Latests findings on DCI and Dive Physiology (Part 1)

Bubbles that make divers bent or cause the so-called Decompression Sickness (DCS) are known by any diver in the world. The gas in question is usually nitrogen, an inert gas that forms these bubbles. DCS is a known dive-related health risk which can cause skin rashes or joint pains if mild, but also life-long permanent paralyses or death if hitting seriously. When an inert gas which has saturated the body tissues during exposure to increased ambient pressure is decompressed too rapidly, it can form circulating or tissue gas bubbles which can block blood vessels, especially small capillaries, in the human body. If it does so in the brain, the spinal cord or the heart, the consequences can be severe and even catastrophic. Better understanding and prevention play a pivotal role in avoiding this kind of risk and mitigating the possible consequences.

In 2009, a group of 14 dedicated researchers started a project, called PHYPODE (PHYsioPathology Of Decompression), which was funded by the European Union under the Marie Curie Initial Training Networks initiative, and had the aim to investigate DCS beyond its pure physical processes.

Now, 4 years later, the project has come to its end. In order to present the research findings, the conference “The Science of Diving” was organized by DAN (Divers Alert Network Europe) at ISEK, in Brussels, Belgium, on December 20th 2014.

The scientists’ assumptions

Since some cases of DCS seem to occur undeserved and cannot be explained by tissue super-saturation only, it is assumed that the current decompression models, which are in use in contemporary dive computers, are not safe enough and need revision. Further, it is assumed that DCS is not a purely physical event but also a complex patho-physiological process influenced and/or triggered by several factors which can differ from person to person. This leads to the assumption that there is an individual risk for DCS in every diver. Thus, the development of more advanced, real-time dive technology will be the scope of future research in this field. The outcome would ideally be the creation of a “super dive computer” with a new algorithm and which is able of real-time monitoring of diver’s medical data (pre, during and post dive), making the future diver a sort of Bionic Diver.

The researchers’ presentations

A multifactorial approach was needed in order to better understand the many physiological factors and mechanisms. Any research in this field that helps increase the knowledge of the exact mechanisms and processes leading to DCS is a valuable step in promoting dive safety, which has always been part of DAN's mission. This is why DAN created the DSL (Diving Safety Laboratory) back in 1994, with the aim of collecting as much data as possible about real dives, including dive accidents. Under the guidance of Prof. A. Marroni, President of DAN Europe and one of the leading scientists involved in PHYPODE, those data have been analyzed with an epidemiological approach, to identify risk factors and their markers.

By 2014 the DSL database had collected 39.944 dives by 2.615 divers (2.176 men and 439 women, average age group 33-51 years).

The Doppler ultrasound technique was used to detect circulating bubble production. Scientists could therefore prove that bubbles are detected 30 to 75 minutes after surfacing but cease after 1.5 hour. It was

found that bubble production increased with age, but was not affected by gender.

New interesting findings dealing with **flying after diving** were also presented. In-flight echocardiography performed on divers returning from a one-week dive trip showed that divers who normally produce high-grade bubbles after their dives may need to wait more (36 – 48 hours instead of only 24 hours) after their last dive, before boarding a commercial flight.

Regarding other diving-related risks, there are good news for **diabetic divers**. In fact, the development of new technologies has recently made possible the continuous monitoring of blood glucose (BG) whilst underwater. Testing was conducted by means of waterproof monitors, with sensors placed underneath the wetsuit.

Research on **breath-hold induced Pulmonary Edema** also brought some insights on a genetic predisposition that might also facilitate DCS in scuba divers. According to several recent studies, certain genotypes producing an enzyme called e-NOS and containing glutamic acid instead of aspartic acid, lead to higher production of nitric oxide (NO), and this may have a protective effect against DCS.

We known a lot about **bubbles** in general, however their precise formation mechanism has remained rather obscure until very recently. C. Balestra, full-time Professor and Head of the Integrative Physiology Lab at the Haute-Ecole Paul Henri Spaak, Brussels, Belgium, conducted research on bubble formation in hyperbaric decompression, i.e. the formation of nitrogen gas bubbles in a scuba diver's vascular system after scuba diving, and the related interactive processes of physics and physiology.
In order to make bubble growth and density visible and explore the precise formation mechanism, Balestra used an experimental set-up for optical recording. He then looked at two different types of tissue surfaces, hydrophilic versus hydrophobic, i.e. muscle versus fat tissue, and found significantly more bubbles on fat tissue (hydrophobic) than on muscle tissue (hydrophilic). This was believed to depend on so-called hydrophobic nucleic spots on which bubbles can form. Age seems to have an influence on increasing the number of these hydrophobic spots in the human vascular system, which may explain the age-related higher risk for DCS, but also the higher risk for diseases like Alzheimer's, celiac disease, allergies, diabetes, and cancer. Hydrophobic spots on the inner layer of vessels, where a gas phase can build, are therefore of far-reaching interdisciplinary importance and the findings of this research may benefit not only divers.

