refresher course if one was offered by their local instructor.[2] While certifying agencies will quickly point out that these refresher courses are currently available, the real need is to market them actively.

Acknowledgements

This study was initiated through a grant from the University College of Central Queensland and supported by Downunder Research. I would like to thank NAUI Australia for access to their confidential records from which the major sample was drawn. Special thanks go to Robert Freitag and his staff at Capricorn Reef Diving, Rockhampton, for their professional assistance throughout the project.

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THE DCIEM SPORT DIVING TABLES

John Lippmann

Historical background

Canadian decompression research began in 1962 in what is now named the Defence and Civil Institute of Environmental Medicine (DCIEM). Kidd and Stubbs set out to develop an instrument which would monitor the diver's depth-time profile, and provide instantaneous decompression information when complicated dive profiles were undertaken, or where wide variations of gas mixtures were used. In these situations, the traditional tabular approach to determine decompression was inadequate.

Initially, their decompression computer was based on the traditional Haldane model in order to duplicate the U.S. Navy 1958 Standard Air Tables. However, parameters were changed and the model was modified until a low incidence of decompression sickness was achieved.

A variety of dives were tested, ranging from fixed depth dives, random depth dives and repetitive dives. Within five years they had developed a fairly successful computer based on 5,000 man-dives.

The final configuration of the computer utilized a "serial model", in which tissue compartments are connected in series instead of the parallel arrangement used by Haldane. The model was again modified in 1970, in order to increase its safety in the 60-90 msw range. The result became known as the KS 1971 Model.

The model was used for some time at DCIEM but a few deficiencies became apparent. One of the problems was that the No-Decompression Limits were much too conservative, in some cases (at shallower depths) being half that of the Royal Navy and U.S. Navy Tables. In other areas the model lacked conservatism so, consequently, more research and modifications became necessary.

The DCIEM model

A very large data-base of decompression information had been accumulated by DCIEM over the years and in order to utilize this information the KS model was chosen as the basis for a new set of air decompression tables. Modifications were made to the KS decompression model and the earlier problems and anomalies existing in the KS model were overcome. This modified model became known as the DCIEM 1983 Decompression Model.

The serial model assumes that the tissue compartments are connected in series. Only the first compartment is exposed to ambient pressure and, as gas builds up in this compartment, it bleeds into the next compartment. In Haldane's model each compartment is exposed to ambient pressure and loads up simultaneously. Each of the four tissue compartments in the DCIEM model has the same half-time, which is approximately 21 minutes. The model utilizes the concept of allowable surfacing supersaturation ratios. Critical ratios of 1.92 and 1.73 are used in the initial two compartments, while the pressure levels in the other compartments are not used to calculate the depth from which a diver can safely ascend.

Features of the DCIEM 1983 model

The DCIEM Model produces decompression times which are more conservative than the U.S. Navy Tables and the decompression profiles have deeper first stops. These tables have been rigorously tested during working dives in cold water. For strenuous dives in cold water, the U.S. Navy procedure is to decompress according to the next longer bottom time. The resulting times are comparable to the DCIEM 1983 times.

The model has been used to generate a complete set of tables, including standard air decompression, repetitive dive procedures, corrections for diving at altitude, in-water oxygen decompression and surface decompression with oxygen.

Testing

The new tables have been extensively tested using the Doppler ultrasonic bubble detector and bends incidence as safety criteria. About 900 man-dives were performed during the validation dive series over a two year period. Because the model was continuous, and because of the large database of both safe and unsafe dives done on the original K.S. model, it seemed unnecessary to test a larger number of depth and bottom time combinations.

During the tests the divers were monitored for bubbles at the precordial site (right ventricle and/or pulmonary artery) and the subclavian sites (both left and right shoulders). At the precordial site, a reading was first taken when the diver stood at rest, and another reading was taken when he performed a deep knee-bend. At the subclavian site, the diver was initially monitored while at rest and then again after clenching his fist on the side being monitored. The Doppler signals were recorded on audio magnetic tape as well as being assessed aurally by experienced technicians.

