Decompression tables and dive-outcome data: graphical analysis.

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Van Liew H.D., Flynn E.T. Decompression tables and dive-outcome data: graphical analysis. Undersea Hyperb Med. 2005; 32 (4): 187-198. We compare outcomes of experimental air dives with prescriptions for ascent given by various air decompression tables. Among experimental dives compiled in the U.S. Navy Decompression Database, many profiles that resulted in decompression sickness (DCS) have longer total decompression times (TDTs, defined as times spent at decompression stops plus time to travel from depth to the surface) than profiles prescribed by the U.S. Navy table; thus, the divers developed DCS despite spending more time at stops than the table requires. The same is true to a lesser extent for the table used by the Canadian forces. A few DCS cases occurred in profiles having longer TDTs than those of the VVal-18 table and a table prepared at the University of Pennsylvania. The TDTs for 2.2% risk according to the probabilistic NMRI'98 Model are often far longer than TDTs of experimental dives that resulted in DCS. This analysis dramatizes the large differences among alternative decompression instructions and illustrates how the U.S. Navy table provides too little time at stops when bottom times are long.

INTRODUCTION

It is generally accepted that decompression sickness (DCS) is caused by bubbles in the body that originate from inert gas that becomes dissolved in tissues while a diver is at depth. Decompression tables are instructions for returning the diver to the surface without contracting DCS. Decompression "models" embody the concepts and parameter values from which decompression tables are generated. A model can be categorized as "deterministic" when it specifies maximal supersaturations or maximal bubble volumes that cannot be exceeded during ascent. Deterministic models are generated from theory and then compared informally with the available dive-outcome data. With tables generated from deterministic models, a diver is expected to avoid DCS if he follows the table's instructions as to depth, bottom time, ascent rate, and time spent at decompression stops.

"Probabilistic" models are generated by formal statistical techniques that fit an algorithm to dive-outcome data (1). Probabilistic models recognize DCS as a chance phenomenon, so instead of being rated safe or unsafe, any specific dive profile can be accompanied by an estimate of the probability that DCS will occur. For practical use, tables are produced from probabilistic models by generating dive profiles that have a given probability of DCS (*Pdcs*). The tolerable risk for a given dive is a matter of policy and may vary with the circumstances. Discussions at the Naval Sea Systems Command brought consensus that more than two cases of Type I (pain-only) or minor Type II (neurological or cardiopulmonary) DCS per 100 dives in routine U.S. Navy diving would hurt diver morale and would slow operational tempo; for serious neurological or cardiopulmonary DCS, the maximum acceptable incidence is one case per 1,000 dives (personal communication, Murray CA; 2000).

It will be shown below that tables from different sources vary widely in the lengths of time they prescribe at decompression stops for a particular depth and bottom time. To visualize the differences between tables, we reflect graphic displays of the table instructions against dive-outcome data -- whether or not subjects contracted DCS on particular experimental dive profiles. In addition to gaining perspective on the differences between tables, the analysis will also bear on earlier contentions that the U.S. Navy Standard Air Table (2) provides too little time at decompression stops for long dives (3-5).

METHODS

We consider decompression tables for air-breathing divers derived from six decompression models:

- The current U.S. Navy Standard Air Decompression Table (2), designated "USN," sometimes called "USN57," was generated from a deterministic model and has been used with few changes since 1957.
- The Canadian Forces Air Decompression Table (6, 7), designated "Can," was generated from a deterministic model and has been used since 1986.
- A table, designated "Penn," was generated from a deterministic model at the University of Pennsylvania and has been used commercially (8, 9).
- A table, designated "VVal," was generated at Duke University from a deterministic model known as the "VVal-18 Algorithm" (5, 10, and 11).
- A table, designated "NMRI'98," was generated from a probabilistic model known as "NMRI'98 Model 2," (12) – we use a table generated from the model at a target risk of 2.2%.
- A table, designated "Duke," was generated at Duke University from a probabilistic bubble-volume model known as "BVM-3" (13) – we use a table generated for a target risk of 2%.

Dive-outcome data.

The binomial confidence intervals for chance phenomena such as DCS dictate that uncertainty about the "true" incidence for groups of subjects diminishes as the number of subjects increases. The high cost of dive trials precludes large numbers of dives, so the confidence intervals tend to be large. To obtain groups of subjects large enough to yield meaningful confidence intervals for DCS incidence, we combined profiles from the U.S. Navy Decompression Database (14, 15) to generate what we call a "Compendium." Our manipulations of the data mean that our Compendium is not a simple subset of the original information. Our Compendium is limited to dives in which the breathing gas was air.

