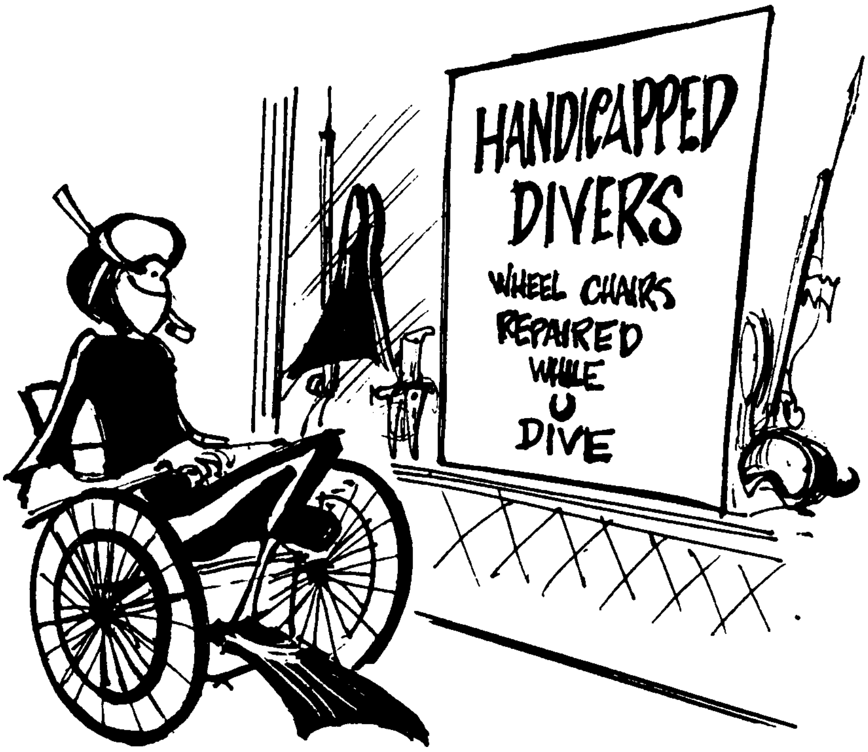
SPUMS JOURNAL
South Pacific Underwater Medicine Society
JANUARY TO MARCH 1983



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OFFICE BEARERS

EDITORIAL

Once upon a time, not so very long ago, diving was a direct confrontation between a brave, hardy and possibly simple man and the dangerous, little understood, underwater environment. Times change and the major problems have probably all been identified, though by no means mastered. This has had as one consequence, the recognition that absolute standards of medical fitness may no longer be appropriate when considering the recreational diver. Should asthma be regarded as a single entity or a syndrome with a wide spectrum of significance, should contact lenses be advised or deplored, and what advice should be given to the applicant who cannot 'clear' his ears? These problems. like the liability to migraine, are important to a significant number of persons wishing to scuba dive. As applicants are now being increasingly directed towards doctors with some knowledge of Diving Medicine, in Australia and the United Kingdom at least, it is appropriate for them to be discussed in these pages. Judging from the report by Dennis Graver, the need for a Diving Medical is by no means undisputed in the USA. There, as here, the question is being raised as to whether a list of 'approved doctors' should be made available to diving instructors. While this is an idea with merit, mere membership of SPUMS, or even of UMS, cannot be taken to indicate a seal of approval. It would be interesting to investigate the evidence for demanding a Medical Examination, logical though the requirement may be.

By a strange quirk of timing, the schizophrenic pragmatism of diving medicine is illustrated by the simultaneous erecting of a medical barrier or hurdle between would be sport divers and their primary courses of instruction and an interest in enabling the obviously disabled to receive instruction and to obtain certification. The papers which detail training of paraplegics (and other disabled persons) say nothing new, but they do indicate the growing interest in this group of people. The problem is certain to grow and, like decisions on the allowability of young persons as scuba divers, those who are involved in 'diving medicine' will have to make decisions on a case-by-case basis. This is considerably more risky than straight-forward assessments, for there will be no thanks to anyone whose patient becomes a morbidity statistic.

There is much more in this issue worth discussion, not least the two provoking and strongly partisan papers which first appeared in UNDERCURRENT. Lou Read makes out the case for carefully planned solo diving, which is far different from swimming off and leaving your buddy. Nigel Froom lets off steam about an over-reliance on complicated apparatus as an alternative to the adequate teaching of basic skills. It is difficult to believe that even in the USA the TWIT organisation would allow Instructor status to such a Pig. Judging from recent legal news it seems likely that the Owl and the Pussycat will soon be receiving a multi-million dollar claim from the Executors of the deceased on the grounds that not only did they fail to practice buddy diving procedures, but they failed to take any steps to institute a search and rescue procedure. But Fairy Tales let the good guys win.

While those with a slightly guilty feeling about their dive profiles may be considering the location of the nearest scintigraph, and those with ideas of a high dive are reading Bruce Basset very carefully, those in the frigid south will be considering 'brewing up' with a few warming 'tea bags' from the CSIRO. But if something goes wrong, DON'T FORGET THE OXYGEN. A recently reported case from Ireland indicates that if you 'know' you have made a safe no-decompression dive and ignore symptoms, you may end up with a permanent spinal deficit. The one absolute certainty about diving problems is that if you do get a problem, it is no good saying it should not happen. There is a lot we still do not know. But at least we are now a little aware of the fact.

In future issues we will be publishing a review of Dr Straun Sutherland's 'Australian Animal Toxins'; some notes on the early days of Australian diving; a report by Dr Hattori on diving casualties from the Monterey Peninsular area; other papers from the 1982 SPUMS AGM; the papers delivered at the SPUMS meeting in Melbourne in November 1982; and the personal story of a handicapped diver.

SPUMS EXECUTIVE COMMITTEE MEETING

Date:	Saturday 20 November 1982
Time:	10 am
Venue:	80 Wellington Parade, East Melbourne
Attending:	Drs RJ Knight, J Doncaster, D Walker, H Oxer, V Brand, JE Mannerheim, J McKee

1. Minutes of Previous Meetings

   a) The SPUMS Executive Committee Meeting planned for Saturday 26 June 1982 at The Madang Resort Motel, PNG, was not held, owing to flight delays.

   b) Minutes of AGM June/July 1982. Madang, PNG.

2. Dr B Hurst proposed that the accountant, Mr Bob Goddard should be paid and not remain in an honorary position.
   Carried.

3. Dr C Lourey proposed three executive meetings per year ie. a regional meeting in the first and last quarter and one at the AGM.
   Accepted.

4. Dr C Lourey proposed subsidisation of executive committee members' interstate air fares.

   Amendment vote.
   38:1 for air fare subsidy equal to 100% of Apex fare to be paid by the Treasurer to committee members attending executive meetings (other than AGM) from interstate, New Zealand or SE Asia.

5. Dr C Lourey proposed a postal ballot for positions on executive committee, so that all SPUMS members would have the chance to vote for executive committee nominees.
   Carried.

6. Committee Membership changes:-

   Dr Chris Lourey retired as secretary Dr Bill Hurst retired as treasurer.

   The following were the only nominations and were declared elected:-

President	RJ Knight
Secretary	JE Mannerheim
Editor	D Walker
Treasurer	J Doncaster
Committee Members	V Brand,H Oxer, J McKee

7. Executive Meeting

   Sunday 4 July 1982 held at the Madang Resort Hotel, PNG.

Attending:	JE Mannerheim, RJ Knight, J Doncaster, V Brand, J McKee
Absent:	H Oxer, D Walker.

   Discussion re 1983 Annual Scientific Conference Venue. Two votes Fiji, two votes Vila, one abstention.
   Decision: to give vote to SPUMS members attending 1982 Annual Scientific Meeting.
   Result: Majority vote for Fiji.

8. President's Report

   a) Chris Lourey's letter re deputising Dr J Miller as voting representative for SPUMS at UMS executive meetings.

   b) Letter from Dr Acott re Rockhampton meeting in October, 1983.

   c) Letter from Health Department, New South Wales, re posters.

9. Treasurer's Report

Balance Bank			$3,913.95
Subs.	Australia		6,464.00
	Foreign		247.64
Interest			82.37
			$11,707.96
Expenses			
Posters		$1,570.40	
Secretarial		1,634.60	
Misc.		77.43	
			$4,027.60

   $5,000 in 30 day account @ 14%

Balance in National Bank	247.64
Investment Account	5,000.00
Balance	1,147.52

   368 Paid Up members

10. Secretary's Report

    Overpayment by new meters and some renewal subscriptions by $5 - 18.00.
    Action: Nil

11. Newsletter

    July-Sept 1982 issue sent out. Oct-Dec issue in preparation.

12. New Members

    Applications approved:-

Associate:	16 Australian 1 overseas
Full:	12 Australian 5 overseas
Corp:	1 Australian 1 overseas
Total:	36 July-November

13. Correspondence

a) Dr W Pettigrew, Army Reserve. Army Diving School is organising Army Medical standards for diving and wanted names and addresses of suitable SPUMS members to present Army proposals to for comment and acceptance.

Action:
List of Australian members who have Diploma of Diving and Hyperbaric Medicine, those who have completed courses at SUM, executive committee members and members who have attended Annual Scientific meetings and shown some expertise, were sent to him, plus suggestion that he write to the Editor of SPUMS Journal re publication of Standards.

b) Letter from Dr G Yacoub, Adelaide, requesting addresses of SPUMS members at Mt Gambier.

Action:
As none there, names and addresses of nearest supplied.

c) Letters from Dr Brian McLaughlin of NUMBS (Newcastle Underwater Medicine and Barotrauma Society) re Scientific Diving Meeting in Newcastle, April 30/May 1, 1983.

Speakers: Neville Coleman "Venomous Critters" Professor White - "Underwater Physiology" Notice in SPUMS Journal.

d) Requests from members who have completed both basic and advanced courses at SUM and have 2-6 years part-time experience in Underwater Medicine, re necessary requirements to obtain Diploma of Diving Medicine:

Dr Mark Fraundorfer	NZ
Dr Greg Deleuil	WA

The Executive Committee discussed the requirements of the Diploma and whether it should be graded eg. Examiner standard and Chamber treatment standard.

Action:
Dr Harry Oxer to formulate conditions.

14. Committee Meeting

The next Committee Meeting arranged to coincide with scientific meetings in:

Hamilton NSW	30/4/83 - 1/5/83
Fiji	20/6/83 - 27/6/83
Rockhampton, Qld	October 1983

15. Presentation of possible venue sites for 1984 Annual Scientific Meeting by Anthony Newly of Allways Travel Service, which has organised SPUMS meetings for the past six years.

SPUMS EXECUTIVE COMMITTEE MEETING

Date: Sunday 21/11/82
Time: 9.30 am
Venue: 80 Wellington Parade, East Melbourne.
Present: RJ Knight, JE Mannerheim, J Doncaster, D Walker, H Oxer.

Presentation of possible venue sites for 1984 Annual Scientific Meeting by Peter Stone (with Jan Stone) from Aquarius Dive Travel.

Action:
Unanimous decision. Allways chosen to investigate Phuket, Thailand, Bangkok and Hong Kong.

Aquarius informed of decision and all executive committee members were sent copies of their letter in reply.

POSTAL BALLOT

The result of the postal ballot held to alter the constitution of SPUMS to allow the committee to be elected by postal ballot was as follows:

YES	110
NO	6
Total Votes received	116

This is more than 25% of the membership of SPUMS so the motion has been carried.

8th ANNUAL CONFERENCE ON CLINICAL APPLICATIONS OF HYPERBARIC OXYGEN JUNE 8 - 10, 1983

The Center for Health Education,
2801 Atlantic Avenue,
Long Beach,
CALIFORNIA 90801-1428

An update of current concepts and accepted uses of hyperbaric oxygen therapy. For further details contact Program Co-ordinator at the above address.

SPUMS MEETING, ROCKHAMPTON
29 and 30 October 1983

In conjunction with the Queensland Branch of the Australian Intensive Care Society.

DIVING, ITU AND ENVENOMATION

The venue of this meeting has been changed from Great Keppel Island to the Leichhardt Hotel, Rockhampton.

The Programme will include the following speakers and subjects:

Dr Chris Acott (Director, ITU, Rockhampton) [Sea Snake Envenomation]

Dr I Airey (Director of ITU, Mater Hospital, Brisbane)[Anaphylaxis]

Dr V Callanagh (Director of ITU, Townsville)

Dr M Colwick [Computers in ITU]

Dr R Jones (Facio-maxillary Surgeon) [Facial injuries]

Dr John Knight [Hypothemia]

Dr M McDonald [Thoughts on ITU in a Country Area]

Dr Hart MacKenzie (Royal Australian Navy)[Hyperbaric Oxygen]

Dr H Mercer (Paediatrician)[Sea Snake Bite]

Dr J Orton (Anaesthetist)[Taipan Snake Bites. Decompression Sickness]

Dr H Stevens [Blue Ring Octopus Envenomation]

Dr Straun Sutherland

For further details, contact:

Dr CJ Acott,
Director of Intensive Care,
Rockhampton Base Hospital,
ROCKHAMPTON QLD 4700

NOTES TO CORRESPONDENTS AND AUTHORS

Please type all correspondence, in double spacing and only on one side of the paper, and be certain to give your name and address even though they may not be for publication.

Authors are requested to be considerate of the limited facilities for the redrawing of tables, graphs or illustrations and should provide these in a presentation suitable for photo-reduction direct. Books, journals, notices or symposia etc., will be given consideration for notice in this journal.

NUMBS

The Newcastle Underwater Medicine and Barotrauma Society will hold a meeting on Saturday, April 30th and Sunday, May 1st, 1983.

The guest speaker will be Neville Coleman.

PROGRAMME

30 April 1983

0900	Registration
1000	Diving
1400	Talks by Neville Coleman John Knight Prof A Smith
1730	Film by Roche
1930	Dinner. Speaker Berry Street

1 May 1983

0830	Talks by Neville Coleman John Knight
1030	Diving
1330-1530	Lunch

Cost $40 (includes all food and drinks)

For further details contact:

Dr Brian McLaughlin
37 Marshall St
New Lambton Heights NSW 2305
Tel. 049-615004

SPUMS 1983 ANNUAL SCIENTIFIC MEETING

PLACE:	THE REGENT OF FIJI HOTEL
DATES:	20 - 27 June 1983
GUEST SPEAKER:	PROFESSOR BRIAN HILLS

DIVING BEFORE, DURING AND AFTER

A BROCHURE WAS POSTED IN NOVEMBER

CONFERENCE ORGANISER:

DR JOHN KNIGHT
80 WELLINGTON PARADE
EAST MELBOURNE VIC 3002
AUSTRALIA.

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REPRINTING OF ARTICLES

Permission to reprint articles from this Journal will be granted on application to the Editor in the case of original contributions. Papers that are here reprinted from another (stated) source require direct application to the original publisher, this being the condition of publication in the SPUMS Journal

SPUMS

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 30th APRIL 1982

Opening Balance

Investment Accounts - CBC Savings Bank Ltd	2234.36	
Investment Accounts - Mutual Acceptance Ltd (11.75%)	1000.00	
Cash at Bank - ANZ Banking Group Ltd	2856.43	
Cash on Hand	2.00	6092.79

Add Income

Subscriptions	8311.79	
Interest Mutual Acceptance Ltd	126.72	
Interest CBC Savings Bank Ltd	248.84	
Refund - Balance of Conference Fees	1526.00	10213.35
		16306.14

Less Expenditure

Secretarial Service	2586.50	
Post	1004.65	
Stationery	256.17	
Journal	3967.20	
Purchase of Filing Cabinet	112.50	
Bank Charges	83.36	
Design of Poster	200.00	8210.38
		8095.76

TOTAL FUNDS 30 April 1982

Represented by:

Investment Account CBC Savings Bank Ltd	2483.20	
Investment Account Mutual Acceptance Ltd (13.25%)	1000.00	
Cash at Bank ANZ Banking Group Ltd	4610.56	
Cash at Hand	2.00	$ 8095.76

AUDITOR'S REPORT

I have examined the above statement of receipts and payments for the South Pacific Underwater Medical Society and state that the statement gives a true and fair view of the financial transactions of the Society.

ROBERT G GODDARD
ARMIT (Com) FASA

SPUMS SCIENTIFIC MEETING 1982

DIVING AND ALTITUDE: RECOMMENDATIONS FOR DIVERS

Bruce E Bassett

There are many scenarios in which diving and altitude exposures are encountered either sequentially or simultaneously. Commercial divers on oil rigs may be flown by helicopter back to shore following air, mixed-gas or saturation diving. They may then proceed onward by commercial aircraft. Scientific divers may require air transportation following similar type diving throughout the world, as might military divers. In some military operations by such groups as the US Air Forces Rescue and Recovery Service or Forward Air Controllers, the US Army's Special Forces or the US Navy's Seal Teams, divers may need to be recovered by helicopter immediately upon surfacing from air or mixed-gas dives. The largest group of divers of all, the sport diver, may easily be lured into diving on the day of departure, by private or commercial aircraft, from vacations at dive resorts throughout the world. One such resort in the Bahamas even advertises, in the Skin Diver Magazine, "Two dives on day of departure".

Commercial divers may be called upon for construction jobs on dams located at high elevations. In some cases sport divers may reside at low elevations and drive to higher elevations to dive, or following dives in high altitude lakes may have to drive to even higher elevations in returning to their origin. This is common in Northern California divers who dive in Lake Tahoe. Likewise, military divers may dive in high altitude lakes located at or near some military operation, or may be transported to and from such locations by land or air.

The final scenario involves the transportation of diving casualties from remote locations by aircraft or over mountain passes by land transportation. Such casualties may include cases of decompression sickness or air embolism being transported to recompression facilities or travelling after recompression therapy. Injured or ill divers may also require transportation to definitive medical care facilities. The extreme within this category is the saturated commercial diver (or scientific diver) who becomes seriously ill or injured while saturated and requires transportation to appropriate medical facilities.

PREVIOUSLY EXISTING RULES

Procedures and Recommendations For Flying After Diving

One of the earliest recommendations regarding flying-after-diving that the author is acquainted with was a US Navy rule which specified that altitude exposures above 18,000 feet could not be made until 12 hours after any dive deeper than 30 feet. This rule, which was also used by the US Air Force, existed for military aircrew members up until the mid-1960's. In examining this rule it can be seen that it allows very dangerous exposures, ie. deep dives followed by immediate ascent to any altitudes not exceeding 18,000 feet or long shallow dives (less than 30 feet) followed by immediate ascent to any altitude. This rule serves as an example of "experts" in aviation and aerospace medicine and physiology not being well enough versed in diving medicine and physiology to make sound judgements. It is noteworthy that at about this same period of time the diving medical experts at the experimental diving unit were using altitude exposures to 18,000 feet to test the "safety" of decompression schedules designed for "straight" sea level dives! The subjects were bending like pretzels and these tests were abandoned. The Naval Aviation rule was subsequently changed to specify no flying for 12 hours following any diving activity.

In the mid-1960's the US Air Force, which was then becoming involved in recompression chamber operations established an interval rule of 24 hours between any dive and any altitude exposure. This was not based on any evidence that 12 hours was insufficient other than the fact that the onset of delayed decompression sickness from altitude exposure had, in a few rare cases, exceeded 12 hours. To be safely conservative, the doubling of the Navy's recommended interval of 12 hours was arbitrarily chosen to protect the personnel working in the Air Force's hyperbaric chambers. This was also felt to be an adequate rule for aircrew members who might be sport divers. However, no thought was given to divers in the Air Force's Rescue and Recovery Service and this oversight created a major problem for that group for many years.

These military divers had two situations where this rule created real hardship. First were operations which called for direct helicopter recovery following dives made at sea level. These were generally special and limited operations for which revised no decompression limits were calculated to allow for direct ascent to 10,000 feet for a duration of four hours. The limits calculated and provided (by myself) always contained the notation that these limits had not been validated by manned testing. There were no reported problems with the use of these limits, but how often they were used and the details of their use were never reported.

The second problem area created was of a greater order of magnitude. Proficiency SCUBA dives are required for these divers, yet whenever they performed such dives they were grounded for 24 hours and could therefore not be scheduled to be on mission alert. In times of minimal manpower allocations this created much hairpulling by those tasked with training and scheduling of the pararescue personnel.

