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DIVING INCIDENT MONITORING STUDY UPDATE 1993

Chris Acott

Introduction

The Diving Incident Monitoring Study (DIMS) has been an ongoing project since 1989. Completed forms were initially received on a sporadic basis, but slowly the study has gathered momentum.

Up to the end of 1992, 553 reports had been received. Twenty reports have been rejected for analysis because they contained inadequate information or failed to describe an actual incident. None of the information in these reports has been used. Analysis of the 533 useable reports is presented here.

So far there has been no duplication of incident reports. 57% of those received have been divers reporting their own incidents, 13% reporting their buddy's, while 30% were reports of somebody else's. As more reports are received and more information gathered previous reports have to be reviewed and constantly upgraded. In this way similar incidents can be identified and re-checked.

TABLE 1

INCIDENTS ANALYSED

Year	Number
1989	48
1990	79
1991	162
1992	244
Total	**533**

These 533 incident reports: gather details of incidents; identify common errors made; give insight into current diving practice and behaviour; identify "equipment faults" either due to design or problems associated with diver usage of his or her equipment, or "pure" equipment malfunction.

Why use incident monitoring and not analysis of diving fatalities and accidents?

Firstly, counting the dead is a poor measure of how well "things are going".

Secondly, when a coroner or other official body is involved, the reports of the event tend to be what should have happened rather than what did happen. Unfortunately, the "blame-model" still operates in recreational diving.

Thirdly, most accidents have multiple components and it is difficult to identify and apportion responsibility to these various components.

Fourthly and most importantly, there are not enough accidents and deaths to make statistical "sense" of the data. For each accident there are at least 1,000 incidents. Incident monitoring is a powerful mechanism and gives considerable insight into the "COCK - UP CASCADE" (Table 2).

The ratio of male to female of 3:1 was constant throughout the reports received. This may well reflect the general ratio of male to female divers. The ratio of male to female divers presenting for treatment of diving related disorders at the Royal Adelaide Hospital (RAH) Hyperbaric Chamber is, on average, 3:1 (one abnormal year of 17:1 has been disregarded!)

Morbidity

Table 3 displays the 233 cases of morbidity (44%) reported in the 533 incidents under review.

TABLE 2

THE COCK-UP CASCADE

Incident reporting looks at all stages

Associated patterns of behaviour
|
Contributing factors
|
Errors and or negative incidents
|
*****Accident or major incident*****
|
*****Injury*****

*** Mortality and morbidity studies only look here**

TABLE 3

233 INCIDENTS ASSOCIATED WITH MORBIDITY

Diagnosis	Number	%
Decompression Sickness	126	54
Ear Barotrauma	29	12
Cerebral arterial gas embolism	21	9
Pulmonary barotrauma	17	7.3
Salt water aspiration	17	7.3
Sinus barotrauma	5	2
Coral sting	4	2
Hearing loss	1	0.4
Other	13	6
Total	**233**	**100.0**

The factors associated with the incidence of decompression illness were rapid ascents, omission of decompression stops, misreading decompression tables, computer error, multiple ascents (yo-yo diving), flying or going to altitude soon after diving, lack of any decompression algorithm (tables or computer), deep diving and a deep dive being the last dive of the day.

The so-called “safety stop” failed to prevent decompression illness in 18 incidents. Fourteen incidents occurred at the safety stop, 11 resulted in morbidity. In some of the incidents, the dive profiles recorded were well within any tables, but a safety stop was used inappropriately; e.g. if a novice is having trouble with his or her regulator then a direct ascent to the surface without a safety stop is prudent management. Poor buoyancy control, free flowing regulators, salt water aspiration and weight belt problems all occurred while at a safety stop and all contributed to panic and the subsequent breath hold ascent, leading to the unfortunate consequences of pulmonary barotrauma and cerebral gas embolism. The safety stop serves to slow down the diver’s ascent. Strictly speaking, it is not a required decompression stop, but it is reported as being so. Extended dive profiles are “made safe” by the addition of this stop, however, the data presented clearly indicates that it is not the panacea divers are looking for. Divers should make sure the safety stop does not become an “unsafe stop”.

