PRE-HOSPITAL MANAGEMENT OF DECOMPRESSION ILLNESS: EXPERT REVIEW OF KEY PRINCIPLES AND CONTROVERSIES

Diving Hyperb Med. 2018 Mar 31;48(1):45-55

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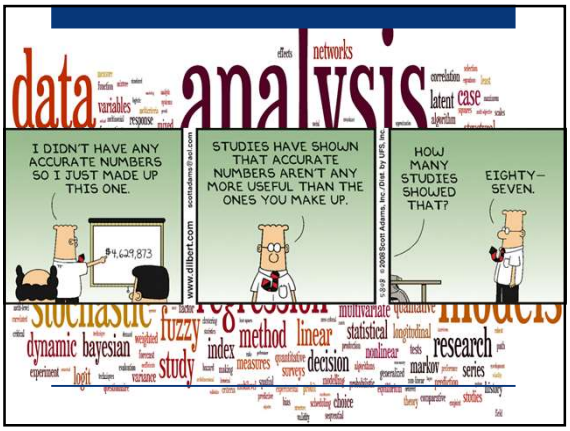
2

- No personal or financial interest to declare.
- No financial support from an industry source at the current presentation.
- Affiliated with DAN Europe as DMO for the DAN Europe Emergency Hotline

Conflict of interest disclosure statement



Corticoids Usefull? UHMS: **Hell No…** ECHM: Maybe…

UHMS Best Practice Guidelines

Prevention and Treatment of Decompression Sickness and Arterial Gas Embolism

12. Adjunctive Therapy – Medications
Low molecular weight heparin for paraplegia – enoxaparin 30 mg q12h or or dalteparin 5000 IU SQ q24h
No aspirin
No corticosteroids
No lidocaine

repeat of initial success.[105] Lidocaine is usually reserved for serious neurological cases with features typical of arterial gas embolism. High-dose steroids worsen outcome in animals[131] and are not recommended in people.[106]

acute spinal cord injury have recently been discussed.[29] A review of the use of high-dose methylprednisolone in DCI has resulted in a recommendation that corticosteroids not be used in DCI.[21]

Moon RE, Ed. Adjunctive Therapy for Decompression Illness. Kensington, MD: Undersea and Hyperbaric Medical Society; 2003.

Preliminary remarks

Corticoids Usefull? UHMS: **Hell No…** ECHM: Maybe…

HOWEVER…

function. There are currently no published data providing unequivocal support for the use of corticosteroids in DCI, although the evidence to the contrary may only be due to the lack of a trial using an appropriate dose. Therefore, the issue of efficacy of these compounds in this disease remains an open question.

Moon, 1998. SPUMS; 28 (3): 144-9

Whether corticosteroids should be administered routinely to divers with neurological DCI therefore remains undecided. On the basis of the information from studies in spinal cord trauma, if corticosteroids are administered they should probably be given early, preferably within the first 8 hours after symptom onset.

