Emergency Ascents: some background information

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A man soon dies unless supplied with adequate oxygen and purged of excess carbon dioxide and anyone so placed that his respiratory requirements can be interrupted at any moment has a constant awareness, to a greater or lesser degree, of the need for urgent action should such a problem arise. The most obvious action would be to rush for the open air, an option that may be difficult to put into practice in the case of a diver underwater.

Such a person has not only a distance to travel to reach the surface, which takes time he can ill afford, but also a pressure differential to traverse that can prove fatal under certain circumstances. Unless an alternative source of air can be obtained rapidly he will be faced with a choice between the possibility of suffering a “burst lung” during an emergency out-of-air ascent and the certainty of drowning should he remain underwater. Should panic intervene the victim will be unable to make any rational decision and forfeits his chances of survival, therefore training must be designed both to reduce the chances of such situations occurring and to inculcate a planned reaction so thoroughly that it will blank out at least the early stages of the panic response. Controversy exists, however, concerning the form such training should take. Some hold that everyone should actually perform one, or several, out-of-air ascents during the “cold” non-panic situation of the initial (or later) diver training sessions that precede each phase of diving fitness certification. The intent is to let every diver discover for himself the practicality of such ascents. Others believe that the possible risks associated with such ascents are unjustified, that thorough training and correct diving discipline will make such out-of-air situations extremely rare, and that one or two practice ascents do not prepare the diver for the conditions of a for-real situation. Dr Glen Egstrom has produced “learning curves” to demonstrate that it required 17-21 trials before one reaches a learning plateau, the “overlearnt” stage where behaviour is reliably reproduced without the need for conscious thought. Such a stage is hardly ever reached by novice divers, even for the basic skills of diving and would not be attainable by them re emergency ascents except at the cost of very many practice ascents. There is a lack of documented evidence concerning the proven need for, or benefit from, such training. The BS-AC has for years prohibited it as a part of their tests for certification, while the French have regarded it as essential for all divers to demonstrate “Free Ascent”. There are, regrettably, no Incident Reports from France so the true safety of their methods must remain conjectural, but the BS-AC. Incident Reports seem to illustrate the small part an ability to ascend in an emergency depends on previous practical training. All parties agree, however, on the need for a thorough teaching of the theory of safe ascents to all divers at an early stage in instruction.

In addition to those who hold strong views on this matter there are many who display a fine balance of indecisiveness, debating the terminology of the various ascent procedures without examination of the basic facts. There is a further group who await an Official Verdict, aware of the balance that exists between the advantages and disadvantages of each teaching routine. It is to these the following is primarily directed.

For convenience the presentation of evidence is in three sections :

1. The opinions and experience of Australian diving instructors who responded to a pilot survey in 1975 concerning Emergency Ascents.
2. Information available from SETT and Chamber incident reports.
3. Information available from published reports of Pulmonary Barotrauma associated with diving.

1. Australian "Emergency Ascent" survey

In 1975 a questionnaire was distributed to members of two groups of diving instructors. This was a pilot survey intended to determine the feasibility of such an approach, divers being notoriously reluctant to put pen to paper, though not averse to verbal commentaries about diving misadventures under informal conditions. They were asked whether they believed it enough to teach but not practice Emergency Ascent (the type of ascent was not strictly defined), what their present practice was and whether they would wish to alter this if free to do so, and what occasions of "real" emergency ascent had either occurred to them or were known to them. There were 32 replies, which was sufficient to indicate the value of this type of investigation. Attempts were made to interest overseas groups in a similar project, unfortunately without eliciting much enthusiasm.

As had been anticipated there was a majority in favour of practicing of Emergency Ascent by pupils, but many qualified their opinions in a significant manner. Some of these comments are shown in Appendix A. It was noted that the term "Free Ascent" (FA) was being interpreted in a wide spectrum of ways. Some required a ditch-and-ascent, others carefully accompanied their pupils as they ascended with full equipment, demand valve mouthpiece in hand ready for immediate use. Some thought the training should be postponed till the diver was sufficiently experienced to seek a 2nd Class Certification, and some reserved this test for certification of instructors themselves. As it is known that the highest fatality rate occurs among the untrained or newly trained group of divers it is somewhat Delphic to state that such practice is "essential, but <u>not</u> desirable to inflict on students in their initial training". The figures were 23 (72%) in favour of practice, 9 (28%) against. The reason for opposing such practicing for emergencies was fear of a fatality occurring.