Incidents during training

There were 70 incidents (13% of the total) reported which occurred during training (Table 4). Forty nine (70%) of the these 70 incidents during training caused harm to the diver. The non-harmful incidents recorded reflect good management by those involved with the training of the divers. However, some disturbing trends were noted:

TABLE 4

70 INCIDENTS DURING TRAINING

	Number	%
Incidents without sequelae	21	30
Harmful incidents	49	70

Harmful incidents	Number	%
Decompression illness	17	35
Ear barotrauma	15	31
Salt water aspiration	5	10
Cerebral arterial gas embolism	3	6
Miscellaneous damage	9	18

Novices are not being instructed on the correct use of buoyancy vests. Some incidents demonstrated that novices neither knew how to inflate nor deflate their vests (particularly when a vest spontaneously inflated).

Medically unsuitable candidates are still being allowed to dive. An asthmatic lied, while 3 candidates were psychologically unfit.

The high incidence of decompression illness among diving students is a surprising statistic. This may reflect multiple ascents during training exercises, lack of medical/ physical fitness to dive or just bad luck. However, these data refute the saying “Decompression sickness is a disease of old divers and gas embolism of novices.”

Not surprisingly poor ear clearance techniques are reflected. One student commented, “They don’t tell you how hard to do it, or when to do it, or when to stop.”

Overall these data shows training can be associated with major morbidity as 21% of all harmful incidents occurred during training.

Experience and training

Not suprisingly six out of the 7 untrained divers, 3 on introductory dives, were involved in harmful incidents. These were three cases of pulmonary barotrauma (2 on introductory dives),1 CAGE, 1 C.V.A.(an introductory dive) and 1 ear barotrauma. Table 5 lists fewer than the total of incidents and of harmful incidents because not all reports included the diver's certification status.

The diver who suffered a C.V.A. (stroke) underwater had lied on his medical questionnaire.

TABLE 5

CERTIFICATION STATUS

Qualification	Incidents	Harmful incidents
Not known	26	
Untrained	7	6
Basic	81	31
Open water	171	84
Advanced	102	38
Divemaster	29	11
Diving Instructor	52	16
Commercial	23	14

Dive tables

In 123 reports the dive tables or computer section were not filled in. 410 reports had this section completed. A total of 120 divers used computers. In 114 reports the diver recorded not using tables. However 43 of these used a computer leaving 71 (17% of those who answered the question) who definitely did not use tables or computer. This is a disturbing figure. Either the divers concerned:

- lacked suitable training and did not understand the need for depth/time calculations;
- or considered that depth/time calculations were unnecessary due to the depth of the dive;
- or had a "macho" attitude toward decompression;
- or they just forgot.

Fifty three (75%) of these 71 non-users of decompression procedures were basic or open water certified divers. In this group there was one diver who dived repeatedly to 30 m (100 ft). The tables recorded as being used are listed in Table 6.

TABLE 6

DIVE TABLES USED (IN ORDER OF FREQUENCY)

Table	Users	Approximate %
PADI	139	34
None	114	28
USN	49	12
DCIEM	29	7
BSAC	25	6
NAUI	22	5
Bassett	18	4
Other	14	3
Total	**410**	**99**

When did the incident occur?

Table 7 shows at which part of the dives the incidents occurred

These were 2 preparation incidents where the diver nearly drowned. Both involved walking towards a boat to load gear. Both divers had their weight belts on, one was fully kitted up, but without air turned on, and the other was not. One was knocked over by a wave and was unable to right him/herself, the other fell into a hole and had to be pulled out. Neither thought about dropping their weight belt.

Harmful incidents were mainly detected following the exit (49%) and during the dive (29%).

TABLE 7

WHEN INCIDENTS WERE DETECTED

Stage of dive	Incidents	%
Preparation	32	6.0
Entry	24	4.5
Descent	45	8.5
During Dive	176	33.0
Ascent	60	11.2
Exit	42	7.8
Following exit	154	29.0
Total	**533**	**100.0**

Contributing factors

The main contributing factors in all incidents are listed in Table 8.