The total decompression time (TDT, defined as the sum of times spent at decompression stops plus time to travel from depth to the surface) is a major feature of our analysis. For example, for a 50-minute dive to 100 feet of seawater, gauge (fswg; 1 fsw = 3.063 kPa; 33.08 fswg = 2 atm absolute), the U.S. Navy Standard Air Table mandates a 2-minute stop at 20 fswg and a 24-minute stop at 10 fswg. Ascent rate is 30 fsw/min. The TDT is therefore 26 min + 3.33 min = 29 min 20 s. We speculate that except for depth and bottom time, TDT is the most influential variable in modeling of DCS. There may be some leeway in the particular pattern of times at stops; Survanshi and coworkers (16) state that with certain probabilistic models, many different stop-time combinations having the same TDT result in nearly the same probability of DCS. For example, the NMRI'93 probabilistic algorithm (16) predicts 4.35% risk of DCS for a dive to 150 fswg for 30 min with 5, 10 and 15 min stops at 30, 20 and 10 fswg, respectively. If the pattern of stops is reversed, i.e., 15, 10, and 5 min at 30, 20 and 10 fswg, respectively, the predicted risk is 4.28%, a negligible difference.

Some decompression models suggest that time spent at deep stops may be more efficacious than the same time spent at shallow stops. We are unable to address this issue because all the dive profiles available to us use relatively shallow stops as is customary in U.S. Navy operations.

Three of the source tables we use mandate an ascent rate of 60 fsw/min (Can, Penn, and VVal-18), and three mandate a rate of 30 fsw/min (USN, NMRI'98, and Duke). Originally the USN Standard Air Decompression Table mandated an ascent rate of 60 fsw/min, but in 1993 the rate was changed to 30 fsw/min, with no changes made in any of the table entries. The ascent rate for the VVal-18 table has subsequently been changed to 30 fsw/min.

The U.S. Navy Decompression Database (14, 15) consists of a number of computer files, each representing a particular study of carefully executed experimental dives. Within the files, specific test dive profiles are listed sequentially; each profile is a record of depths, times, and gas mixture changes, if any, throughout the dive. For groups of subjects who dived together on a given profile, divers who were DCS free are listed together but divers who developed full-blown DCS and marginal DCS are listed separately. Marginal cases are defined as "transient aches or pains following a dive that seem related to the pressure exposure, but were not of a severity or persistence to warrant treatment" (17). The details seen in a database entry are essential for probabilistic modeling (1, 12), in which the entire dive profile is considered. However, the way the details are compiled makes it impossible to envision the data as a whole. There are no summaries that show the number of divers tested and the number of DCS cases observed for particular dive profiles.

In the files we used here, we carefully studied the details of the time and depth profiles of each entry, using the depth, bottom time, and TDT listed in the heading of the entry as a guide. We deleted profiles having more than one distinct bottom depth or an indistinct series of bottom depths. When the recorded information in a profile indicated that the heading was inaccurate or that there was a small deviation from a square-wave exposure to depth, we made appropriate corrections so that the pattern of corrected depth and bottom time corresponded approximately to square-wave behavior. Delays at the beginning and end of the dives necessitated by far the most corrections and datafiles DC4D, DC4W, and EDU885A required the most corrections.

Specific procedures for correction follow: a) we took the bottom time to be the difference between the time when the divers left a depth of 3 fswg or shallower and the time when the divers left the bottom depth. b) All profiles of EDU885A needed correction for lags at 7 fswg at the beginning of the dives, with average correction of –2.5 min $\pm$ 1.3 min (SD). c) We adjusted for irregularities in the depth and compression rate in such a manner that the area under a graph of depth vs. bottom time was approximately equal to the area under an uncorrected graph; when the summary heading did not account for a delay near the final bottom depth, we made the bottom depth less; when the summary heading did not account for a slow descent to depth, we shortened bottom time and/or decreased bottom depth; and when the summary heading did not account for small variations in bottom depth, we took average depth. d) We took the TDT to be the difference between the time when the divers left the bottom depth and the time when the divers reached a depth of 3 fswg or shallower. e) We verified that the patterns of decompression stops in the test dives were generally in line with Navy practice – the stops began at depths that were relatively shallow compared to the bottom depth and stop times lengthened at successive stops.

