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MULTI-DAY DIVING; THE EXPERIENCE OF THE HYPERBARIC MEDICINE UNIT, ROYAL ADELAIDE HOSPITAL

Steve Goble and Lindsay Barker

Introduction

The advent of dive computers (DCs) along with the increasing number of live aboard dive vessels has encouraged the growth of multi-day, multi-dive holidays. This has important implications for the safety of diving practice, as it may be postulated that repetitive nitrogen loading, with inadequate "off-gassing" may lead to an increased risk of decompression illness (DCI). Moreover, as many of these types of holidays are either interstate (e.g. Queensland) or overseas (e.g. Truk), divers often have altitude exposure soon after part of the dive trip has finished. Anecdotal reports indicate that this type of diving practice may predispose to an increased risk of DCI compared with less intense diving programs. The aim of this survey was to identify cases of DCI which presented to our unit which were preceded by multi-day diving.

Methods

All divers treated for DCI at the Royal Adelaide Hospital (RAH) are asked to fill in a diver's questionnaire. This questionnaire asks for details about; post-dive altitude exposure, environmental conditions, type of decompression table or computer used, dive profiles, types of symptoms, time of symptom onset post-dive, delay to recompression post symptom onset, first aid measures etc. All of the information gathered is transferred to a computer database using DBase III Plus (Ashton-Tate Inc). This database also records treatment profiles, medication etc. We reviewed the database for divers treated between 1st January 1987 and 31st October 1993, noting all divers who had been involved in multi-day diving. We then reviewed these divers' case notes to gather more detailed information. The definition used for multi-day diving was a series of dives with a minimum of two dives per day for a period of at least two consecutive days.

Results

During the period studied 185 divers were treated for DCI. Of these, 62 divers (or 33.5% of total divers treated) had profiles consistent with our definition of multi-day diving. The divers, the majority of whom were male (male:female ratio 4.6:1), had a mean age of 32 years (range 15-52 yrs). While the greatest number were recreational divers, 10 (16%) were occupational divers (fishermen/commercial). Diving experience as indicated by years diving ranged from 1 month to 30 years, with a mean of 8 years. Most divers (47 of 62) presented following dives in their home state; 32 from South Australia and 15 from Victoria (before the Alfred Hospital chamber was installed). The other divers dived in the following areas; Queensland 6, Truk Lagoon 6, Papua New Guinea 1, Solomon Islands 1 and the Maldives 1.

The dive profiles showed that the mean number of dives was 6 (range 4-30) over 4 days (range 2-21), some examples being; a diver who had logged 30 dives over 8 days, maximum depth 32 m, a diver who dived between 38 m and 63 m 2-3 times a day for 6 days, a diver who made five dives over 3 days with the last dive being 37 minutes at 30 m and then flew home only a few hours after the last dive. While a pattern of diving could not be clearly identified from the database, the mean dive depth was to 28 m (range 5-63 m). Dive computers were used by 12 of the 62 divers. It would appear that the profiles used by this group showed more frequent dives, associated with multi-level profiles compared with those divers using dive tables.

Twenty divers ascended to altitude (defined as over 300 m), while 12 flew home in commercial, partially pressurised, aircraft within 36 hours of completion of their diving.

The majority of divers presented with at least two major symptoms; these would consist of joint pain (arthralgia), headache and excessive fatigue. Only 5 of the 62 divers presented with one symptom. Symptoms typically had a mean onset time of 13.2 hours (range 0-100 hours). The mean delay from the onset of symptoms to initiation of hyperbaric treatment was 100.5 hours (range 4 hours to 42 days). There was a fairly close direct relationship between treatment delay and number of hyperbaric treatments in the non multi-day group, but this did not hold for the multi-day dive group. While the above symptoms were the main ones reported by the patients further inquiry revealed a wide range of signs and symptoms. These included; skin tingling, numbness, problems with memory and thinking and pruritus.

We compared these results with those of the entire group of 185 divers, and also against the 123 divers who were not involved in multi-day diving (Table 1). Symptoms were similar in both groups. There was a greater proportion, about double, of computer users and of divers

ascending to altitude in the 62 multi-day divers. The multi-day divers mean depth was greater although the range was much the same for both groups. Mean age was similar for both groups though the age range was greater for the other divers. The diving experience range was the same for both groups but the mean years of diving was higher, about double, for the multi-day divers. The non-multi-day group noticed their symptoms on average 6 hours earlier than their multi-day counterparts, and reported for treatment an average of 39 hours earlier. The range of delay was the same for both groups but the mean delay was one third longer for the multi-dive group. Recompression delay is defined as the time from symptom onset to recompression.