TABLE 8

MAIN CONTRIBUTING FACTORS

Factors	Incidents	%
Error in equipment	133	25
Inexperience in diving	107	20
Poor dive planning	96	18
Inattention	80	15
Failure to check equipment	64	12

Table 9 lists the contributing factors which, when present, were causes of morbidity in the majority of incidents. These less common contributing factors, associated with diver harm, are similar to those associated with harm in the review of the first 125 incidents.[1] Of the 11 incidents associated with drug or alcohol intake 7 (or 67%) resulted in harm. Similar percentages were associated with the other factors.

TABLE 9

HARMFUL CONTRIBUTING FACTORS

Factor	Incidents with factor	Incidents with harm	% with harm
Drug or alcohol intake	11	7	67
Failure to understand table	26	17	65
Lack of medical clearance	22	14	63
Insufficient training	48	30	62
Poor physical fitness	53	27	50

There are certain people who are medically or physically unfit to dive who are escaping the medical net. This may be due to the fact that the diver lied (4 incidents) or the medical practitioners were ignorant of the medical requirements for diving (i.e. 5 asthmatics were allowed to dive). Consider the scenario where the diving instructor knows the medical contraindications to dive and the medical practitioner does not and the candidate is allowed to dive and comes to grief. Who is to blame? Both, I am sure, will be sued and both found negligent.

There were 4 reports of psychological problems, 3 resulting in panic. Two of these were associated with claustrophobia and one with agoraphobia. Psychological fitness to dive is hard to assess at the best of times, however there may be clues in the candidates background. Diving instructors are probably are best suited to judge a particular candidate's "water skills and water fitness."

Dive plan

The majority of the incidents did not change the dive plan (Table 10).

Even if the incident involved harm it had little effect on the dive plan. There were 167 (72%) harmful incidents where the incident did not change the dive plan, while the remaining 66 harmful incidents (28%) caused the dive to be aborted or the dive plan to be changed.

TABLE 10

INCIDENT INFLUENCED THE DIVE PLAN

	Incidents	%
No effect on dive plan	329	61.8
Delayed the dive	22	4
Changed the plan	58	11
Aborted the dive	123	23
Not recorded	1	0.2
Total	**533**	**100**

Equipment issues

One hundred and seventy five incidents (33% of the total) involved equipment (Table 11). Many of the incidents involved more than one piece of equipment.

Twenty three incidents (13% of the equipment incidents) involved using somebody else's equipment, while 69 (39%) involved equipment malfunction or fault. Nearly a third (24) of these were due to poor maintenance and servicing.

Buoyancy jackets

There were 57 incidents with buoyancy jackets (11% of total incidents). Many of the buoyancy jacket incidents involved more than one problem as can be seen in Table 12.

There were 16 incidents where no buoyancy vest was used. The buoyancy compensator/jacket/vest is often stated by diving experts to be a safety device. However, of the 57 reported incidents, 21 (37%) involved diver harm. All these harmful incidents, with 3 exceptions, were associated with rapid ascents and its consequences. There were 3 divers who developed evidence of pulmonary barotrauma and of CAGE who appear twice in Table 13, as do others, as it shows the diagnoses of those injured.

TABLE 11

175 INCIDENTS WITH EQUIPMENT

Equipment		Incidents
Buoyancy jacket		57
Anchor		7
Boat		7
Camera		3
Compressor		6
Computer stopped working or was inaccurate		2
Contents gauge		18
High pressure hose rupture	3	
Depth gauge		7
Maximum depth indicator	3	
Flag		4
Fins		10
J Valve		2
Mask		13
Oxygen equipment		7
Reel line		1
Regulator		30
Regulator hose rupture	6	
Safety sausage		3
Shot line		3
Scooter		1
Spear gun		1
Suit		15
Surface buoy		1
Tank		11
Watch		4
Weight belt		27
Weight belt dropped	12	
Weights		5
Weights dropped	4	
Exit ladder		5

TABLE 12

57 BUOYANCY JACKET PROBLEMS

Confusion between the deflate and inflate buttons	11
Confusion between the inflate and deflate buttons	1
Inflator spontaneously inflated the jacket	4
Inflation device not connected properly	8
Unable to vent the jacket to slow down	29
Jacket leaked	2
Jacket provided inadequate buoyancy	7
Jacket uncomfortable to wear	3
Unfamiliar with its use	19
Jacket used inappropriately	20

