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THE BS-AC '88 DECOMPRESSION TABLES

Greg Adkisson

The British Sub-Aqua Club 1988 (BS-AC '88) Decompression Tables were introduced, after numerous delays, into general usage in the latter months of 1988. I was first introduced to them by a patient I was treating for an episode of neurological decompression sickness (DCS). Before I create the wrong impression, I should state that the patient was not using the new tables, but had completed his dive in accordance with the older RNPL/BS-AC tables of 1972.

The dive in question was to 26 m for 31 minutes with appropriate decompression conducted for 5 minutes at both 10 m and 5 m depths. As I monitored this patient's extended RN table 62 treatment, I had a chance to read through the new tables. I was surprised to find that using the new tables, while the definitions were slightly different, a more lenient dive of 27 m for a bottom time of 32 minutes could have been performed and would require only a 1 minute decompression stop at a depth of 6 m. I examined them further and noted that, for the same 10 minutes of decompression, the allowable bottom time would have been 43 minutes. I was fascinated.

Call me old fashioned, call me conservative, but this notable reduction in decompression requirement or, conversely, increase in available diving time, seemed just too good to be true so I went looking for the magic formula upon which these changes were based. I found myself, within a very short time, embroiled in controversy with the BS-AC. I had the pleasure of several lengthy discussions with the author of the tables, Dr Tom Hennessey, but I find myself still in search of the magic formula and remain as firmly against their general use now as I have been since the first day I read them. I have been asked here to comment on the format, design, algorithms and testing of these tables.

The BS-AC gives four basic reasons for introducing new tables in their BS-AC '88 Decompression Tables Instructor's notes. Since the introduction of the RNPL/BS-AC tables, "the pattern of diving has changed, the possibilities available to sports divers have developed, much experience has been gained in the use of the tables and understanding of decompression has improved". To quote *DIVER*, the magazine of the British Sub-Aqua Club, August 1988, "it has become increasingly clear that the RNPL/BS-AC table is insufficiently flexible for the patterns of diving required by divers today".

It is my personal opinion that, despite other objectives, the single most important factor in the introduction of a new set of tables is that they must not increase the risk of DCS and other accidents in the general diving population. The introduction of a new set of diving tables is no easy task and for acceptance in the commercial diving world one of two conditions must apply. The tables must be more conservative than previous versions or must have undergone extensive testing and evaluation prior to their use. While it is laudable that the BS-AC would desire to give its members greater flexibility in their diving, it must also accept the responsibility that any new tables it introduces should be safe and well tested.

Testing and evaluation of the BS-AC '88 tables

To my knowledge, the BS-AC '88 tables have never been tested in any type of controlled situation. Dr. Hennessey maintains that the BS-AC '88 tables are more conservative and provide a "greater margin of safety than the classic military-based tables". This is despite significant reductions of in-water decompression requirements and with an emphasis placed on decompression stop and repetitive diving. When asked about the lack of testing, Dr. Hennessey has argued that actual in-water testing would be impossible to do across the range of the tables. He says that limited testing might be conducted, but would not be statistically valid, and relies on unproven theoretical considerations to claim that the tables are more conservative than their predecessors and do not, therefore, require testing.

Comparisons of BS-AC '88 and established tables

Admittedly, it is difficult to do straight across comparisons of diving tables. The wide variation of designs makes exact comparisons impossible but I believe that

general comparisons are not only possible but prudent. The gold standard for tables within the diving community for years has been the U.S. Navy standard air decompression tables. In England, the standard is the RN table 11. Either of these tables, properly used by experienced divers, produce very low levels of DCS. Several navies, notably Canada, Sweden and the Netherlands have produced new diving tables in an attempt to minimize the risk of DCS still present in the US and RN tables.

In 1968, the Royal Naval Physiological Laboratory (RNPL) at Alverstoke, England, produced a set of Air Diving Tables for the same purpose but they never came into general use. It is interesting to note, however, that these tables, designed when Drs Hempleman and Hennessey were working together, are arranged in a similar fashion to the new BS-AC '88 tables. The similarity stops quickly, however, as the 1968 Air Diving Tables are far more conservative than their latter day cousins.

The preceding is important because the BS-AC tables are said to be based on original RN table data but are said to benefit from the experience and knowledge acquired since they were first published. Additionally, it is said that distinct changes were made in the underlying principles behind the design of the tables and the way in which they are to be used. It is difficult for me to understand how tables can be based on same data but with "distinct changes in principles".

To my knowledge, Dr Hennessey has never revealed the algorithm upon which the BS-AC '88 tables are based. I have heard numerous lectures about new, improved theories and, indeed, continue to be told that the new tables are more conservative than their predecessors. I have yet to be convinced.