In 1969 Edel et al. reported their recommendations regarding flying-after-diving based on calculations and manned testing performed under contract to NASA. NASA's requirement existed because of water-immersion weightlessness simulation exercises conducted in conjunction with the Apollo programme. Astronauts were exposed on compressed air to depths to 50 fsw for rather lengthy periods, sometimes repetitively. NASA needed to know how soon after such exposures these busy astronauts could safely fly or be flown back to Houston or some other location. While the report to NASA contained such options as reducing the surface interval by breathing 100% oxygen, the recommendations that were picked up and promoted by various groups for various divers were that dives made exclusively within the no decompression limits of the USN tables during the preceding 12 hours could be followed by flight in commercial aircraft (cabin altitude not above 8,000) after a surface interval of two hours. If decompression dives were made, the surface interval requirement was increased to 24 hours. I have passed these recommendations along to thousands of sport divers. It became the rule adopted by, among others, the British Sub-Aqua Club.

The 1973 edition of the US Navy Diving manual states that divers must definitely not fly for at least 12 hours after diving with surface supplied air. No mention is made of restrictions regarding flying after SCUBA diving on air. No restrictions for any other diving in this edition of the manual may be found. In a later amendment the time restrictions were changed to two hours after No Stop air dives and 12 hours after air dives involving decompression. For saturation dives on mixed gas, 24 to 36 hours was the rule at the USN Experimental Diving Unit.

The Royal Navy Diving Manual takes a different approach and specifies surface intervals according to the altitude involved. For No Decompression dives the surface interval is under one hour before ascent to 1,000 feet one to two hours for 5,000 feet and over two hours for "unlimited" exposure altitude. For decompression dives the intervals are under four hours for 1,000 feet, 4-8 hours for 5,000 feet and over 8 hours for "unlimited". For saturation dives the interval is 48 hours.

The Canadian Defense and Civil Institute of Environmental Medicine rules are 12 hours for No Decompression dives, 24 hours for decompression dives and 72 hours to one week for saturation dives! Duke University, like the USAF, specifies 24 hours for any dive and 72 hours to one week after saturation.

Now we come to the rule most widely promoted in the Sport Diving community and also in the second edition of the NOAA Manual. This rule specifies that flights can be made in commercial aircraft as long as the USN Repetitive Group is no higher than D. This has two interpretations. If one surfaces from a dive with a D group then immediate ascent to altitude can occur. If a higher Repetitive Group is incurred, a surface interval which allows decay to a D group is specified. NOAA, also being concerned with saturation diving, specifies 36 hours before flight following such exposures.

Procedures and Recommendation for Diving at High Altitudes

Most professional/military organizations have ignored this problem. Thus there have been no USAF, USN, Canadian or University rules for this specific decompression problem. Sport divers seem to have come to grips with this problem due to diving in such locations as Lake Tahoe. One Sport diving publication, *Skin Diver Magazine*, reported on a procedure for diving at high altitudes in the late 1960's and again in the early 1970's. This procedure, which was apparently first promulgated by a Frenchman, came to be called the "Cross correction" after ER Cross who published the procedure in the Technifacts column in *Skin Diver*. This procedure attempts to compensate for surfacing from a dive at a pressure less than one atmosphere by reducing exposure limits for depths. It does so by assuming the dives at altitude are performed at greater depth than sea level. A factor is calculated from the barometric pressure at sea level divided by the barometric pressure at altitude, which always gives a value greater than 1.0. This value is then multiplied by the actual depth to give a "High Altitude Compensated Depth", which is greater than actual. This procedure, while never validated by manned testing, has apparently been used by many sport divers. It has also been recommended as a procedure for flying immediately after diving. In this application you dive at sea level as though you were at altitude thus reducing your limits or increasing your decompression obligation.

In 1976 the Swiss reported on man-validated Air Decompression Tables for different altitudes. As an example of their tables, a dive to 60 feet at an elevation of 8,100 to 10,500 feet would have a no-decompression limit of 5 minutes, but in fact all their "no-decompression" limits involve a three minute stop. In this altitude range the stop is at 7 feet.

RESULTS OF RECENT STUDIES

Altitude Diving

In 1979 Bell reported on dives tested at Lake Tahoe, both in chambers and in open water. His derived limits at 6,000 feet were 40/148, 50/84, 80/30, 100/19 and 160/5. In 168 exposures in 15 subjects no bends were encountered, nor were circulating bubbles detected. The results of these tests are very surprising when his limits are so drastically less conservative than others. This is the only recent work done or reported on diving at altitude. The Swiss tables continue to be used by the Swiss and they report no problems.

Flying After Diving with a Surface Interval

In 1979 Balladin reported on manned tests involving no-decompression dives (50/100 or 130/10), a surface interval of three hours, followed by exposure to 10,000, 6,000 or 3,000 feet for two hours. While no cases or bends occurred, 60% had venous bubbles at 10,000 feet, 30% at 6,000 feet and 10% at 3,000 feet.

Flying After Diving Without a Surface Interval

My experience is in the situation of flying immediately after diving. A validation test programme was conducted during 1979-1981 which exposed a total of 59 subjects to 110 tests of six dive schedules followed by immediate ascent to 10,000 feet for four hours. The dive schedules were 130/7, 100/10, 80/14, 60/20, 40/34 and 10.75/1440. These exposures resulted in 6.4% early termination for bends or serious intravascular bubbling. Of the remaining subjects who were then taken to 16,000 feet for one hour, an additional 4.8% experienced bends or serious bubbling. When the altitudes were lowered to 8,500 feet and 14,250 respectively, the termination rates in 28 subjects on 57 tests of three dive schedules, were 0% at 8,500 feet and 5.2% at 14,250 feet. In the 10,000/16,000 feet tests the overall bends incidence was 4.6% and serious bubbling was 6.4%. In the lower altitude tests they were 1.8% and 3.5%.

Flying after Saturation Diving

No manned testing has ever been performed in this area aside from my 10.75/1440 flying after diving exposures. In the areas of deep oxy-helium or shallower nitrox saturation dives no tests have been conducted. The rules previously described have been based on gut feelings or occasional case histories of "hits" during flight in previously saturated divers.

Edel has recently provided guidelines for either the use of surface oxygen breathing to reduce the surface interval before flight following Nitrox and Heliox saturation, or modification of the final stages of saturation decompression for the same purpose. As an example, six to 12 hours after a nitrox saturation dive, oxygen would be breathed for four hours (on a 60/15 intermittent schedule) and flight could follow five hours later. Thus the surface interval would be from 15 hours 45 minutes to 21 hours 45 minutes. These procedures, generated by Edel's AUTODEC program and supplied to the Association of Diving Contractors have not been validated by manned testing.

RECOMMENDATIONS RESULTING FROM A RECENT WORKSHOP

In January 1982 a workshop was sponsored by the UK association of Offshore Diving Contractors and the Diving Medical Advisory Committee in response to questions posed by air carriers transporting commercial divers from operations in the North Sea. This two day affair consisted of a review of the data and of the rules, recommendations and procedures discussed above, followed by operational inputs from diving contractors, vigorous discussion and finally a set of recommended guidelines. The proposed guidelines are detailed in Table One.

COMMENTS ON THESE RECOMMENDATIONS

Air Diving

All in all I feel the recommendations proposed by the workshop are adequately conservative. The few areas of concern involve the question of just how long bubbles, once formed, persist and/or how long do they continue to form once initiated. There is anecdotal evidence from case histories that this may involve exceptionally long periods, in excess of 48 hours, in at least some cases. In two studies cited, those of Balladin and myself, there is evidence that asymptomatic and/or undetectable bubbles persist for at least three to four hours after dives made to the no-decompression limits which then become detectable and may produce symptoms with an ascent to only 3,000 to 4,000 feet altitudes or elevations. In the case of my findings and those in other laboratories as well, the change that may be necessary is a revision of the dive limits with or without the addition of "safety stops" for no-decompression dives.

TABLE ONE

SURFACE INTERVAL ON AIR BEFORE FLIGHT
TO A MAXIMUM CABIN ALTITUDE OF:

		2,000 ft	8,000 ft
AIR DIVING			
a.	No Stop Dives Total time under pressure less than 60 minutes within the previous 12 hours	2 hrs	4 hrs
b.	All other Air Diving (less than 4 hours under pressure)	12 hrs	12 hrs
c.	Air or Nitrox ** Saturation More than 4 hours under pressure ** Caution	24 hrs	48 hrs
MIXED GAS		12 hrs	12 hrs

DYSBARIC ILLNESS

Time from Completion of Therapy

		2,000 ft	4,000 ft
a.	Successfully Treated	24 hours	48 hours

b. Residual symptoms after treatment or flying restrictions to be decided on an individual basis by a diving medical consultant.

Regarding decompression dives on air, there is no published evidence that these are more likely to produce problems, and yet the restriction for exposure to altitude is greater by a factor of three to six fold. The twelve hours restriction here however, as with mixed-gas diving, was based on operational considerations more than scientific evidence. That is, most commercial offshore operations require a twelve hour observation period at the site of the chamber following such dives. So why reduce it, especially since no laboratory evidence can be offered to justify a change?

The restrictions on altitude exposure following Air or Nitrox saturations were almost totally pulled out of thin air. No laboratory data and little operational experience exists to back up or refute the recommendations. This was an acknowledged deficiency recognized at the workshop, and resulted in a "caution" note being added to the 48 hour restriction for such dives.

Mixed Gas Diving

Since no human laboratory evidence is available, the restriction here was based 100% on the operational input. That is, there have been no problems reported following operational dives, be they surface supplied, bell operations or saturation exposures, with the 12 hour "bends watch" being the standard. The anecdotal evidence of problems arising during flights after saturation, with much longer surface intervals than 12 hours, were discounted because they occurred following "experimental dives" as opposed to "operational dives". The bottom line was basically "who can argue with success?" In view of the lack of hard evidence to the contrary, the answer is obviously, "no-one!"

Dysbaric Illness

Since provisions do exist in the North Sea for the evacuation of injured or seriously ill divers under saturation (at least to about 750 fsw), this problem area was not considered at the workshop. Variations on this problem are thus left to those individuals charged with the medical responsibility for such operations, be they scientific, experimental or operational (ie. in areas other than the North Sea). Rigid physical screening of divers, safety engineering considerations, safety review board considerations of procedural aspects, and luck are on the side of those responsible as well as the diver's side. Murphy's Law is on the other side along with the postulate which states that Murphy was an optimist! Donald Boon of Taylor Diving and Barry Cannon of the US Navy are evidence of the latter.

Regarding successfully treated cases of dysbaric illness, the restrictions are again based on little more than an educated guess. And for the untreated case or those with residuals, it is back in the laps of those charged with such decision making responsibilities. That is the price paid for being a member of a small, elite and unrecognised group of medical specialists.

CONTACT LENSES AND DIVING: WHAT ARE THE RISKS?

Mary M Matzen

The findings of two Naval Research Institute doctors explain many of the eye problems reported by divers wearing contact lenses.

Do you or your divers wear contact lenses while working underwater? If so, you will be interested in the recent findings of a team of medical officers from the Naval Medical Research Institute in Bethesda, Maryland.

Because of the greatly increased use of contact lenses by divers in recent years, Captain ME Bradley and Commander DR Simon studied the effects of wearing contact lenses during and after decompression from high pressure. Their subjects were two male Navy divers (ages 40 and 47) who routinely wore contact lenses.

An instrument known as a slitlamp was used to examine the corneas of the subjects before, during and after the exposures and the corneas were photographed with a slitlamp camera before and after the exposures. The slitlamp provides magnification and a narrow beam of intense light; it is used by eye doctors for examining the eyes.

Damaged Corneal Tissue

For the hyperbaric exposures, the subjects were placed in a double-lock hyperbaric chamber in which compressed air was the breathing medium. Exposure depth was 150 fsw; bottom time, 30 minutes. Decompression followed a standard US Navy decompression table for a 160 fsw, 40-minute exposure. Throughout the repeated exposures, subjects wore polymethylmethacrylate (hard) lenses or membrane (soft) lenses in one eye and no device in the other eye. Two kinds of hard contact lenses were used: a fenestrated lens, which had a 0.4 mm hole in the centre, and a non-fenestrated lens, which had no hole in it.

As decompression progressed from 150 fsw, small bubbles in the pre-corneal tear film under the hard lens were first noticed at 70 fsw en route to the 30 fsw stop. The bubbles increased in number and expanded during the 30 fsw stop; they grew together at both the 20 fsw and 10 fsw stops. By the time the divers reached the surface, there was a reduction in size and number of the bubbles. After 30 minutes at sea level, no bubbles were left under the contact lens, but coin-shaped patches of damaged corneal tissue could be seen in the areas where the bubbles had been.

At the time of bubble formation, divers expressed a feeling of soreness in the involved eyes, saw halos and radiating spokes when viewing lights and had decreased sharpness of vision. Symptoms lasted for about 2 hours after return to sea level.

“As decompression progressed small bubbles under the hard contact lens were noticed .... After 30 minutes at sea level patches of damaged corneal tissue could be seen in the area where bubbles had been.”

Tears Must Flow

No bubbles were seen if no contact lens was worn, if a soft lens instead of a hard lens was worn or if a single 0.4 mm hole was made in the centre of the hard lens.

Soft lenses are larger than hard lenses and contain a large amount of water. They are designed to cover the entire cornea. The permeability and flexibility of the soft lens allows exchange of gas and nutrients such as sugar and each blink pumps the nutrient tears across the cornea-lens interface. These features in the soft lens are responsible for rapid turnover of the nutrient tear film and dissolved gases; thus bubble formation does not occur during decompression.

“... divers (wearing hard lenses) expressed a feeling of soreness, saw halos and radiating spokes when viewing lights, and had decreased sharpness of vision.”

The eye symptoms experienced by the subjects wearing the hard lenses without the hole in the centre were the result of corneal epithelial oedema (excessive fluid in the thin skin covering the cornea). This oedema was caused by formation and trapping of the nitrogen bubbles in the pre-corneal tear film. The formation and trapping of these bubbles resulted from the outgassing of mainly nitrogen from the cornea and tear film as pressure was decreased. Because the movement of the hard lens with blinking did not completely uncover the central cornea, gas remained trapped, which disturbed tear exchange and interfered with the nutrient exchanges that normally occur between the tear film and the corneal epithelium. Thus, the corneal epithelium was deprived of oxygen and excessive retention of carbon dioxide occurred; tissue damage resulted.

When hard lenses with a 0.4 mm hole were used, the hole did not permit the movement of bubbles from one side of the lens to the other, but it did serve as a channel through which tiny amounts of tear could pass, which allowed tear exchange and the flow of gas and nutrients in solution. The subject’s sharpness of vision was not affected, because the hole filled with tear did not alter the contact lens’s ability to transmit light.

Conclusions

Doctors Bradley and Simon conclude:

1. The use of hard contact lenses by individuals working in the hyperbaric environment can cause injury to the cornea.
2. The injury causes discomfort and temporary visual impairment.
3. The injury causes the cornea of the eye to be prone to infection.

The researchers recommend that the nasty effects of wearing contact lenses during decompression can be avoided by the use of fenestrated hard contact lenses, membrane contact lenses, or, preferably, a prescription facemask instead of contact lenses.

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POSTSCRIPT -

CONTACT WEARERS - BEWARE!

Following a recent offshore accident (1981), where a diver lost his cornea secondary to an infection contributed to by a contact lens, the Association of Diving Contractors Medical Committee has warned that contact lens (hard or soft) should NOT be worn in the water, in the chambers, or on deck while offshore or in any isolated area. They quote the National Society for the Prevention of Blindness (USA) has having come out strongly against the use of contact lenses in industry, a warning equally applicable to a person on a vessel or oil rig. Far from protecting the eyes, they may pose a greater hazard and safety goggles or full face shields must be still worn. Dangers may arise from situations where some chemical needs to be washed from the wearer's eyes by another person, should small foreign particles become trapped beneath the lens, or a lens become displaced causing a sudden change in vision. The problem of "spectacle blur", the occurrence of blurred vision which may occur for over an hour after lens are put in or taken out, could reduce safety in industrial situations such as on a rig.

LOW LEVEL SUPPLEMENTARY HEATING FOR DIVERS

DR Burton
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For the great majority of divers who work at present without the benefits of supplementary heating, some degree of body cooling is normal. Often, particularly in the temperate and cold water areas of the world, such body cooling is a matter of great practical importance. Within relatively short duration dives the familiar perceptions of cold discomfort, shivering, and numbness of the extremities become apparent. These reactions serve as personal warning signs for the diver to limit the safe duration of his dive, because the consequences of further exposure include more severe loss of sensory and motor functions which are hazardous to safety.

However, short duration diving tends to be both unproductive and expensive. For this reason many commercial diving contractors use supplementary heating for long duration tasks. Supplementary heating is even more important in deep water because the insulation performance of diving garments becomes very poor at depth, and the dense breathing gas must also be heated. The supplementary heating systems presently in use rely on a free flooding hot water suit fed through an umbilical hose from a surface installation. Thus the diver loses some of his freedom by being tied to the surface, and the very high heat losses of the heating arrangement consume a great deal of power. These features are of no consequence for diving performed from an installation such as an offshore oil rig, but there remain many types of diving for which such systems are either inconvenient or impossible to use. Scientific work, photography, military, police, and recreational diving are some cases in point.

Work recently completed at the CSIRO Division of Energy Technology was aimed specifically at providing the free diver with an inexpensive light and easily used local supply of supplementary heating. The first task was to find a portable energy store which could be capable of releasing heat steadily and safely underwater, and to ensure that this heat could be distributed over the diver's body. Some of the high energy chemical reactions that might be suitable are inherently too fast, and would generate high temperatures or even explosions. On the other hand, many of the slower chemical reactions and storage systems are not energetic enough, and many kilograms of reactant would be required to keep a diver warm for a few minutes.

The reaction of magnesium metal with water was found to be a good compromise. One kg of magnesium releases more than 4 kWh of energy when it reacts with water, and at temperatures like 20 - 30°C the reaction is so slow that there is no danger of explosion. To be of use for diver heating, the reaction rate must be accelerated, and this was done by using the magnesium in the form of particles mixed with controlled quantities of a cathode material such as cast iron or steel turnings. The two metal mixture behaves like a multitude of short circuited batteries producing neat rather than electrical energy and the reaction rate in sea water is controlled by the mixture ratio, the sizes of the particles, and the method of packaging. For example a small tissue paper sachet containing 10g of mixture is capable of generating between 1 and 10 Watts of power for periods up to 3 hours, when flooded with sea water. Like tea bags, which they resemble closely, they can be kept for many months in dry storage and must be discarded after use. Unlike tea bags they generate hydrogen gas and warm the sea water in which they are dunked.

The first laboratory and field tests involving people were designed to assess the thermal performance of actively heated mittens. The fingers could be prevented from becoming cold and numb for about two hours, even in freezing water. It was later found that by using the diver's personal wet suit, and placing an array of local heating pads in the torso area between overlapping areas of the suit, a useful degree of body heating could be achieved. Controlled tests with several professional and experienced amateur divers revealed that the telltale subjective signs of cold discomfort, shivering, and numbness of the extremities could be delayed, so that the voluntary diving duration of heated subjects was significantly increased.

A most interesting finding was the extraordinary efficiency with which such increases of duration could be obtained by quite low levels of supplementary heating. The voluntary tolerance time for a man in shallow water in a wet suit can be measured or even calculated with reasonable accuracy if the amount of muscular activity is known. At a water temperature of 11.5°C for instance, a person doing light work will become fairly cold in 100-110 minutes without any supplementary heating. If the diver is equipped with local heating pads that deliver, say, 50W, the time required to become cold increases to 230 minutes. This is a substantial improvement in tolerance to cold, but the amount of heating required is only about one quarter of the amount required to keep a person warm. For most of the dive, however, the person would consider himself reasonably comfortable. In an ideal situation it would be desirable to install 200W of heating to keep the subject warm indefinitely. However it is very much more cost effective to reduce the supplementary heating to a low level and to accept a tolerance time that is reasonable.

