Customized Decompression : O'Dive TEK
Sensor Presentation (Air/Nitrox/Trimix)

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1. O'Dive technological innovation: the missing link in decompression

Azoth Systems has developed an innovation that - for the first time in the world – allows scuba divers to personalise their diving practice by taking into consideration gas microbubbles detected in their venous system after diving.

O'Dive Connected Doppler Technology

This innovation is the result of knowledge developed over 10 years of research and development by Azoth Systems in collaboration with research laboratories, diving doctors, physiologists and safety professionals in scuba diving.

In total, about thirty experts from various backgrounds contributed to this knowledge. It is based on the analysis of hundreds of thousands of dives and the development of a technology shaped by years of user testing.
This momentum has given rise to 4 research theses[1][2][3][4], numerous scientific articles and several patents.

What does the O'Dive innovation bring to scuba diving and in particular to Tek diving?
A tool that allows divers to know themselves better, to measure the quality of their practice and to improve their safety.

This article presents the basis and approach behind this innovation; it specifies its benefits, limitations and opens up horizons.

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[1] **Vers une modélisation biophysique de la décompression** J. Hugon (2010) - Thèse de doctorat. Université de la Méditerranée, UMR - Physiologie et Physiopathologie en Conditions d'Oxygénation Extrêmes - Institut de Neuroscience J. Roche, Faculté de Médecine Nord, Marseille.

[2] **Détection et caractérisation d'embolies gazeuses ; application à la prévention des accidents de décompression** D. Fouan (2013) - Thèse de doctorat. Université Aix-Marseille, ED 353, 25nov. 2013.

[3] **Détection et localisation de microbulles par méthodes ultrasonores** Y. Desailly (2016) - Thèse de doctorat. Université de Paris Diderot - Paris VII.

[4] **Caractérisation de la diversité d'une population à partir des mesures quantifiées d'un modèle non-linéaire. Application à la plongée sous-marine.** Y Bennani (2015) - Thèse de doctorat. ED STIC Nice - I3S Sophia-Antipolis

2. The context: the limits of decompression tables and models; the occurrence of decompression sickness (DCS) despite the respect of decompression procedures

Decompression sickness is the leading cause of diving accidents (sources: FFESSM annual reports, DAN annual reports) in general, before immersion pulmonary oedema and barotrauma.

Most of these accidents (about 80%) occur when diving procedures are followed, i.e. the diver followed instructions provided by their computer properly.

This situation, which is well known to experienced divers, shows that all the diving procedures (stop lengths, ascent rate, gas inhaled) are not necessarily suitable for all types of divers.

Therefore, divers must consider the relevance of the procedure they use. So, given the number of possible settings of decompression algorithms, it must be noted that the diver has no tangible criteria - other than the possible occurrence of DCS that we wish to avoid - to assess the level of suitability of tables to his own body.

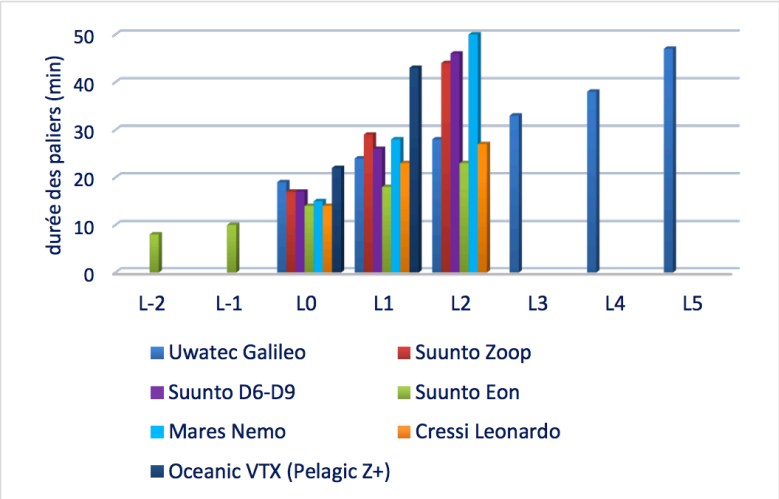


Illustration of the decompression stops duration for a 30'/30m dive for seven computer models, in accordance with the conservatism levels
(Source : thesis for the national instructor title – S. Le Maout, 2015)

The table above illustrates the fact that for an identical dive of 30 minutes at 30 meters with air - and based on the same level of conservatism at "0" on his computer, the diver will be offered 12 to 21 minutes of decompression stops, depending on the computer model. Note that this is a minimum range. In practice, divers may be offered 8 to 50 minutes of stops if the full range of conservatism levels available is taken into consideration (conservatism levels at -2 to +5).