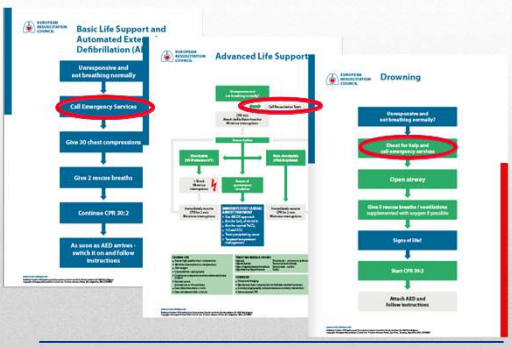
Moon, 2000. SPUMS; 30 (2): 99-112

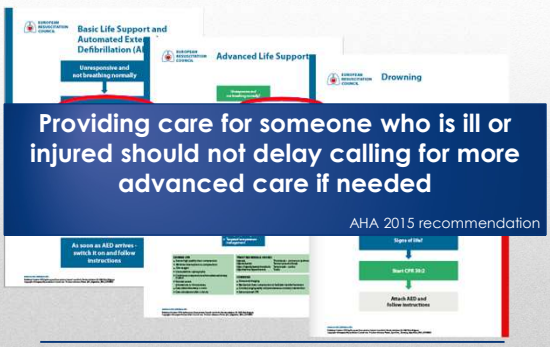
Preliminary remarks

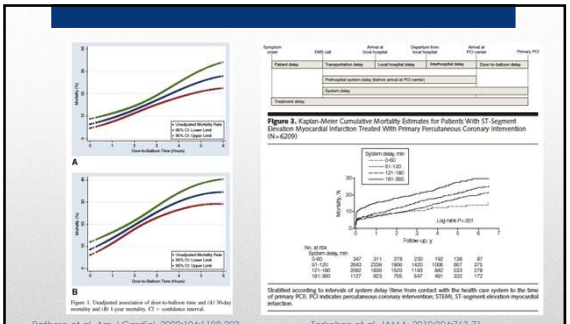
Preliminary remarks

- Almost no evidence or of low quality
- Mainly expert opinion
- Other fields potentially useful?
- Physiopathology makes logical sense

Preliminary remarks

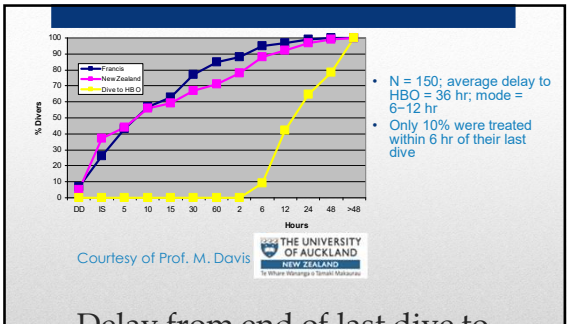






Rathore et al. Am J Cardiol, 2009;104:1198-203. Terkelsen et al. JAMA, 2010;304:763-71.

Calling for help



- N = 150; average delay to HBO = 36 hr; mode = 6–12 hr
- Only 10% were treated within 6 hr of their last dive

Courtesy of Prof. M. Davis

Delay from end of last dive to Symptoms & HBOT

Authors	DCI Type	N° patients	TTR cut off	Association
Rivera 1964	Type I & II	888	<3 hours (n=516) >3 hours (n=172) >6 hours (n=91) >12 hours (n=70) >24 hours (n=27) >48 hours (n=18)	Yes in severe cases
Kizer 1982	Type I & II	50	>12 hours (n=50) > 24 hours (n=20)	Yes
Van Hulst 1990	Type I & II CAGE	121	<12 hours (n=34) >12 hours (n=73) >24 hours (n=14)	Yes
Vann 1993	Type I & II	1,159	Unknown	No
Ball 1993	Type II Spinal cord	49	<12 hours (n=21) >12 hours (n=8) >24 hours (n=20)	Yes in severe cases
Boussuges 1996	Type II Cerebral & Spinal cord	96	Unknown	No
Desola 1997	Type I & II	466	<3 hours (n=112) >3 hours (n=104) >6 hours (n=88) >12 hours (n=42) >24 hours (n=69)	No
Ross 2007	Type II	390	Unknown	Yes in severe cases
Gempp 2010	Type II Inner ear	99	>6 hours (n=7)	Yes
Gempp 2010	Type II Spinal cord	63	>3 hours (n=15) >6 hours (n=13)	No
Blatteau 2011	Type II Spinal cord	279	>3 hours (n=73) >6 hours (n=82)	No
Xu 2012	Type I & II Mild to severe	5,278	>6 hours (n=1,802) >12 hours (n=555) >24 hours (n=234) >36 hours (n=119)	Yes
Mutzbauer 2013	Type II Mild to moderate	28	> 17 hours (n=13)	No
Lee 2015	Type I & II CAGE	195	>24 hours (n=90)	Yes
Hadanny 2015	Type I & II	204	>48 hours (n=76)	No

Is TTR delay relevant in DCS?

