowspan="5">Refer</td><td>• Discuss with the Duty Diving Doctor for Scotland (based in Aberdeen):
- 0345 408 6008 and ask for Hyperbaric Consultant on-call.</td></tr>
<tr><td>NHS Scotland approved hyperbaric chamber</td><td>Telephone</td></tr>
<tr><td>Aberdeen Royal Infirmary</td><td>0345 408 6008</td></tr>
<tr><td>Oban</td><td>01631 567500 (Lorn & Islands Hospital Switchboard)</td></tr>
<tr><td>Orkney</td><td>01856 888000 (Balfour Hospital Switchboard)</td></tr>
<tr><td colspan="2">• Patients will initially be seen and assessed in the Emergency Department.</td></tr>
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6	Transport	• Continue high flow oxygen **IRRESPECTIVE OF S_PO_2.** • Delay to hyperbaric treatment >6 hours is associated with worse outcomes from DCI. • Decreased atmospheric pressure associated with altitude can worsen DCI. • If fixed wing transfer is used pressurise cabin as near to sea level as possible. • Road transfers can also induce relevant altitude changes. • Balance urgency of transfer against safety aspects of a “minimum safe altitude” helicopter flight: - consider a route which avoids high ground. - discuss with Duty Diving Doctor if in doubt. • There is some evidence to suggest excessive vibration may increase nitrogen bubble load: - but this should not preclude helicopter transfer. • Transfers may be prolonged: - consider drugs / oxygen / batteries. - a ZX oxygen cylinder at 15l/min lasts 3hr 20min.
7	Be aware	• The diver’s “buddy” may be at risk of DCI: - discuss transporting them for a “bend watch” at the hyperbaric chamber with the Duty Diving Doctor. • Divers can suffer acute illness (e.g. AMI, drowning, immersion pulmonary oedema, SAH) or injury unrelated to the breathing of compressed gas which can trigger a diving incident and onset of barotrauma / DCI (or mimic these).
8	Considerations at scene	• Be mindful of tidal activity. • Other divers may provide a history and know how to remove equipment. • Most equipment has quick release buckles to facilitate removal. • Open circuit diving cylinders work with a demand regulator valve and are safe; lay them flat. Re-breather circuits are more complicated but safe. • In the event of the death of a diver at scene, ensure that all of the diver’s equipment, suit, weights, computer and log are preserved as evidence for Police Scotland.

1b. Diving Pathology		
1	Terminology of Diving Emergencies	• **Barotrauma**: Injury due to pressure-related volume changes of gas in enclosed spaces within, or adjacent to, the body on ascent or descent. • **Decompression Illness** (DCI) includes: - **Arterial Gas Embolism** (AGE). - **Decompression Sickness** (DCS; “Bends”; “caisson disease”). • AGE (escaped gas disease) and DCS (evolved gas disease) can coexist.
2	Non-Pulmonary Barotrauma	• Most commonly affects middle ear or sinuses. • Can be severe enough to distract diver from diving profile and precipitate a diving incident. • Inner ear barotrauma can mimic DCS.
3	Pulmonary Barotrauma	• Of ascent, is called Pulmonary Over-inflation Syndrome (POIS): - expansion of trapped gas in the airways leads to rupture within or outside the lungs. • Caused by: faulty equipment, breath-hold ascent or rapid ascent. • Leads to: pneumothorax, pneumomediastinum, surgical emphysema. • Can cause AGE if escaped gas embolises via pulmonary veins.
4	AGE	• DCI that presents <10 minutes after surfacing is probably AGE. • Caused by: POIS or DCS with a PFO. • Leads to: death (coronary artery embolism) or a major neurological presentation - confusion; loss of consciousness; seizure; stroke mimic; visual loss • May rapidly recover and then relapse. • Co-existing pulmonary barotrauma requires treatment.
5	DCS	• Inert gas (nitrogen) bubbles form in the tissues and circulation. • Caused by: a diving profile that prevents adequate off-gassing of absorbed inert gas during ascent. • Leads to: joint pains, loin or girdle pain, paraesthesia not consistent with nerve distribution, altered sensation, weakness, paralysis, ataxia, vertigo, nausea, undue fatigue, cognitive impairment, visual disturbance, skin rash, dyspnoea & haemoptysis (rare). • All neurological symptoms in divers are DCI until proven otherwise. • Symptoms almost always develop only after surfacing. Can be soon after or significantly delayed. 99% present within 48 hours of last dive. • Commonly occurs within “safe” diving limits: Variation between and within divers; multi-day diving (and multiple dives in one day) increases risk. • More likely with buoyancy problems, uncontrolled or rapid ascent, cold, dehydration, obesity, heavy workload or stress during dive.

