Dive Computer Validation Procedures

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> *"In the beginning God created the heavens and earth. It was not necessary to create the oceans; it was raining at the time. He neglected, however, to devise decompression tables that Adam and his descendants would require. They would need them, so they have been trying ever since to do it themselves."*
> C. J. Lambertsen (1989)

INTRODUCTION

The meaning of the term "validation" is fundamental to the objectives of this 2011 dive computer workshop. A number of efforts have taken place to characterize the functionality and effectiveness of dive computers (Lang and Hamilton, 1989; Hamilton, 1995; Wendling and Schmutz, 1995) and dive tables (Schreiner and Hamilton, 1989; Simpson, 2000). Before the dive computer validation process can take place, a consideration is in order of the function of a dive computer (also see papers by Huggins, Angelini, and Lang, this volume).

DIVE COMPUTER FUNCTIONALITY

The dive computer is supposed to step the diver from a pressure exposure back to the surface without any adverse residual effects, or, if symptoms are present, they should be trivial and easily managed. A wrist-worn, or air-integrated, console-mounted dive computer is exposed to the same pressure and environment as the diver throughout the dive. Therefore it is not limited to the square-wave type dive profiles that dive tables prescribe; it follows the actual multi-level profile of pressure exposure. An acceptable dive computer should also consider the breathing gas, as well as temperature, which is important in dealing with a biological creature. These parameters can be recorded and processed by dive computers. The word 'record' is used here as a verb. The dive computer will perform calculations, but it also records the exposure, the time-pressure profile, the gas profile and the activity of the diver. The ascent rate monitor built into the dive computer provides an accurate speed of pressure reduction, often with a safety stop countdown at approximately 3 msw, and the downloading function of most dive computers allow for a graphic post-dive profile display.

The gas mixtures are an important part of the diver's environment, and most existing dive computers will work with oxygen-enriched air, also known as 'nitrox'. There are also more sophisticated dive computer models that work with helium/oxygen mixtures. Most dive computers allow the diver to control and change the breathing mixture during the course of the dive. The diver may pick up a different breathing gas during the dive but then needs to tell the computer about the change at that time; it is not automatic and has to be done by the diver. Dive computers may incorporate other functions such as navigational tools (electronic compass) or a locating device to help the diver find a boat or perhaps another diver, or a heart rate monitor (Lang and Angelini, 2009).

Many manufacturers use the term 'air integrated,' a fairly straightforward function that records and tracks the gas supply (air or mixed gas) and that also should be able to predict the remaining dive time coupled to a warning system for the diver. Dot matrix displays vary in degrees of sharpness with some showing a high level of detail in either black and white or color, and others in greyscale. The earlier versions had alphanumeric characters that were functional and allowed the diver to tell the computer what to do and then see what it was doing.

Many dive computers can also interface with a desktop or laptop computer, which improves the dive planning function, and affords a chance to print out profiles. The dive computer will simulate the exposure and in that way the diver can walk through the dive without actually entering the water. In some cases 'buddy' monitoring is possible, i.e., the computer can follow more than one transmitter, the sort of thing that a mother might want to do if her kids were all out diving! It's a mechanism to keep track of the dive team.

Several of these dive computer systems will take the individual biological data (i.e., breathing frequency, breathing volume and heart rate) to show the level of activity of the diver and also read environmental temperature. Temperature is a difficult parameter to use; of interest is the temperature of the diver, but the environmental temperature is what is being measured. Even knowing the temperature of the diver does not simplify matters; it is a complex issue that relies on a large database to determine the effects of temperature on the diver. However, if this information is recorded, eventually there will be enough data accumulation to effectively use in model predictions. At least one of the models projects display information into the mask (an aviation term called ‘heads-up display’) so that the diver can see dive information without having to look down.

DIVE COMPUTER VALIDATION STEPS

What specifically is meant by validation and what steps are taken to do it?

1. Ergonomics.
A term that is used to embrace studies of this type is ‘ergonomics.’ This concept embraces the interface of dive computer with the diver; what information is displayed to the diver and what controls the diver has over that information. The display must be clear and without ambiguity. Numbers appearing on the display must be discernible as to what they mean. In most cases, the diver has to learn how a particular dive computer works by reading the manual, using the dive computer repeatedly in simulation mode in the dry and then later in dive mode under water. Of primary importance in the evaluation of a dive computer is ensuring that there is no ambiguity, and if any information displayed is unclear, finding out exactly what that information means.