Concerning "for real" emergency ascents, seven claimed that not only had they personally never needed to take such action but they had no real knowledge of others taking it. This was in great contrast with some others who regarded an out-of-air situation as a normal occurrence experienced by most of their pupils, the instructors being so used to buddy breathing with the pupils for this reason that they regarded it as a non-event. Excluding such in-training events there were 64 incidents reported (Table 1 and Appendix A). Though the accuracy of stated depths and causes cannot be assessed and these must represent but a small fraction of the emergency ascents that occur, it is likely that the statements indicate the experience and beliefs of this group of instructors. No information was supplied as to the training, if any, these divers had received. Four cases of possible lung overpressure, non serious, were mentioned. One was a blackout near to the surface after running out of air at 100 feet at Mt Gambier luckily the buddy had an octopus rig. One diver experienced chest pain following a rapid involuntary ascent from 10 feet, the result of dropping his weight belt while instructing pupils in rough low visibility water. The third case was of subcutaneous emphysema following a hurried ascent from 20 feet when regulator trouble occurred, while the fourth was a blackout associated with an ascent from 150 feet. It is unlikely that these are the only cases that occurred, given the methodology of this survey. Pulmonary barotrauma is possibly both much more common and more benign than is generally stated, though always potentially dangerous through entry of air into the circulation.

Attention should possibly be directed strongly to the alleged causes of the out-of-air situation developing. The term "regulator failure" may in reality indicate an empty tank if the low-air situation has not been recognised, or it may indicate the need for an urgent investigation to identify the trouble accurately, "Reserve" failures are best avoided by the discontinuance of this type of unit, the use of a tank contents gauge and possibly also a sonic warning of low-air would meet requirements of safety. Hookah failures are a matter worth special consideration, if only because so many seem to think no training is necessary before they are used. The occurrence of simply out-of-air situations in the absence of equipment malfunction can be regarded as indicating bad diving discipline, though the answers of several instructors suggest an easy acceptance of this type of diving. That so many cases occur at Mt Gambier may indicate an excess of “cowboys” among occasional visitors to this area. Their survival indicates that the “terms of trade” seem to favour survival under emergency no-air ascents.

Those responding to this survey were not necessarily fully representative of the opinions and experience of all instructors but they do at least illustrate the problem as viewed by non-medical but safety orientated and active diving instructors.

2. <u>SETT and Chamber reports</u> (see also Appendix B)

There would probably be no opposition to the practicing of “Free Ascent” (FA) by all pupils under initial scuba training were it not for the strong and repeated warnings issued to civil diving groups by personnel of both the US Navy and Royal Navy. This has been due to their experience during the training of submarine crew in Submarine Escape Training Tank (SETT) ascents where deaths have unexpectedly occurred in carefully supervised physically fit men apparently making faultless exhalations. There have even been Air Embolism cases among such fit personnel undergoing Chamber pressure tests to 100-112 feet prior to the in-water training (USA, UK, South Africa). Though many question the relevance of SETT experience to the diving situation, because the ascent made is different and the subjects lack the motivation of pupil divers towards being <u>in</u> the water, the point at issue here is that carefully supervised ascents in carefully checked healthy young men in warm, well lit water and with emergency recompression facilities a few seconds away from the point of emergence may nevertheless prove fatal. The deaths may be insignificant statistically but are not unimportant to the victim and the relatives. Moses gives an apparent incidence of extra alveolar air and/or air embolism as <u>1 per 7,200</u> ascents (<u>all</u> types). His figures are subject to error as the records had not been kept in a manner designed to furnish such details, though the New London Tank figures were available.