6	Oxygen Toxicity	• Oxygen is toxic to the CNS and lungs and individual susceptibility varies. • PaO_2, duration of exposure and other factors are relevant. • Leads to: **VENTID-C** – Vision (blurred), Ears (Ringing), Nausea, Twitching, Irritability, Dizziness, Convulsions. • Likely presentation is an unconscious diver on the surface (major differential diagnosis is AGE) and much more likely if they have been breathing oxygen-enriched air mixture (e.g. Nitrox) than air. • Commonly leads to drowning or near drowning. • Continuous high flow oxygen by trauma mask is still indicated, is not harmful at surface pressures and will alleviate co-existing DCI.
7	Nitrogen Narcosis	• The narcotic effect of nitrogen increases with partial pressure of nitrogen in the tissues. • Onset when breathing air is usually at a depth between 30m and 40m but there is wide individual susceptibility. • Effects are similar to excess alcohol. • Relieved by ascent but may be the cause of a diving incident.

2. Document History			
Reference Number	CG020		
Version	1		
Writing group (Lead author in bold)	Roland Armes	Hyperbaric physician	ARI
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Distribution	BASICS Scotland		✓
	Referring centres via service websites		✓
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	ScotSTAR	EMRS West	✓
		EMRS North	✓
		Paediatric	X
		Neonatal	X
	Tayside Trauma Team		✓

3. Scope and purpose

- Overall objectives:

The aim of this guideline is to summarise management of diving related pathology, provide basic information as to those pathologies and some of practical aspects for dealing with divers.

- Statement of intent:

This guideline is not intended to be construed or to serve as a standard of care. Adherence to guideline recommendations will not ensure a successful outcome in every case, nor should they be construed as including all proper methods of care or excluding other acceptable methods of care aimed at the same results. The ultimate judgement must be made by the appropriate healthcare professional(s) responsible for clinical decisions regarding a particular clinical procedure or treatment plan.

- Feedback:

Comments on this guideline can be sent to: sas.cpg@nhs.scot

- Equality Impact Assessment:

Applied to the ScotSTAR Clinical Standards group processes.

- Guideline process endorsed by the Scottish Trauma Network Prehospital, Transfer and Retrieval group.

4. Explanatory statements		
4.1 Give Oxygen	**Authors' recommendation**	**Level [Reference]**
• Give continuous high flow oxygen by trauma mask **IRRESPECTIVE OF SPO_2**. • Improvement or resolution of signs and symptoms of decompression illness (DCI) whilst receiving oxygen does not preclude the need for hyperbaric treatment.	Strong	Guidelines [1,2]
4.2 Recompression & Hyperbaric Oxygen		
• Rapid transport to an NHS Scotland approved hyperbaric chamber is required for severe DCI or arterial gas embolism.	Strong	Guidelines [1,2]
4.3 Other interventions		
• Prolonged immersion: Ensure horizontal extrication to avoid cardiovascular collapse. • C-spine: Unlikely to be a concern unless history of injury under, or whilst exiting, water. Neurological signs/symptoms are common in DCI. • Lay flat: To limit cephalad migration of bubbles. • Rehydrate: aim for one litre of oral or IV fluid (two if prolonged transfer to definitive care): - hypovolaemia is due to capillary leak (bubble injury), cold, immersion diuresis and pre-existing or exercise-related dehydration. - rehydration aids dispersal of micro-bubbles and may improve outcome. • Hypothermia: treat conventionally.	Strong	Guidelines [1,2,3,5]
4.4 Information required		
• History of incident dive: - which breathing gas and any problems with supply; total dive time; maximum dive depth; dive profile (e.g. reverse; "sawtooth"); missed decompression/safety stops; uncontrolled ascent; buoyancy/equipment issues; other difficulties. • Diving activity on incident and preceding days (surface intervals). • Dive Computer (worn like a watch or connected to cylinder) and Dive Log should travel with diver for later interrogation. • Photographs: consider taking photographs of any rash on the patient's own telephone. *Photos of the skin rash are helpful as they tend to change over time and with treatment. Suit rash and suit squeeze can mimic DCI so pictures (preferably taken on the patient's own phone if happy to do so) may be helpful.* • Status of diving "buddies".	Strong	Guideline [4]