U.S.N. Experimental Diving 1980 - 1989

		Time to Resolution		Complete Recovery	
	# cases	During Compression	≤10 minutes at depth	First Treatment	Eventually
N_2-O_2	91	26	36	88 (97%)	91
He-O_2	75	34	19	73 (97%)	75
Total	166	64	55	161 (97%)	166

"little or no delay between symptom occurrence and treatment"

Thalmann. 45th UHMS Workshop 1996

Short Delay to Recompression

Table 2 Analysis of clinical outcome at 1 month in divers with spinal cord DCS according to diving information, clinical characteristics, and treatment procedures

Variables	Full recovery	Sequelae	Univariate analysis		Multivariate analysis	
			P value	OR (95% CI)	*P* value	Adj OR (95% CI)
Total (n = 279)						
Age (years)						
<42	117	25				
>42	89	48	0.001	2.5 (1.4–4.4)	0.042	1.04 (1–1.07)
Dive time (min)						
<33	103	39				
>33	103	34	0.71	NA		
Depth (meters of sea water)						
<39	130	25				
>39	96	48	0.007	2.2 (1.3–3.8)	0.031	1.04 (1–1.07)
Inadequate decompression						
No	150	54				
Yes	56	19	0.97	NA		
Repetitive dive						
No	158	60				
Yes	48	13	0.417	NA		
Delay onset of symptom (min)						
>30	53	8				
<30	153	65	0.014	2.8 (1.3–6)	0.987	
Recompression delay (h)						
<3	94	30		1		
3–6	66	13		0.7 (0.3–1.4)		
>6	52	30	0.024	1.8 (1–3.3)	0.191	

Blatteau et al. Neurocrit Care (2011) 15:120–127

Longer Delay to Recompression

Best outcomes after recompression are likely to be obtained by immediate recompression.

Green et al. *Undersea Biomed Res.* 1989; 16:465-70
Thalmann et al. *Proceeding of the 45th UHMS Workshop.* 1996: 75-95
Blatteau et al. *DHM.* 2011; 41:129-34

Delay prior to recompression is unlikely to be associated with any worsening of long term outcome in case of mild symptoms,

Mitchell et al. DAN Workshop Proceeding. 2005; 239p

Limited evidence that delays longer than 6 hours result in slower or less complete recovery in case of severe symptoms.

Blatteau et al. *Neuro Crit Care.* 2011; 15:120-7

Is TTR delay relevant in DCS?

Best outcomes after recompression are likely to be obtained by immediate recompression.

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Blatteau et al. *DHM.* 2011; 41:129-34

If needed/mandatory, therapeutic recompression has to occur within 6 hours of symptoms onset

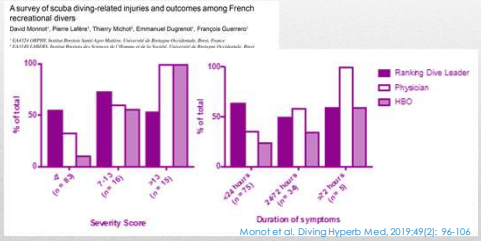
Limited evidence that delays longer than 6 hours result in slower or less complete recovery in case of severe symptoms.

Blatteau et al. *Neuro Crit Care.* 2011; 15:120-7

Is TTR delay relevant in DCS?

- 53.7% of time delay is diver-related (n=183, 1996-2000):
  - fail to identify DCS due to unclear presentation
  - hope that the symptoms will vanish spontaneously
  - deny symptoms
  - underestimate the potential consequence of untreated DCS
  - influence of the layperson

Grandjean. Indian Ocean Scientific Meeting, Mauritius - 2001



Monot et al. Diving Hyperb Med. 2019;49(2): 96-106

	Severity Score	After first HBO			Final Outcome		
		Complete resolution	Mild residual	Severe residual	Complete resolution*	Mild residual	Severe residual
Received First-aid & HBO	<7 (n=9)	8	1	0	8	1	0
	7-13 (n=8)	2	4	2	4	2	2
	>13 (n=16)	2	6	8	1	9	6
Received First-aid	<7 (n=31)	-	-	-	25	6	0
	7-13 (n=2)	-	-	-	1	1	0
Not seeking help	<7 (n=30)	-	-	-	29	1	0
	7-13 (n=4)	-	-	-	2	2	0
Total		12	11	10	84 (73.7%)	22 (19.3%)	8 (7%)