The figures offered of morbidity refer to clinical cases and there is now evidence that many less apparent lesions are occurring. Ingvar et al. in Sweden demonstrated the occurrence of asymptomatic EEG changes after supervised SETT ascents and James in the USA has shown the presence of extra alveolar air in 2 of 170 consecutive trainees, each apparently making three ascents. This is a risk rate of 1 case per 255 ascents. While it must be stressed that these people were not clinically disturbed to any significant degree by the changes noted it may also be noted that they would not have been included in the conventional listing of morbidity following training ascents, yet would have been at risk of an air bubble reaching a vital area of the brain. Such a risk may be justified by the benefits of such training, but such benefits require to be proven first if any less stringent management of civil ascents was proposed than that followed by US and Royal Navies. It is possibly of interest that the first ever necessitous escape from a submarine, that of the three man crew of the “Sea Diver” in 1851, was totally successful from 60 feet despite an absence of training for such an eventuality. And the RN investigation of successful WW2 submarine escapes (all nations) showed that a large proportion were made without equipment or prior training. Necessity is certainly a convincing teacher.

The available figures indicate certain additional conclusions can be drawn as to the relative risks of the various ascent modes (Table 2). Under training conditions a “Free Ascent” is the most dangerous, a buoyant ascent less so, and one using a Submarine Escape Apparatus (SEA) the safest. A correctly used SEA should be as safe as a rapid scuba ascent but the use of the apparatus is disconcerting to some at the

SETT and apparently often unsuccessful under the stress of a subsunk situation.

3. Diving Training and other cases of Pulmonary Barotrauma

It is generally believed that there are few, if any, fatalities or clinical incidents associated with ascent training and that this illustrates the basic safety of the procedure. Setting aside the fallacy that nil reports indicate nil cases, there have been numerous case reports published. These cases (Appendix C) have occurred in depths as little as 8 feet. Many have not been fatal but to be reported at all they must have been significant, so it is highly probable that many less severe cases have remained unreported. In the Australian "Stickybeak" diving fatalities survey there have been four scuba dive deaths where air embolism has been a probable cause, one being a FA training ascent several years ago. Even apparently uneventful diving may be followed by evidence of pulmonary barotrauma. The US Navy has even reported an air embolism in a snorkel diver ascending from 30 feet. As an example of the need to give restricted credence to nil reports a case of a fatal practice (training) 100 feet FA is known (overseas) where not only was there neither police investigation or Inquest into the event but those involved called a person who reported the case to a friend an (expletive-deleted) troublesome fellow. The official cause of death was drowning.

It is hoped that readers will supply the author with details of incidents associated with training or emergency conditions known to them, for the presently available reports may represent a biased sample of diving incidents.

Discussion

There are several points of interest that emerge from the available facts. First, cases of pulmonary barotrauma can occur during normal diving and are of clinical significance in a statistically relevant proportion of ascents of an "irregular" nature, however thorough the precautions. Second, extra alveolar air and cerebral air embolism, the result of pulmonary barotrauma of ascent, have effects ranging from immediate death to damage discoverable only by the use of special tests (Chest X-Ray; EEG). There does not seem to be a reason why some become victims and others suffer nil ill effects while undertaking similar ascents, but the work by Walder and others suggests that in man, as in guinea-pigs, bronchospasm or bronchial obstruction by mucus may have occurred. He quotes a fatality that occurred during decompression of a man who had been effected by fumes. Thirdly, various methods of "irregular ascent" are at present being performed by many pupils under initial training courses. There is also probably, a significant degree of poor diving occurring if measured by the occurrence of out-of-air incidents glimpsed at in the survey.

It is of relevance to note that the only BS-AC. specific investigation for making Emergency Ascents (Hume Wallace, Kingston Branch 1956-1961) indicated that the failure of inferior demand valves then entering the UK was the commonest cause, with poor diving discipline also significant. Since 1966 the BS-AC has prohibited practice of "free ascents" and they have not been required for certification. Incident Reports since then have shown no need to change this rule. The recent introduction of Deep Rescue training has itself produced casualties, a practical example of the need to ensure that training for safety is itself safe. PRIMUM NON NOCERE should ever be our guide.