The high effectiveness of the low level supplementary heating system is related to the way the body protects itself when it starts to become cool. The skin temperature in the extremities and limbs of a cooling person drops as a result of decreased blood flow to the skin. This markedly reduces the rate of heat loss to the environment as the exposure progresses. If the rate of heat loss is not too high it may take a very long time to accumulate a substantial heat debt and reach a tolerance limit. Small changes to the heat supply can therefore have large effects on tolerance time.

ADDENDUM

Cost

Based on the high cost of analytical grade imported magnesium, the 'materials only' costs are $0.15 per sachet. This would be much reduced with appropriate sources.

Availability

Availability is not good because we have been unable to offer patent protection to potential licensees. However Mr Crawford Grier of Croft Cottage, Croft Road, Oban, Scotland, has expressed an interest in manufacture. The Antarctic Division at Channel Highway, Kingston, Tasmania 7150, have been manufacturing in house. Their contact is the officer-in-charge of R & D, Mr Atilla Vrana.

Safety

Local heating pads must not be placed on the skin because local temperature may rise above the burn threshold of about 45 C. However, we have found that pads may be safely placed between overlapping areas of wet suit. A Farmer John pattern of suit without modifications allows placement of heating pads over most of the torso area. We have been interested in possible toxic effects on skin, of metals such Chromium, Manganese and Nickel which are present in cast iron. X-ray fluorescence analysis shows these metals to be present in trace amounts in samples of water taken from the vicinity of the skin during heated dives. However their concentration does not significantly exceed the levels to be found in clean sea water. One cause for concern is that such water samples tend to be slightly alkaline, a pH value of 9.6 was found for water squeezed from active local heating pads. For some people not tolerant to alkalinity this may be a problem, but application of a barrier cream prior to diving should give effective protection. No evidence concerning skin problems has been reported to date, the total exposure probably being a hundred hours or so and about 50 subjects.

O_2 BE ALIVE

Gavin Dawson

Oxygen is a gas, lethal at low concentrations, poisonous at high concentrations and extremely dangerous at pressure. 2,000 pounds per square inch in a cylinder of medical oxygen can cause a lot of damage! It is considerably more than you would put in your motor car tyres! Today I intend to concentrate on hyperbaric oxygen. I am not going to go into any statistics or complicated tables. We have been running the chamber at Prince Henry's Hospital for 11 and a half years and have not treated all that many patients, but we do have a lot of clinical impressions and good results in certain directions.

Before starting on hyperbaric oxygen let us take a quick tour around the field of oxygen; its role in life, industry, aviation, rocketry, combustion, steel manufacture, mountaineering and diving. We will not spend too much time on diving. This already has been very well covered in the previous paper.

Here we are on planet earth and for some reason breathe 20.98% oxygen. Oxygen was discovered in 1774 by Joseph Priestly and independently by a Swedish chemist, Scheele, at the same time. Both produced oxygen by heating mercuric oxide. Its uses are vast.

In aviation, pilots of high flying aircraft wear oxygen masks. You may not think oxygen was vital for the flight of Gossamer Albatross but if you ask Brian Allen he will tell you that it was! He did not have any extra oxygen apart from fresh air and his lowest recorded altitude on the Channel crossing was six inches. He did need oxygen to produce the energy and horsepower for his leg muscles that were peddling that man-powered machine 22.5 miles across the Channel. Oxygen was used as a rocket propellant in the doodle-bug V2 designed by Von Braun which pestered London towards the end of the Second World War. Liquid oxygen and 75% ethyl alcohol were the propellants. America's first man into space, Alan B Shepherd, in 1961 ascended in Mercury Redstone. Then came Atlas and Friendship 7 and John Glenn's first orbit. Titan 3C launched the Gemini space capsule and Ed White was the first American to walk in space. He naturally depended on oxygen for his life support system and the rocket depended on oxygen for its propellant. Finally in the rocket era we come to that gigantic piece of technology, the Saturn V, which uses liquid oxygen in all 3 stages with RPI kerosene in the first and liquid hydrogen in the second and third stage. By using this third stage it was able to escape from the earth's atmosphere and progress onwards to land Armstrong on the moon. Later on, there were more missions involving lunar Rovers. It enabled man to leave the moon which had never even been done before. In the Lunar Module a different sort of propellant with oxygen was used in a hypergollic propellant solution. Nitrogen tetroxide and oxygen combined and spontaneously combusted lifting the lunar module off and returning to earth. We then found that human beings can survive in space for many months and they require appropriate concentrations of oxygen. There was a time when the Americans and Russians were talking to each other and found they could dock in space even though the Soyuz had an air environment and the Apollo had an oxygen 0.3 atmosphere environment.

Oxygen is used in the Bessemer converter for the manufacture of steel from iron, a very important use. It was used in the conquest of Everest, although Everest has been climbed without oxygen. You would be pretty grateful in this situation to find that on what has been called the highest rubbish tip in the world, there were two full oxygen cylinders left by a previous expedition. The oxygen bottles lay at 26,000 feet and Everest is 29,000 feet to the summit.

So on to hyperbaric oxygen. This is the inhalation of oxygen at a partial pressure greater than one atmosphere. In Prince Henry's Hospital (Ward 3 South) we have a Vickers mono-place chamber. It is a radiotherapy model 7 feet long. It is made of perspex, a similar material to aircraft windows. It has double layers, one cylinder inside another, so you have a pressure tested cylinder centrally and an outside cylinder. If your pressure tested cylinder blew you would not kill the patient and everybody else around you. The outer cylinder, (although it will not hold the original pressure) would allow the gas to gradually leak away. In 1967, the William Buckland Foundation gave a donation of $15,000. At that time a chamber was $14,000 and the price now is $45,275.

The chamber has a big oxygen inlet and an exhaust line. There is no recirculation. We use very high flows of gas, between 200 and 400 litres a minute. The oxygen is dumped out into the environment above the balcony in Ward 3 South. High above the balcony because we do not want it too low down in case somebody lights a cigarette nearby. It is a fairly simple piece of equipment. There is a normal supply pressure of about 65 psi. The chamber pressure is graded in pounds per square inch or atmospheres absolute.

The pressure is selected by a dial on the side of the chamber. There is a compression rate knob, and an intercom on the side which causes a few problems with communication. I find that the density alters the tone of your voice. But more important is the fact that you have got between 200 and 400 litres of oxygen blowing through the head end of the chamber. That is where there is a microphone and two loud speakers, so there is a lot of feed-back which is a problem. The simple way to overcome it is to switch the oxygen off while you talk. You can do that because it is a portable model. It should not be done for longer than 4 minutes, but if you switch the oxygen off all your problems are solved. At the door there are electrical and pneumatic connections to cater for an ECG, give intravenous fluids, take blood pressure, etc. All we have monitored is ECG but we have had a fluid logic ventilator inside which is a very, very risky business. The Vickers Company do supply a support unit (and many times we have had need of this) at $4440 and that will provide information on blood pressure, information through a stethoscope, administration of intravenous fluids and positive pressure ventilation. The reason that hospitals use liquid oxygen is that you get 840 volumes of gas for 1 volume of liquid. I will give you a little more information on oxygen. We use at Prince Henry's Hospital 104,400 cubic metres of gas a year. We pay 9.6 cents per cubic metre. The cost to the hospital is $10,022 per year for oxygen for which CIG charges 25% delivery fees. Prince Henry's Hospital now has a larger liquid oxygen than they used to have. The old one was 30,000 cubic feet and the present one is 70,000 cubic feet which means that it will produce two million litres of gaseous oxygen.

The advantages and disadvantages of the monoplace or one man chamber compared to the large multi-man chamber which can accommodate medical attendants, nurses, etc, are as follows:

Advantages: cheaper, low running costs, total body immersion in oxygen which means that the patient does not have the inconvenience of having a tight fitting mask on his face. There is some evidence that oxygen has a therapeutic effect on open mucous membranes to increase the rate of wound healing. There are no decompression dangers to patients or attendants because pure oxygen is used.

Disadvantages: are that there is a high fire risk because it is 100% oxygen. I will go into fire a little bit later. It has limited pressure capability. However, three atmospheres is quite enough pure oxygen if you wish to avoid the CNS effects of oxygen toxicity.

There is minimal environmental control. Another model has a recirculating system whereby you can control humidity and temperature and monitor CO_2. There are isolation problems of therapy. By isolation I do not mean claustrophobia. I mean you just cannot get at the patient. You cannot monitor them properly. You cannot support them. You really have not got much control apart from psychological persuasion.

Problems: Apprehension, boredom and claustrophobia can occur. Some patients do get claustrophobic and some are frightened. We rarely have to sedate patients and often the best way of sedating them is to talk and explain what it is all about.

Really when you are lying in the chamber and relax it is quite comfortable. Oxygen is a pleasant gas. To avoid aural barotrauma, we tell them how to fix their ears, we take them up slowly and watch them. We have little tricks of pressure dropping with which we can equilibrate to the outside pressure. I will go into oxygen toxicity and fire risk later. My personal experience with equilibrating ears is that swallowing opens my own Eustachian tubes. For others the Valsalva manoeuvre works better. At Milwaukee they have a very nice idea. A baby's bottle and you just swallow a little water each time you want to equilibrate your ears.

On the subject of problems let me give you a few cases involving litigation in hyperbaric oxygen. This is quite important.

In 1971 a 42 year old man was being treated for a scrotal Clostridial infection. He became permanently blind. He lost his vision during his last hyperbaric session. There was no clinical justification for that session. He had complained at one stage that his sight was going off. During the three week trial they found there was no record of any blood pressure. In 1978 he was awarded $65,000.

In the second case a 21 year old footballer suffered a compound fracture of tibia and fibula. The bone was pinned and on the fourth post operative day he developed gas gangrene. He was given, despite a history of allergy, intramuscular penicillin and anti-gas gangrene serum. Most of us in the intensive care unit here do not agree with this, certainly not intramuscular penicillin. On the fifth day the gas gangrene was spreading alarmingly. He was referred to another hospital for hyperbaric oxygen, but even so had to undergo a below knee amputation. Negligence was proved. It was said that gas gangrene should have been diagnosed earlier and that he should have been referred earlier for treatment of hyperbaric oxygen. The settlement was £28,000.

The final case, in the United States (and this case could only be in the USA), was carbon monoxide poisoning. A 26 year old male was found in his car with the garage doors closed and the motor running. Doctors referred him to the hyperbaric oxygen unit at Wayne County, Michigan Hospital. The hospital did not follow the referring doctor's advice and the patient suffered severe permanent brain damage. His parents filed suit against the hospital and the jury awarded them over $3,000,000.

The effect of hyperbaric oxygen on vision appears at 3 atmospheres. If you have 3 atmospheres for 3 hours there is a definite contraction of your visual fields from the normal cone of between 60 and 80 degrees. Your visual field contracts to a tunnel becoming as narrow as 10 degrees, which lasts about an hour. After returning to atmospheric pressure you are back to normal. In my personal experience of 3 atmospheres of oxygen I found vision incredibly clear. I could read very small print and noticed this with patients. They look at all the small instructions in small typewriting on the notice board near the hyperbaric chamber. This may just be an impression but there seems to be something that improves the visual acuity. Somebody asked me whether the shape of the chamber acts as a magnifying glass for those inside. It did not seem to when I had a look at it in air.

Just briefly to discuss pressure. We talk in terms of 1 atmosphere absolute (ATA) at sea level so that we can go up into the air or down into the ocean. Fortunately 1 atmosphere is 10 metres or 33 feet of sea water. As you go down 10 metres or another 33 feet in the sea you add another atmosphere. When you go up, the pressure starts reducing. If you are in a pressurized civilian aircraft with a cabin pressure of 8,000 feet, or around the altitude of Mexico City, you are at 0.75 ATA. On the top of Mount Everest (29,000 feet) the pressure is one third of an atmosphere.

To remind you of the pressure-volume relationship. If you double the pressure, you halve the volume of gas. If you triple the pressure, you reduce the volume to one third. Quadruple the pressure and you quarter the volume. So at five times the pressure and if the volume was 10 litres before you increased the pressure you are down to two litres. What happens to a bubble? I have told you about reduction in volume. But reduction in the diameter of the sphere is a very different matter. A bubble present at 1 atmosphere absolute at sea level will expand as you go up in a civil aircraft pressurized to about 8,O00 feet. If we give 2 atmospheres absolute of pressure, the bubble compresses. With 3 atmospheres absolute of pressure it gets smaller. The reduction in diameter gradually gets less and less, so there is really not much point in producing more and more pressure. Because of this slowing in the reduction of bubble size you often get the best mileage in the treatment of decompression sickness by treating it with 3 atmospheres absolute of oxygen. This therapy produces a high oxygen gradient going into the plasma and displaces the nitrogen from the bubble with reasonable bubble compression.

A partial pressure of 1 ATA of oxygen (100% at sea level) fully saturates haemoglobin and from there on any more oxygen is dissolved in the plasma. When the oxygen partial pressure is just under 3 atmospheres you have 6 ml of oxygen dissolved in the plasma and that is enough to support life without haemoglobin. The experiment was done on pigs with no red cells and they survived. The experiment has also been confirmed on Jehovah's Witnesses after surgery where they have been put into oxygen chambers, fed spinach every two hours and then put back again while their haemoglobin built up.

At Prince Henry's we have treated 163 patients in 11 years. Hyperbaric medicine here is a part-time job. We use hyperbaric oxygen therapy for emergencies, an important medical tool. There was a great burst of interest in the late 60s and early 70s, not knowing anything about it! We were treating all sorts of funny infections, etc. Then we got to know more and more about the indications. Our enthusiasm has kept going. We have treated about 16 to 18 patients a year.

A quick run through the patients. We have treated too many ischaemic limb disease for infections, because we have a lot of vascular surgeons at Prince Henry's. Operations go wrong and Clostridial infections have been treated. It was not really worth it as they were not gas gangrene. I will say a little more on decompression sickness, gas gangrene and carbon monoxide poisoning. They are the main points of interest.

On carbon monoxide I will give you a record of what we have treated. Being on natural gas it is not as many as Ian Unsworth in Sydney, who seems to receive a large number of cases. Over the years we have treated at Prince Henry's five people for carbon monoxide poisoning. Four males and one female and only one of those five was a simple carbon monoxide poisoning. By simple I mean he had not combined his carbon monoxide with drugs such as sedatives, hypnotics, tranquillisers or alcohol. They were all deliberate. There were several pathetic suicide letters in the cars. All piped their exhaust gases in through the back window with the engine running and just sat there. Three combined their gas poisonings with sedatives and one combined it with a whole bottle of whisky.

I feel that the treatment of carbon monoxide poisoning with hyperbaric oxygen is important but it must be started early. If you have been on 100% oxygen for an hour your have already got rid of half of the carbon monoxide in the body. This is due to the half-life times. If you are in air it would take you about five hours to recover from carbon monoxide. In 100% oxygen it is about 80 minutes. And with 3 atmospheres of oxygen it is about 20 minutes.

In some areas of medical practice hyperbaric oxygen is used to overcome certain types of hypoxia. The Peter McCallum Clinic use it in radiotherapy because certain rumours are resistant to treatment and are made more sensitive to treatment if they are well oxygenated They are resistant to treatment while the cells are hypoxic, and hyperbaric oxygen gets oxygen to these cells, that is the theory. Hyperbaric oxygen is essential in gas gangrene. It is a primary mode of therapy in decompression sickness. Over the years there has been a lot said about hyperbaric oxygen. Its reputation has been affected by certain anecdotal references by various people on rejuvenation and so forth, which very readily catches the attention of the lay press. The Americans (the Undersea Medical Society) formed a committee to classify the role of hyperbaric oxygen. This committee decided that there should be four categories of indications in which category one is fully reimbursed by their Blue Cross insurance. Category two, which shows good evidence, perhaps should be reimbursed in the future but would be re-looked at. Categories three and four are for things like turning your grey hair dark again, sexual rejuvenation, etc.

Gas gangrene is any condition of necrotic muscle associated with the production of gas. We diagnose it, not so much on crepitus but on wound, blackness and straw fluid blebs. The first thing that has to be done is for the wound to be opened. There often is crepitus and the patient is frequently very toxaemic and for some reason the pulse rate is much higher comparatively than the temperature elevation. Unless they are moribund, the conscious state is usually reasonable. Our last case was a schizophrenic who jumped off Puffing Billy while it was crossing an 80 foot bridge. He did not land on his head. If he had we would have had no problems. But he did manage to fracture his sternum, bilateral tibia and fibula, one was compound, radius and ulna at the wrist. He had a pin through his wrist and got gas gangrene of the arm. That was the least of our problems because at the time he had a shock lung and other multiple problems. He would have benefited greatly from a large chamber.

How does hyperbaric oxygen work? It is the alpha toxin, the Lecithinase C, that does all the damage. If we can stop that toxin being produced then the systemic toxaemia is very much improved. I have seen patients come in one day virtually moribund and the next day, after treatment, sitting up in bed reading the paper. The alpha toxin seems to destroy everything, muscle cell, red blood cells, and it advances very, very rapidly. There are several Clostridial organisms, mainly welchii (perfringens). Perfringens destroy membranes and produces haemolysis. When you have got haemolysis the situation is quite serious. This is how I think hyperbaric oxygen works. I believe it stops the production of the toxin. It reduces the systemic toxaemia by inhibiting the production of alpha toxin and sustains by oxygenation the viability of damaged tissues. It also reduces pain because as the patient goes under pressure the gas is compressed. Also the penicillin given intravenously gets a better chance to get to the muscles. By doing this we have reduced the need for early and radical surgery.

In one of the first cases we treated the surgeons were going to do a disarticulation of the hip, and I said, "Let's give him a go with hyperbaric oxygen." He had already had an above knee amputation and he finished up having nothing further done. So hyperbaric oxygen is an adjuvant. You need everything. First of all surgery to clean up the wound, open it and remove the debris. You need very high doses of penicillin. We have given up to 40,000,000 units a day intravenously. In fact, we give so much penicillin that there is enough sodium for the whole body in the penicillin alone without giving any other form of sodium. And we give hyperbaric oxygen and tremendous supportive care from the intensive care unit with fluid therapy, etc. One finds that you get a demarcation. The spread of infection stops, and the pulse comes down along with the temperature. Haemolysis also stops, the mental state improves, and pain is diminished. As I said before, the pain diminishes because we decrease the volume of tissue gas by pressure and improve the oxygenation of the tissues.

Some people today still give antitoxin, we do not. For the reasons that it is not necessary if hyperbaric oxygen is available. It does not always work. Ten percent of patients have a reaction to it. It has also been abandoned by all other hyperbaric centres that know anything about gas gangrene. It has been banned by the US forces.

Abalone divers have been one of our problems. That wise old gentleman Albert Behnke made a very important, clear and simple statement. “It is useful to remember that time, air and oxygen is cheaper than nervous tissue and bone”. If there is any doubt about the diagnosis of decompression sickness we will treat them because to date we have done no harm to anyone in our hyperbaric chamber. We have treated 11 cases of joint bends with or without symptoms. They were not neurological symptoms, they were pains in the stomach and minor type 1 signs.

In 1977 the Institute of Aviation Medicine at Point Cook sent us three cases in fairly rapid succession. Were they cases though? Now let me elaborate for the benefit of the RAAF. They might be interested in the case histories. Between March and October 1977 we had three cases from their altitude chamber. One had an A run which is 24,000 feet and they were worried because he had skin tingling, paraesthesia and not much else. The second was a C run following half an hour of pre-oxygenation and a brief exposure at 43,000 feet. He had complained of left shoulder and back pain but was asymptomatic on arrival. The third was an A run to 24.000 feet. He had knee pain which was relieved on oxygen. They all recovered on 100% oxygen at two atmospheres. As they had no symptoms at two atmospheres I really did not see any need to go to a higher pressure and they were decompressed over a two hour period. As far as I know, the lowest recorded case occurred at 18,500 feet.

Cases have occurred at 5,000 feet after diving and there is a rule that scuba divers should not fly for 24 hours following a dive which involves decompression stops. The only difference between decompression sickness from diving and decompression sickness from sudden exposure to altitude is that there is less spinal involvement in altitude decompression sickness.