Monot et al. Diving Hyperb Med. 2019;49(2): 96-106

A physician trained in diving medicine should advise whether hyperbaric chamber treatment is required and its urgency. Laypersons and even physicians without diving medicine training are generally insufficiently trained to give such advice

MEDSUBHYP, SUHMS, GTÜM recommendation

Oxygen in First-Aid

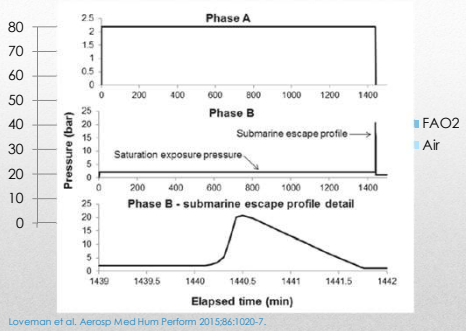
Administration of oxygen is not considered a standard first aid skill.

AHA 2015 recommendation

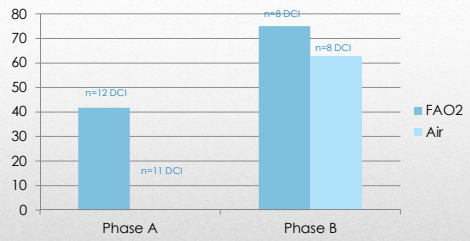
This recommendation suffers one major exception, which is the relief of decompression sickness.

AHA 2015 recommendation

Oxygen in First-Aid



Loveman et al. Aerosp Med Hum Perform 2015;86:1020-7.



Permanent resolution of DCI (%)

Loveman et al. Aerosp Med Hum Perform 2015;86:1020-7.

Table 5
Final outcome and applied treatment among DCI cases (n = 114); mild residual symptoms are mild paresthesia, weakness, residual pain or some impairment of daily activities. Severe residual symptoms are difficulty walking, paralysis, uncompensated vertigo, or speech disorders; 14 divers (13 with a severity score <7, 1 between 7–13) had a spontaneous recovery with full resolution without any treatment, although they activated the emergency response system.

	Severity score	After first HBOT			Final outcome		
		Complete resolution	Mild residual	Severe residual	Complete resolution*	Mild residual	Severe residual
Received first-aid and HBOT	<7 (n = 9)	8	1	0	8	1	0
	7–13 (n = 8)	2	4	2	4	2	2
	>13 (n = 16)	2	6	8	1	9	6
	(n = 33)	12	11	10	13	12	8
Received first-aid	<7 (n = 31)	–	–	–	25	6	0
	7–13 (n = 2)	–	–	–	1	1	0
Not seeking help	<7 (n = 30)	–	–	–	29	1	0
	7–13 (n = 4)	–	–	–	2	2	0
Total					84 (74%)	22 (19%)	8 (7%)

FAO_2 among Humans

TABLE 2
OXYGEN FIRST AID AND HYPERBARIC TREATMENT RESULTS (percentage)*

Surface Oxygen	Complete recovery	Partial/ temporary	None	Residual symptoms
No	2	38	60	47
Yes	13	54	32	42

Lippmann. *SPUMS*. 2003; 33: 192-198

MARRONI'S EUROPEAN DAN DATA 1989-1993

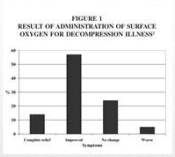
	Oxygen		No Oxygen	
	Divers	%	Divers	%
Total divers	119	59	83	41
Symptoms before treatment				
Resolved	14	12	1	1
Improved	66	55	0	0
Unchanged	39	33	82	99
Symptoms after treatment				
Full resolution	114	96	58	70
Sequelae	5	4	25	30

Marroni. *Handbook on Hyperbaric Medicine*. 1996; 265-276

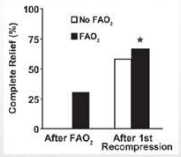
Improved outcome?
Effect of surface O_2 alone?