Naval experience indicates that it is safest to ascend with buoyancy and with some source of air, conditions best met with the shot line ascents with demand valve in hand already practiced by some instructors. This will significantly reduce, though not eliminate, the risks.

As the vast majority of emergency situations are potentially avoidable, by watching the remaining air level and rigorously investigating all cases of equipment malfunction, great effort should be put into the reporting of all such incidents as may occur in order that dangers may be recognised and remedied before fatalities occur.

CONCLUSIONS

1. Scuba diving is a remarkably safe procedure, in part through the tolerance of the body to the majority of barotrauma incidents.

2. Cerebral Air Embolism occurs in a significant number of cases of carefully supervised SETT and Chamber pressure exposures but is rarely fatal. Minor cases are probably undiagnosed, but frequent.

3. Prevention of diving morbidity and mortality should be based both on a reduction of the likelihood of emergency situations developing and a thorough indoctrination of a course of action for any out-of-air situation. Such training should be less dangerous than the risk of the problem itself. Input of information is required to monitor both the causes of problems and the response/ outcome when they do occur.

4. 100% safety is never attainable. If practice in ascent is considered necessary, a shotline ascent with mouthpiece in hand seems the safest.

TABLE 1
AUSTRALIAN "EMERGENCY ASCENT" PROJECT 1975

PROBLEM ASCENT MODE:	Free Ascent	Buddy Breathing	TOTAL
Out of Air	17	9	26
Regulator failure	6	4	10
Reserve failure	3	1	4
Hose supply failure	9	Nil	9
"Mechanical" failure	4	1	5
Sudden XS buoyancy	3	Nil	3
Other causes	5	Nil	5
Total	**47**	**15**	**64**

TABLE 2
EXTRA ALVEOLAR AIR AND AIR EMBOLISM ASSOCIATED WITH SETT TRAINING

New London (USA) and HMS Dolphin (UK) tanks

		SEA	FA	Buoyant	Steinke	Fatal	RCC cases	
Moses	1928-51	1:16,100	1:1,030	1:3,250				
Peirano et al	1929-54	1:21,776	1:1,483	-	-	4	14	
Waite et al	1938-65	1:27,571	1:1,172	-	4	4		
Lambeth	1954-57	-	-	1:3,000	-	-		
Elliott et al	"20 yrs"		"better than" 1:2,300 ascents				5	3

Appendix A
Reported Emergency Ascents

Report	Depth fsw	No Air Air	Reg Fail	Reserve Fail	Hose Supply	Other	Additional Details Supplied
A1	100	BB					
	100	BB				FA	Mt Gambier: Octopus share ascent blackout near to surface accidental drop weight belt while teaching. Rough sea, poor visibility:- chest pain
A2	80	FA					
A3	?					FA	Tank entangled: murky water at power station
A4	20-40				FA		
	20-40				FA		
	20-40				FA		
	100	BB					Mt Gambier:
	20		BB				Subcutaneous emphysema resulted
A6	?				FA		
A9	60					FA	"Mechanical failure of equipment"
	90					FA	*ditto*
A10	40	FA					
	50						
	100			FA			Mt Gambier
A11	?				FA		Mechanical failure
	?				FA		Mouthpiece dislodged
	?	FA					
	?	FA					
	?	FA					
A12	?			BB			
	?		FA				
	?		FA				
A13	120						All students use up air and need to FA
A14	30				FA		Know of other hookah failures also
A15	40					FA	Full facemask cracked, under “Leviathan”
	30	BB					Pupil, sea, low air; BB with Instructor
A16	60	FA					Freeing anchor after a dive
	20	FA					Reserve already “on” in error
	100	FA					Mt Gambier-recovering dropped torch
	25					FA	“Some Idiot turned the air off”
A18	20		BB				occurred at a decompression stop
	150		BB				"dive required decompression so BB not FA"