If one takes a sample of dives conducted at various depths and times, the observation is that the BS-AC '88 tables advocate a markedly reduced decompression requirement in comparison to any other table. For comparison I have chosen the 1972 RNPL/BS-AC table, the USN table, RN table 11 and the new SAA table. Any number of examples might be selected to compare these tables on equivalent or near equivalent dives, either as single dives or in the more likely context of repetitive diving. The reduction in decompression requirements is particularly significant for repeat dives, a factor involved in 63% of U.K. recompression treatments in 1988. Several examples are listed below. My conclusion is that many dives advocated by these new tables allow so little decompression time that they must be regarded as highly dangerous.

It is well known that the U.S. Navy Tables, particularly in the deeper ranges, carry a 5% or greater risk of DCS, especially when pushed to the limits. It must also be remembered that the USN tables are a combination of tested tables plus years of adjustment based on empirical diving experience of hundreds of thousands of dives. They were not designed for sports diving use and the risk of DCS was balanced against operational requirements. The US Navy trains its divers carefully in the use of these tables and emphasizes the importance of staying within clearly defined limits.

In the first example (Table 1) the USN table allows for the least total decompression time of any table except for BS-AC '88. For that reason, I have selected these two tables for a more in depth comparison. It has been argued that these two tables are too different in their design to allow adequate comparison but, indeed, the same comparison may be conducted with any of the tables I have listed and the results are the same. As a diver goes deeper, goes longer or goes more often, three significant factors in the development of DCS, the decompression required by the BS-AC '88 tables becomes dangerously lean.

It has also been argued that sports diving is so different from military diving that a military table should not be used for comparison. The argument is that a military diver is more likely to do a "square profile" dive than a sports diver who is likely to do a multi-level dive. This has not been my experience in over 10 years of treating accidents, but it is a moot point. Any table introduced into general use must allow for all types of diving that are likely to be conducted.

Table 2 shows a comparison of decompression requirements on a series of dives using BS-AC '88 and USN tables. The reduction in decompression requirements is argued to be possible on the basis of a more efficient table. On a single dive, a diver may get by with the seemingly small reduction in times but the danger becomes more apparent when one looks at the repetitive dives possible in 90 minutes time.

TABLE 1
DECOMPRESSION TIME REQUIRED BY VARIOUS TABLES

Dive	RNPL/BSAC	USN	RN	BS-AC'88	SAA
26m/32min	10 min	8:30 min	10 min	4 min	10 min
39m/25min	30 min	12:10 min	20 min	11 min	27 min
40m/25min	30 min	18:20 min	20 min	14 min	27 min
42m/23min	30 min	18:20 min	20 min	11 min	47 min

TABLE 2

DECOMPRESSION TIMES FOR VARIOUS DIVES

Dive	USN	BS-AC '88
33 m/40 minutes	24:50	23:00
36 m/30 minutes	16:00	13:00
39 m/30 minutes	23:10	20:00

TABLE 3

DECOMPRESSION TIMES FOR REPETITIVE DIVES

	Decompression Time	
1st dive	USN	BS-AC '88
39 m/30 minutes	23.10	20.00
Surface interval	90min	
2nd dive		
18 m/39 minutes	27:40	10:00
30 m/16 minutes	27:00	10:00
42 m/10 minutes	46:20	11:00

TABLE 4

DECOMPRESSION TIMES FOR A THREE DIVE SEQUENCE

	Decompression Time	
1st Dive	USN	BS-AC '88
39 m/30 minutes	23.10	20.00
Surface interval	90 minutes	
2nd Dive		
30 m/16 minutes	27.00	10.00
Surface interval	90 minutes	
3rd. Dive		
18 m/30 minutes	15:00	5:00
Total required	**65.10**	**35.00**

Let us follow a series of dives based on a first dive to 39 m for 30 minutes. (Tables 3 and 4).

The third dive is listed to highlight one of the design flaws in the BS-AC '88 tables. It is generally accepted that the risk of DCS increases significantly if a diver does a repetitive dive to a depth deeper than his or her original dive. This is allowed by the BS-AC '88 tables but would not be allowed on the USN or most other tables.

If this example is continued, listing the 30 m/16 minute dive as the 2nd dive, a routine 3rd dive might be to 18 m for 30 minutes (Table 4). During the day's diving, the USN table would have required a total decompression time of 65 minutes 10 seconds. The same dives, conducted according to the BS-AC '88 tables would require a decompression time of just 35 minutes. This is an impressive reduction as this is the kind of diving after which we often see very serious neurological DCS.

I would feel more confident if there was some degree of testing to verify such a schedule but, in the same way that I believe unwitting divers are being used to prove the tables on which the algorithms in the majority of decompression computers are based, I consider it difficult to justify issuing new tables which, to the best of my knowledge, are completely untested. Had these new tables been proposed for US or Royal Navy use, they would have required ethical approval prior to extensive controlled trials. Time alone will tell if the BS-AC '88 tables are inherently safe or dangerous. My greatest concern is that these tables are designed to promote what I view to be dangerous diving practices.