FAO_2 among Humans

FIGURE 1
RESULT OF ADMINISTRATION OF SURFACE OXYGEN FOR DECOMPRESSION ILLNESS[1]



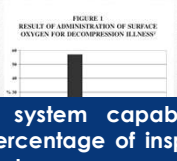
Lippmann. *SPUMS*. 2003; 33: 192-198

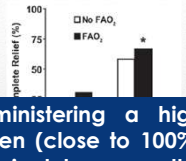


Longphre et al. *Undersea Hyperb Med*: 2007; 34: 43-9

- Improvement on symptoms before recompression, up to complete relief
- Decreased odds of a diver requiring more than one recompression

FAO_2 among Humans





A system capable of administering a high percentage of inspired oxygen (close to 100%) and an oxygen supply sufficient to cover the duration of the most plausible evacuation scenario is highly recommended for all diving activities

- Decreased odds of a diver requiring more than one recompression

FAO_2 among Humans

Best FiO_2?

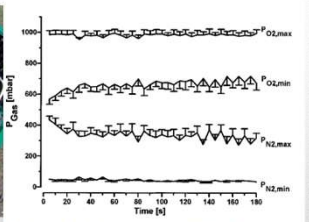
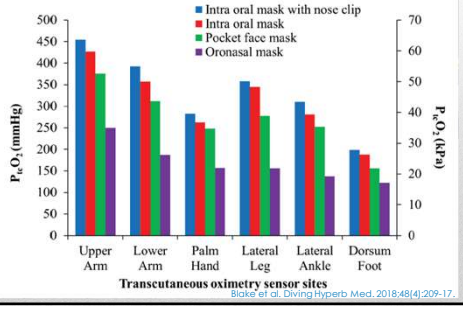


Fig. 3: Means ± SE for minimal and maximal values in 5 s intervals using System 3 with mouth piece (n = 9).

Hoffmann et al. Int J Sports Med 2001;22:424-9.

Best FiO_2?

Transcutaneous oxygen partial pressures (median in mmHg) while breathing oxygen using the demand valve with four different mask configurations



Blake et al. Diving Hyperb Med. 2018;48(4):209-17.

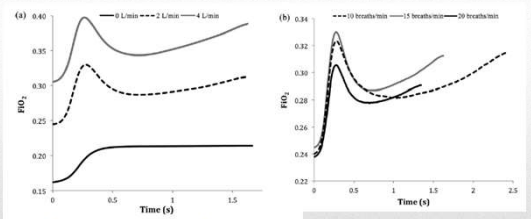
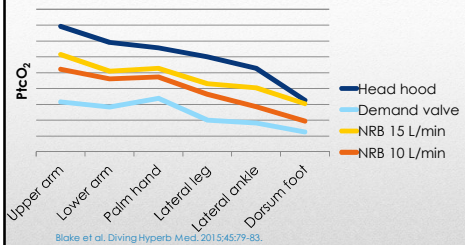


Figure 2 Mean fraction of inspired oxygen (FiO_2) waveforms: (a) effect of oxygen delivery rate on FiO_2 at 15 breaths/min (0 L/min, 2 L/min and 4 L/min); (b) effect of respiratory rate on FiO_2 at 2 L/min (10 breaths/min, 15 breaths/min and 20 breaths/min).

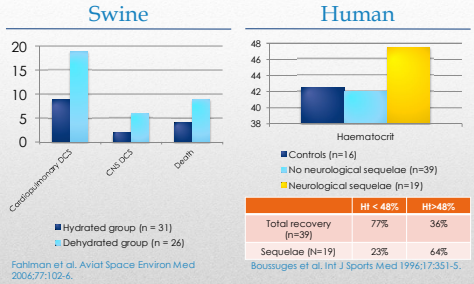
O'Reilly Nugent et al. Respirology 2014;19:538-43.

Is the choice of O_2-administration-device critical?



Blake et al. Diving Hyperb Med. 2015;45:79-83.

NRB, best device?

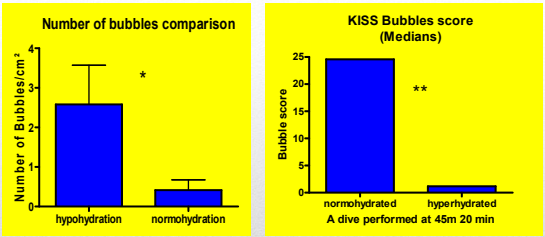


	Ht < 48%	Ht>48%
Total recovery (n=39)	77%	36%
Sequelae (N=19)	23%	64%

Fahlman et al. Aviat Space Environ Med 2006;77:102-6.