Peter Germonpré (Medical Director, Centre for Hyperbaric Oxygen Therapy of Military Hospital Brussels, Belgium), stressed the importance of the so-called **Preconditioning**, interventions every diver can do to lower the risk of DCS. In general, it is assumed that there are two possible bubble-reducing mechanisms: a biochemical one, i.e. influencing the oxidative inflammation reaction induced by the presence of decompression bubbles in the body, and a mechanical one, i.e. decreasing the number of bubble "seeds" in blood vessels. In order to reduce bubbles, recommended interventions before diving are: exercise, heat, hydration, breathing oxygen, vibration, and the consumption of anti-oxidant foods.
Venous or vascular gas embolism (**VGE**) has long been seen as a cause, and a marker, for DCS. The more bubbles in the blood, the more likely it is to develop decompression symptoms. As learned before, bubbles build on hydrophobic nucleic spots on the surface of blood vessels. Consequentially, keeping one's own vascular system in good quality and oneself in good shape can lower the risk for DCS.

Basically, **exercising** will increase ventilation and shake off bubbles. Heat stress will produce Heat Protection Proteins which may prevent bubble formation, sufficient **hydration** has a known preventive effect, but hydration needs to be done long before the dive so the water can reach the body tissues. Drinking a lot of water immediately before a dive will not help; it will just increase the liquid volume in the vessels, leading to sudden loss of liquid volume during the dive, thus increasing the risk of DCS. Whole-

body, pre-dive external mechanical **vibration** will decrease the risk of DCS, possibly by shaking off pre-existing microbubbles. This is why some dive operators often choose to go on a fast boat ride while heading to the dive sites. Nonetheless, the lymphatic system also has an important role in eliminating the bubble forming micronuclei by lymphatic drainage, and this too is enhanced by pre-dive vibration. And last but not least, breathing 100% **oxygen** prior to diving is an effective way of getting the nitrogen out of the system.

As seen, mild exercise before diving has a known protective effect but **heavy exercise** in combination with diving is considered to be a major risk factor in developing DCS due to its inflammatory effect on blood vessels. The effect of different intensities of exercise before, after and between dives were investigated by Z. Dujic from the School of Medicine, University of Split, Croatia.
Exercise after diving can provoke arterialization – the opening of apertures, facilitating passage of bubbles, from venous blood into arterial blood – a phenomenon also called shunting or shunts, which is associated with an increased relative risk of DCS. Arterialization is individually different. In some, the simple task of surface swimming or carrying equipment after a dive may be intense enough to cross the arterialization threshold.
It was found that arterialization during exercise is preventable by breathing 100% O2. O2 is a vasoconstrictor and can close shunts. This may as well explain the mechanism responsible for the positive outcomes associated with O2-breathing as a first aid treatment for DCS.
In two comparative studies, pre-dive aerobic running and anaerobic cycling had a protective effect and reduced microparticles (i.e. the seeds for bubble formation). However, exercise after diving showed open shunts and therefore arterialization in 50%. In conclusion, divers who are “high-grade bubblers” and “easy shunters” are at a very high risk for DCS.

Other interesting research findings, such as the role played by the vascular endothelium in DCS, oxygen toxicity, and the concept of the "Bionic Diver", will be presented in the second part of the article, to be published in the next Alert Diver issue.

Featured publication

“The Science of Diving, Things your instructor never told you”

Published by Lambert Academic Publishing, it can be purchased online here, or can be ordered via any bookstore using ISBN number 978-3-659-66233-1. The book is sold at 49.90 €, and all royalties from the sales are donated to EUBS, to promote further diving medicine research.

Educational Resources: a DAN Membership Benefit
DAN Members regularly receive information about and are invited to interesting conferences, seminars and events focusing on diving safety. Discounts on the entrance fee or free participation in such events is just one of the several DAN Membership benefits.
To keep you up to date with events similar to the PHYPODE conference, please register on the DAN Europe website. You will regularly receive our newsletters, and valuable information about first-aid training opportunities, dive insurance plans, online webinars, and much more.