For the Tek diver, this dispersion is even more pronounced. Indeed, most Tek computer models use a Bühlmann decompression algorithm (ZHL-16) that offers even finer and wider setting possibilities (Gradient Factors or GF).

In this context, O'Dive's interest is to provide divers with a criterion for assessing the quality of their practice, thus giving them the possibility to better control it.

3. O'Dive's underlying approach: understanding the risk of DCS for a better prevention

As a reminder, in the context presented above, the occurrence of a DCS does not correspond to a deterministic approach, i.e. "such a cause leads to DCS and that cause can be precisely identified".

As a matter of fact, if the formation of one or more bubbles is the first cause of DCS, there are mechanisms within our body that, most of the time, help eliminate these bubbles without damage.

Causes that may lead to the production of bubbles in an organism, unable to be eliminated therefrom - resulting in DCS - are difficult to identify; they are often not quantifiable, most are interdependent and most of them - especially those occurring at a microscopic level – remain unknown.

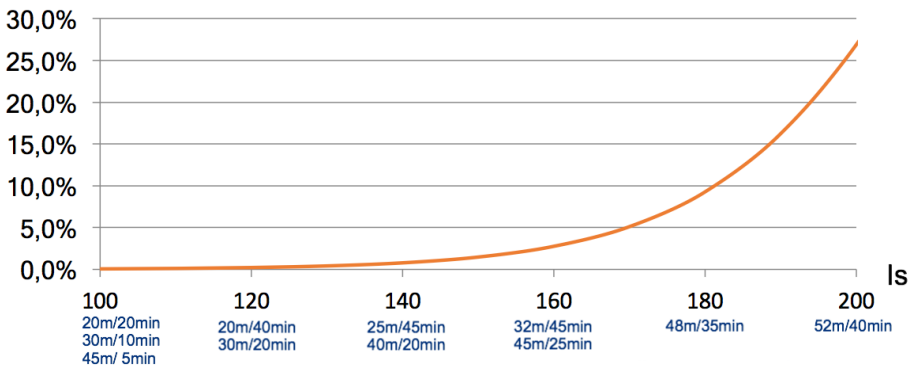
To answer the question of DCS risk prediction, modern scientific techniques use a probabilistic approach involving mathematical models that use parameters which contribute to risk - or at least correlate with risk - and can be measured.

Azoth Systems has developed a series of predictive models called BORA[5] (for Bubble Occurrence - Risk Attrition) to report results observed in multiple databases. The parameters of hundreds of thousands of dives (air, nitrox, trimix, open-circuit and closed-circuit heliox), the bubble dynamics (Doppler measurements) of several thousand of these dives and the hundreds of accidents they led to, have been studied to calibrate these models.

What main results does this data bring to light?

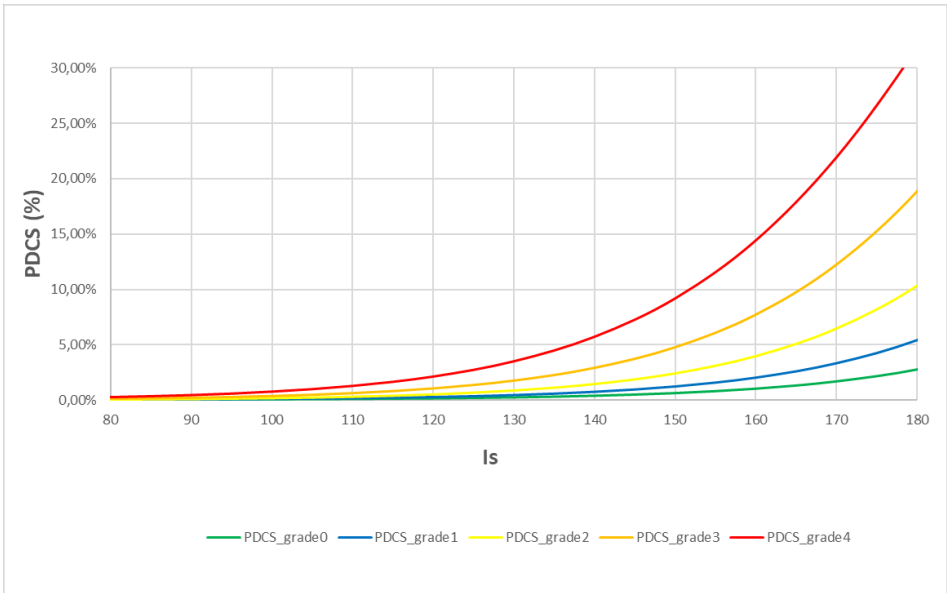
- They corroborate first of all previously acquired results and make it possible to better define their contours. For air diving, risk increases with the depth and duration of the dive and decreases when the total decompression time (stops) increases according to a severity index SI represented by the graph below.