Report	Depth fsw	No Air Air	Reg Fail	Reserve Fail	Hose Supply	Other	Additional Details Supplied
A19	30					FA	failed to fully open on/off valve before water entry: know of other cases
	100			FA			Air cut off when pulled reserve: know of other cases
A20	120					FA	Interrupted air supply
	70	FA					Mt Gambier 2nd descent same tank; pulled reserve then no air. Untrained in FA.
A23	70	FA					Gear exchange test: given empty tank
	?	BB					Horizontal shallow swim till safe to ascend
A24	130					FA	Mt Gambier: ABLJ valve jammed so rapid ascent
	?					FA	Mt Gambier: *ditto*
A26	60				FA		
	150		BB				Husband/wife team; wife's regulator failed
	100				**FA		Hookah filter "blew-off screw" came free with
	100				**FA		two divers below. Both successful
	60				FA		Hookah hose changed to wrong outlet
	(100 snorkellers FA after diving to scuba divers at Mt Gambier)						
B1	130		FA				Mt Gambier
	60	FA					
B1	150	FA					
	150	FA					Shallow water black-out": checked at SUM
B2	40	FA					
	25		FA				
	150	FA					
	130		FA				
B3	?	FA					Night dive, out of air after 5 minutes; with an instructor. "Often needed to FA since then: ALL divers do"
B4	?	BB					during a training session
	?					BB	faulty J-valve
B5	20	FA					"1-3 students run out of air every course"
	?	BB					"Student took my demand valve so BB with the instructor"

Some comments offered concerning practice of Emergency Ascents:

A2 possibly <u>allow</u> for 3rd class certificate, and <u>encourage</u> for 2nd class certificate
A5 perform up shot line, demand valve mouthpiece in hand: RCC at site
A6 with demand valve in hand and in all equipment, all present students.
A10 7 foot ascent after ditch scuba, never in open water; allow, instructor present.

A11 Allow, not obligatory, 6 metre depth water.
A13 Require FA with instructor present; believe practically every diver on a shallow dive (20 feet or less) sometimes sucks tank empty knowing can FA.
A14 Require ascent wearing equipment, mouthpiece in hand, from 60 feet. Avoid BB ascents. Would suggest ditching scuba or hookah if “for real” emergency
A15 Desire that pupils practice but forbid because of legal liability risk.
A16 Undecided: D&R in pool and sea but forbid solo FA. Suggest modify test to ditch-swim to buddy and BB - return to and don scuba again, at constant depth
A17 Essential but not desirable to inflict on students at initial training, include later. At least one FA from over 10 metres.
A18 Teach pupils feel of an empty tank; forbid FA; teach NAUI bail-out not D&R
A19 Require 3 metre D&R instructor monitored, pool and open sea.
A20 Instructor demonstrates FA, prohibit pupils: horizontal swims set to set in 1 metre water suggested as good substitute for FA practice.
A21 Instructor may show FA in shallow water: possibly ditch and ascend for more experienced divers, forbid for trainees.
A22 Suggest increasing depths FA for 2nd class divers; forbid at basic level.
A23 Instructor present allow ascent with mouthpiece in hand, then after ditch
A24 Encourage FA in pool then sea with shot line, mouthpiece in hand
A26 Forbid for pupils; suggest instructors train ascents 100 feet to 30 foot level.
A27 Forbid beginners, possibly allow for 2nd class certification.
B1 Require all pupils to FA; never dive deeper than able to EFSA; 25 feet basic.
B2 Require, even if only Ditch & Recovery test ascent: 15-20 feet.
B3 Require EFSA practice; criminally negligent if did otherwise: 10-40 feet
B4 Require but never more than 20 feet: would prefer 45-60 feet for basic divers
B5 Require, 10-15 feet increasing to 60 feet for advanced trainees.

Regarding practice of Emergency Ascent by all trainee divers:

In favour: A1, A2, A3, A4, A5, A6, A10, A11, A12, A13, A14, A15, A16, A17, A19, A22, A23, A24 B1, B2, B3, B4, B5.

Against: A7, A8, A9, A18, A20, A21, A25, A26, A27.