TABLE 1. DATASET FOR PRODUCTION OF THE COMPENDIUM: DETAILS OF SOURCE FILES

	Source file	File date	Entries	Person-dives	Cases Obs	% Obs
1	DC4D	10/9/97	209	657	16	2.4%
2	DC4W	12/21/93	108	187	4	2.1%
3	EDU1157	9/23/97	27	46	15	32.6%
4	EDU1351NL	12/3/96	43	143	2	1.4%
5	EDU159AVL*	9/30/97	3	6	4	66.7%
6	EDU545	11/20/97	42	94	18	19.1%
7	EDU557	5/29/97	81	371	13	3.5%
8	EDU849LT2	5/5/97	74	141	26	18.4%
9	EDU849S2	6/27/97	34	52	13	25.0%
10	EDU885A	12/20/93	82	483	30	6.2%
11	EDUAS45	1/15/98	10	14	3	21.4%
12	NMR97NOD	8/19/97	9	103	3	2.9%
13	NMRNSW	1/29/91	28	48	5	10.4%
14	NSM6HR	12/20/93	14	36	3	8.3%
15	PASA	5/26/92	26	72	5	6.9%
16	RNPL52BL	7/20/95	23	177	1	0.6%
17	RNPL57L	7/21/95	50	50	9	18.0%
18	RNPLX50	9/19/97	10	39	4	10.3%
	Totals		873	2,719	174	6.40%**

* EDU159AVL is a modification of file EDU159A made after re-reading the original material.
** total Cases Obs/total Person-dives

The Compendium.

Table 1 lists the files in the U.S. Navy Decompression Database that contributed to our analysis of single-level, non-repetitive, air-breathing dives. Each of the 18 files is based on a particular published report and is reviewed in a summary Navy Report (14). The entries in the source files provide information about one or many persons who followed a particular dive profile. For our purposes, we assigned marginal cases as having the status of "no DCS," because they do not disrupt operations and do not appear to be associated with long-term health consequences.

To restrict the dataset to the range of the U.S. Navy Standard Air Table, we eliminated dives with bottom times longer than 720 min, depths shallower than 40 fswg, and depths greater than 195 fswg. We rounded depths to the nearest 10 fswg and bottom times to the nearest 5 min. We next sorted the information by increasing depth, sorted within depth by increasing bottom time, sorted within bottom time by increasing TDT, and then combined like entries to make a row in the Compendium. These like entries are often identical profiles in which all divers have the same rounded depth, rounded time at the bottom, and total decompression time, but sometimes we combined dives having a small range of TDTs to increase the numbers of person-dives in the row.

RESULTS

Table 2 is a summary of the Compendium. A row in the Compendium gives a data point on the graphs in the Results section. Data points show average TDT when a range of TDT was combined for the row. Table 3 gives details of the profiles that have high DCS incidence.

The traces in Figure 1 show decompression prescriptions for a depth of 150 fswg. The TDTs increase as bottom time increases because long dives require more stops and longer stops; thus the lowest trace prescribes TDT of 62 min when bottom time is 40 min, and TDT of 176

TABLE 2. SUMMARY OF THE COMPENDIUM OF DIVE-OUTCOME DATA	
Depth	40 to 190 fswg
Bottom time	5 to 720 min
TDT	1 to 1,445 min
Number of rows	240
Rows with no DCS	163
Rows with DCS	77
Rows with DCS incidence greater than 5%	19
Rows with DCS incidence greater than 2%	39 (includes 5% rows)
Person-dives per row	1 to 107, average 12 ± 1.5 (SD)
DCS cases per row	0 to 21, average 0.7 ± 1.8 (SD)
Incidence of DCS (100 x cases/person-dives) per row	0 to 100%, average 7% ± 16% (SD)
Person-dives in rows having 95% confidence that DCS incidence is greater than 5%	305, with 89 DCS cases
Person-dives in rows having 95% confidence that DCS incidence is greater than 2%	573, with 130 DCS cases (includes 5% rows)
Person-dives in rows having DCS cases but no confidence that DCS incidence is greater than 2%	627, with 44 DCS cases