The bubble signals were classified according to the Kisman-Masurel (KM) code which utilizes three criteria, each on a scale from 0 to 4. (Other systems only use 2 criteria to establish bubble grades). The criteria used were the number of bubbles per cardiac cycle, the percentage of cardiac cycles with bubble signals and the amplitude of the bubble signals relative to the background sounds. The resulting 3-digit code is converted to bubble grades from 0 to 4, resulting in a similar bubble grade to that developed by Spencer (and used to assess the PADI Recreational Dive Planner).

The divers were monitored before the dive(s) and at half-hour intervals for at least two hours after diving. When repetitive dives were undertaken, the divers were monitored between the dives as well as after the second dive.

The test dives were conducted in a hyperbaric chamber, with wet-working divers in cold water at 5-10^{o} C, as well as with dry-resting divers. All dives were done using a real-time on-line decompression computer, following the exact decompression profile as specified by the DCIEM 1983 Decompression Model. The Standard Air Table was tested by 267 man-dives. Fifty-five dives had decompression times shorter than 30 minutes, and 90% of these subjects showed no, or few, detectable bubbles.

Eighty-four no-decompression stop dives were tested with no detectable bubbles resulting. No cases of bends were observed. The remaining 128 dives (66 single dives and 62 repetitive dive pairs) were near, or at, the normal air diving limit with decompression times between 48 and 88 minutes. Eight cases of bends occurred after single dives, and 4 cases occurred after the second dive of a repetitive dive pair. However, some of these incidents were thought to have other contributing causes and may not have been attributable to the dive profiles alone.

No diving tables can be expected to totally eliminate the occurrence of decompression sickness, but the DCIEM Tables are considered by many experts to be much safer than most other published tables. In the period from October 1987, when the DCIEM Sport Diving Tables were first released, to the time of writing, no cases of decompression sickness were reported in divers who had used the tables. They appear to be sound, well-tested tables (i.e. on "rectangular" dives) which should generally be quite suitable for the recreational diver.* However, a diver's individual susceptibility to bends must still be considered when planning the bottom time for a dive.

In the Instructions for Using The DCIEM Sport Diving Tables © 1990, it states:

"The DCIEM air decompression model was tested empirically using a relatively diverse group of human subjects. This takes into consideration certain assumptions about the fitness of the subject. These same considerations apply to divers who use the DCIEM Sport Diving Tables.

It is assumed that:

1 The diver is physically fit, with a good exercise tolerance.
2 The diver is free of any acute or delayed effects of alcohol or drugs of any kind.
3 The diver is not overly fatigued, dehydrated, motion sick, sunburned or otherwise affected in a detrimental way.
4 The diver has no acute illness, especially of a respiratory or musculo-skeletal nature, has had no recent physical trauma and has not recently undergone surgery.
5 The diver has no chronic illnesses such as asthma, high blood pressure, diabetes, epilepsy, inner ear barotrauma or spontaneous pneumothorax.
6 The diver is free of any decompression debt, other than that allowed for or calculated in the DCIEM Sport Diving Tables.

If any of the above apply, or if there is any doubt, do no scuba dive. Seek advice from a physician experienced in hyperbaric medicine.

Acknowledgements

Much of the text of this paper has been taken directly from the literature and reports accompanying the DCIEM Sport Diving Tables (written by Ron Nishi and Gain Wong). The author wishes to thank DCIEM and UDT Inc. for their co-operation and assistance with the preparation of this paper.

* It is important to realise that no testing was conducted to determine their validity for multi-level diving.

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The above paper is taken from a larger chapter about the DCIEM Tables in a recently released book titled "Deeper Into Diving" by John Lippmann. "Deeper Into Diving" provides an in-depth review of various decompression procedures and of the physiological aspects of deeper diving. It contains more than 600 pages of detailed information and can be obtained from J.L. Publications, P.O. Box 381, Carnegie, Victoria 3163, Australia.