TABLE 13

21 BUOYANCY JACKET INCIDENTS ASSOCIATED WITH DIVER HARM

Diver damage	Incidents
Cerebral arterial gas embolism	14
Decompression illness (DCS)	10
Pulmonary barotrauma	6
Ear barotrauma (of ascent)	2
Salt water aspiration	2

One salt water aspiration incident was due to the vest providing inadequate buoyancy on the surface in rough sea. The other diver deflated his jacket instead of inflating it while on the surface.

Fortunately in these reports there are no fatalities recorded, however, rapid changes in buoyancy and depth clearly have the potential to cause fatal accidents.

Many vests have the power inflate and manual deflate buttons in close proximity on the vest's hose. These power inflators were added to the oral inflator and the vest's manual deflate device without any consideration of the potential harm this configuration could cause. Confusion between the inflate and deflate button featured in 11 (21%) of these buoyancy vest incidents showing that this configuration is ergonomically unsound. The inflate and deflate mechanisms should be separate, perhaps on opposite sides of the vest. Confusion between the inflate and deflate buttons is not only a problem for the diver, but also for the diver's buddy and would be rescuer.

Inflators that spontaneously inflate without activation are extremely dangerous. These incidents reflect either poor maintenance/servicing of these devices (very few divers have their inflators serviced or checked), or a design fault. A design fault would be indicated by a number of these incidents involving a particular type of vest and or model. Statistically, no particular vest inflator/vest model has been identified, although one particular model does feature repeatedly in the incidents reported (there is also anecdotal data suggesting there is a fault in this particular brand of vest). However, more reported incidents are needed and vests named in reports before conclusions can be reached.

Buoyancy jackets provided inadequate buoyancy due to:

i) inadequate tank pressure to fully inflate the jacket;
ii) low tank pressure so that the jacket inflated slowly or appears not to be inflating at all;
iii) incorrect size jacket for the diver concerned.

Like anaesthetists and pilots, divers should do an equipment check before water entry. This check should show how each piece of equipment works, its location and if it is not working correctly the fault should be corrected. Inability to vent the vest shows that this pre-dive check had not been done. A pre-dive check will also show if the inflator is connected correctly.

The function of each vest should be shown to each diver at purchase or when it is hired, as there were incidents reported where the diver concerned lacked the knowledge on how to inflate the vest, either orally or with the power inflator.

Frequent use of the power inflator to maintain buoyancy control was not a major cause of the out of air/low air situation, however, it has the potential to be. Better weighting of divers, emphasis on good buoyancy control and the use of oral inflation should perhaps be stressed more during training. Oral inflation, however, does require good co-ordination and frequent practice.

Regulator

There were 10 regulator incidents (6% of the total incidents), 6 of which which caused harm to divers (20% of the regulator problems). These and other regulator problems are shown in Table 14. It can be seen that many of the problems with regulators overlapped. For instance problems with the regulator despite frequent service was often associated with a free flowing second stage.

These data indicate that first stage problems occur as frequently as free-flowing second stages. However free-flowing second stages were associated with three episodes of salt water aspiration which caused panic.

The seven hose ruptures provided 23% of regulator problems. Hose maintenance is therefore important and a visual inspection should precede every dive.

TABLE 14

REGULATOR INCIDENT PROBLEMS

Problem	Incidents	Harm caused
Free flowing second stage	15	4
First stage problem	14	-
Problems with regulator despite frequent servicing	15	6
Hose rupture	7	1
Problems with mouth piece	2	-
Total	**30**	**11**

A disturbing feature is that in 15 incidents (50% of the incidents) the regulator had been recently serviced. Six of these (40%) caused harm. All divers should test their regulators after servicing **before** it is tested during a dive. Perhaps these data are a reflection on the poor standard of servicing offered by some dive shops!