TABLE 3. DIVE PROFILES THAT HAVE INCIDENCES ABOVE 5% AND ABOVE 2%, ACCORDING TO THE BINOMIAL THEORY

Depth fswg	Bottom time, min	TDT, min	Dives	DCS cases	% DCS
True incidence is 5% or greater					
40	720	1 - 2	91	21	23%
60	180	72	10	3	30%
60	180	111	10	4	40%
100	30	4	22	4	18%
100	55	4	18	5	28%
100	85	61	26	9	35%
120	50	57	6	3	50%
130	55	76 - 80	21	4	19%
140	240	353	2	2	100%
140	240	421	4	2	50%
140	240	440	2	2	100%
140	240	489	2	2	100%
140	240	517	6	2	33%
140	360	700	6	2	33%
150	30	6	32	8	25%
150	35	6	15	7	47%
150	45	73 - 89	5	2	40%
150	60	260 -290	20	5	25%
160	25	18 -19	7	2	29%
True incidence is 2% or greater but cannot be said to be 5% or greater					
40	360	1 - 2	39	3	8%
100	60	112 - 113	27	3	11%
100	100	82 - 86	14	2	14%
100	720	723	2	1	50%
100	720	1,445	2	1	50%
110	90	88 - 93	12	2	17%
120	20	9 - 10	8	2	25%
120	50	36 - 38	12	2	17%
120	70	213	10	2	20%
120	80	267	10	2	20%
130	50	47 - 54	18	2	11%
140	40	64 - 65	21	3	14%
140	80	135 -138	10	2	20%
150	26	6	10	2	20%
150	30	46 - 50	12	2	17%
150	40	81 - 85	25	3	12%
150	45	57	2	1	50%
150	45	65	2	1	50%
170	10	18 - 23	22	3	14%
190	40	238	10	2	20%

min when bottom time is 80 min. The next-to-highest trace prescribes TDT of over 200 min when bottom time is 40 min. At the right-hand side of the graph, TDTs for the highest trace are two or more times longer than those of next-to-highest trace.

Figure 1 shows outcomes for dive profiles having various bottom times at a depth of 150 fswg. Circles represent a row in the Compendium for a dive profile that did not cause DCS. A triangle represents a row in the Compendium for a dive profile that caused one or more cases of DCS. Black triangles represent profiles for which it can be said with 95% confidence that the DCS incidence is greater than 5%. Gray triangles represent profiles for which it can be said with 95% confidence that the DCS incidence is greater than 2% but it cannot be said that incidence is greater than 5%. Because the gray and black triangles are based on relatively few person-dives, the true risk of DCS may be substantially greater or less than 2% and 5%, respectively.

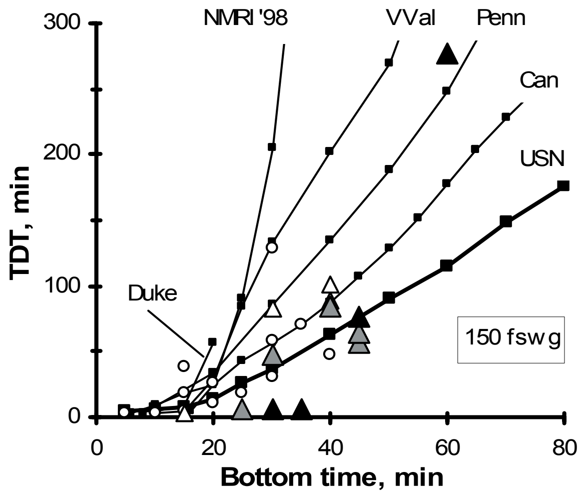

Fig. 1. Traces for five decompression tables; total decompression time (TDT), defined as the sum of times at decompression stops plus the time it takes the diver to ascend from the bottom to the surface, is plotted against bottom time, defined as the elapsed time between leaving the surface and leaving the bottom depth. For explanation of dive-outcome symbols, see text. The examples are for dives to 150 feet of seawater, gauge. Nodes on the traces show TDT at specific bottom times.

The white triangles are smaller than the other triangles; for them it cannot be said with 95% confidence that incidence exceeds 2% and isolated cases of DCS could occur by chance in relatively safe dives. White triangles that are based on only a few person-dives may actually represent high risks, but white triangles that are based on profiles having a large number of person-dives may represent risk less than 2%. If several white triangles occur close to each other, risk may be appreciable in the region.

Because of the probabilistic nature of DCS, circles and triangles lie in the same region on the graph. For a profile that causes DCS in a small percentage of the subjects, we can expect many trials that have no DCS, unless the subject groups are large. Also, we can expect a gradient of the symbols. Black triangles should predominate where decompression stops are inadequate near the zero axis of TDT. Gray triangles should be at higher TDTs. At high TDTs, we can expect a mixture of triangles and circles. At very high TDTs, we can expect circles only: decompression stop time is more than enough to prevent DCS. Unfortunately, there are not enough dive trials to show such a gradient pattern. Note that the presence of a circle or the absence of a triangle does not mean that a region has *Pdcs* less than 2%; it means only that there is no information to the contrary.