Pain only bends are treated on a two hour table. We did not use the long table because we only had oxygen. Now we have designed an air breathing system where we can use air breaks. We have made up an air break system. It is an ordinary anaesthetic face mask supplied with compressed air from a cylinder between the patient’s legs. It is pretty narrow in the Vicker’s chamber, only two feet in diameter. The system works but there is too much resistance on the expiratory valve. We may change to a T-piece or something else. We have only had to treat pain only bends. I would not care to, and I am sure I would not treat anything more complicated than pain only or minor neurological bends. If you have a serious neurological problem you must have a multiman unit as you ought to have someone in the chamber who can care for the patient. They can assess the improvement and look after the airway. We just cannot do that in a single man chamber.

Let me tell you a very interesting story about what happened to a chap in the States. A 24 year old male was cleaning the interior of a 6 x 6 foot cylindrical vacuum chamber which was used for coating metal. His mate, as a result of a prank, closed the lid and started to decompress him thinking he could turn it off at any time. However, he suddenly realised he could not and panicked. He went to look for the supervisor in a hurry. In about three minutes the victim had gone to almost three times the height of Mount Everest (your blood is supposed to vaporise at 63,O00 feet) and he was held there for four minutes. The supervisor arrived. The victim was recompressed over a one minute period back to ground level. On opening the lid the patient was deeply unconscious, cyanotic, frothing from the lips and blood was coming up from his lungs. He was taken to a hospital ten miles away where he was intubated, given 100% oxygen and his colour improved but he was still unresponsive to painful stimuli. There was a consultation with the Physician of the USAF School of Aerospace Medicine of San Antonio and he was transferred in a pressurized jet to St Luke’s Hospital, Milwaukee. There was, of course, a mixed diagnosis, of massive aviation decompression sickness, burst lungs, possible cerebral air embolism, post-hypoxic state and status post-embolism (vaporisation of blood).

He was pressurized to 6 atmospheres absolute on 50%-50% nitrogen and oxygen. He was there for a few minutes and then was brought back to 60 feet and placed on oxygen. He was treated on an extended table 6A. He had five and a half hours of hyperbaric treatment and then went to intensive care where he was put on a respirator and gradually became more alert. A series of psychological tests were performed because he wanted to get as much money out of the business as possible. Three months later they found there was a 15% decrement on what his psychological testing should have been.

Oxygen convulsions occur. Oxygen is toxic to the lungs after a while and is acutely toxic to the brain. Three or four weeks ago when I was enjoying the first quarter of a football match at the MCG between Richmond and St Kilda I was summoned over the loud speakers. I had to go to Prince Henry’s Hospital to attend a patient who had gas gangrene. We took him to three atmospheres in the Vickers Chamber. Until then I had not seen an oxygen convulsion in our Chamber. This fellow convulsed after about 30 minutes at 3ATA. He said he felt banging in the ears and that is one of the warning signs. The convulsions lasted for two minutes and, of course, if a person convulses there is nothing you can do. The worst thing you can do is to suddenly decompress him. If you suddenly decompress him it is like bouncing up with a full lung of air from 66 feet. Because of the decreasing pressure there is a threefold expansion of the gas in the lungs and this usually results in a burst lung. A burst lung can give you a pneumothorax, or if you are very unlucky you can get an air embolism or surgical emphysema. It is completely illogical to decompress a patient during oxygen convulsions because they are so full of oxygen in their blood and body fluids that they would stay for 10 minutes or more completely pink. The convulsions only last for about three minutes just like an epileptic convulsion.

Anyway having done that, the next day I did it again. Not by intention but because I thought the first convulsion could have been due to the Ethane anaesthetic he had recently had. Ethrane produces an epileptiform ECG tracing during anaesthesia. We took him to three atmospheres again the next day and he vomited, he got banging in the ears, echoing, apprehensive and he had time to say "Oh no, not again" and then off he went into a full clonic convulsion lasting three minutes. We then reduced the pressure a bit and completed treatment. Following that episode, and with advice from a colleague of mine in Sydney the next day he was treated at a slightly lower pressure. Dr Unsworth has been using 5% Ethrane on goats at 3 atmospheres and has had no convulsions. He has also used Ethane on patients in the chamber. His is a multi-man chamber. He was certain that Ethane was not to blame. You do need to get to 3 ATA to get the oxygen gradient for gas gangrene. This time we used dilantin and we reduced the pressure to about 2.6 - 2.7 atmospheres and he was fine.

We have also had two penicillin convulsions, one of which occurred before the patient even got into the chamber. If the patient goes into renal failure then the penicillin builds up and they can easily convulse.

At the time we started using hyperbaric oxygen we were terribly frightened, and we still are, about fire after the Apollo One tragedy. The spacecraft was pressurized with pure oxygen slightly above normal atmospheric pressure and some wiring overheated. There were certain materials in the capsule that should not have been there, Velcro and Nylon, which were inflammable and burnt. The fire flashed through and blew the spacecraft to pieces. We make absolutely certain that matches, cigarette lighters, etc., are not in the chamber. Incidentally, there was a President of the Royal College of Surgeons of England who wanted to try out a hyperbaric chamber. He had never seen one before. He was put in wearing his ordinary suit and they closed the door. Looking through the perspex the onlookers suddenly realised that his pipe was glowing brightly, in his breast pocket. Professor Sir Hedley Arkins was very quickly removed from the chamber! To keep down the risk of static sparking we try to keep the relative humidity to 60% and use pure cotton, 100% cotton material and no synthetic fibres. The machine is earthed. You can play music, tapes or radio over the intercom but that is all part of the Vicker's design. We do not allow any modification of the intercom. We avoid oils, grease, ointments, etc. We keep it clean.

It is interesting that at the RAF base at Wroughton in England, they use air in the Vickers Chamber to pressurize it and the patient breathes oxygen. The reason I went there was that I wanted to do it the other way around to give air breaks in oxygen. The reason they did it was because they were very frightened about the fire risk to patients in pure oxygen from the flash fire experiments from the Institute of Aviation Medicine at Farnborough.

In conclusion Priestly said some very true words in 1774 when he discovered oxygen. He said "From the greater strength and vivacity of the flame of the candle in this pure air it may be conjectured that it might be peculiarly sound treatment for the lungs in certain morbid cases. But perhaps we may also infer from these experiments that though pure dephlogisticated air might be very useful in medicine, it might not be so proper for us in the usual healthy state of the body. For as the candle burns out much faster in dephlogisticated than in common air, so we might, as may be said, live out too fast and the animal powers be too soon exhausted in this pure kind of air. But I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but in time that this pure air might become a fashionable article of luxury. Hitherto only two mice and myself have had the privilege of breathing it. And a moralist may say that the air which nature has provided for us is as good as we deserve."

This paper was presented by Wing Commander Gavin Dawson, RAAF, at the Tri-Service Medical Officers Meeting held at Prince Henry's Hospital, Melbourne, on 7 June 1980.

MEASUREMENT OF EUSTACHIAN TUBE FUNCTION USING ELECTRO-ACOUSTIC TECHNIQUES

WD McNicholl

A variety of procedures have been designed to assess Eustachian function in subjects with intact tympanic membranes; no single test has proved entirely satisfactory.

The finding of a negative middle ear pressure after a Toynbee test indicates excellent tubal function, since the Eustachian tube has to actively open. The production of a positive middle ear after performing the Valsalva manoeuvre does not indicate that there is positive Eustachian function but that the tube is distensible.(1) Elner et al (2) found that 74 out of 94 subjects had a positive Toynbee manoeuvre while 86 out of 100 subjects had a positive Valsalva manoeuvre.

The purpose of this paper is to present a test of Eustachian tube function that can be performed using an electro-acoustic instrument which has the added facility for testing Eustachian function. This test is performed in conjunction with tympanometry, inflation-deflation test and Toynbee's and Valsalva's tests. This test provides confirmation of positive or negative Eustachian function in ears with intact tympanic membranes.

Two hundred and twenty-one male subjects were assessed; they were divided into two groups:

Group 1: One hundred and seventy-one subjects who had an unsuspected Eustachian dysfunction, who were volunteers to the Submarine Branch of the Royal Navy.

Group 2: Fifty subjects who had an unsuspected Eustachian dysfunction, who were non-volunteers to the Submarine Branch of the Royal Navy.

The subjects in both groups had intact, normal tympanic membranes that were immobile on otoscopy when the

Valsalva and Toynbee manoeuvres were performed. All the tympanic membranes were found to be mobile on using Sieglets pneumatic speculum. All the subjects were unable to equilibriate their middle ear pressures when exposed to an increase in ambient pressure in excess of three metres of water.

Each subject had been found to be unable to equilibriate his middle ear pressures at a depth equivalent of three metres of water. A Grason Stadler 1723 middle ear analyser was used to measure the middle ear pressure for the given ear; once the compliance and middle ear pressure had been ascertained the Eustachian function test was performed. During the test sequence the pressure system established a selected pressure within the external auditory meatus. The pressure transducer detects any changes in the pressure level when the Toynbee or Valsalva manoeuvre is performed. In those ears that had an unsuspected Eustachian dysfunction, no deflection was produced on the positive pressure curve. Fig 1 demonstrates the tympanogram and Eustachian function test of a subject with bilateral Eustachian dysfunction. It is to be noted that the middle ear pressures lie within the range regarded as normal, while the induced positive pressure curve on the Eustachian function test reveals no deflection either positive or negative on performance of the Valsalva or Toynbee manoeuvre.

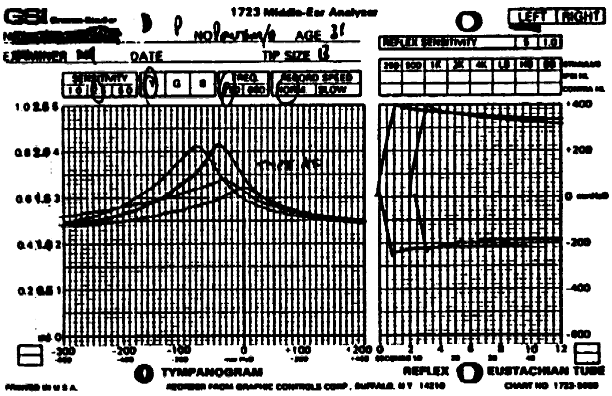

Fig 1 Tympanogram and Eustachian function test of a subject with bilateral Eustachian tube dysfunction. The tympanogram shows normal middle ear pressures and compliance curves, while the Eustachian function test demonstrates flat positive pressure curves with absent upward deflections on performance of the Valsalva manoeuvre.

Fig 2 demonstrates the deflections obtained on the positive pressure curve when the Valsalva manoeuvre is performed, while Fig 3 shows the deflections produced on performance of the Toynbee manoeuvre in ears with positive Eustachian function.

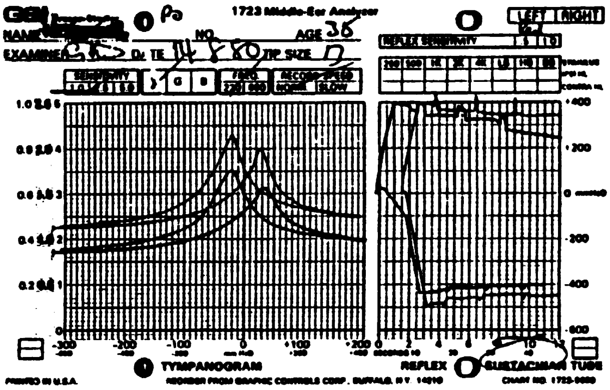

Fig 2 Tympanogram and Eustachian function test of a subject with bilaterally positive Eustachian tube function. The middle ear pressures on the tympanogram are within the normal range with normal compliance curves; while the Eustachian function test demonstrates upward deflections on the positive pressure curves on performance of the Valsalva manoeuvre, and deflections are produced on the negative pressure curve on performance of the Toynbee manoeuvre.

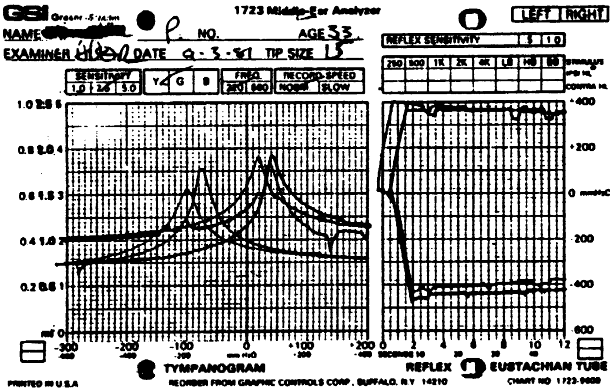

Fig 3 Tympanogram and Eustachian function test of a subject with bilaterally positive Eustachian tube function. Deflections are produced on both the positive and negative pressure curves on performance of the Toynbee manoeuvre.

It should be noted that on performance of the Valsalva manoeuvre the deflection is upwards and is virtually instantaneous, while on performance of the Toynbee manoeuvre the deflection is downwards, though the negative deflection may be preceded by an initial small positive deflection which coincides with the initial positive pressure phase in the nasopharynx, which is immediately followed by the negative pressure phase.(3) In a proportion of ears the induced positive middle ear pressure can be vented without the performance of any muscular activity. Fig 4 demonstrates that both ears are venting an induced positive pressure and equilibriating an induced negative pressure without any muscular activity being performed.

The 171 subjects who were volunteers underwent submucous resection of the septum and vomero-ethmoid suture. Six weeks after operation Eustachian testing was carried out, after which each subject was exposed to an increase in ambient pressure.

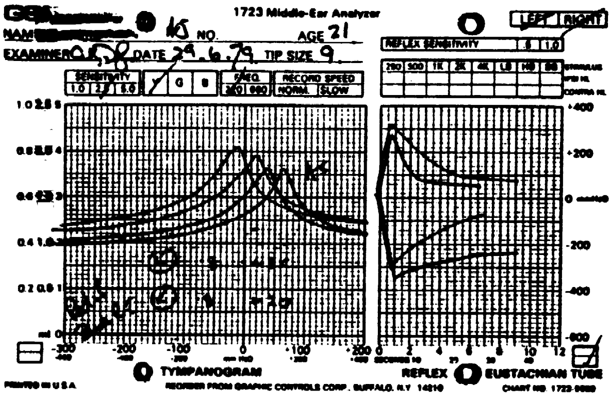

Fig 4 Tympanogram and Eustachian function test of a subject with bilaterally positive Eustachian tube function. Both middle ears are able to vent an induced positive pressure and equilibriate an induced negative middle ear pressure without the use of an muscular activity.

Four hundred and forty-two ears in 221 subjects were assessed. Twenty-three subjects had a unilateral Eustachian dysfunction. Fig 5 demonstrates that positive function is present in one ear but absent in the other. Those ears that had positive Eustachian function were able to equilibriate their middle ear pressures at a depth equivalent of three metres of water, while those ears with absent Eustachian function sustained a Grade 1 otic barotrauma.

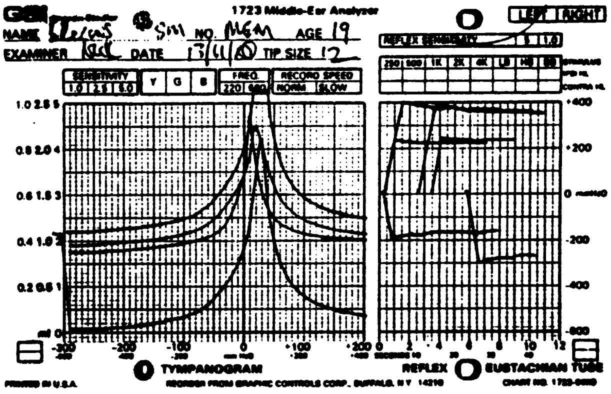

Fig 5 Tympanogram and Eustachian function test of a subject with a unilateral Eustachian tube dysfunction. One ear is able to vent an induced positive pressure and equilibriate an induced negative pressure without the use of any muscular activity. The other ear shows no evidence of deflections on the positive or negative pressure curves on performance of the Valsalva or Toynbee manoeuvres.

All those ears that on Eustachian function testing had no deflection on the positive pressure curve on performance of the Valsalva or Toynbee manoeuvres were found to be unable to equilibriate their middle ear pressures at a depth equivalent of three metres of water. Six weeks after operation, 161 subjects were demonstrating either venting of an induced positive pressure or deflections on the positive pressure curve on Eustachian function testing.

Figs 6 and 7 are the pre- and post-operative function tests of a subject who presented with bilateral Eustachian dysfunction.

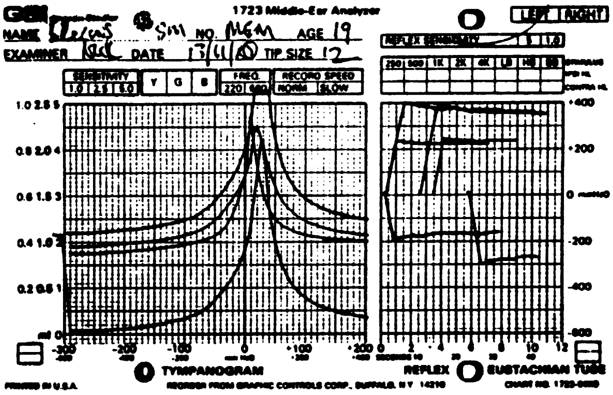

Fig 6 Tympanogram and Eustachian function test of a subject with bilaterally negative Eustachian tube function. Deflections are absent on both the positive and negative pressure curves when the Valsalva and Toynbee manoeuvres are performed.

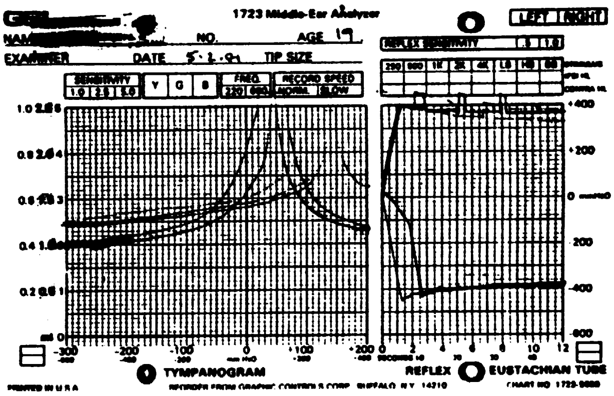

Fig 7 Tympanogram and Eustachian function test of the subject in Fig 6, six weeks after operation. Upward deflections are produced on the positive pressure curves on performing the Valsalva manoeuvre.

All those subjects who were found to have positive Eustachian function tests were able to equilibriate their middle ear pressures at a depth equivalent to 10 metres of water.

The findings on Eustachian function testing correlated with the individual’s ability to equilibriate his middle ear pressures but did not in all cases confirm the otoscopic findings.

Those subjects who did not undergo operation did not have return of positive Eustachian function. All the subjects in this series had auditory acuities of between 0-20 dB related to the ISO standard, 1964.

Interestingly although the Eustachian function tests closely correlated with the ability of each subject to either succeed or fall in equilibriating their middle ear pressures, 26 subjects who had positive Eustachian function post-operatively, confirmed by equalising their middle ear pressures at a depth equivalent of 10 metres of water, had immobile tympanic membranes on otoscopy when they performed the Valsalva and Toynbee manoeuvres, nor was any movement apparent on microscopy. The tympanic membranes were mobile on using Siegle's pneumatic speculum.

COMMENT

Resting Middle Ear Pressure

The finding of normal middle ear pressure at rest does not necessarily indicate normal Eustachian function, but the finding of a negative middle ear pressure is presumptive evidence of Eustachian tube dysfunction.(1)

Inflation-deflation Test

The test may be successful in subjects with excellent Eustachian function but is not useful in differentiating between normal and abnormal function.(1)

Toynbee's and Valsalva's Tests

The ability to develop a negative pressure in the tympanic cavity during Toynbee's manoeuvre, plus equilibriation of the induced negative pressure to the initial resting pressure by recurrent swallowing indicates excellent tubal function, but the ability to produce a negative middle ear pressure on Toynbee's test and a positive intratympanic pressure on Valsalva's test does not differentiate between normal and abnormal function.(1)

Middle Ear Pressures

Middle ear pressure recordings outside the range of ±25mm of water indicate poor Eustachian tube function. Normal middle ear pressure indicates adequate tubal function, but only at the moment of testing and under test conditions.(4)

CONCLUSIONS

A technique for assessing Eustachian function in ears with intact tympanic membranes is presented. Four hundred and forty two ears were investigated, 23 of which initially had positive Eustachian function at presentation. The positive function was confirmed by carrying out Eustachian function testing and exposing the subjects to an increase in ambient pressure. Those ears that had positive Eustachian function were able to equilibrate their middle ear pressures at a depth equivalent of three metres of water, while those ears with Eustachian tube dysfunction sustained a Grade 1 otic barotrauma. Out of the 171 subjects who underwent operation, 161 subjects had bilateral Eustachian function six weeks after operation, as demonstrated by the production of a deflection on the positive pressure curve on performance of the Toynbee and Valsalva manoeuvres or by the ability of the ear to vent an induced positive pressure. Those ears that produced a positive Eustachian function test were able to equilibrate their middle ear pressures at a depth equivalent of 10 metres of water.