Weight belts

There were 27 incidents involving a weight belt (Table 15). Twelve of these being dropped when the diver left the water. Other incidents included buckle problems, inadvertent release of tongue slipping through, and a combined incident of a weight slipping off during weight belt handling when leaving the water.

There were 4 other incidents involving weights. These were due to weight being dropped during handling while in the water during buoyancy adjustment.

Better designed weight belts and buckles are needed to avoid inadvertent release during a dive with the subsequent rapid ascent. Design changes are needed to stop weights dropping off the belt during exit from the water.

Better management procedures are needed for the handling of weight belts at exit.

TABLE 15

WEIGHT BELT INCIDENTS

Incidents involving weight belt		27
Weight belt dropped	12	
Incidents involving weights		5
Weights dropped	4	

Miscellaneous behaviour

The following featured prominently in the incidents reported:

1. Standard buddy separation procedures were rarely adhered to.
2. A trend is emerging which shows that more divers are doing their deepest dive last.
3. An absence of any "missed decompression regime".
4. Divers are still diving without any reference to tables or computer.
5. Lack of simple safety procedures:
   a. buddy check before a dive;
   b. lack of a boatman while divers are diving;
   c. unfamiliarity with equipment being used (buoyancy jackets, compressors);
   d. lack of safety lines in wrecks.

6 Lack of basic knowledge of the physics of diving i.e. not knowing that the deeper the dive the greater the air consumption.
7 Total ignorance concerning the symptoms of decompression illness/cerebral arterial gas embolism and of the importance of seeking medical advice concerning vertigo.
8. Lack of suitable knowledge of the first aid management of diving related disorders.
9 Poor entry procedures.
10 Poor management of the air supply in regard to retrieving an anchor at the end of a dive. (This may become a greater problem now that anchors need to be placed and retrieved carefully to avoid reef damage.) Anchor retrieval is another descent and ascent.
11 Lack of the ability to use the diving table correctly.
12 Lack of knowledge of what decompression sickness is.
13 60% of all rapid ascents resulted in harm.

Discussion

Similar trends were noted in these reports as were reported previously in the analysis of the first 125 incidents.[1]

Equipment problems predominate. Misuse, misassembly and lack of understanding of how the equipment functions is common. More emphasis is needed during training on equipment, maintenance, use, function, assembly and safety aspects.

Decompression procedures should be taught thoroughly during training. Divers should be taught **a set of tables** thoroughly. Eligibility to dive should be based on their use being correctly understood and demonstrated before certification. At present a basic decompression rule "deep dive first, shallow dive last" is being neglected. This trend is seen more in computer users. Omitted decompression procedures related to the particular table used should be taught and understood.

Basic understanding of the physics of diving is needed. If this is lacking then the fundamental knowledge of how long a diver's air supply will last at depth can not be calculated.

Once again a correlation between the lack of medical fitness to dive and morbidity has been demonstrated.

Alcohol and diving do not mix safely.

This study correlates well with other studies in human error, particularly in medicine (anaesthesia) and aviation, in which the thorough checking of equipment before use is an important aspect of safety.

Weight belt problems at exit featured again. A planned exit from the water is always needed on every dive. Those responsible for divers diving from boats should discuss and plan the exit from the water with their divers, particularly when the conditions are rough. Special needs can then be sorted out and planned accordingly. There may be some physical limitations in elderly divers which would prevent them from entering and exiting the water in a fast and controlled manner in rough conditions. Those problems need to be identified and the diver stopped from diving if necessary. **Divers should always plan the exit and dive the plan.**

Other problem areas have been identified:

There is a lack of knowledge and recognition of the symptoms of diving maladies. Emphasis on the positive aspects of recognition are needed, and less on the negative side e.g. "You're bent. You must have screwed up somewhere!" Decompression illness **is a diving related disease**, the more one dives, the greater chance one has of becoming a statistic. Divers do not have to have done "something wrong" to get decompression sickness, although if one does break the rules then one can expect trouble .

The incident reports show that some very basic rules are being broken. Some examples are:

Never dive if you have had a recent illness. Allow at least one or two weeks for recovery.
Never dive a computer or table to the limit.
Never dive while under the influence of drugs or alcohol.
Never dive while dehydrated.
Never save the deepest dive for last. (This includes diving for the anchor.)
Never dive without consulting a set of tables or reputable computer.
Never dive a "yo-yo" plan. Try to do only one ascent per dive. Remember that an ascent may be going from 18 to 9 m and back again.