TABLE 1

COMPARISON OF MULTI-DAY, MULTI-DIVING AND OTHER DCI PATIENTS

	123 Non-multi divers	62 Multi divers
Computer users	7	12
Altitude exposure	8	20
Mean depth (msw)	19	28
(range)	(4-65)	(5-63)
Mean age (years)	31	32
(range)	(12-58)	(15-52)
Mean years diving	3.5	8
(range)	(1 month-30 years)	(1 month-30 years)
Symptom onset (hours)	7	13.2
(range)	(0- 72)	(0- 100)
Recompression delay		
(hours)	61.2	100.5
(range)	(2 hours- 42 days)	(4 hours- 42 days)

Discussion

The above survey offers interesting information about the demographics and profiles of multi-day diving practice. It does however suffer from all the problems of a retrospective, non-controlled survey. Data examination forms were not universally complete, they are completed by the divers during a treatment and often the patient has trouble remembering a number of the details. Likewise when reviewing patient records it is noted that different medical staff have different styles of history and examination, some will obtain and write down a complete life history, while others glean the bare facts about symptoms and next to nothing about the dive that caused the problem. Despite these misgivings, the survey does illustrate a well defined group of divers who developed DCI following a multi-day diving exposure.

The main points to come from this survey are that these multi-day dive trips tend to produce a significant (about 1/3) proportion of divers who present to the RAH for recompression therapy. This seems to be aggravated by the relatively early exposure to altitude, be it ascending into the mountains or flying at reduced ambient pressure in a commercial aircraft. Other possible factors include the higher number of computer users and the greater number of years experience. Finally, symptom onset tends to be late in this group of divers with a concomitant delay in treatment. All of these could possibly be due to an over-confidence in one's ability.

If the symptoms of these multi-day divers is compared with the Divers Alert Network (DAN) 1992 statistics,[1] the major symptoms are almost identical (pain, numbness, headache and extreme fatigue). While the onset of symptoms in our group and that of DAN was similar, there was a significantly greater delay in recompression treatment. This probably reflects the geographical isolation of many parts of Australia and the South Pacific region.

Although our multi-day groups mean experience in years was some 4.5 years longer than the non multi-day group, the range was the same, so overseas or interstate trips on luxury live aboard vessels are going to attract the experienced fanatic, the weekend club diver and the novice diver. It may be inappropriate to expose the novice diver to the same diving practice as the fanatic who would dive 24 hours a day if it was possible. A newly qualified diver or an infrequent club diver would probably be at a higher risk of DCI when participating in intense multi-day diving trips. Just the increase in physical exercise and associated fatigue is likely to be a factor in assessing risk in these divers.

A significant number of multi-day divers (32%) went to altitude after their diving. Most of these did so within 36 hours and noted the appearance of symptoms while flying home. It seems likely that there needs to be a review of the current recommended restrictions for flying after diving.

It was clear that many of the symptoms were quite vague, e.g. excessive fatigue, concentration problems, memory loss, many patients were content to suffer from these "vague" symptoms for a number of days before realising that they might have a problem and seek treatment. Divers need to realise that these "vague" symptoms actually indicate a neurological problem which needs to be assessed immediately, not three days down the track. Talks with the local recreational diver population also indicate that, among those who have been diving for a number of years there is still a stigma attached to DCI, a feeling of having done something wrong which, in many cases, is totally unfounded. Happily, that attitude is being frowned upon by the training agencies and the newer divers appear to be less reticent about reporting symptoms.

During our review of the dive profiles it became clear that many divers appeared to pay scant regard to dive

planning, the most common problem appears to be the almost blanket approach to insert deep dives between shallow dives. It was common to see 1st dive 18 m, 2nd dive 30 m, 3rd dive 22 m etc. While many modern decompression tables allow these types of profiles to be calculated, it seems to us that the old tenet of "always do your deep dive first" is not being regarded quite as highly as it used to be. Surely doing your deep dive first and then doing progressively shallower dives, must reduce your risk.

In our group of multi-day divers we found that 20% of our divers had been using decompression computers, however that is an increasing figure, for instance in 1989 only 20% of all divers treated had been using DCs, in 1993 that figure rose to 50%. That probably reflects more of an increase in their use than anything about their safety. However, it seems that some divers are forgetting basic dive planning principles in favour of just heading off into the deep and letting the DC compute how to get back to the surface.

We are aware that some dive operators actually require all divers to use DCs because the DC gives longer bottom times and computes decompression for a multilevel ascending dive, instead of having to plan a square dive and then do an ascending multilevel dive with possibly less time in the water than the DC user. While that may seem good in theory, good dive planning by the diver, not just the dive master, must still be carried out. Computers are not infallible and if you have not bothered to plan your dive you could be left wondering.

We feel that basic diver training needs to put more emphasis on teaching good dive planning and stressing that the DC is a useful back up but should not be used to control the dive, many do not let the divers know that they are doing something which could be construed as unwise. Also while decompression stop diving is not advised for recreational divers, is it more dangerous than a dive on the edge of the no-stop table? The DCI risk associated with some tables no-stop times is actually more than some profiles that the same table would regard as a decompression stop dive.