[5] **Decompression models: review, relevance and validation capabilities** Hugon J. (Vol 41, No 6) Undersea Hyperb. Med. (2014)



DCS Probabilty law (Air dive) according to a severity index SI considering the depth, the diving duration and the global decompression duration

- They also show that the level of vascular microbubbles observed after diving is an important information for risk prediction and for all types of dives previously mentioned. In this case, the presence of microbubbles acts as an amplifier of the risk associated with the severity of the dive.



DCS probability law according to the severity index (SI)
for 5 microbubbles production levels after the dive

On average, an air dive conducted beyond the safety curve that generates no or a few vascular microbubbles (grade 0-1) is ten times less risky than the same dive when it generates many bubbles (grade 4)[6].

- For mixed diving, risk follows a pattern similar to that of air/nitrox diving, with the difference that the severity index (SI) - and therefore the risk - decreases as the helium fraction in the mixture increases.

[6] **Reliability of venous gas embolism detection in the subclavian area for deco. stress assessment following scuba diving** Hugon, Metelkina, Barbaud, Nishi, Bouak, Gempp, Blatteau - Diving and Hyperb. Medicine Journal, Vol. 48 No. 3 Sept. 2018

4. How does the O'Dive application operate? What information is provided to divers?

After each dive followed by a microbubble measurement and based on the dive parameters entered in the application, O'Dive provides divers with an information on the quality of their practice. This indication is expressed by means of a quality index QI with a value lying between 0 and 100%.

How is the quality index QI calculated?

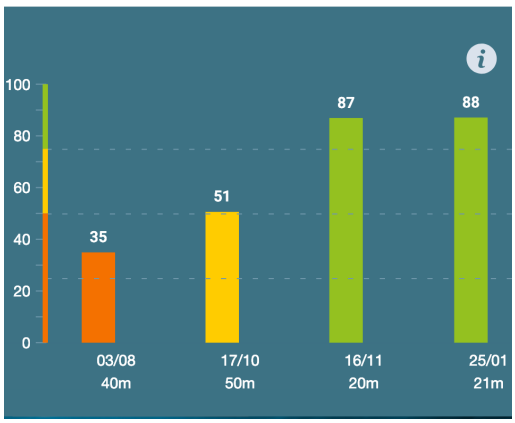
The QI takes into account on one hand, the severity SI of the dive performed by the diver (SI reflects physiological stress related to diving parameters) and, on the other hand, the level of microbubbles measured after the dive using the vascular Doppler sensor.

For mixed diving, the severity index SI is calculated based on the exact diving profile, the percentages of gases inhaled during the dive and the settings of oxygen partial pressure8 (closed circuit diving).

The 100% value corresponds to a reference level. It is indicative of the level of physiological stress experienced by a diver's body during an air dive carried out on the no-decompression limit, when it does not generate any vascular microbubbles.

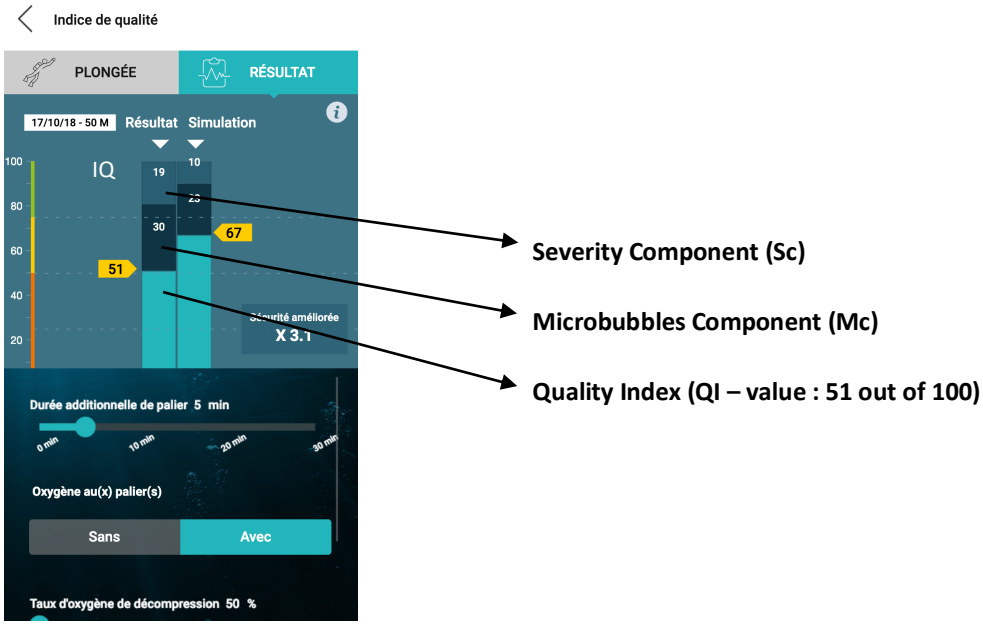
75% à 100%	Good quality procedure, where optimisation is still possible
50% à 75%	Intermediate quality procedure, with significant room for improvement
0 à 50%	Procedure and/or practice (recommended) to be improved