Confidence intervals for the true incidence are large. For example, the gray triangle at 40 min in Figure 1 is for 3 cases among 25 person-dives; the two-tailed 95% confidence interval for the true incidence is 3% to 28%, so although the observed incidence is 12%, the dive could actually be either reasonably safe or very dangerous. For circles, it takes 58 person-dives with no DCS cases to say with 95% confidence that incidence is below 5% and 148 dives with no cases to say that incidence is below 2% (one-tailed binomial distribution). For circles on the graphs, the average number of person-dives is 9.3 $\pm$ 8.4 (SD) with maximum of 72, so we cannot say with 95% confidence that probability of DCS is less than 2% for any of the circles.

The triangles lie both above and below the USN trace. The five triangles below the trace show DCS cases that are expected according to the table because the divers did not spend the prescribed times at decompression stops. For example, consider the black triangles near bottom times of 30 and 35 min: USN prescribes about 35 minutes at decompression stops, but the divers actually spent little or no time at stops.

In Figure 1, five triangles are above the USN trace, an indication that the USN table prescribes insufficient time at decompression stops: that is, the divers completed the prescribed time, or more, at decompression stops, but they developed DCS nevertheless. Adding time at decompression stops would make the trace steeper and thereby reduce the number of unpredicted cases. The high black triangle at 60-min bottom time is particularly worrisome; TDT would have to be more than twice that prescribed by the USN table to avoid it.

From the position of the triangles in Figure 1, it is reasonable to infer that the VVal-18 table furnishes adequate decompression times. There are no decompression trials in the region of high TDTs where the NMRI'98 trace lies. The Duke table rises steeply but stops at short bottom times. The trace for the Can table is higher than the USN trace; it lies above gray triangles at 30 and 40 min, whereas USN lies below them. The trace for the Penn table is between the VVal-18 and Can traces.

Other depths.

Figure 2 presents graphs similar to those of Figure 1 for depths from 40 to 190 fswg. Cases of DCS are sparse; depths that are particularly lacking in DCS cases are 40, 50, 70, 80, and 90 fswg; there are no DCS cases at all for 50 and 70 fswg. In all the panels of Figure 2 that have appreciable numbers of dive-outcome points, the patterns are similar to the pattern in Figure 1. For example, consider dives at a depth of 100 fswg. Except at very low TDTs, no circles or triangles are near the NMRI'98 trace. As in Figure 1, VVal-18 is above the triangles; the Penn table is below VVal-18; and the Can table is above USN.

Black and gray triangles in Figure 2 provide evidence that some of the tables do not prescribe enough time at decompression stops: a) USN table at 60, 100, 120, 140, 150, 170, and 190 fswg; b) Can table at 60, 100, 120, 150, 170, and 190 fswg; c) Penn table at 100, 120, 150, and 170 fswg; and d) VVal-18 table at 170 fswg.

Positions of the table traces relative to the triangles in Figure 2 invite contentions about the safety and efficacy of the six tables: a) The Can table is safer than USN; its traces lie near the top of the regions that contain triangles, in contrast to traces for USN, which lie lower down. b) The Penn table is safer than the Can table but not as safe as VVal-18. c) The VVal-18 table appears to be safe; its trace is above all the triangles except for the gray triangle at 170 fswg with 10-min bottom time. d) Traces for the Duke Table rise steeply at relatively short bottom times and then stop. e) Near the tops of all the graphs, the NMRI'98 traces are far above traces for the other tables; we might conclude that the NMRI'98 table mandates excessive, inefficient decompression times, but this conclusion is not certain because there are no decompression trials in the region of high TDTs where the NMRI'98 traces lie. g) Both the VVal-18 and NMRI'98 tables avoid DCS cases but the VVal-18 traces mandate less time at decompression stops than the NMRI'98 traces.

Short dives.

On the scale of Figure 2, the groups of table traces in each of the panels resemble fans. Figure 3, which enlarges the lower-left corner for several of the graphs in Figure 2, illustrates how the traces cross over each other when bottom time is short. The NMRI'98, Duke, and VVal-18 traces tend to lie together. Black and gray triangles lie above some of the table traces in all panels. In particular, there is a gray triangle above the USN, Can, and Penn traces on the 100-fswg plot and a gray triangle above all the traces on the 170-fswg plot.