The 161 subjects with bilateral positive function have all undergone submarine escape tank training, and have made escapes from 30 metres without sustaining otic barotrauma.

The technique described is an adjunct to and not a replacement for the limited investigations available for assessment of Eustachian function in ears with intact tympanic membranes.

With the new generation of electro-acoustic instruments which are readily available, it is now possible for the clinician or audiologist to carry out Eustachian function testing during clinic hours with minimal expenditure of time.

The principle involved in this test is the same as that used in the classical Toynbee's and Valsalva's test, except that an upward or downward deflection is produced on a horizontal trace.

The ability of certain ears to vent an induced positive pressure appears to be dependent on the size of the mastoid air cell system; a poorly aerated system vents an induced positive pressure, while a well aerated system does not vent. This difference is being investigated at the present time.

ACKNOWLEDGEMENTS

I should like to thank CMT E Nickson BEM, POMA G Doyle and LMA A Doran, the audiometric technicians in the ORL Department, RNH Haslar; the staff of the Submarine Escape Training Tank at HMS DOLPHIN, who exposed the subjects to an increase in ambient pressure in the compression chamber; the recruits and volunteers to the Submarine Service who have made this work possible and who are participants in further investigations into Eustachian function, and the Department of Clinical Photography who produced the figures demonstrating the Eustachian function tests.

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BONE SCINTIGRAPHY AS AN INVESTIGATIVE AID FOR DYSBARIC OSTEONECROSIS IN DIVERS

RR Pearson, MA Macleod, AJB McEwan and AS Houston

Dysbaric osteonecrosis is an occupational hazard occurring as a direct result of exposure to altered environmental pressure. It is especially prevalent in compressed air workers (1,2) and, to a lesser extent, in divers.(2,3)

Although osteonecrosis is associated with many forms of disease processes and trauma (4,5) the various aetiologies have a common denominator in that they are forms of aseptic and avascular necrosis. In compressed air workers and divers, the lesions have a characteristic distribution which is limited to the upper tibia, femur and upper humerus. It is conventional to classify the lesions as “shaft” lesions, which are also sometimes referred to as HNS (head, neck and shaft) lesions, or “juxta-articular” lesions affecting the bone underlying the articular surfaces of the humerus and femur in the shoulder and hip joints. Juxta-articular and shaft lesions may be referred to as “A” or “B” lesions in accordance with the classification introduced by the Medical Research Council Decompression Sickness Panel.(1) Shaft lesions are generally regarded as benign, whereas juxta-articular lesions have a crippling potential due to collapse or “in-fracture” of the overlying articular surface. For reasons that are not entirely clear, juxta-articular lesions in divers rarely involve the hip joint whereas a significant proportion of juxta-articular lesions in compressed air workers do involve the hip joint.

PREVALENCE AS ASSESSED BY RADIOLOGICAL TECHNIQUES

The diagnosis of dysbaric osteonecrosis has traditionally been by radiological techniques and many radiological surveys of groups of divers have been carried out in the last 30 years. These have revealed a prevalence of positively diagnosed lesions ranging from 1.7 percent (6) to an alarming 65 percent.(7) A comprehensive survey of Royal Navy clearance divers carried out between 1966 and 1971 (8) revealed a 5 per cent incidence of positively diagnosed lesions. Current prevalence in active Royal Navy clearance divers is under 2 per cent but this figure must be interpreted with caution in view of the very small numbers of divers with positive lesions and the fact that in the late 1970’s a significant number of experienced but relatively young divers left the Royal Navy to go into the commercial diving industry.

The most comprehensive figures available for prevalence in the commercial diving industry are those available from the Medical Research Council Decompression Sickness Central Registry where X-ray records of commercial divers have been kept since 1970 together with details of their routine medical examinations. Recent reports from this Registry (3,9) which now holds data for nearly 5,000 divers, have highlighted positive correlations with certain features of the claimed diving history such as depth of deepest dive (Table 1), depth of deepest saturation dive (Table 2), length of diving career (Table 3) and history of decompression sickness (Table 4). Certain physical and physiological characteristics of the divers with positive lesions appeared to be significant. These were increases in the mean body weights, skinfold thickness and the packed cell volumes.

The overall prevalence of proven dysbaric osteonecrosis in commercial divers has been shown by the Registry to have risen from 1.9 per cent in 1975 to 4.1 per cent in 1981. If suspected lesions are added, the current prevalence becomes 6.2 per cent. The percentage of juxta-articular lesions represents 30 per cent of the total number of proven lesions but only 14.5 per cent of the juxta-articular lesions have progressed to symptomatic and other evidence of joint dysfunction.

Tables 1 to 4 are condensed versions of the tables in UEG Technical Note 25 “Aseptic bone necrosis in commercial divers”.

TABLE 1

DYSBARIC OSTEONECROSIS AND MAXIMUM DEPTH DIVED IN 4,421 COMMERCIAL DIVERS

Maximum depth dived (msw)	Divers	Divers with radiological lesions
1 - 30	317	0
31 - 50	1025	0.8
51-100	1171	1.6
101-200	1718	8.1
201+	190	15.8

TABLE 2

DYSBARIC OSTEONECROSIS AND MAXIMUM DEPTH OF SATURATION DIVES IN 1725 COMMERCIAL DIVERS WITH SATURATION DIVING EXPERIENCE

Maximum depth of saturation dive (msw)	Divers	% divers lesions with
1 - 100	215	1.4
101 - 150	664	6.5
151 - 200	589	10.2
201 - 300	118	13.2
300+	42	22.1

TABLE 3

DYSBARIC OSTEONECROSIS AND DIVING EXPERIENCE IN 4316 COMMERCIAL DIVERS

Length of diving experience (yrs)	Divers	% divers with lesions
0 - 4	1262	0.7
4 - 8	1300	2.2
8 -12	885	5.5
12+	869	10.7

TABLE 4

DECOMPRESSION SICKNESS HISTORY (CLAIMED) AND DYSBARIC OSTEONECROSIS IN 4206 COMMERCIAL DIVERS

History of decompression sickness (all types)	Divers with lesions	% divers
No	3030	1.7
Yes	1375	10.7

Limitations of Radiological Diagnosis

No apology is necessary for reproducing the Registry figures for they represent the best available information on prevalence. They do however reveal the shortcomings of radiological diagnosis in determining other important aetiological features of dysbaric osteonecrosis. It is known that, at best, radiological evidence post-dates the hyperbaric insult (or insults) by at least three months and, as will be described in this paper, may take as long as two years to appear. There is some post-mortem evidence to show that radiological changes may give a very poor indication of the full extent of bone damage.(10,11) A further limitation of radiological techniques is their inability to give any information about the precise pathological process initiating the chain of events that result in the radiologically evidenced mineralisation that is associated with bone repair. Although the precise pathology is not fully understood, it is generally accepted that the lesions result from some form of vascular occlusion in the bone marrow which then results in infarction and subsequent reactive osteoplastic activity.

RATIONALE FOR BONE SCINTIGRAPHY

In an attempt to provide earlier diagnosis of the lesions of dysbaric osteonecrosis than was possible by radiology, the technique of bone scintigraphy was first investigated by the Royal Navy in 1972 when a preliminary scintigraphic survey was carried out on eight Royal Navy divers with radiologically established lesions that had been identified in the 1966-1971 radiological survey. The bone-seeking imaging agent used in this survey was 99mTechnetium (Tc) Polyphosphate. Although some radionuclides such as Fluorine and Strontium are boneseeking in their own right, $99m_{Tc}$ is highly suitable for labelling non-radionuclide boneseeking compounds for imaging purposes. $99m_{Tc}$ has a relatively short half-life and gives a very low whole body radionation dose together with a suitable low radiation dose to the target organs (in this case) of cortical and medullary bone (Table 5). It is also easy to produce $99m_{Tc}$ and label compounds for imaging techniques. Initially, bone scintigraphy was carried out with $99m_{Tc}$ Polyphosphate but after some experience with $99m_{Tc}$ Disodium Etidronate (Osteoscan) a change was made to $99m_{Tc}$ Methylene Diphosphate (MDP) in 1977 and this remains the imaging agent of choice (Table 6). Claims have been advanced for the superiority of $99m_{Tc}$ Hydroxymethane Diphosphonate (HMDP) as an imaging agent but a recent report (12) suggests that $99m_{Tc}$ MDP and 99m HMDP have equal merits as bone imaging agents, allowing both quantitative and qualitative estimates from scintigraphy.

The 1972 experience with bone scintigraphy showed an increased uptake of radionuclide in lesions whose X-ray appearance was still "soft" whereas a dense sclerotic X-ray lesion showed no increased uptake. Two X-ray lesions were of particular interest in that they had been initially detected some six years previously and yet still showed increased uptake of radionuclide. Such an increase in uptake is generally held to be evidence of increased osteoplastic activity and evidence of new or reactive bone formation (13). In view of the limitations of radiology which were evident and the need to assess the diagnostic ability of bone scintigraphy, a formal project commenced in 1974.

Experience with Bone Scintigraphy

Experience to date has fulfilled the initial aim of the formal project and has proved conclusively that $99m_{TC}$ MDP is a highly sensitive bone imaging agent capable of consistently detecting lesions of dysbaric osteonecrosis within three days of causative hyperbaric exposure (14). However, the experience over the period 1974-1982 has answered certain questions, raised others and has seen the extension and refinement of the scintigraphic techniques and complementary investigations. These are best considered in the distinct areas of diagnosis, screening and research.

Diagnosis

In the period 1974-1980, a controlled study was carried out on 30 divers (average age 28.7 years) who took part in 17 oxygen/helium dives at the Admiralty Marine Technology Establishment (Physiology Laboratory) (AMTE (PL)) Alverstoke. Tables 7 and 8 give details of the saturation dives carried out and the number of dives carried out by individual divers. Divers were subject to scintigraphy in the week before the dive, three days after the completion of decompression, and then at intervals of three months, six months and one year after the dive unless further saturation dives intervened. Thereafter scintigraphy was carried out annually. No change was made to the routine annual requirement for long bone and joint X-rays.

TABLE 5

RADIONUCLIDES OF POTENTIAL USE FOR BONE IMAGING
(adapted from Gorton 1974)

	^{85}Sr	^{87m}Sr	^{18}F	^{99m}Tc
Source of isotope	Reactor	^{87}y generator	Cyclotron	^{99}Mo generator
Physical half-life	65 days	2.8 hr	1.8 hr	6 hr
Dose used for scintigraphy (mCi)	0.03	4	4	15
Delay to start of scintigraphy	5 days	1 hr	4 hr	2-4 hr
Bone localisation	30%	30%	50%	50%
Radiation dose to				
bone	3.6r	0.6r	0.6r	0.6r
marrow	1.1r	0.6r	0.6r	0.1r
whole body	0.4r	0.2r	0.1r	0.01r
Chemical form of radionuclide	SrN0$_3$	$SrHCO_3$	NaF	^{99m}TcMDP

TABLE 6

RADIOPHARMACEUTICALS USED BY RN SURVEY 1974-1980

Radiopharmaceutical	Period Used	Dose	Definition ratio abnormal/normal
^{99m}TcMDP Polyphosphate	3/72 to 3/74	8mCi	20 to 100:1
^{99m}TcMDP Disodium Etidronate (Osteoscan) - contains 15% Stannous Chloride	3/74 to 1/77	10mCi	75 to 100:1
^{99m}TcMDP Methylene Diphosphonate (MDP)	1/77 to date	15mCi	80 to 100:1

TABLE 7

SATURATION DIVES STUDIES 1974-1980

Dives	Decompression Table	No of divers
420m x 1	RN Operational*	2
300m x 4	RN Operational*	9
250m x 3	RN Operational	9
200m x 1	RN Operational	2
180m x 1	RN Operational	2
100m x 3	RN Operational	9
540m x 1	AMTE(PL) Experimental	2
420m x 1	AMTE(PL) Experimental	2
180m x 2	AMTE(PL) Experimental	4

**Extrapolated for operational 250m tables*

Thirteen of the 30 divers showed post-dive scintigraphic changes of a persisting nature in that they were evident at three days and persisted for a minimum of six months.

TABLE 8

DISTRIBUTION OF DIVES AMONG DIVERS

Divers carrying out 1 dive	- 22
Divers carrying out 2 dives	- 6
Divers carrying out 3 dives	- 1
Divers carrying out 4 dives	- 1

Table 9 shows that they were scattered fairly evenly throughout the dives and that two of the scintigraphic changes occurred in divers who had overt signs of “joint pain” only decompression sickness. In both cases, the divers suffered from bilateral knee pain and sustained unilateral scintigraphic changes to the lower femur. However, in one diver the scintigraphic change was in the leg least affected and the other diver was symptomatically less troubled than his companion diver who remained normal on post-dive scintigraphy.

There was only one transient post-dive scintigraphic change affecting a knee joint known to have been subject to trauma during the dive.

TABLE 9

DISTRIBUTION OF POST-DIVE SCINTIGRAPHIC CHANGES IN DIVE SERIES STUDIED

Dives	Decompression tables used	Number of Divers	Cases of Decompression Sickness	No of divers with post-dive scintigraphy changes
420m x 1	RN Operational*	2	0	0
300m x 4	RN Operational*	9	0	2
250m x 3	RN Operational	9	0	4
200m x 1	RN Operational	2	0	2
180m x 1	RN Operational	2	0	1
100m x 3	RN Operational	9	0	3
540m x 1	AMTE (PL) Experimental	2	2	1
420m x 1	AMTE (PL) Experimental	2	0	0
180m x 2	AMTE (PL) Experimental	4	1**	1**

* *Extrapolations of the RN 250m operational decompression table*

** *The scintigraphy changes were in the diver treated for decompression sickness*

The anatomical distribution of the lesions (Table 10) is entirely typical of the distribution of radiologically diagnosed lesions and no lesions were seen in any atypical sites during scintigraphy. That 22 scintigraphic lesions occurred in 13 divers is explained by the fact that eight divers had two distinct post-dive lesions and one diver had single post-dive lesions after two separate dives.

Four of the scintigraphic lesions converted to typical early X-ray appearances of dysbaric osteonecrosis after intervals of nine months, 13 months, two years and five years. The lesions converting at 9 and 13 months were in both lower femurs of a single diver. Both this diver and the diver with the lesion becoming X-ray positive at two years did not have any further hyperbaric exposure following the dives giving rise to the scintigraphic changes. In all cases there was good anatomical correlation between the scintigraphic and X-ray changes although the early X-ray changes were much smaller in extent than the scintigraphic lesions. The finding has been reinforced by further studies since 1980 *(vide infra)*.

TABLE 10

ANATOMICAL DISTRIBUTION OF SCINTIGRAPHIC CHANGES

Site of post-dive Scintigraphic changes	Long-lasting changes	Transient changes
Right upper humerus	4	-
Left upper humerus	-	-
Right hip joint	-	-
Left hip joint	-	-
Right proximal femur	-	-
Left proximal femur	1	-
Right distal femur	9	1
Left distal femur	5	-
Right proximal tibia	1	-
Left proximal tibia	2	-

The 18 lesions which did not progress to X-ray changes proved to be the most interesting and puzzling part of this study. Four have persisted unchanged for periods of five years (now approaching seven in two cases), four have persisted for periods in excess of two years, and three have persisted for over one year. Conversely, seven lesions reverted to normal in periods ranging from one to five years. The significance of these various lesions will be discussed later.

There was no correlation with the actual length of dives which, with varying times spent at maximum depth, lasted from 5 1/2 to 29 days. All dives maintained an oxygen partial pressure of 0.4 bar throughout the dive. Many of the dives involved intensive physiological and biochemical monitoring but no correlation was observed between any of the measurements and the post-dive scintigraphic changes.

Full details of this study have been reported more extensively (14) and the study of experimental dives has continued with results that are entirely in keeping with those reported here.

Further Studies

In an attempt to understand the significance of the persisting scintigraphic lesions revealed by the 1974-1980 study, which did not progress to X-ray changes and as further scintigraphic changes were discovered in divers, the opportunity was taken to study five of these divers with changes in the femur using the techniques of emission and transmission computerise axial tomography (“E” and “T” CAT scanning). These techniques, in conjunction with normal scintigraphy and radiology, allowed a three-dimensional visualisation of the scintigraphic (E-CAT) and X-ray (T-CAT) changes. Both techniques showed clear evidence of the lesions being medullary and T-CAT scanning showed evidence of endosteal involvement with septate changes in the medullary tissue. Of the two techniques, E-CAT scanning proved more suitable as an investigative tool as 99m$_{Tc}$ is used in doses identical to those for normal scintigraph whereas considerably more radiation exposure ensues from T-CAT scanning. However, the T-CAT scans appeared to confirm the concept of reactive marginal medullary and endosteal osteogenesis following infarction. This process has been ascribed to the effects of infarction on the medullary fat.(15)

More recently, significant contributions to the understanding of these scintigraphic lesions have been made by the Nuclear Medicine Department, Royal Naval Hospital, Haslar. Using quantification of accretion rate constants of $99m_{Tc}$MDP in the areas of interest, it is possible co assess the medullary perfusion of affected bones. To date, eight divers with changes on routine scintigraphy have been investigated with this technique. When studied, only one had evident radiological changes. This diver and two others showed significantly diminished accretion rate constants over the affected areas and the two divers without previous X-ray changes became X-ray positive within a further three and four weeks respectively (in both cases six months after the appearance of the initial scintigraphic changes). The other five divers had normal or increased accretion rate constants. This technique, described more fully by Macleod elsewhere(16) appears to be able to identify those scintigraphic lesions which will progress to X-ray changes, the critical factor being diminished medullary microvascular perfusion typical of infarction. This technique has been successfully extended to predicting the fate of scintigraphic abnormalities in steroid-induced osteonecrotic lesions. What remains an enigma is the aetiology involved in persisting scintigraphic lesions with normal perfusion which do not progress to X-ray changes and which now appear to exist in other forms of osteonecrosis as well as the dysbaric variety. The concept of continuing reactive osteoplastic activity is attractive in terms of explaining the increased uptake of $99m_{Tc}$MDP but the pathological reality of such long term osteoplastic activity seems much less plausible. The answer to this enigma awaits an histological solution.

Other Diagnostic Studies

Even though radiology is still regarded as the definitive diagnostic procedure for dysbaric osteonecrosis and the criteria for a positive diagnosis are well established (17) the earliest X-ray changes are often very difficult to assess and other non-related radiological abnormalities of bone may add to the diagnostic difficulties.(5) Bone scintigraphy offers a valuable determinant of any osteogenic activity in these doubtful X-ray lesions and has been routinely used in this sense for the last four years. Where routine X-ray screening of divers occurs, bone scintigraphy should, at least, be regarded as an essential complementary investigation for any doubtful abnormalities discovered.