4.5 Refer		
• Discuss with the Duty Diving Doctor for Scotland (based in Aberdeen): - **0345 408 6008** and ask for **Hyperbaric Consultant** on-call.	GPP	
• Patients will initially be seen and assessed in the Emergency Department. *Patients are triaged and stabilised in ED first: ABCDE assessment, CXR, access, bloods etc and assessed by hyperbaric doctor prior to secondary transfer for recompression. An ambulant patient with ear barotrauma might require grommets (prior to chamber treatment).*	GPP	
4.6 Transport	**Authors' recommendation**	**Level [Reference]**
• High flow oxygen must be continued **IRRESPECTIVE OF SPO_2.** • Delay to hyperbaric treatment >6 hours is associated with worse outcomes from DCI. • Decreased atmospheric pressure associated with altitude can worsen DCI. • If fixed wing transfer is used pressurise cabin as near to sea level as possible. • Road transfers can also induce relevant altitude changes. • Balance urgency of transfer against safety aspects of a "minimum safe altitude" helicopter flight: - consider a route which avoids high ground. - discuss with Duty Diving Doctor if in doubt. • There is some evidence to suggest excessive vibration may increase nitrogen bubble load: - but this should not preclude helicopter transfer. • Transfers may be prolonged: - consider drugs / oxygen / batteries.	Strong	Guidelines [1,2,6,7,8]
4.7 Be aware		
• The diver's "buddy" may be at risk of DCI: - discuss transporting them for a "bend watch" at the hyperbaric chamber with the Duty Diving Doctor. • Divers can suffer acute illness (e.g. AMI, drowning, immersion pulmonary oedema, SAH) or injury unrelated to the breathing of compressed gas which can trigger a diving incident and onset of barotrauma / DCI (or mimic these).land approved hyperbaric chamber is required for severe DCI or arterial gas embolism.		
4.8 At scene		
• Be mindful of tidal activity. • Other divers may provide a history and know how to remove equipment. • Most equipment has quick release buckles to facilitate removal. • Open circuit diving cylinders work with a demand regulator valve and are safe; lay them flat. Re-breather circuits are more complicated but safe. • In the event of the death of a diver at scene, ensure that all of the diver's equipment, suit, weights, computer and log are preserved as evidence for Police Scotland.	Conditional	Guidelines [2,9]

5. References

1. Vann RD, Butler FK, Mitchell SJ, Moon RE. Decompression illness. Lancet 2011;377:153-64.
2. Mitchell SK, Bennett MH, Bryson P et al. Pre-hospital management of decompression illness: expert review of key principles and controversies. Diving and Hyperbaric Medicine 2018;48:45-55.
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5. Gempp E, Blatteau JE, Pontier JM et al. Preventive effect of pre-dive hydration on bubble formation in divers. Br J Sports Med 2009;43:224-228.
6. Auten JD, Kuhne MA, Walker HM, Porter HO. Neurologic decompression sickness following cabin pressure fluctuations at high altitude. Aviat Space Environ Med 2010;81:427–30.
7. Oode Y, Yanagawa Y, Omori K et al. Analysis of patients with decompression illness transported via physician-staffed emergency helicopters. J Emerg Trauma Shock. 2015;8:26-29.
8. Blake DF, Crowe M, Mitchell SJ et al. Vibration and bubbles: a systematic review of the effects of helicopter retrieval on injured divers. Diving Hyperb Med. 2018;48:235-240.
9. Mitchell SJ, Wachholz DJ, Vann RD. Management of mild or marginal decompression illness in remote locations. 2004 Workshop Proceedings. Washington, DC: Undersea and Hyperbaric Medical Society; 2005. Available from: http://archive.rubicon-foundation.org/5523.

6. Additional resources

https://www.ddrc.org/diving/diving-emergency/advice-paramedicsmedical-personnel/

https://www.rcemlearning.co.uk/reference/decompression-illness/#1567502920236-96a835e2-60e9