Dive computer controls should be intuitive. Extensive training should not be a requisite to using a particular dive computer. With some experience a diver should be able to select a different model and after a brief review be able to successfully dive it. Comfort and fit is also important, i.e., does it feel good on your arm? If the dive computer is not easily viewed, is too heavy, or there are other accessibility problems, a different model should be selected. When modern electronic, diver-carried computers first appeared in 1983 (Lang and Hamilton, 1989), the divers who used them most successfully were underwater photographers. They had the necessary skills and knew how to seal electronic equipment under water to keep their cameras dry. Therefore, at some point in the dive computer validation process some leak testing must occur to ensure that the computer does not allow water penetration. The battery compartment must stay dry and salt water intrusion of the circuit board guarantees permanent malfunction.

2. Model function and algorithms.
What is a dive computer supposed to do? Its basic function depends on the model or the computational algorithm with which it calculates the decompression requirements. We are not focused on algorithms as an objective of this workshop, but the algorithm is the business end of the dive computer, the tool that is used to calculate the dive profiles. There are several effective algorithms available, but their treatment is outside the scope of this paper. Schreiner and Hamilton (1989) reviewed the procedures for the validation of decompression tables, the central concept of which also applies to dive computers.

3. Testing dive computer function.
A key consideration that the decompression table validation workshop participants addressed was how to inject 'judgment' into the process of evaluating tables or, in this case, dive computers. How the judgment function of what is acceptable is taken care of is important because many of these decisions are not simple or obvious. At this stage a dive computer is put through its paces and made to do all the functions, such as specific profiles, in simulation mode. The results are carefully compared to reference tables where some judgment is needed. Selected profiles are then physically reproduced and monitored in a dry pressure chamber mode, hoping that the dive computer performs as expected, usually benchmarked to, for example, the U.S. Navy decompression tables.

4. Field testing.
Then comes the fun part: diving the dive computer. When the U.S. Navy first tested their decompression tables, the profile to be tested experienced six exposures and if each one of these six was problem free, it was declared OK and testing proceeded on to the next profile. This protocol was a little optimistic, but that was the way it was done. When testing a dive computer, relatively few profiles can be used or quite a lot. Judgment at this stage determines how many profiles are required to declare a profile as safe?

There is an interesting bit of 'word study' here: the word (diverse) is sometimes pronounced as 'de-verse' and sometimes as 'di-verse', and is essentially the same word as 'divers.' The point being that in order to adequately test a dive computer, its evaluation needs to be done using a variety of different people of all sizes, shapes, ages, weights and skill levels. The broad diversity within the diving community mandates inclusion of this range of divers. That diving community is different from the select group of individuals present today. As I mentioned earlier today, if the bus was driven into the river on its way to this workshop, then it would have set diving technology and decompression research back by a few years! We do need to think about the diversity of exposures when these computers are validated in the field.

CONCLUSION

The judgment component is again emphasized here with reference to the dive computer workshop. During the development of a new decompression table a decompression monitoring board was suggested as the mechanism to be engaged in order to involve an organization with the process. In order to implement a judgment function, there has to exist a committee or board that is charged with this responsibility. The findings of the decompression validation workshop stipulated that it should not be a government body, but preferably an agency of the organization that is doing the development. There are other opinions but the judgment function must enter somewhere in the validation process. I do not purport to have all of the answers, only some of the questions as they relate to validation of dive computers.

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LITERATURE CITED

Hamilton, R.W., ed. 1995. *The Effectiveness of Dive Computers in Repetitive Diving.* Kensington, MD: Undersea and Hyperbaric Medical Society. 71 pp.

Lambertsen, C.J. 1989. Introduction to the Workshop: Background history and scope of diving table validation. In: Schreiner, H.R., and R.W. Hamilton, eds. pp. 3-9. *Validation of Decompression Tables.* Bethesda, MD: Undersea and Hyperbaric Medical Society.

Lang, M.A., and R.W. Hamilton, eds. 1989. *Proceedings of the AAUS Dive Computer Workshop*. USC Catalina Marine Science Center, September 26-28, 1988. Costa Mesa, CA: American Academy of Underwater Sciences. 231 pp.

Lang, M.A., and S.A. Angelini. 2009. The Future of Dive Computers. *In:* Lang, M.A., and A.O. Brubakk, eds. *The Future of Diving: 100 Years of Haldane and Beyond.* pp. 91-100. Washington, DC: Smithsonian Institution Scholarly Press.

Schreiner, H.R., and R.W. Hamilton, eds. 1989. *Validation of Decompression Tables*. Bethesda, MD: Undersea and Hyperbaric Medical Society. 167 pp.

Simpson, M.E., ed. 2000. *HSE Workshop on Decompression Safety*. Report Number AEAT-4621 Issue 2. Kensington, MD: Undersea ad Hyperbaric Medical Society. 79 pp.

Wendling, J., and J. Schmutz, eds. 1995. *Safety Limits of Dive Computers*. Basel: Foundation for Hyperbaric Medicine. 88 pp.