Boussuges et al. Int J Sports Med 1996;17:351-5.

Dehydration and DCS



Gempp et al. Br J Sports Med 2009;43:224-8.

Preventive effect of pre-dive hydration

- Nature of Fluid=?
- Timing of administration=?
- Best access (Oral vs IV vs IO)=?
- Volume to administer=?
- Duration of administration=?
- Improved final outcome=?
- Any benefice=?

NO EVIDENCE

Only 130 years of Experience

Therapeutic effect of post-dive fluid administration

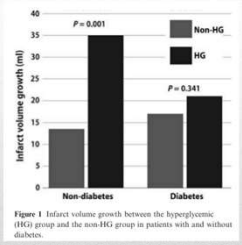


Figure 1 Infarct volume growth between the hyperglycemic (HG) group and the non-HG group in patients with and without diabetes.

Shimoyama et al. Eur J Neurol 2014;21:402-10.

DW5

Oral Hydration is recommended but should be avoided if the patient is not fully conscious.

Fluids should be non-carbonated, non caffeinated, non alcoholic and ideally isotonic. (drinking water ok)

If suitably qualified and skilled responders are present, intravascular rehydration with non-glucose containing isotonic crystalloid is preferred.

If casualty breathing place in recovery position

The 'how' position

More stable position

Positioning the victim

Human evidence of enhanced inert gas washout in horizontal subjects

In vivo evidence of cephalad bubble distribution if upright

In vivo evidence that head down position is harmful in DCI

Positioning the victim

- Empasized in the late 60'and 70'
- Place in First-aid = ?
- Mostly based on physiopathology
  - IV Pentoxifyline + Nicergoline
  - Aspirin
  - Lidocaine
  - Corticosteroids
- Limited success

Adjunctive therapies

- Empasized in the late 60'
- Place in First-aid = ?
- Mostly based
  - IV Pentoxi
  - Aspi
- cess

No possible recommendation based on evidence Only expert opinion available

Adjunctive therapies

- Double-blind prospective RCT
- 20mg tenoxicam daily (n=90) *vs* placebo (n=90)
- No NSAID related complications in tenoxicam group

Outcome	Placebo	Tenoxicam	P value (95% CI)
Health status at discharge >1	25 (30%)	31 (37%)	0.41 (21% to –7%)
Health status at 4-6 weeks >1	16 (20%)	14 (17%)	0.58 (9% to –20%)
Median treatments required to discharge (range)	3 (1 - 8)	2 (1 - 6)	0.01 (0 to 1)
Subjects requiring more than 2 treatments	53 (61%)	35 (40%)	0.01 (6% to 34%)

Bennett et al. UHM 2003;30(3):195-205.

NSAID & DCS

Fluoxetine Protection in Decompression Sickness in Mice is Enhanced by Blocking TREK-1 Potassium Channel with the "spadin" Antidepressant

Thirty-five Day Fluoxetine Treatment Limits Sensory-Motor Deficit and Biochemical Disorders in a Rat Model of Decompression Sickness

Future Trend?

Treatment with NSAID is appropriate if no contraindications

No evidence to support/refute the use of other agents:
Corticosteroids, pentoxyphylline, aspirin, lidocaine, nicergoline,…

Flight evacuation

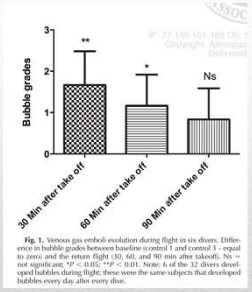


Fig. 1. Venous gas emboli evolution during flight in six divers. Difference in bubble grades between baseline (control 1 and control 3 – equal to zero) and the return flight (30, 60, and 90 min after takeoff). Ns = not significant. *P < 0.05; **P < 0.01. Note: 6 of the 32 divers developed bubbles during flight; these were the same subjects that developed bubbles every day after every dive.