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	Spinal "bend" (air embolism?) with imperfect resolution.	
Los Angeles	Cases include successful FA by minisub non-diver from 250 feet!	
Nemiroff	Diver, entangled at 15 feet, dragged to surface by tender. Diver, age 14, first dive, "deep", suddenly surfaced. Screamed & sank: rescued: decerebrate. Treated as drowning, no RCC. No cure	
Okalyi	3 pearl divers FA from 15-30 feet	FATAL
Pollock	Holding onto fixed buoy; large waves washing over	FATAL AE
USN 1972	5 feet training dive with semi-closed circuit scuba giving positive pressure gas supply. Probable AE signs.	CURED
USN 1971	35 feet depth using SSBN unit; free flowing regulator while swimming. Snorkel diver 30 foot dive	
Uni Rhode Island	Numerous PBT cases are briefly reported in Scuba Safety Report No 3	
Walker	Case SC 71/3 (unpublished) 6ft ascent in calm tepid water	FATAL

APPENDIX B

SETT and Chamber cases of extra alveolar air and/or air embolism are noted in varying degrees of detail by a number of writers. Moses gives brief details of 71 incidents, of which 54 were with ascents and 17 in the pre-ascent pressure exposure test in a chamber at “112ft”. There were in addition three cases of decompression sickness in instructors acting as attendants during therapeutic recompressions. This indicates a weakness in the therapeutic tables. Some of these cases are reported in greater detail by Behnke, Brown, Chrisman, Kinsey, Lieblow, MacClatchie, Polak and Adams, Polak and Tibbals, and Periano et al. A more recent case has been fully documented by Collins. In some of these US Navy cases some divergence from correct ascent procedure was either observed or later admitted but in others the drill appears to have been correctly performed. At all relevant times the trainees were under very close observation by highly trained and motivated instructors.

In the UK, SETT cases have been described by Elliott, Forbes, Honor, Lambert and Warner. Brief quotations may explain the strong views held by many Naval personnel involved in SETT training of submariners when advising against practice of out-of-air ascents by civil diving groups:

- “Accidents have happened to the actual training staff”. (Warner, 1967)
- “The RN has considerable experience of free ascent training and reports that, in spite of the closest possible supervision, an appreciable number of incidents occur. Some of them, unfortunately, fatal”. (Warner, 1969)
- “Case 1, a submariner, was a good swimmer in his early 20s. He volunteered to make a 100 foot ascent with instructors present. Wearing goggles, nose-clip and stole (life jacket) he made a “copybook” ascent. A loud exhalation of air was heard as he broke surface. He was unable to understand the order to put the tube back into the loop of the stole, caught the ladder with his left hand only, said “I feel...” and collapsed. It was only 6 feet to the RCC and he was compressed to “165 feet” less than a minute after leaving the tank bottom. He was conscious there so decompression was commenced. At 10 feet he said “When will I be able to see?” and it was realised that he was blind. He died 27 hours later”. (Honor, 1970)
- “Despite all precautions, incidents occur. Over 20 years these have averaged 1 in every 2,500 ascents and have, in many cases, followed ascents which appeared to be in every respect normal and correct”. (Forbes, 1975)
- “Since the adoption of free ascent with buoyancy by the RN in 1954 about 34,000 escapes have been made (15, 30, 30, 60 and 100 feet). There have been 10 casualties with symptoms primarily of cerebral air embolism and two with wide spread damage in the thorax without associated neurological symptoms, an incidence of only slightly more than 1 in 3,000 ascents. (Lambert ,1958)
- “The main group (studied) consisted of 112 subjects in which 4 cases of proven lung rupture and air embolism were observed. In addition to routine clinical investigations, EEG records were carried out before and after diving in the main series. It was found that free escape as such affects the EEG only slightly ... in some subjects without neurological symptoms (the changes) were so marked that the records following the diving were classified as abnormal.” (Ingvar, Adolfson and Lindemark, 1973)

Caisson workers are apparently at risk of air embolism during their routine decompression after working under pressure, though the length of pressure exposure is not a critical factor. Warner reports that 6 cases occurred during the construction of the Dartford tunnel. They had been at less than 3 ATA for less than 4 hours. One victim who fell unconscious after leaving the lock, was later shown to have a lung cyst. It was supposed that bronchial blocking was occurring in victims and tests were carried out on guinea-pigs that showed air embolism was produced in 75% of animals if bronchiolar obstruction was induced by a histamine spray in the chamber. Later experiments have shown air embolism can be produced in guinea-pigs after short exposure to 2 ATA. A case is noted where a fatal air embolism on decompression followed exposure to irritant fumes.