For most military, commercial, and recreational diving, bottom times are short enough that decompression stops are not needed. No-stop dive profiles are the lowest points on the table-trace figures. We might expect no-stop dives to be well established so that the

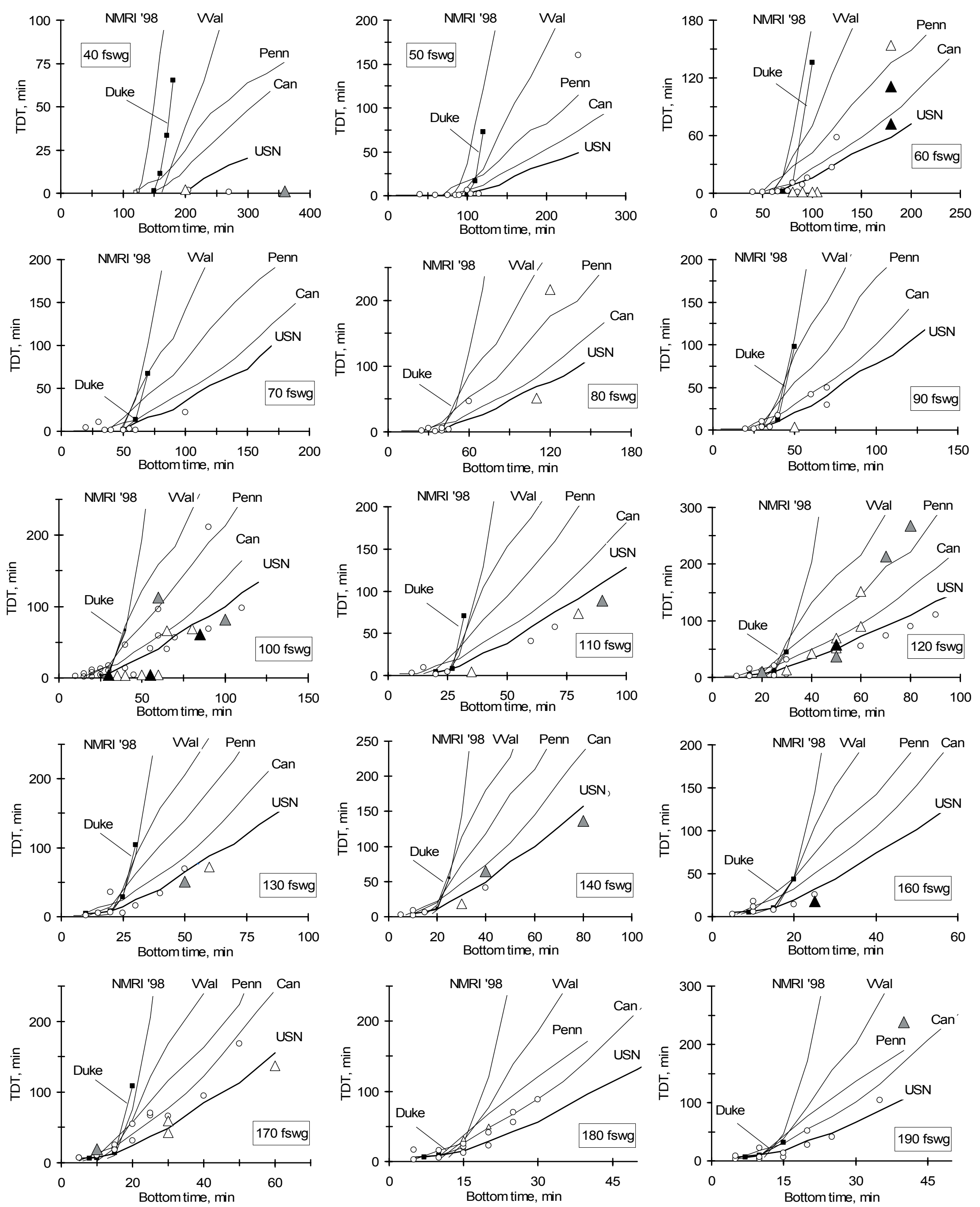

Fig. 2. Total decompression time vs. bottom time for various depths, showing instructions for ascent for six tables (traces) and dive-outcome data (symbols). For description of syumbols, see text. Nodes for the table entries are omitted from the traces, except for the trace for the Duke table.