Every ascent from every dive should be as slow as possible. A slow ascent needs good dive planning to carry it out.

Corrective strategies

PRE DIVE CHECK

Each diver should be responsible for his or her equipment and should test and inspect it before every dive. Each diver should also do a buddy check. A thorough check should only take a few minutes.

BUOYANCY COMPENSATORS

Check that the scuba feed is connected and will inflate and deflate.

Check the jacket for leaks when fully inflated.
Check oral inflation.
Check the emergency vent holes.
Check that the tank is secure in the back pack.
Check the position of the inflate and deflate buttons, test them and practice emergency venting of the jacket.
Perform the same inflate and deflate procedure on your buddy's jacket.

All buoyancy compensation devices (BCDs) need to be carefully and critically looked at. Poor ergonomic design of the inflator/deflator mechanism needs attention. Even more basic, however, is the testing to see if the vest will float an unconscious diver face down in the water. I know of no such testing that has been done on all the current buoyancy vests/devices. BCDs are supposedly "safety devices", however as these data show, if there are problems, then statistically the diver is likely to be involved in a harmful incident.

When a buoyancy compensator is bought or hired from a dive shop, it would be prudent for the dive shop to ensure that:

1) the diver knows how the jacket works;
2) that all the inflate and deflate mechanisms work correctly;
3) that the jacket fits the diver correctly and is comfortable.

REGULATORS AND CONTENTS GAUGES

1 Visually inspect all hoses before connecting the regulator to the tank. Inspect the hoses again after connection to the tank and when the air supply turned on.
2 When the air supply is on note the full position on the contents gauge.
3 Switch the air supply off.
4 Purge both second stages and check purge buttons.
5 Note the empty position.
6 Switch air supply on. Note full position again. Check that it correlates with No. 2.
7 Check, with the air supply turned fully on, that the diver is able to breath through both 2nd stages (if an octopus is fitted).
8 Check that breathing does not cause oscillation of the pressure gauge needle. If it does then the air supply should be checked to make certain that it is turned on fully.
9 Check that there is no positional free flowing of either second stage.
10 If the contents gauge is bumped before getting into the water, these checks should be performed again.
11 Check that the diver and the buddy knows where both second stages are, particularly the octopus.
12 Once in the water, do a surface check for any positional free flowing of the regulators.

WEIGHT BELT

1 Check the quick release.
2 Check the "tongue overlap".
3 Check whether the weights will fall off if the weight belt is handled incorrectly.
4 Think again about the "correct weight" and adjust the weight belt accordingly. Has there been a change of wet suit? Has there been a change of water environment, salt v fresh? A rough guide to weighting is:
   1 kg weight for each mm thickness of wet suit;
   1 kg extra for hood and "Long John" additions;
   1 kg for aluminium tank;
   1-3 kg for individual variation in buoyancy.

MEDICAL FITNESS

There is still a need for more medical practitioners trained in diving medicine. Courses are available at the Royal Adelaide Hospital (2 per year), HMAS PENGUIN, Fremantle Hospital (one a year) and the Diving Medical Centre, Brisbane, organises courses in the Eastern States. As more and more medical practitioners are trained, there will be little excuse for a diving candidate not seeking a knowledgable opinion.

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DIABETES MELLITUS AND THE SCUBA ENVIRONMENT

Mark Sullivan

Diabetes mellitus has been recognised as a lethal malady since the beginning of recorded history. It was first recorded in writing in the 1st century A.D. by Areteus, who described an illness characterised by a "melting down of the flesh to urine". He named the malady *diabetes* derived from the Greek word meaning "a siphon". The word *mellitus* was added in the 5th century by Susruja, to describe the sweet-smelling urine so often associated with diabetes mellitus. Until 1921, when Banting and Best first introduced insulin for the treatment of diabetes mellitus, there was no substantial remedy for this malady, and worsening cachexia and death were the inevitable result.