Design Considerations

DECOMPRESSION DIVING

The BS-AC '88 tables are designed to promote decompression stop diving. The instruction manual states "It can easily be seen that use of the BS-AC '88 tables will introduce a new approach to sport diving in the BS-AC". The first major change will be that "Decompression Diving" will be seen to be inevitable, and "Decompression Stop Diving" will become preferable.

Many of the tables are deceptively conservative in their approach. An example of this is a first dive on Table A to 18 m. The allowable bottom time is 50 minutes. If one looks closer, however, it is noted that a diver may gain an additional 17 minutes of diving time for a single minute of decompression at 6 m. If a diver is willing to spend 3 minutes, the trade off is an additional 27 minutes. This approach seems to tempt a diver away from the safer practice of no stop diving into the realm of decompression stop diving.

REPETITIVE DIVING

The tables are designed specifically with repetitive diving in mind. This was one of the goals in "increasing flexibility". The BS-AC will allow any number of dives a

diver cares to make in a 24 hour period while most tables recommend a limit of 3 dives. Also, and perhaps more significantly, the BS-AC '88 tables allow repetitive dives to depths deeper than the original dive, a practice known to increase the risk of DCS.

FLYING AFTER DIVING

This is confusing so hang on!

The BS-AC manual states that a diver may fly in "a normal commercial aircraft with a pressurised cabin if their current tissue code is B. The maximum time this can take is 4 hours." If a diver wishes "to fly in an unpressurised aircraft, probably a private aircraft or a helicopter, then they must wait until they reach code A. The maximum time this can take is 16 hours."

A commercial airliner normally pressurises its cabin to an altitude of 8,000 feet so a diver with a tissue code B (some residual nitrogen load) is exposed to a reduced pressure of approximately 0.75 of an atmosphere. Helicopters and commercial airliners that do not pressurise their cabins are restricted from flying at altitudes greater than 8,000 feet and normally fly about 2,000 feet. This is based on the partial pressure of oxygen rather than pressure requirements. Pressure is only slightly reduced from atmospheric.

What this boils down to is that it is normally safer to fly in an unpressurised craft than a pressurised one and the requirement to have less nitrogen in your system makes no sense. The only situation in which it might apply is that of an unpressurised private aircraft that flies above the recommended 8,000 foot level. Here oxygen partial pressure is reduced below the equivalent of 16% at sea level and no one will be thinking clearly!

This particular contraindication was discussed with the BS-AC and, hopefully, they have seen fit to modify the rule.

ASCENT RATE AND BOUYANCY CONTROL

This is an area in which I am in complete agreement with the BS-AC. Ascent rates by most divers, in most situations, are simply too fast. I believe, as does Dr Hennessey, that too fast an ascent adds to the risk of DSC. An old study by Spencer on the rates of ascent showed divers routinely exceeding the recommended limits and in some cases reaching 118 feet/minute. My problem is in the degree of accuracy expected of BS-AC divers. A high degree of buoyancy control is necessary to follow the rules laid out in the new tables. Controlled ascents can be difficult under the best of circumstances and it takes practice, experience and a constant degree of vigilance to maintain controlled rates of ascent.

On diving holidays, divers will be trained and put into the water with minimal experience and I do not believe they will be able to maintain such a degree of accuracy. Even well trained and experienced divers will have difficulty. It can be argued whether these rates are critical but if it achieves the desired goal of slowing divers down the rule makes sense.

General Layout

The tables were designed to minimize the number of required calculations and allow for greater flexibility in one's diving. The layout of the BS-AC '88 tables is confusing at first, particularly to someone trained with different tables but is easy to use once one gets familiar with them.

I would not say, however, that there are fewer calculations. The first thing one must do is to calculate the actual bottom time allowed by subtracting out the ascent time to the first stop. If you forget to do that on the surface, hopefully one will be thinking clearly enough at depth to do it. If you overstay your planned time, it is a good idea to have a submersible dive table with one. I tried to memorise the tables but just could not manage it. If one overstays one's time limit and does not have, or cannot read, the submersible table, the rule says that a "safety stop" of 3 minutes at 6 m will be "adequate in the majority of occasions." I hope you are in the "majority" if it ever happens to you.

Summary

Dr William Shane, a senior NOAA diving physician was quoted in an old *Undercurrent* article as saying "The truth is that every time anyone dives with a decompression meter (and on most tables, for that matter), he or she becomes a human experiment. In essence, most times we dive we are exploring unknown physiological terrain. Under these circumstances, caution, and not a cavalier approach, should be our guide".

It is my belief that the price of the freedom sought by recreational divers is already far too high and that these new tables could well make the price even higher. To paraphrase Dr Shane's concluding remarks, "Today I am at a conference in Palau, the temperature is 84^{o} and the seas are calm. I am going diving. However as I do, in contrast to most sport divers, believe I have some slight idea of the risk".

Dr Greg Adkisson is a medical officer in the U.S.Navy. He had recently completed exchange service with the Royal Navy when this paper was presented.

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