RELATIONSHIP BETWEEN DECOMPRESSION SICKNESS AND DYSBARIC OSTEONECROSIS

Although logic dictates that mild decompression sickness, particularly in the form of joint pain or other musculo-skeletal manifestations, has a quite different aetiology to dysbaric osteonecrosis (except in terms of their common link to decompression itself), the MRC Registry figures appear to show a group susceptibility to dysbaric osteonecrosis in divers who claim to have had decompression sickness. It has also been claimed that the aches and pains which are often thought to be an inevitable accompaniment of decompression, particularly from saturation diving, may be connected with the medullary infarction which leads to dysbaric osteonecrosis (18). The 1974-1980 study suggested that for most divers post-dive scintigraphic lesions could not be linked to any symptoms. Since 1980 a total of 14 divers with musculo-skeletal manifestations of decompression sickness (some with multiple joint pain) from air and oxygen/helium diving have since had scintigraphy after therapy or completion of saturation decompression. Only three of these divers have had scintigraphic changes and in only one case was the scintigraphic lesion in the same area as the pain (is left knee pain with a scintigraphic lesion in the left lower femur). Therefore the relationship can only be casual in the individual and the impression is reinforced that dysbaric osteonecrosis is a separate manifestation of an inadequate decompression which may also give rise to decompression sickness. One interesting case in this particular study was referred to the Navy after hyperbaric therapy had only been partially successful in relieving his shoulder, elbow and wrist pain. Scintigraphy showed a distinctive picture of an inflammatory process in these joints and the patient was shown later to have Reiter’s syndrome and not decompression sickness.

BONE SCINTIGRAPHY AS A ROUTINE SCREENING PROCEDURE

Following the demonstration of the ability of bone scintigraphy to identify bone infarcts at a very early stage, bone scintigraphy is particularly attractive as a routine screening procedure for divers. The low whole body radiation exposure involved (provided a high fluid intake and frequent voiding of the bladder is encouraged) compares very favourably with the exposure necessary for current X-ray screening procedures, although the important gonadal doses are equivalent if shielding is used when X-raying male divers. Excluding the capital cost of equipment, scintigraphy again scores as a cheaper screening method than X-rays.

Accordingly, a pilot study has been in progress since January 1982 which uses scintigraphy as the sole routine screening method for a group of 25 Royal Navy saturation divers. The protocol allows for limited X-ray investigation of any areas of scintigraphic abnormality. Importantly, initial experience does not suggest that a large number of unsuspected scintigraphic lesions will be revealed.

JUSTIFICATION FOR CONTINUING RESEARCH INTO DYSBARIC OSTEONECROSIS AND ROUTINE SCREENING OF DIVERS

The prevalence of dysbaric osteonecrosis in commercial divers continues to rise and, in selected groups, is as high at 17 per cent. If it is accepted that there is a causative medullary infarct, it must be conceded that there is a very slight but significantly increased risk of subsequent malignant disease of bone (19) and three cases of sarcomatous change have been described in the lower femoral shafts of compressed air workers. There is also a risk of crippling joint disorders from juxta-articular lesions and it is generally accepted that early diagnosis of such lesions and a cessation of hyperbaric exposure may influence favourably the prognosis in terms of progression to joint dysfunction.

In the face of such evidence it can only be wise to continue research and screening. In both respects scintigraphy is a valuable and sensitive investigative technique of proven worth.

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BOOK REVIEW

SUBSEA MANNED ENGINEERING

Gerhard FK Haux. Best Publishing Co.

Available in Australia through Pro-Diving Services, 27 Alreda Street, Coogee NSW 2054.

This book, as its title accurately indicates, describes the engineering basis for commercial underwater activities and scientific exploration of the sea's depths. It is a valuable review of the remarkable range and variety of engineering products of current interest. The author, Gerhard Haux, has grown up intimately involved with meeting the problems affecting the rapidly escalating involvement of man deeper and longer underwater and has acquired a possibly unique understanding of the principles behind the development of the necessary equipment. This book does not seek to balance the advantages of one piece of apparatus, or one brand, against any other. It is rather a dispassionate review of what is, and the list is long. He deals with the various types of pressure chambers, from the one-man to the complex saturation complexes where several diving teams may be accommodated under differing ambient pressures. There is a clear and basic description of the engineering problems of passing the air-water interface, of the difference between a submersible and a submarine, of life-support systems and regulator designs. The size of the subject is demonstrated by the fact that in 500 pages the author has only dealt with the basics of each matter without venturing into the many variations introduced by different manufacturers.

The question arises as to the target readership for such a book. It is suggested that it would be of benefit for three particular groups, though of interest to other readers. First would be doctors likely to become involved with off-shore diving support, as a knowledge of the hardware would improve their appreciation of their patients' problems. Next would be divers intending to enter the "big league diving" as the text is lavishly illustrated and clarified by excellent deceptively simple line drawings. Only someone with a real understanding of the principles involved could so clarify the multiplicity of variations on a theme of pots and chambers. Lastly, there is the lay reader who is in a position involving the use of divers and diving apparatus but not personally involved in the practicalities involved. It could make communication and understanding easier between the diving group and the customer, enabling the latter to understand that there is more involved than just "sending a diver down".

The book has one limitation, it describes what is without giving even a sideways glance to what should be. There is no real mention of making the equipment optimal for diving efficiency, though there is no reason why this book should include human factors. To be fair, Diving Medicine and Physiology also tends to treat the diver as a lay figure within which interesting pathology occurs. Still, ergonomics are now a reputable part of engineering and hopefully influence new designs. As it says in the Introduction, "some of the diver's qualities are irreplaceable". The real purpose of the engineering and human endeavour is to get a job done efficiently and this may increasingly involve the use of 1 ATA suits and submersibles, matters discussed in the book.

The book is a veritable mine of information and exceedingly helpful drawings. The most humanising touch is the portrait of the author and two colleagues standing on Helgoland just prior to its first descent: it is sadly appropriate that the habitat is in focus, the men not.

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DECOMPRESSION SICKNESS:

TWO CAUTIONARY TALES

C Gordon Daugherty

These two cases involve commercial divers, the group of divers with which most of my work is concerned. They illustrate important points of general applicability as well as showing how serious problems can evolve and affect even trained and experienced personnel when correct procedures are not followed.

Case 1

A dive was planned to a depth of 330 feet to inspect a valve. The diver was to be tended from a bell 50 feet shallower by a second diver, the bellman. At the start of the dive, the diver was lowered to 230 feet but the bellmen, upon entering the water, developed a communication problem and was returned to the surface to change helmets. After a period of ten minutes, the diver was also returned to the surface, then both men were lowered to the bottom after the communication problem was corrected. Bottom time was uneventful. The diver noticed pain in his left elbow as he was leaving his first stop at 170 feet. During the remainder of decompression in the water, pains developed in the other extremities also. These pains tended to improve during each stop, only to become worse as the diver travelled to the next stop. This pain was not reported to topside personnel.

Upon reaching the surface, the pain was sufficient to cause the diver to have difficulty climbing the ladder. During surface decompression on oxygen, the pain continued, primarily in the elbows. At the end of routine decompression, the diver left the chamber momentarily, then re-entered and received US Navy Table 5. This apparently relieved all pain, but at the end of treatment, the diver noted that he was extremely fatigued and went below to his bunk where he slept for five hours. Upon awakening, he again noted marked pain in all extremities and was treated with a US Navy Table 6, with one extension at 60 feet. During this treatment, all pains were relieved except the most severe pain in the left shoulder. No further treatment was given. The diver remained at the dive site for one additional day, doing minor chores. The pain in the left shoulder persisted and continued to be very noticeable. He did no further diving.

On the second day following his accident, he returned to shore and then drove to his company's office in the next state. There further treatment was administered with satisfactory resolution of the problem.

This case is almost a catalogue of errors. The diver should have been returned to the surface promptly when the bellmen developed difficulty with the microphone in his helmet. Failing this, the ten minute bottom time for the first "dive" should have been figured into the decompression of the actual dive, but this was not done.

The situation of bends symptoms developing while still in the water is an entire subject in itself. Suffice it to say that there are various strategies which might have been attempted, though there is no official method. Nothing was done because of the diver's failure to report the symptoms, allowing them to become worse as decompression continued.

Use of Table 5 was inappropriate, as symptoms under pressure are considered serious and a Table 6, probably with both extensions, would have been correct. Upon completion of the inappropriate Table, the presence of extreme fatigue should have been recognized as a possible sign of inadequate treatment.

Leaving the chamber area to go below and sleep was an additional error, as it is customary for a treated diver to remain the chamber area for at least one hour after treatment.

Failure to relieve all pain with the Table 6 which was given after the diver awakened should have been recognized as a definite sign of inadequate treatment. At the very least, advice should have been obtained from the company physician on shore who might have recommended additional treatment. After a further delay of two days, the final treatments that were given relieved all but a very small amount of residual pain in the shoulder which subsided over a period of about four days.

This case also illustrates that often the first error leads to a second which starts a chain reaction, with each error compounding the next. This is certainly not unique to diving but reminds us (in any field) that the best way to deal with a mistake is to do so early.

Case 2

During a slack period, two commercial divers decided to go spear fishing below the rig where they were working. They were wearing helmets and breathing surface-supplied air, but did not take bailout bottles. They were lowered on a stage to 160 feet, where, after ten minutes, the air supply was suddenly interrupted to both divers. One diver immediately removed his helmet and began a free ascent. The second diver notified the surface that they were out of air, then also removed his helmet and started up. Both divers made their ascent by pulling themselves hand over hand up the line connected to the stage. At some point personnel at the surface began to pull up the stage also.

At the surface, the first diver vomited some sea water. The second soon began to notice weakness in both legs. Both men were treated on a US Navy Table 5. Following completion of this Table, both divers appeared normal and the first diver did well from then on. The second diver was observed for a period of three or four hours, and then was sent to shore.

That evening, he noted tingling in his right leg, but did nothing. Three hours later on, he arose from bed but immediately fell to the floor because of profound weakness in both legs. He was taken to a chamber elsewhere, a trip which required two hours. About midnight he was recompressed on a US Navy Table 6A. Improvement was noted initially, but the patient's condition deteriorated each time movement to a shallower depth was attempted. The remainder of the night was passed in this fashion, attempting to get the patient to the surface. Apparently no precise Table was followed, although those at the scene attempted to stay as close as possible to Table 6A. At 10:00 the following morning, the patient was at 30 feet in the chamber and was seen by a physician. Urinary retention and constipation were noted. The patient's bladder was catheterized. Upon completion of treatment the patient still had weakness in both legs, urinary retention, and constipation.

If a more detailed neurological examination was performed, it was not recorded. Treatment with a US Navy Table 5 was begun twice daily and continued for nine days, when treatment was stopped because of pulmonary oxygen toxicity. By then the patient had regained some bladder function and his constipation was improved. But there was marked weakness and spasticity of both legs, and impotence. The patient was later sent to a rehabilitation institute for further care and his final neurological status is not known.

A cruel irony in this case is that two professional divers did not observe an ordinary precaution while diving for sport that would have been routine had they been working. I refer to the bailout bottles which were left at the surface while they were spear fishing. Weakness in both legs, a symptom of spinal cord decompression sickness, should be treated by Table 6, not Table 5. Aggressive treatment at the first recompression might have avoided all further problems.

Note the variability of decompression sickness. Given the same exposure and inadequate treatment, one diver did well and one did not.

Although it was prudent to observe the diver for four hours on the rig before sending him to the shore, in a case involving spinal symptoms, plans for possible further treatment could have been considered ahead of time. The diver himself ignored the earliest signs of recurrence, wasting precious time, which was added to the delay of the two hour trip to the chamber.

The most poignant aspect of the case is the desperation of those trying to help the injured diver, not knowing what to do when their chosen Table proved inadequate. In a properly equipped chaser, a diver exhibiting this deterioration would be returned to the depth of relief, held for a period of hours, then decompressed on a saturation schedule. This was not possible in this case.

DISCUSSION

With a diver exhibiting relief at 165 feet, yet deteriorating after the initial bottom time on a Table 6A, a US Navy Table 4 could be used, giving a longer bottom time. This Table could have then been followed to a depth of 60 feet, at which point a Table 6 could have been substituted, ideally with extensions at both 60 and 30 feet. Another alternative which has been successful is to use a US Navy Extreme Exposure Table (or equivalent) for the decompression from 165 to 60 feet. Probably best of all (in my opinion) is the Royal Navy Table 71 or 72 to 60 feet, because of the linear decompression.

If saturation decompression is not possible, and one is running completely out of bottom time on any sort of Table, probably some form of deterioration can be accepted during travel from 165 to 60 feet, in the hope that this would then be corrected by the large amounts of oxygen given from that point on. There is a limit to what can be done simply with depth. Once one has reached the level of 60 feet or less, long holds are possible.

For a more detailed discussion of this problem I refer readers to the article, '"Handling a Tough Treatment Without a Sat System", by RW Hamilton, PhD. Reprints of this article may be available from the Commercial Diving Journal, 1799 Stumpf Boulevard, Building 7, Suite 4, Gretna, Louisiana, USA, 70053. Alternatively, write to Dr Hamilton at: 80 Grove Street, Tarrytown, New York, USA 10591.

Dr Daugherty has offered to answer questions or enter into discussion concerning these cases if contacted through the Editor.

THE PIG, THE OWL AND THE PUSSYCAT

A Fable of Simplicity and Self Reliance

Nigel Froome

There was once a pig (a very bumptious, obese and arrogant pig), an owl (a very wise, sensible and responsible owl), and a pussycat (a very beautiful, charming but naive pussycat) who chanced to meet on a tropical island where they had gone for their diving holiday. One sparkling morning they put to sea in a boat (a beautiful pea-green boat, no less) and headed out to an exotic offshore reef. On the way they chatted excitedly about their past deeds and experiences ... except the owl who listened and winced occasionally at some of the more bombastic statements, especially those of the pig.

"You don't have to worry about me because I'm an experienced instructor," boomed the pig, "and I always insist that my pupils use the very latest in the way of equipment. I sell it in my diveshop you know". He paused to light a cigarette, flicking the still smouldering match into the bilge.

"My instructor made me buy all the latest equipment too," said the pussycat, "and it was very expensive so it must be good! He made us spend hours in the classroom learning all about the theory and techniques of diving, and we had to learn by heart the laws of Henry, Boyle and Dalton and the decompression tables too. We spent more time in the classroom than we did in the water!"

The owl said nothing.

Rummaging in his voluminous dive bag, the pig dragged out a dazzling array of shiny hardware: fittings, clamps and buckles plus a deluge of miscellaneous chrome-plated items. “Look at this!” snuffled the pig proudly, “the latest top-of-the-line RIPSNORTER Mark Seven, ten stage regulator with fully balanced snot bypasses, multiple saliva outlets and automatic self-clearing mucus recycling valves. Breathes like a dream! Wouldn’t use anything else.” He then displayed his back pack which consisted of an enormous mass of flaccid rubberized material with numerous tubes flopping in all directions. “Dig this!” he grunted, “The brand new Unitized Dunkpak Push-Button Buoyancy Compensator and Tank Assembly, put out by the Rigor Mortis Diving Company. It all fits on your back and provides 500 lbs of lift when you press this button. To deflate it you lift up this tube and press another button. Simple! As it’s all in one unit you just inflate it and drop it into the water, then you jump in, slip your arms through the special harness, vent the air and off you go!”

The pussycat gazed at the pig, her eyes wide with adoration. “What a handsome, knowledgeable pig you are,” she purred, “and such wonderful equipment!”

The pig grunted with delight and flourished a flamboyant certification card. “I’m a TWIT,” he blared arrogantly, “which means that I’ve passed my Turbulent Water Instructor’s Training.”

The owl blinked, but remained silent. The pussycat now began showing off her own equipment, exclaiming enthusiastically, “My instructor recommended this latest model GAGMASTER regulator with automatic foul language filtration, self-adjusting venturi action puke diverter and a two-way-stretch mouthpiece. And I swear by this perforated, lead-lined, off-the-shoulder sheepskin CADAVERFLOAT buoyancy compensator with its built-in genuine Swiss cow bells for attracting attention in an emergency. It’s also inflated from your tank and is made by the Rupturelung Company.” She delved into her bag. “I’m a Mouser with Experience in Open Water,” she mewed, producing a gaudy plastic MEOW certification card.

“And what sort of equipment do you use, son?” asked the pig patronisingly, turning to the owl.

With an air of complete confidence the owl produced an elderly twin hose regulator, a simple inflatable safety vest and a small weightbelt. There was a long silence.

“Is that all?” breathed the pussycat at last.

“What else do you need?” replied the owl with surprise. “The water’s warm so I don’t require a wet suit, which means that I won’t need buoyancy compensation either. With the right weightbelt I’m just a wee bit negative underwater and I can regulate my buoyancy at will by the way I breathe. Most of all, I’m not dragging an enormous load of cumbersome fancy equipment around with me that just isn’t needed on a pleasure dive like this. If I should have a serious emergency, my vest will support me face up in the water ... not like that,” the owl indicated the pig’s horrendous heap of hardware, “which will float an exhausted diver firmly face down when he needs help the most!”

The pig bristled. “That’s a load of hogwash!” he snorted, “why, I always depend on my Dunkpak and I certainly wouldn’t dive with anything else, and neither would my pupils. I insist on it! And as for that,” he broke off, sneering contemptuously at the owl’s regulator while his snout curled as if he’d encountered an unexpected unpleasant smell under his nostrils, “I thought they’d quit making those things years ago!”

“Yes, it’s a Columbus Mark 1, Model 1492 twin hose, single stage regulator,” admitted the owl, “but I’ve only had it for ten years so it’s too early to know if I’m going to have any problems with it. There’s only a couple of moving parts inside, and the unit was made by the Santa Maria Bilge Pump & Suction Corporation. It’s not very fancy, but it is reliable, it balances comfortably in the mouth, it doesn’t freeze up in icy water or annoy my ears by filling them with bubbles all the time, nor do my own exhalations get in the way of vision when I’m trying to take underwater pictures. Most of all, however, it’s SIMPLE, and to me simplicity of equipment plus a trained self-reliance on the part of the diver are the very essence of safe, relaxed diving.”

The pig shuffled indignantly and ground his cigarette out on the new pea-green paintwork. Again the owl winced.

By this time they had arrived at the reef, so the pig dropped anchor and the boat rose and fell on four-foot waves.

The pig and the pussycat fussed and fumbled over their equipment, wrestling with hoses, fittings, attachment rings, chromed connectors and associated plumbing. It looked as if they were trying to assemble grotesque bagpipes. The owl, already dressed, was sitting on the rail and waiting for the others who still battled with their sophisticated gadgetry, all of which seemed to be fighting back.

Finally they were ready. The pussycat gathered the last of her stray tubes and connectors and plugged herself in like a telephone switchboard. The pig pressed a button and his Unitized Dunkpak inflated with a loud hiss, consuming several cubic feet of air in the process. It sat bloatedly on the deck, looking like some grossly obscene stomach that had just escaped from an antacid TV commercial. With a cry of, “OK, let’s go!” the pig heaved the blimplike mass over the side, donned his mask and fins and jumped overboard after it.

The Unitized Dunkpak floated majestically, waving its appendages from the top of a wave while the pig wallowed in the trough beneath, as pigs are wont to do. Then as their positions were reversed, the pig rose on the next wave where he collided violently with his Dunkpak which was now on it’s way down. It struck him on the snout in passing and the pig squealed with pain. Again and again the pig tried to struggle into his harness, but the Dunkpak eluded him, dancing on the waves and slapping at him with its flying tubes and gauges. Winds and slight surface current bore the threshing pig slowly along, and by the time he eventually managed to subdue his Dunkpak and get everything together, he was far from the boat and quite out of breath. He tried to snorkel back on the surface, but the sheer bulk of his Dunkpak plus the slapping of waves and his basically inefficient fin action prevented any progress. He decided to try underwater, so activating the appropriate valves among the plumbing, he vented air from his contrivance and sank beneath the waves. As he angled down, the lead ballast inside the Dunkpak trundled the length of its container with a rumble like balls in a bowling alley. His console informed him that he was rapidly running out of air, the water temperature was 82 degrees Fahrenheit, his depth was twenty feet, his heading was somewhere between north and south with a touch of east and west and it was 3 am the day before yesterday in Tokyo. The deflated mass of materials made an excellent drogue as it flopped flaccidly up and down above the toiling pig, giving him the appearance of a rutting manta ray.