A major part of any diving operation is risk assessment. Operations that cater for large numbers of divers obviously will have to consider an overly cautious approach to risk assessment. These operations frequently have to cater for both the new diver and the experienced regular diver. If there are enough dive masters or guides to be able to split into two or three groups then all should be well, provided that there is a separate risk assessment done for each group. However, a risk assessment for the client is all very well, but is anyone adequately assessing the risk for the occupational diver at these dive sites. While I am well aware that the concept of the employed instructor or dive master being an occupational diver is not well regarded by a large part of the industry, until such time as there is definite guidance to the contrary anyone in full time employment, regardless of the industry, must expect to be asked to comply with relevant occupational health and safety legislation.

On a live aboard vessel there are regulations with which all vessels masters and crew must comply. Why should the persons expected to be responsible for the welfare of the customers be any different. Adequate risk assessment may mean having enough dive masters aboard that they dive less than the customers, one must then ask "Is the customer at risk?", possibly, but that is another question. Do not forget the employed diver is diving almost daily, the customer will go home and have a rest.

Having risked upsetting all the live aboard operations, we do realise that many operations are taking steps to prevent many of the problems just mentioned. We believe that many operations have instigated rest days, and are addressing the problem of whether to put deeper dives at the beginning or the end of the trip. That last is an interesting problem, if the deeper dives are at the end of a trip then the less experienced or infrequent diver has a few days diving to polish up skills before moving on to the deeper diving. However by diving deeper at the end of a trip, having absorbed more nitrogen each day, the diver is then at greater risk of DCI if he intends flying home within 24-36 hours.

We also feel that insurance is essential for all divers. Most travel insurances cover the cost of diver retrieval in Australia but will not cover the cost of repatriation for treatment from another country. Medical retrievals from other countries are expensive. For instance the cost of being flown from Fiji to Melbourne for hyperbaric treatment recently cost $26,000.

Conclusions and recommendations

It seems from our study that a significant number of divers report symptoms of DCI following multi-day diving. We conclude that prospective studies are required to elucidate the importance of repetitive diving and its risk of DCI.

A large number of divers with repetitive dive profiles, who subsequently develop symptoms of DCI, are exposed to altitude within 36 hours of diving. We believe that the current recommendations on safe times to fly need to be reviewed.

Diver safety begins with the basic dive course. Basic planning skills need to be adequately taught. And the instructor must be sure that students only qualify when they are comfortable in the water. Modern technology cannot prevent problems in a diver who is uneasy and ill prepared for the dive.

It is also obvious that if problems do arise then an adequate insurance policy is mandatory for potential retrieval to recompression facilities, and in some countries for the cost of the treatment.

References

1 DAN 1992 report on Diving Accidents and Fatalities.

Key Words

Altitude, decompression illness, hyperbaric facility, risk, safety, training, treatment.

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STAGED DECOMPRESSION FOLLOWING NO-DECOMPRESSION DIVING

Geoff Gordon

So far we have all gained insights into the safety of diving, the techniques it uses in diver education and some figures on where divers make errors. The medical people have given us a different perspective on the same set of data; namely why are divers ending up in recompression facilities, what were they doing in order that they earned that long dive notation in their log books. My paper today is rather ethereal in that it attempts to look at what data is currently available in the diving literature to support our current diving practice, and is there any clear evidence that we need to change tack? If we sincerely believe that too many divers are being damaged, we need to develop strategies for reducing even further the published incidence of decompression illness (DCI). If, on the other hand, we are agreed that we are doing alright, then this paper will, I hope, stimulate some thoughts in your minds as to how you might reduce your own risk of developing DCI.

The risk of developing DCI following a single air dive has been long studied. Data derived from the theoretical analysis of risks has been combined with that obtained from the analysis of thousands of actual dives, and at least with respect to the single dive, we are now able to predict the probability of an injury following a single dive (p(DCI)).

The morbidity and mortality suffered by divers in the late 1800s stimulated the British Admiralty to commission work into the nature of those afflictions and how they could be overcome. These studies culminated in the publication in 1908 of the first set of tables that provided guidance to the diver on how to avoid Compressed Air Illness. The credit for this work is attributed to John Haldane. His method of "staged decompression" as he called it, dramatically reduced the permanent injury associated with compressed air work and all but eliminated the fatalities. This method has since grown in popularity with many iterations, the most prevalent adaptation of the Haldane computational algorithm being the US Navy Tables.

Up until the 1970s, nearly all the diving being undertaken was primarily commercial or working diving. Given the task to be undertaken a certain "hit rate" of DCI was accepted. Recompression chambers were immediately available, and the diving was rather repetitive and stereotyped. Since this time however, we have seen an almost exponential growth in recreational diving, that only now may be peaking. Associated with this popularity in recreational scuba diving, treatment facilities have seen a new wave of diving morbidity. Although much debate