The German civil chamber incident was an example of the tragic results one can produce when dealing with forces one does not understand.

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APPENDIX C

Air Embolism cases associated with training

Cooperman	Pool - 9 feet ditch and recovery test	FATAL
Davis, Bassett	Lake - 35 feet swimming ascent training: unconscious. Recovered "and 2 additional cases have occurred"	
Denney, Read	Pool - 15 feet lesson in buddy breathing failed	FATAL
Harveyson et al	Sea - 20 feet FA test. Bubbles in coronary arteries	FATAL
Hattori	Sea - 25 feet 3 cases during FA training.	
Kruse	"tank"? - ditch and recovery test. Hemiplegia but recovered.	
Miles S	Sea - 20, 34, 35, 60 ft - Free Ascent training.	4 Fatalities
	Sea ? - 29, 25, 30 ft - FA training	non-fatal incidents
Nemiroff	Pool - 8 feet ditch and recovery test, at night.	Recovered
	Quarry ? - Free Ascent test: became unconscious	Recovered
Strauss,Prockof	Pool - 12 ft ascent followed by blindness, emphysema	Recovered
USN 12-70	Sea - 15 feet Buoyant ascent	
Uni Rhode Island	Pool	
(report 3)	- 8 feet Doff & Don test: breath help as ascent:blind	Case 1
	- 40 feet Doff & Don and FA	Case 4
	- 43 ft FA exercise: convulsed, paraplegic: recovered	Case 5
	- 90 ft FA exercise: part blind, right paralysis: slow recovery	Case 15

Air Embolism diving incidents

Anderson	Helmet diver; rapid ascent from 30 feet	FATAL
Davis, Bassett	Panic ascent (untrained) from 80 feet. Legs paralysed:recovered "and know of case from 10 feet"	
Denney, Glas	Sea - 20 feet ascent. "19 such deaths in Michigan since 1959"	FATAL
Elliott DH	Impaired consciousness after rapid ascent from 10 feet noted	
Harpur	Sea - unconscious diver: buddy suffered fatal AE in rescue	
	Sea - unconscious diver: bystander ascended, holding breath while buddy successfully rescued victim. Bystander got FATAL AE	
Hattori	Sea - at 75 feet ascended 25 feet over a rock and suffered hemiplegia and disorientated. Rescued by instructor. Recovered fully. Also cases from 60 feet (fatal), 30 feet and 90 feet dives.	
Jones	SA Navy diver ship bottom-search, on back; developed chest pain. Other cases PBT also reported	
LaCarda	Betty G cleared mask forcefully while holding anchor line at 10 feet.	

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Barotrauma after apparently normal diving

Bayliss G	Four non-fatal barotrauma cases. (Unpublished thesis on underwater diving 1971).
Colebatch	See previous reference
Jones AG	See previous reference
US Navy	Naval safety Report OPNAVINST 9940.2A 1971

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Davis, Bassett.	Diving Casualties, Lessons learned. *NAUI Conference "IQ6"*, 1974
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Harveyson et al.	Fatal air embolism from use of a compressed air diving unit. *Med J Australia* 1956; 21 April: 658-659
Hattori.	A review of air embolism among divers in the Monteroy Peninsular. *SPUMS Journal* 1975; July-Dec.
Kruse.	Air Embolism and other skin diving problems. *Northwest Medicine* 1963; 62: 525-527.
Miles S.	165 Diving Accidents. *J Royal Naval Medical Service* 1964; 50(3): 129-139.
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US Navy.	*Research Report*, 12-70
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US Navy.	Naval Safety Report *OPNAVINST* 9940.2A ref 1971 and 1972
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