Outgoing Flight: no bubble

Diving week:
- non-bubblers (n=16)
- occasional bubblers (n=10)
- consistent bubblers (n=6)

24 hours free-interval

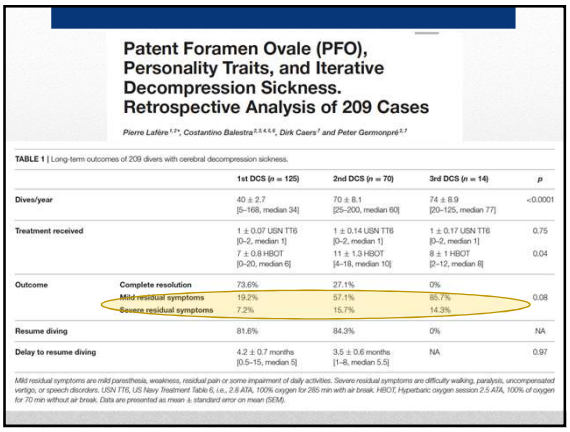
Return Flight: no bubble pre-flight

Cialoni et al. ASEM 2014;85(10):993-8

Accurate recommendation?

- Is it worth the risk of drowning?
- No medically supervised demonstration of the efficacy of IWR
- Some evidence
  - Efficacy of short delay to recompression
  - Efficacy of shallow recompression
- Threshold delay for retrieval versus IWR?
- Training level for IWR?

IWR Controversy



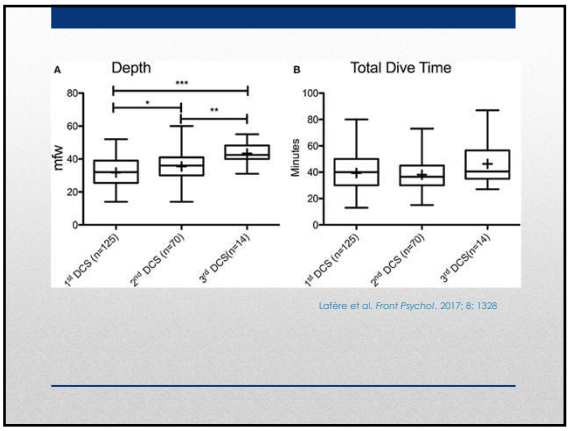
Patent Foramen Ovale (PFO), Personality Traits, and Iterative Decompression Sickness. Retrospective Analysis of 209 Cases

Pierre Lafère[1,2], Costantino Balestra[2,3,4,5,6], Dirk Caers[7] and Peter Germonpré[2,7]*

TABLE 1 | Long-term outcomes of 209 divers with cerebral decompression sickness.

		1st DCS ($n = 125$)	2nd DCS ($n = 70$)	3rd DCS ($n = 14$)	p
Dives/year		40 ± 2.7 [5–168, median 34]	70 ± 8.1 [25–200, median 60]	74 ± 8.9 [20–125, median 77]	<0.0001
Treatment received		1 ± 0.07 USN TT6 [0–2, median 1]	1 ± 0.14 USN TT6 [0–2, median 1]	1 ± 0.17 USN TT6 [0–2, median 1]	0.75
		7 ± 0.8 HBOT [0–20, median 6]	11 ± 1.3 HBOT [4–18, median 10]	8 ± 1 HBOT [2–12, median 8]	0.04
Outcome	Complete resolution	73.6%	27.1%	0%	
	Mild residual symptoms	19.2%	57.1%	85.7%	0.08
	Severe residual symptoms	7.2%	15.7%	14.3%	
Resume diving		81.6%	84.3%	0%	NA
Delay to resume diving		4.2 ± 0.7 months [0.5–15, median 5]	3.5 ± 0.6 months [1–8, median 5.5]	NA	0.97

Mild residual symptoms are mild paresthesia, weakness, residual pain or some impairment of daily activities. Severe residual symptoms are difficulty walking, paralysis, uncompensated vertigo, or speech disorders. USN TT6, US Navy Treatment Table 6, i.e., 2.8 ATA, 100% oxygen for 285 min with air break. HBOT, Hyperbaric oxygen session 2.5 ATA, 100% of oxygen for 70 min without air break. Data are presented as mean ± standard error on mean (SEM).



Lafère et al. *Front Psychol.* 2017; 8: 1328