His frenzied kickings were getting him nowhere and very soon he flapped himself into a state of complete exhaustion. With the last squirt of air he inflated his Dunkpak which bore him far too rapidly to the surface,

“Bully for Rigor Mortis Divers! Their Dunkpak has saved my bacon! I’ll just float around until I’m rescued.” thought the pig triumphantly. His relief was short lived, however, for he found himself immediately face down among the waves. Desperately the panicking pig kicked himself upright and saw to his horror that he was farther from the boat than ever. At that moment another wave slapped the Dunkpak and the unfortunate porker was on his snout again. Gagging and retching he once more righted himself. In the quiet waters of lake, quarry or swimming pool, his cumbersome apparatus would indeed hold him upright just as the advertisements claimed, but in a choppy ocean the pooped pig was in trouble. Because all buoyancy was located entirely on his back, a certain amount of work was needed to keep right side up and no matter what the hapless pig tried, waves insisted upon inverting him as he kicked and struggled among his now useless clutter of tubes, bladder, gauges and push buttons. He considered abandoning his beloved Dunkpak altogether and trying to snorkel back to the boat but realized he’d never make it in his totally exhausted condition. As each wave tipped him over, the pig’s efforts to right himself grew more and more feeble until at last he succumbed. In his final moments, the laws of Messrs Boyle, Dalton and Henry flashed before his eyes, as did a complete set of decompression tables, but these were of no consolation to the stricken pig who had from the outset neglected to teach himself or his pupils the very basics of good snorkelling ability with a smooth, efficient fin action, or to insist on adequate practical training with a dependence on self rather than on mechanical ‘assistance’. The pig was never seen again.

Meanwhile, the owl and the pussycat were exploring the wonders of the reef. The cat’s enjoyment, however, was marred by her preoccupation with the festoons of dangling things which emanated from her Cadaverfloat compensator. Her paws flitted nervously from one gadget to another, checking and inspecting her tank pressure gauge every few seconds.

The owl tucked his wings snugly behind his tank and, thus streamlined, sank gently into the depths. A casual stroke of his fins overcame the slight current, and a full inhalation at the end of his descent wafted him to a standstill. The drag from his completely deflated safety vest was minimal and his weightbelt held him nicely in suspension at all levels. With a gentle sweep of fins and the use of breath control, the fully relaxed owl soared effortlessly over coral heads and glided in slow motion into canyons where he gazed enraptured at the beauty around him.

The pussycat marvelled at the ease with which the owl manoeuvred himself and tried to emulate him. She fumbled with her plumbing and finally, after much trial and error, managed to attain some semblance of neutral buoyancy. By alternately adding and venting air, the pussycat laboriously roller-coastered her way like an animated pogo stick behind the effortlessly gliding Owl.

Then, with her Gagmaster’s faulty pressure gauge still indicating 1,000 lbs, the cat ran out of air. She pulled her reserve, but nothing much happened. Panic! Her eyes bulged like an organ with its stops out, and with a yowl of terror into her two-way stretch mouthpiece she beat her way frenziedly to the surface. Once there she pummelled madly at the Cadaverfloat’s inflator button, but her tank was so empty that barely a belch emerged and the enormous flotation bag remained depressingly limp. She was far too puffed and panic stricken to blow manually into it so she tried to snorkel, but her training hadn’t included this activity while burdened with an empty tank, and her fin action was therefore too weak and unco-ordinated to propel her. Waves slopped into her snorkel and the cat spluttered and choked. Her Cadaverfloat was now useless and the petrified pussy tried to jettison it, even though she knew she’d never be capable of snorkelling back to the boat anyway. More waves engulfed her and, like the pig, the diving laws and theories jammed into her in the classroom at the expense of practical time in the water passed before her eyes but were no help at all to the drowning pussycat, now in extremis.

Then the owl was beside her, supporting and towing her bodily with smooth, powerful sweeps of his fins back to the boat. Once again the pussycat’s eyes became wide with adoration, only this time the owl was the recipient of her admiration.

“0 you wonderful owl,” she purred, “you’ve saved my life! How can I ever thank you?”

When the cat had recovered from her fright, the owl explained all about the dangers of a training system that stresses dependence on equipment instead of self. Quoth the owl, “Neither you nor the pig would have had any trouble at all if only you'd been taught how to use your fins and snorkel properly in the first place. For pure sightseeing dives in warm, clear water you don't need all that fancy, sophisticated equipment which holds you back and makes you work harder just to drag its sheer bulk through the water .... and some of this equipment is actually dangerous!" He thought of the pig's devilish device and shuddered.

"But my instructor was very strict and he made us do everything," said the pussycat.

"Did he make you snorkel half a mile on the surface while wearing your tank, regulator and weightbelt, without stopping to rest or to inflate your vest?" asked the owl.

"No of course not!" replied the cat, "and I don't think any certification course requires such a feat."

"Well it should!" said the owl emphatically. "Every diver, before getting a C card, should be required to snorkel that half mile in his own time, at his own pace, without pausing to rest and while wearing complete SCUBA equipment. It could be done in lake, quarry or in circuits of a pool ... anywhere! This would build up a style, stamina and, above all, a self-confidence that would always remain with that diver and enable him to face almost any situation he or she is likely to meet anywhere. So what if your gauge floods or sticks like yours did? It's quite common. What if you have a mechanical problem? Small ones happen all the time. If you known you can handle yourself, no matter what, you are then a completely relaxed and safe diver, so thoroughly at ease that you can revel in each dive without any nagging apprehensions about your equipment. A poorly trained athlete merely loses his event but a poorly trained and overcluttered diver may lose everything!"

"You are such a wise and elegant fowl ... would you be willing to teach me how to dive safely and gain self confidence?" pleaded the cat.

The owl looked up at the stars above, and sang to a small guitar, "0 lovely Pussy! 0 Pussy, my love, what a beautiful Pussy you are ... I shall be delighted!"

And this is really why the owl and the pussycat went to sea in a beautiful pea-green boat ... and how Mr Edward Lear got the idea for his famous poem in the first place.

About the Author of the Pig, The Owl and The Pussycat

Until his retirement in 1981, the author of this fable, Nigel Froome, spent 23 years as the resident diving instructor at the Grand Bahama Hotel on the Island of Grand Bahama. Though the thesis of his fable is self-evident, a bit about Froome himself, in his own words, seems appropriate:

"In 1935 while at school in Guernsey, Channel Islands, Great Britain, a small group of us enjoyed our first hilarious and somewhat suffocating descents with a homemade diving helmet. It was made of wood, ballasted with scrap iron, had a glass window and was fed a reluctant trickle of air via a well-perforated garden hose, and old tyre pump salvaged from the garbage dump of a local garage, and by a lethargic operator. This was undoubtedly the seed from which grew my mania for diving. I drooled over Guy Gilpatrick's book, 'The Compleat Goggler', which was published about then.

"Back in Guernsey, after returning from Germany in WW2, I began diving professionally for a one-man trawling and salvage operation. It was strictly on a drown-as-you-learn basis. My equipment was again Woolworth's garden hose (on special sale at 3 cents a foot), and old pneumatic tool compressor driven by a geriatric car engine and, for transportation, a very leaky ex-ship's lifeboat, also propelled slowly and spasmodically by the same engine. The unreliability of this ensemble necessitated frequent emergency free ascents, some from within the bowels of wrecks and some from well over 100 feet. All these antics were to stand me in good stead and without doubt saved my bacon many times over on future occasions when a customer would get his knickers in a knot over some trivial matter (or sometimes over nothing at all) and would refuse to relinquish my mouthpiece on the way up. (Octopus rigs were not invented then).

"In the early 50's, sport diving in Europe began to boom and I slowly got out of salvage work in favour of instructing as soon as the Cousteau lung became available. In addition to portering about with homemade closed circuit oxygen re-breathing units (old bus innertube, tin can of soda-lime, oxygen bottle from a crashed German plane, and sundry bits and pieces which worked quite well in shallow water, but tasted like freshly squeezed armpits), I did some scuba instruction in the Mediterranean and explored some Greek and Roman galleys that had gone down over two thousand years ago.

"In recent years, my partner Shelby Tostevin and I have become very alarmed indeed at the poor quality of training that many certified divers seem to possess. We are both somewhat fanatical about the need to teach self-reliance as the basic foundation upon which to proceed with the training, and we are concerned by today's training methods which appear to stress altogether too much reliance on sophisticated gadgets (that frequently malfunction) and not enough on self. An underwater Christmas tree does not a relaxed diver make, and we are constantly appalled by the inept flappings of so many of our over-cluttered divers, a lot of whom have to be rescued. Thus it was as far back as 1964, after some particularly horrific experiences with a large diving club that we refused to accept any more large groups. Since then we have only taken out small groups, a maximum of four at a time, and dive with them personally. This makes for a relaxed, leisurely and safer trip, so popular that much of our business is from repeat and regular customers. Thus have we managed to keep a perfect safety record all these years.

"Our strict operating procedures may have aroused the ire of some gung-ho groups in search of special discount 'cattle boat' type trips, but if one life has been saved in the process, then it has been worth it."

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A FEASIBILITY STUDY INTO THE TEACHING OF PARAPLEGICS TO DIVE IN THE POOL AND OPEN OCEAN ON SCUBA

P Bethune and L Menary
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Queensland

This study concerns the training of two disabled males, both paraplegics, one T5 and the other T8, in both snorkel and scuba diving.

The course involved theory training to a level required for certification as a basic Scuba Diver under the National Qualification Scheme, and practical pool sessions. An open ocean dive was successfully completed, at 15 metres depth for 45 minutes, 5 kilometres off the South Queensland coast at Mooloolaba. This study has been conducted in an area in which not a great deal of research has been carried out. The guidelines for course organisation and content were established through discussion with fellow divers and instructors on diving. Also much direction was obtained from a paper entitled “Training Paraplegics and double amputees to dive in the sea with scuba” by NC Fleming and Y Melamed.(1)

This project has been conducted as an open ended exercise, with the intention of following up, in the near future, with further research aimed at developing training guidelines for diving courses for the disabled, and eventually, the possibility of certification for disabled divers, who cannot meet the present practical standards as set down by the Australian National Qualification Scheme, and other recognized diving associations. A training programme for instructors to teach the disabled to dive will also be developed in the future. The ability of disabled divers to rescue and resuscitate another diver will also be examined.

While being of great value to all individuals sport and recreation is perhaps of even greater value to the disabled, providing scope for physical rehabilitation and remediation, apart from the universal benefits of providing enjoyment, and satisfaction, and in many cases, settings for desirable and necessary social interaction, and integration.

Scuba diving for disabled people is a relatively new field of endeavour, but certainly one that is eminently feasible, and practicable. Courses in scuba diving for the disabled have been run successfully in the past, notably by Fleming and Melamed in Israel, which have resulted in a small number of isolated courses scattered throughout the world.

The positive benefit to be obtained by placing disabled persons in an environment in which their physical disability almost becomes of less consequence, would point to the need for many more courses of this type to be initiated, and much more thought is required by able bodied divers, dive clubs, and associations in making provision for disabled persons who may wish to enter into the sport and participate regularly in diving.

The medical and physiological requirements for the participants were taken from Fleming and Melamed (1) and are reproduced below:-

“The examination included a precise medical history plus a description of the present physical status, as well as the character of the applicant as far as it could possibly be judged. With regard to disabled divers, all the factors mentioned above were taken into consideration, plus the eight following special points:-

1. The respiratory system should be completely normal. All the respiratory muscles should be under control, and the spinal lesion not above T5, preferably not above T8.
2. It is of extreme importance that the skin condition of the paraplegic is proper without injury or pressure sores. For amputees the scars should be completely healed or perfect, meaning at least three months after amputations.
3. The paraplegic should not have any urinary tract infection, and should have full control of urine and bowel movements, with or without artificial aids.
4. Fullest consideration should be given to the personality of the disabled person. He should show self-discipline, with a full knowledge of his own abilities and disabilities. He should be of steady character with the capability of withstanding anxiety and panic. He should also be of a co-operative nature, accepting orders from his superiors without resentment.
5. He should be an excellent swimmer, participating regularly in intensive swimming, including sea swimming.
6. He should pass physical tests and exercises concerned in preparation for the course, and if necessary undergo special physio-therapeutical training.
7. If he is a paraplegic, his disability should not have been caused by a spinal bend (discussion below), nor by arteriovascular malformation, nor by transverse myelitis.
8. It should be pointed out to persons with partial spinal lesions, from whatever cause, that there is a possibility that diving might make the lesion complete. There is no record of this ever having happened other than with bends cases, but it is a possibility. There are several cases of people with partial traumatological lesions diving with no ill effect.”

DETAILS OF THE TRAINEES

A.

Date of birth:	1946
Date of injury:	8/4/1977
Type of injury:	Motor vehicle accident. Spinal fracture T4, complete paraplegia below T5.
Treatment:	Bed rest for 8 weeks. Mobilisation in a wheel chair and rehabilitation in the Spinal Injuries unit of the P A Hospital.

Status after treatment: No neurological recovery.
Fully independent in a wheel chair.
Medical history: No previous medical or surgical history.
Present physical status: Blood pressure - 120/80
Pulse - 72
Chest - without pathological finding
Chest X-ray - clear
Neurological - paralysed below T8.
Lung data: Forced vital capacity (FVC) - 3.81
Forced expiratory volume in 1 second (FEV 1) - 3.321
FEV 1/FVC - 87%

A. passed the course successfully and performed all the exercises to the satisfaction of the instructors. He overcame initial respiration problems experienced when water entered his air ways, this was due to much reduced intercostal muscle use.

B.
Date of birth: 1956
Date of injury: 23/9/1978
Type of injury: Motor cycle accident resulting in a traumatic aortic aneurism which has resulted in an incomplete paraplegia below T8.
Treatment: Operation. Surgical repair of aorta followed by rehabilitation in the Spinal Injuries Unit of the P A Hospital.
Status after treatment: No neurological recovery.
Independent in a wheel chair.
Medical history: No previous medical or surgical history.
Present physical status: Blood pressure - 140/80
Pulse - 84
Chest - without pathological finding
Chest X-ray - clear
Neurological - paralysed below T8.
Lung data: FEV - 5.11
FEV1 - 4 1
FEV1/FVC - 78%

B. passed the course of training successfully, and performed all the exercises to the satisfaction of the instructors.

Both candidates were elated at their open ocean diving success. They described a new confidence in the water and a readiness to try other aquatic activities now the fear of drowning had been overcome. Being able to use scuba and breath hold dive under the water acted as an "overkill" for previous fear of water. Now boating and fishing no longer embargoed by the fear of drowning. Both are keen to try subaquatic activities such as photography and marine biology. The social and environmental interactions were positive and important adjuncts to learning to dive. Future studies should assess improvements in self esteem.

This particular course of diving instruction had two main aims.

1. To acquaint the candidates with the theory necessary for safe diving, and also to train them in the practical aspects of scuba required for safe diving in enclosed swimming pools and in the open sea.
2. To integrate the course candidates, if possible, into able bodied dive clubs, and groups, to enable them to participate in the sport in the future. This second aim requires the training of supervisors for disabled divers as well as instructors to teach the disabled to dive. The Australian Underwater Federation (Queensland Branch) (AUFQ) club system and the Federation of Australian Underwater Instructors (FAUI) can play an important role to achieve these aims.

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Another course for paraplegics will begin in December 1982 at the Cotton Tree pool, Maroochydore. At the time of writing, one totally blind male, one partially sighted male and one visually handicapped female are being trained.

An expanded version of this paper is available from the authors.

LETTERS TO THE EDITOR

University of British Colombia
School of Rehabilitation Medicine
Faculty of Medicine
T105 - Third Floor - ACU,
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Vancouver BC V6T 1W5,
CANADA

25 October 1982

Dear Sir

In March of this year, a very enthusiastic group of five wheelchair athletes decided to learn to scuba dive. The group consisted of one left lower extremity poliomyelitic and four paraplegics, ranging from T2, a complete and an incomplete T5, and a T12. The complete T5 paraplegic had not participated in any sports activities since his accident, however, the other four were very active in all aspects of wheelchair sports, such as marathoning and basketball. The Canadian Wheelchair Sports Association approached the diving community in Vancouver, which at that time had not heard of any other disabled individuals who were scuba diving. A pilot project was launched. Wheelchair basketball, marathoning and work commitments on the part of the candidates necessitated an intensive weekend course for the theory and pool sessions. A certified PADI instructor and a half dozen interested and enthusiastic assistants participated. Fairly quickly it became apparent that the candidates would have little difficulty in diving but that equipment and diving gear modifications would have to be made. The ocean checkout dives could not be done until the end of April (due to other sport commitments) and unfortunately, the diving conditions were not optimal at that time. However, the candidates' enthusiasm had not waned in the interval and two checkout dives were completed and all five candidates were given PADI certification. Again, it became apparent that two of the candidates would have minimal entry difficulties from the beach, but the other three would require carefully selected beach sites or boat assisted entries from beach sites.

At this point Dr Peter Graystone, of the School of Rehabilitation Medicine, and I started planning a research project to investigate the viability of teaching scuba diving as a therapeutic means of rehabilitating disabled individuals, particularly spinal cord patients, amputees and polio victims. We had determined that there was a need for adapted and special safety equipment, as well as specialized instruction techniques. From the experience gained in instructing, we expected to compile a resource manual offering instruction techniques for teaching disabled scuba divers. This would include information for the lay person (assistants) concerning the various disabilities and the problems encountered by the disabled individual as a result of the disability. We planned to interview other disabled divers about the problems they encountered while they were learning to dive, and to incorporate their suggestions for adapting equipment and mobility techniques.

During my preliminary research into this project, I found that there is a Handicapped Scuba Association in the USA and also that a NAUI group in Ontario, Canada, have produced a film entitled "Free Dive" which involved teaching several disabled children to dive.

Numerous applications for funding have been completed and we are now awaiting word from these sources. In the meantime, the two more ambulatory of our original group have gone on to become competent divers and the remaining three are eagerly looking forward to better diving conditions and assistance with equipment and dying gear modifications.

We would appreciate hearing from any of your readers, who have participated in a similar project. The writer may be contacted at the above address.

Yours truly,
Margaret Campbell

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10 San Benito Way
Novato
California 94947
USA

Dear Sir

AQUATIC RESCUE AND IN-WATER CPR

Because of the large number of drownings and near drownings that occur each year, there has been considerable interest in developing an effective method of performing in-water cardiopulmonary resuscitation (CPR). Recently, attention has focused on the method of aquatic CPR reported by March and Matthews and, unfortunately, a number of articles in the lay press have made it appear that the techniques described by these authors have been thoroughly tested and endorsed by the responsible medical associations. This is hardly the case.

Although they have reported some interesting preliminary trials, March and Matthews have not developed a satisfactory technique for aquatic CPR. Actually, it is debatable whether such is even theoretically possible. In their reports, March and Matthews (1,2) describe the results of six trained rescuers who performed single person in-water CPR on a submersible mannikin utilizing a specially calibrated scuba regulator for positive pressure ventilation and a horizontal, behind-the-victim position in which the rescuer provides the support platform and delivers external cardiac compressions by various cross-chest hand positions. Testing was carried out for 15 minutes in a swimming pool. During the in-water trials, the test rescuers demonstrated compression depths of 2.0 to 4.5 cm, compression rates of 34 to 48 deflections per minute, and respiratory rates of 6 to 8 ventilations per minute. Although some of the rescuers were able to achieve acceptable depths of compression, none was able to perform chest compressions and ventilations at currently recommended minimum rates for single rescuers.(3)

Given this and the fact that CPR performed by highly trained persons under optimal conditions provides only about 30% of the normal cerebral blood flow, it is unclear to me how they can claim that their "study shows that a trained person may successfully sustain a victim of cardiorespiratory arrest at the surface of an aquatic environment."(1,2)

Several years ago Dr Archer S Gordon studied the effectiveness of CPR performed in water and various other special situations in animals, human volunteers, and mannikins. He found that in-water CPR was quite ineffectual in moving blood to the brain when the test subjects were tilted to a 30° feetdown position; the mean carotid blood flow was reduced to 3% to 6% of control values when the patient was in this position (personal communication, May 1980, AS Gordon). Anyone who tries to perform in-water CPR in the horizontal, behind-the-victim position proposed by March will find it difficult to maintain a purely horizontal position while propelling oneself through the water. During informal observations of scuba diving students and instructors simulating rescues utilizing this technique in calm ocean water, I observed that a 20° to 30° feet-down position was about the best that could be maintained for distances greater than a few feet.