For book review see page 230.

QUEENSLAND DIVING ACCIDENTS

John Knight

July 1988 to June 1989

The Queensland Dive Tourism Association of Australia (QDTAA) has published a Dive Tourism Accident Bulletin which appeared in Neville Coleman's "Underwater Geographic" (ISSN 1032-5212) No 28, pages 72 and 73.

The QDTAA is to be congratulated on providing such a report. Unlike other diving accident reports there is a mention of the number of dives involved (250,000) but unfortunately this is just an estimate of dives carried out in Queensland in the time covered by the report, not a record of the number of dives performed under the auspices of the reporting companies. Minor injuries were probably under reported as 74.1% of the injuries were classified as serious.

In twelve months there were 27 accidents reported by members of the QDTAA, three of which were fatal. Two of these were attributed to drowning (one not on scuba and so classified as a minor accident) and one to cerebral arterial gas embolism (CAGE). The minor accidents reported were divided into non-scuba and minor injuries. Non-scuba included a death (mentioned above) while swimming, facial laceration from a trigger fish, an exploding scuba tank in a dive shop and a person reported lost and later found alive. At least three of these were very major problems for those involved and difficult to classify as minor incidents. Minor injuries were salt water aspiration, a bleeding ear and reverse ear squeeze.

Of the 20 serious accidents while using scuba 80% were decompression sickness (DCS). However the pie chart of major scuba-related accidents shows 10% were drownings and 10% CAGE so presumably one drowning was resuscitated and one CAGE victim survived leaving 16 cases of DCS.

Nearly 50% of the serious diving related accidents occurred off Cairns and over 35% off Townsville. These two centres provide the bases for most dives in Queensland.

Of interest is the fact that females outnumbered males in the ages groups 15-24 (M 2, F 5) and 25-34 (M 2, F 3) but in the age group 35-54 it was the other way round (M 3, F1). But as the numbers are small it is quite possibly due to chance.

July 1989 to June 1990

The QDTAA report for July 1989 to June 1990 is now available. In this year there were 34 accidents, three fatal. One was attributed to drowning while the other two were cardiac, which were classified as minor accidents as they were not related to scuba diving.. 21 of the accidents (62%) were classified as serious.(13 DCS, 3 CAGE and 5 scuba related drowning or near-drowning). Besides the two cardiac deaths there were 11 other minor accidents, mostly salt water aspiration.

The estimate of recreational scuba dives, from regional membership and certification surveys, was about 884,000 dives in the twelve months. There were no statistical differences between the incidence of accidents between the two years.

Young (aged 15-24) and older (35-54) females outnumbered males in the accident statistics, but in the 25-34 age groups males predominated. However with 9 females (43%) to 12 males (57%) females, who are estimated to be about 25% of the Queensland diving population, are over-represented. The report draws attention to the fact that if the two years are combined it seems that females are three times as likely to have a major diving accident (usually DCS) than males. The QDTA is to be congratulated for drawing attention to this and recommending that there is a need for improved diving training for females.

This year the accident winner, if one can use the term, is Townsville with 10 accidents per 100,000 dives, up from just over six last year. This may be due to the fact that the boats that visit the Yongala wreck, which is in deep water, are mostly based in Townsville. Unfortunately no absolute figures for accidents by area are provided this year.

These reports, and an interesting table of the 1989 accidents are available from the Mr David Windsor, Secretary of the Queensland Dive Tourism Association of Australia (Inc.), PO Box 122, Chermside, Queensland 4032, Australia.

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THE DILEMMA OF THE PATENT FORAMEN OVALE

Michael Gatehouse and Tom Wodak

The SPUMS Journal, (Vol 19, No 4) contained two papers dealing with the latent condition, patent foramen ovale, (PFO), one by D.F.Gorman and S.C.Helps[1], and the other by D.Davies.[2] In addition a thought provoking editorial[3] on the subject has prompted the writers to address the legal issues which PFO raises.