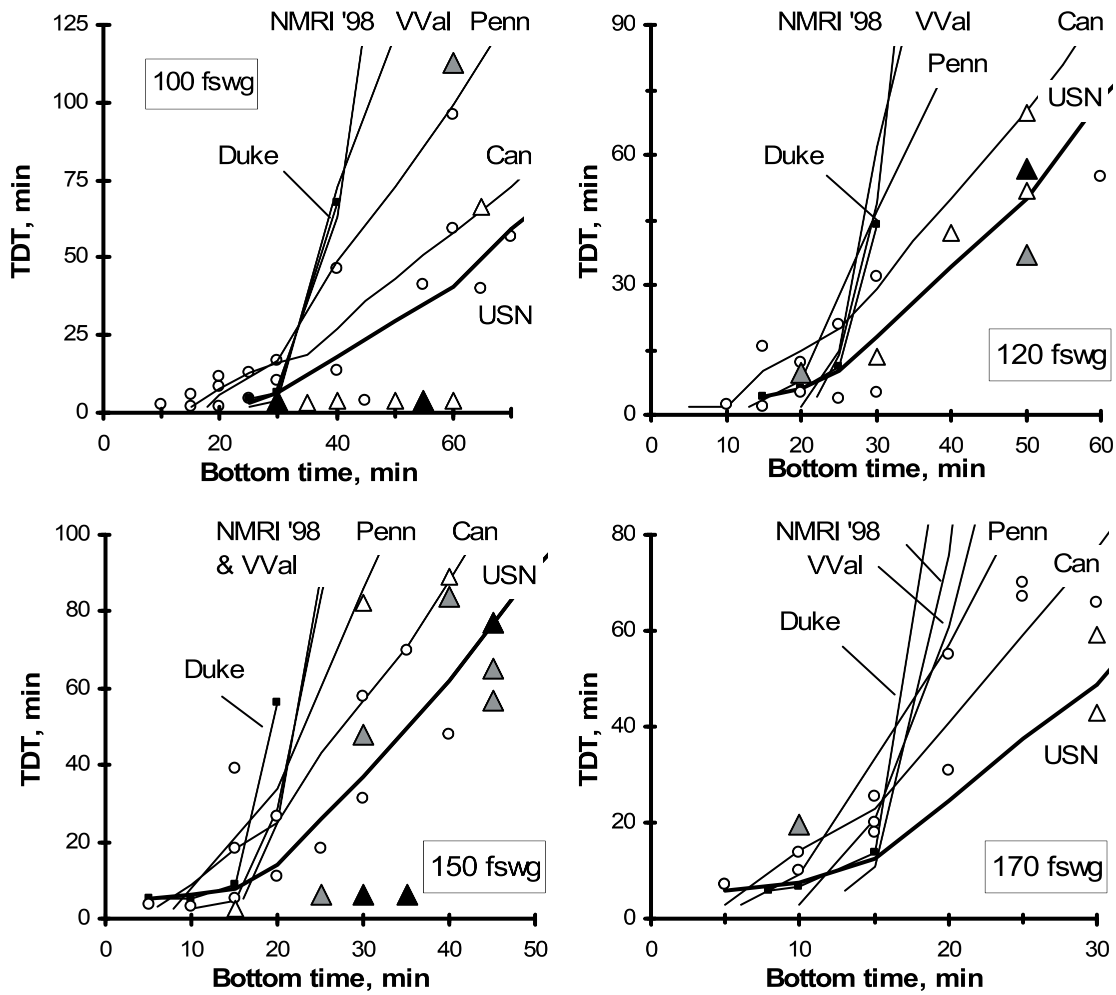

Fig. 3. Enlarged scale for sample depths to show dives having short bottom times and short TDTs. Format is the same as in Figure 2·

different tables would agree, but the bottom ends of the traces in Figure 3 show that there are considerable differences between the tables. We provide additional discussion of no-stop dives of the various tables elsewhere (18).

DISCUSSION

Any graphical display of dive outcomes is only partially satisfying because only a few variables can be plotted. In addition to dive depth, bottom time, total time at decompression stops, and incidence of DCS, which we account for, the pattern of depths and times for decompression stops is also pertinent, along with other variables such as the type of dive (dry or in the water), the intensity of diver exercise, and the environmental temperature.

Probabilistic models can be generated for any desired level of DCS risk. We chose a risk near 2% for the two probabilistic tables examined in this analysis. In the past, probabilistic modelers have made other risk choices: up to 5% for decompression diving, and up to 10% for exceptional exposure diving (19). We give special attention to the data points for which we are 95% confident that the true

DCS incidence is above 2%. Gray and black triangles above or to the left of a table trace on our graphs are strong evidence that TDTs prescribed by the table are insufficient.