Several other questions about in-water CPR have not been adequately answered. There is no published data about the efficacy of the proposed method in the open water situation where a rescuer must contend with waves, surge, current, sometimes frigid temperatures, inclement weather, and other conditions not encountered in the reported swimming pool trials. If trained test rescuers are unable to meet the basic CPR standards in a swimming pool, it is hard to conceive that such could be achieved in less hospitable water. Similarly when CPR is performed in the horizontal, behind-the-victim position, all the work of chest compression must be done by the arms. In all but very well-muscled individuals, this is exhausting, especially if simultaneously propelling oneself through open water. Rescuer exhaustion, waves breaking over the rescuer's head, and other conditions likely to be encountered in real open water situations pose significant rescuer hazards.

Another aspect of in-water CPR that needs further investigation is the problem of assessing pulselessness in an aquatic accident victim who may be cold, wet, bradycardic, and possibly wearing a wet suit with a tight-fitting hood that obstructs neck access. How effective is in-water palpation of carotid pulsations in this victim, particularly if the rescuer has cold hands or is struggling against a surge? What is the risk of inducing ventricular fibrillation in a chilled bradycardic heart (which may be providing adequate cerebral circulation) that receives chest compressions because a pulse was erroneously not felt? Similarly how does wearing a wet suit, which increases chest wall stiffness, affect the pumping action of intrathoracic pressure fluctuations?

Perhaps the major value of the in-water CPR method proposed by March is identification of the scuba regulator as a means of providing in-water positive pressure ventilation. Studies by Eastman et al (4) also have suggested the usefulness of scuba regulator positive pressure rescue breathing. However, neither of these studies reports the use of this method in actual in-water casualty situations. Thus, although this method of pulmonary resuscitation appears promising, it is of unproved efficacy.

Despite the current enthusiasm displayed for in-water CPR by some, I cannot recommend the method proposed by March and Matthews. The efficacy is far from established, and the method poses significant rescuer hazards in certain situations. The most likely result of performing in-water CPR as currently recommended would be to prolong the time it takes to get the victim to a place where more effective resuscitation can be accomplished. Therefore, I recommend the following approach for aquatic rescues: 1) move the victim out of the water and onto firm, horizontal surface as quickly as possible, deferring CPR until this is accomplished; and 2) perform in-water, mouth-to-mouth rescue breathing in cases in which the rescuer is a strong swimmer or has adequate flotation devices, and when the victim's head can be safely tilted back and turned to the side for rescue breathing. Specially calibrated scuba regulators may be useful for administering in-water positive pressure ventilation if future studies verify their efficacy.

Kenneth W Kizer

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We are grateful for permission to reprint this letter from ANNALS OF EMERGENCY MEDICINE. Dr Kizer is the President of the North Pacific Chapter of the Undersea Medicine Society.

SCUBA WORKSHOP REPORT CONFERENCE OF NATIONAL CO-OPERATION IN AQUATICS

1982 COLUMBUS, 0HI0

Dennis Graver, Chairman

The general theme for the scuba workshops at the conference was, "The physical screening of divers and discussion of theoretical levels of participation for those generally screened out because of medical conditions or physical disabilities". Experts in the areas of diving medicine, diver training, and physical disabilities assembled in Columbus, Ohio for four days of discussions related to the general theme. CNCA was fortunate to have the medical conmnunity represented by noted physicians, to have representatives of two diver training agencies - PADI and YMCA - and to have the disabled community represented by two disabled diver organisations and a number of disabled individuals who dive.

Medical Conditions Workshops

Two workshops were devoted to the discussion of various medical conditions which can adversely affect divers. An attempt was made to categorize various conditions as either absolute or relative contraindications to diving. 0nly two conditions were discussed before the emphasis shifted to a broader topic area. One of the conditions addressed was epilepsy, which was identified as an absolute contraindication, even if an individual is symptom free for years and requires no anti-convulsant medication. Physicians present were aware of at least two instances where persons with long histories of absence of seizures above water experienced seizures at depth and subsequently embolized. The other condition discussed was diabetes. It was decided that participation in diving may be allowed if the diabetes could be controlled by diet and/or oral hypoglycaemics, but could not be condoned if an individual was insulin dependent.

It was discussed and agreed that the various medical conditions were so varied and individualistic that the establishment of a fixed, objective policy regarding them is not possible. The workshop participants concluded that persons with medical conditions which might be detrimental should be examined by a physician knowledgeable about diving, and that the acceptability or unacceptability of the person’s participation in diving should be determined by the physician. To achieve this, several needed actions were identified:-

1. A list of all licensed physicians familiar with diving and diving medicine is needed. Dr Alfred Bove indicated that the Undersea Medical Society (UMS) was computerizing its directory and may be able to provide such a list very soon. Dennis Graver will contact UMS and request an annual listing of appropriate members. Other sources of physician’s names include the Diving Accident Network, and the organizations which conduct diving medical courses for physicians.

2. Dr Chris Dueker proposed that a physical examination by a licensed physician be strongly recommended for all prospective divers. This proposal received strong support. Some objection was expressed, however, due to the cost ineffectiveness of a required physical examination and the lack of assurance of diving familiarity by the examining physician.

3. New forms to assess the medical condition of potential divers are needed. Considerable discussion led to agreement that the following items are needed:-

A. A new medical history form that will identify undesirable medical conditions through a series of questions is to be developed. Dr Werner Lissauer stated that 85% of all medical problems could be identified through a medical history. Several questions regarding each condition will be asked on the new form to help identify a condition by asking about it in various ways. The desirable response to each question will be varied from question to question to encourage careful reading of the questionnaire. A person will not be able to mark all “yes” or “no” and skim over the questionnaire lightly. Conditions indicating possible problems will be identified by a key prepared for the questionnaire. This method will enable a diving instructor to objectively determine when a diving student should be required to obtain medical approval for participation in diving. Dr Arthur Dick agreed to develop a draft of the medical history form and key. This form, along with the others go be described, will be finalized and offered to all diving training agencies under the auspices of CNCA.

B. An informed consent statement on medical considerations is needed, and will be drafted by Dr George Harpur. The statement will identify various medical conditions and concerns regarding the effects of diving upon an individual with the conditions. The recommendation for a physical examination will be included in the statement, which will be worded in such a way that prospective divers will be informed, but not intimidated. A statement will be included to the effect that the medical history form (reverse side) has been completed accurately, and that the informed consent statement has been read, understood, and appreciated. Spaces for date, signature, and parental consent for minors will be included on the form.

C. A set of brief guidelines for physicians conducting examinations for divers is needed. Dr Harpur also agreed to draft these. The guidelines will parallel the conditions listed on the medical history and informed consent forms, and will not exceed four quarto pages. A physician’s statement will also be included to indicate approval or disapproval for participation in diving activities. It was decided that a “Conditional” approval not be included, but that any limitations recommended by a physician, eg. prescription lenses, be part of the approval portion of the physician’s statement. Glen Egstrom will draft this statement.

Drafts of these new forms and statements will be reviewed by all workshop participants and submitted to the Undersea Medical Society for approval. Hopefully, with the endorsement of UMS and CNCA, the medical assessment of divers can be standardized through the development of these materials.

4. A final desirable action is the development of a standard medical conditions presentation to be included in instructor training courses. This presentation is to familiarize new instructors with the effects of various medical conditions as they pertain to diving. This concept is strongly supported by all workshop participants. Glen Egstrom suggested that Dr Jeff Davis may be able to co-ordinate a group effort among physicians to produce a script for the presentation. Dr Bove recommended that the Undersea Medical Society be contacted regarding co-

ordination and possible funding for the final product. Dennis Graver will contact them on this matter.

The medical workshops were very productive. If the materials identified can be developed on a widespread basis, diving organisations will experience less confusion and concern with the medical conditions of prospective divers. It will be very helpful to have better informed instructors and would-be divers.

Disabled Diver Workshops

In addition to physicians and instructional representatives, the following were in attendance at these workshops: 6-8 disabled divers, representatives of the American National Red Cross Adapted Aquatics group, instructors experienced in teaching disabled people to dive, an occupational therapist, and the leaders of two disabled diver associations.

Several slide presentations demonstrated that many individuals with various disabilities, some quite severe, are capable of performing the skills required for safe diving. Performances such as surf entries and exits performed independently by paraplegics were depicted, as well as independent performance in open water by persons with quadraparesis.

It is important that those with disabilities causing insensitivity in parts of the body be made aware of potential problems such as tissue breakdown caused by hard surfaces, possible injuries to exposed extremities, hypothermia from heat loss in extremities, increased risk of decompression sickness, and the inability to detect the symptoms of diving maladies. Possible respiratory problems for those with high-level injuries were also identified.

A conservative approach to diving for disableds who can safely participate in diving is recommended. Favourable environmental conditions, shallow dives, and the application of the cold and arduous rule for the dive tables were suggested.

Those who would teach diving to the disabled are encouraged to obtain information and training in advance. Proper attitudes and understanding are important. Suggestions include visits to rehabilitation centres, discussions with disabled divers, simulation of disabilities by the instructor, and studying information on disabilities. Information sources include articles on disabled divers, adapted aquatic books, and the disabled diver associations. Rusty Murray and Jim Gatacre, disabled association leaders, have agreed to compile information about training.

The majority of the discussions centred around the certification of disabled divers. It was agreed that anyone who could meet the standard requirements established by an agency could be certified. It could not be agreed, however, as to what form certification, if any, should be issued to a disabled individual who can safely dive under certain circumstances but who could not meet certain current objective performance standards for certification. It was agreed that perhaps a set of comparable functional performance standards for disableds could be created. A committee, consisting of Dr Harry Heinitsch, Rusty Murray, Jim Gatacre, Bill Miller, and Fred Crowner was formed to develop recommended standards for disabled divers.

Instructional techniques were shared, and it was determined that similar techniques had been discovered independently in different regions of the country. The need to compile these procedures and make them available from one source was identified. Jim Gatacre and Rusty Murray offered to initiate such a project. Examples of information shared in the workshop include:

1. Buoyancy control (balance and stability) was the general problem most frequently experienced in training.

2. Fear of falling, fear of injury from improper handling, and injury from insensitivity were concerns of disabled students.

3. If a disabled person can keep up with a class, the person should be mainstreamed into training. Severe injuries require separate training, however.

4. Instructors should not assist disableds unless asked and then should act on instructions from the disabled person.

5. Equipment considerations include use of purge masks for paraplegics, use of low pressure inflator mechanisms at the outset of training, and the division of weights on two weight belts for open water training.

6. Activities outside of regular class hours are suggested for disableds. The suggested activities include swimming, snorkelling, and skill practice.

7. More time is required for the training of disableds. Time must be allowed for injuries and illnesses. Often the course is not set, but is an on-going programme.

8. Disabled individuals who are experienced divers are helpful in training other disableds to dive.

More information is needed concerning disabled divers. Documentation of diving activity will help provide a means of compiling data and statistics. Physical and physiological studies would be beneficial and add to existing knowledge. The safety record of disabled divers needs to be established. A single, central source to co-ordinate information and studies is needed. Rusty Murray and Jim Gatacre have expressed interest in forming a national agency to meet this need. They can be contacted at 128 Castle Road, Nahant, Massachusetts, 01908 and 1104 El Prado, San Clemente, California, 92672, respectively.

It was decided to continue the discussion of disabled divers at the next CNCA conference, and also to have a demonstration of diving skills by disableds.

Meeting with Camp Aquatics Group

The Camp Aquatics Group expressed interest in what the scuba training agencies could do to enhance aquatic programs at camps. Bob Smith of the YMCA and Dennis Graver of PADI outlined diver training programmes which could be useful for aquatic camps. Suggestions included skin diving classes, introductory scuba courses, refresher courses for certified divers, and the use of camps as instructor training course sites. It was also suggested that the agencies train the aquatic directors to teach skin diving. PADI offered its field representatives to assist with co-ordination and training. It was decided that the possibilities should be brought to the attention of the entire camping community through their periodicals. Armand Ball will co-ordinate the preparation of an article outlining the aquatic support which can be provided by diver training organizations.

Diver Re-Evaluation Workshop

An unscheduled workshop was conducted to address the topic of re-evaluation and updating of divers. This was a matter of general concern among the scuba workshop attendees. It was agreed that periodic updating would be valuable to refresh skills and knowledge, to familiarize divers with new information and equipment, to review dive table procedures, and to sharpen diving ability after periods of inactivity. Completion of such a program on an annual basis was recommended for all certified divers. It was felt that the course could be completed in about four hours. Groups of divers, such as dive clubs, can provide the best means to attract divers to such a course. It was agreed that such a program could not, nor should not be mandatory, but should be highly encouraged. It was unanimously agreed that a diver refresher programme is highly desirable for all divers. The YMCA refresher course was brought to the attention of the workshop participants, and the PADI "Scuba Review" course was introduced. These courses meet the needs identified within the workshop. It is hoped that all agencies will soon offer refresher courses and that the diving community will encourage periodic updating by all divers.

THE TECHNIQUES FOR DIVING ALONE
THOUGHTS ON A TABOO TOPIC

Lou Fead

SOLO DIVING

Have you made more than 50 open water dives?

Are you capable of surviving routine dives without any assistance, physical or mental, from a diving buddy?

"Yes" answers to the above mean you're probably experienced and capable enough to discuss another kind of sport diving - SOLO DIVING.

Solo Diving lets you satisfy the sudden urge for a dive immediately. It lets you linger underwater wherever and for however long you want - or jet away at full speed - or do whatever strikes your fancy. It evens lets you change your mind at any time and not dive if that be your pleasure.

That's the main benefit of Solo Diving ... diving with a freedom of choice not hassled by any other humans.

Without a buddy, the burden for enjoyment is on the soloist. There's no one else to point out attractions, share the dive delights, or swear to the size of the one that got away. All that comes with the camaraderie that most buddy divers say attracts them to the buddy system.

You can be ready to dive solo if you'll accept the responsibility for your own enjoyment your own actions, and your own safety in the water. Accepting those responsibilities may be difficult in this day of suing someone else for not protecting you from yourself, but if you want to leave the beaten path and solo successfully, all you have to do is plan adequately to meet the personal responsibilities of solo diving to enjoy that special sport.

The Land Plan for Your Solo Dive

Planning differs from that for a buddy dive mainly in that it doesn't involve anyone else, obviously. In fact, the best solo dive planning is done to *eliminate the need for anyone else.*

There is one situation, however, in which even the finest of solo planning cannot achieve its purpose of eliminating the need for outside assistance. That's when a diver becomes incapacitated in the water. Survival then, without assistance, is just a matter of luck, the major disadvantage of being alone.

Since planning is the crux of a good solo dive, let's discuss the long-term variety where we'll find the first major benefit of diving alone - not having to co-ordinate your plans with a buddy, not 'anybuddy'. You can plan your dive to do what you want, when you want, where you want, and why, all without factoring 'anybody' else's preferences in.

You wanna go into cold dirty water? You got it - with no squeals from the less adventurous. You wanna dive only in the Tropics? You can have that too, without some macho dummy berating your preference.

Other long-term planning, that of checking equipment, health, and the expected weather, is the same as for buddy dives. Its purpose is to give the greatest chance for a successful dive by confirming that everything's ready for the dive beforehand.

Immediately prior to taking off for a solo dive, take the one action that comes closest to involving a sort of a buddy - tell someone who's staying home where you're going, for how long, and what to do if you don't return as scheduled. You might call that 'buddy' your *Search Organiser* - the one who will lead the way to your disabled boat, or your broken down dive van when you're late coming home. So file a dive plan, just as a flier files a flight plan and a boater a boat plan, to schedule some help in case of unforeseen breakdown.

The next step in planning comes at the dive site - deciding whether or not to dive. After comparing your current personal, physical and mental capabilities to the demands that will be placed on them by the environmental conditions and the in-water dive plan, your decision should be based on whether you can have fun safely.

Being alone for this decision makes it all yours. There's no one else to influence your, to stop you from diving when you shouldn't or coerce you into diving when you don't want to. As a solo diver, you can decide "to hell with it", pack up your gear, and go biking without feeling you have to justify your decision to anyone. Or, you can make a dive in conditions within your capabilities that might not be pleasing to a buddy. The decision to dive or not should be a personal one for all divers, but isn't - egos often stand in the way of common sense when there's an eager, pushy buddy nearby.

The decision to quit at anytime should also be free, without fear of mental retribution from anyone else.

Planning the Underwater Needs of Your Solo Dive

An acronym for organising the details is SEA BUDDY. S for *signals*. E for *emergencies*, A for *Activities*, and BUDDY for *buddy gear check.*

Signals of the diver-to-diver variety aren't patently necessary for a solo diver, but those summoning help in a sticky situation are. A whistle, a flare, perhaps a mirror can be carried for attracting attention.

A float and flag tell others where you are - and double as surface support for carrying goodie bags. Of course, the standard sport diving signals should be known for interfacing with any other divers you might meet underwater.

Emergencies are somewhat the same for solo as for buddies - out-of-air, entanglement, and surfacing down current. For a solo diver there will be no 'lost buddy' emergency. On the other hand, the solo diver can face another more serious emergency - 'incapacitation'.

Unconsciousness, cramps and fatigue cause more trouble for a solo diver than the inconvenience they do for buddy divers. A solo diver has no one to count on for help when incapacitation strikes. A solo diver unable to help him or herself can only hope for the best.

The best emergency plan for solo divers therefore is to avoid situations which generate emergencies, especially the incapacitating kind.

Out-of-air, for instance, can be eliminated simply by never depleting your air supply before terminating the dive. For further backup in case of unlikely equipment failure, there are pony bottles, BCs which can be breathed from, redundant second stages, and even separate regulators mounted on Y-valves. Practice with a backup is necessary, just like practice with buddy breathing is necessary to make an out-of-air option ready for use. Saving some air for the surface is by far the best technique.

Entanglement can be avoided by watching where you're going, and is usually corrected by backing out or doffing gear. Surfacing down current from your boat or beach exit is better avoided than corrected - dive upstream, stay upstream, and known where you are at all times.

As for 'emergencies' on the boat or beach - dead battery, lost keys, flat tire, out-a-gas, etc. - a CB or VHF radio is mighty handy for summoning assistance. An obvious 'emergency' card, like MedAlert, can also be a lifesaver in case a non-diver finds you passed out. The best contingency is still a capable buddy - even a dry one is better than none at all.

Activities, the A in SEA BUDDY includes what you're going to do for fun, and the limi*ts* within which you'll do it. Maximum depth, maximum time, and minimum air pressure - the limits - are not for changing underwater where narcosis can muddle your thinking. To abide by the limits, you'll need your own depth gauge, time piece, and air pressure gauge, of course, you've got no buddy to supply them for you.

Depth and time limits recommended for solo divers are those for 'no decompression' diving. Pushing or exceeding the 'no-decom' tables can put your solo dive into the disaster category for several reasons: (1) no buddy to confirm you calculations; (2) no buddy with instruments to compare; (3) no buddy with spare air; and (4) no buddy to help if you do get hit.

The minimum air pressure limit is best interpreted for two specific occasions on your solo dive - turn-around and surfacing. Turn-around is set for trekking home, with enough air to make it, and then some. Surfacing likewise is done with enough air to solve some last minute problems on the bottom, and some on the surface later. Both pressures should be set with room for errors in location and air consumption predictions.

BUDDY is for the buddy gear check that you'll do on yourself before entering the water. As with a buddy, it's to confirm that your inflators and releases can be used quickly to make you float well for survival. Touch and operate your BC inflators, your weight and tank releases to ensure they're clear and operable.

To feel more comfortable with your 'buddy' capabilities, you might even exercise those same operations, and your skills, at the beginning of your dive. Inflate your BC a bit every way you can, doff your weights, your tank, shuck your second stage and retrieve it, clear your mask, breathe without a mask, whatever gives you more confidence underwater. Early, when you have lots of air, you might even try a moderate depth emergency swimming ascent, with your regulator in your mouth, just to retrace that avenue of escape from an out-of-air situation.

With SEA BUDDY out of the way, plunge in for fun - as a SOLO diver. Maintain an awareness of what's going on around you - a 'global awareness' so to speak - to avoid emergencies while savouring the wonders of the world underwater. And *dive your plan* to have a great solo dive.

For you inveterate buddy divers, at least try the planning procedures in this article ... they just might make your buddy dives more fun and less hassled.

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Lou Fead is Chief Instructor at UNEXSO in Freeport, Bahamas. He feels that he is diving alone most of the time in his work as an instructor and guide.