Of the six tables we examined, the U.S. Navy Standard Air Decompression Table (2) is the oldest and has the shortest TDTs. Our graphs show that many experimental DCS cases have TDTs that are substantially longer than the TDTs prescribed by the USN table. A conclusion that the TDTs in the USN table should be lengthened or the USN table should be replaced concurs with other warnings about it (3-5), but conflicts with operational data from the Naval Safety Center (personal communication, Commander, Naval Safety Center, 1997). During the period of 1971 to 1996, the DCS rate for decompression diving on the USN Standard Air Table was 0.5% overall; only six schedules showed incidence higher than 2%. The confidence limits of all six do not allow a statement that their true incidence is 2% or above; they would appear as white triangles on our graphs. One of the six is off scale for our analysis with bottom time of 220 min and depth of 50 fswg. Depths, bottom times, and TDTs of the others are 100/60/40.3, 140/40/48.7, 150/25/26, 170/40/84.7, and 190/50/150.3.

Differences between operational and experimental diving may account for the apparent divergence between the experimental results and operational experience. Of all the possible reasons why the observed DCS rate in operational diving is lower than our analysis predicts, we judge that the most influential are decreased susceptibility to DCS due to acclimatization that occurs with repeated exposures and shorter and shallower dive profiles than those prescribed by the table. Operational divers seldom follow the USN table exactly. In practice, delays in reaching the target depth are counted as bottom time, depths and bottom times are usually less than the maximum permitted by the table, and instead of the instructions for the actual dive, table instructions designed for a greater exposure are often used on an *ad hoc* basis, especially for dives perceived to be arduous or dangerous. Such changes can be shown to reduce the risk of DCS substantially. Finally, it can be argued that the carefully controlled dive trials in the U.S. Navy Decompression Database are not good representations of actual operational dives. Some of the experimental dive trials were performed by immersed divers and some by divers in dry chambers, and levels of thermal stress and exercise for test dives may be greater or less than those levels for operational dives. The pattern of decompression stops in some of the test dives may contribute to the differences even though we screened the data to see that the decompression stops were generally in line with Navy practice. To maintain the current safety record with the USN table, it will be crucial to maintain the current pattern of diving and schedule jumping. If the pattern were changed to a more aggressive one, the inadequacies of the USN table would be quickly revealed.

The two tables based on probabilistic models differ from the four tables based on deterministic models (Can, Penn, VVal-18, and USN) in that the probabilistic tables either prescribe longer TDTs (NMRI'98) or point upward toward long TDTs but avoid them by ending at short bottom times (Duke). The statistical technique for generating a probabilistic table uses the totality of the data points across depth to estimate risk of DCS (1). The process is analogous to the familiar exercise of drawing a best-fit straight line through X-Y points: the points determine the position of the line. It is therefore surprising that the NMRI'98 Model has such high TDTs when the graphs show no DCS cases in regions where its traces are located. The NMRI'98 Model was built from a much larger dataset than we use in our displays, including many different kinds of dives in addition to standard air dives; this may account in part for the high TDTs the NMRI'98 Model prescribes for 2% risk. In other work we have shown that including saturation dive data in calibrating a probabilistic model of air diving lengthens TDT substantially (20). To use either the NMRI'98 Model or the Duke Model to produce an air decompression schedule with realistic TDTs, one would have to increase the risk given by the model well beyond 2%. How the nominal risk given by a model will correspond to the actual risk for air dives is unknown.

CONCLUSIONS

a) The graphical analysis presented here provides a general basis for comparing decompression tables for single-level dives from any source. The graphs present a visual impression of the results of dive-outcome information and facilitate insight into the safety and efficacy of decompression tables produced from different assumptions. b) The six tables we studied differ markedly. c) The analysis provides quantitative background information for recommendations about decompression from dives with long duration: i) the USN table and, to a lesser extent, the Canadian table appear to specify insufficient amounts of time at decompression stops for dives of long duration; ii) the VVal-18 table and, to a lesser extent, the Penn table provide adequate time at decompression stops to avoid almost all the DCS cases in the Compendium; and iii) the NMRI'98 probabilistic table seems to mandate excessive times at decompression stops for standard air dives, as judged by comparison of its prescriptions with the experimental dives documented in the U.S. Navy Decompression Database (14,15). d) No-stop times for deep dives appear to be dangerously long in some of the tables.

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