Thus, when the QI decreases, the risk of developing a DCS increases. 3 zones have been identified to guide the user:



Quality Index (QI) determined for four dives (40 m, 50m, 20m and 21m)

When the quality index does not reach 100%, the diver can access detailed information that specifies which part of this result is attributable to the severity of the dive (parameters) and which additional part is potentially attributable to the level of detected vascular microbubbles.



The decompression optimisation margin (i.e. the complement of the QI to 100%) can be visualised according to two components: the severity of the dive profile and the production of vascular microbubbles.

For Tek diving, the severity component (Sc) also takes into account the fraction of helium contained in the gas (display not shown here).

5. What other feature does O'Dive ONE offer?

Giving divers the opportunity to better know themselves, to assess the quality level of their practice individually after each dive and to observe its evolution over time are the first innovative features of the O'Dive system.

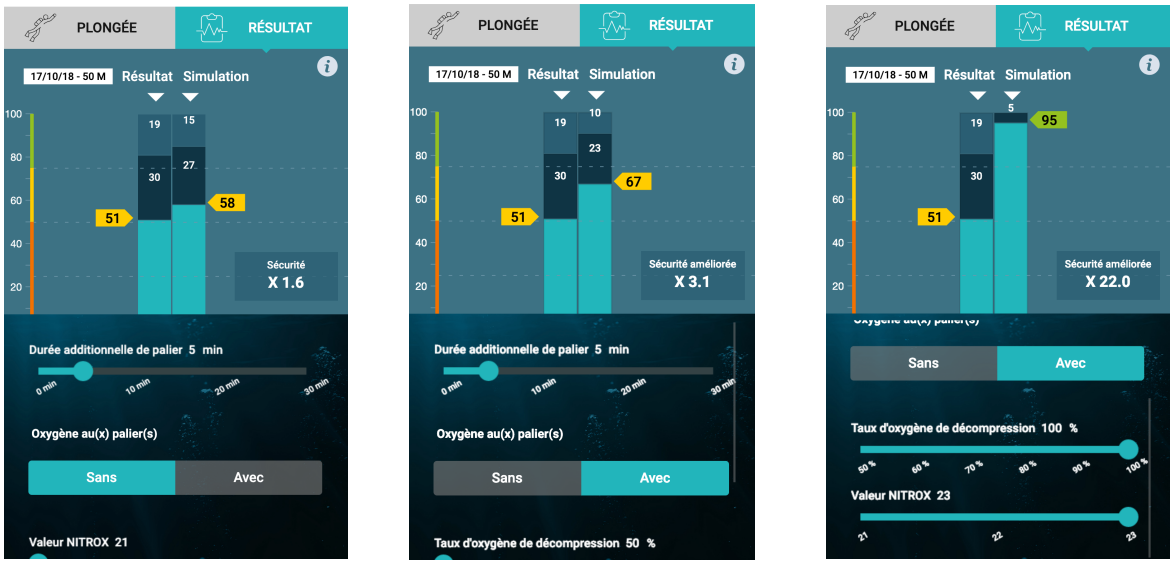
Beyond dynamic results obtained after each dive, it is also the possibility of visualising the respective effect of different options on diving technique that is of interest.

By means of a simulation entirely unique to divers, they can thus quantify the added value of the following options (alone or combined):

- Open-circuit air diving:
    - extend the duration of the last stop;
    - breathe a nitrox richer in oxygen;
    - nitrox diving;
    - modify the gradient factors GF.
- Additional option for Trimix open-circuit diving: change the bottom mixture.

- Other options for Trimix closed-circuit diving, including the specific case of an air diluent: change its diluent and modify the partial pressure of oxygen at stops.

Dive after dive, a customised model that is specific to each diver is refined to reflect as accurately as possible the added value of each of the above options on his safety.
In this case, the quality index QI has been designed in such a way that when it increases by 33%, the diver's safety level is multiplied by 10.



Individual simulation options presenting the relative safety gain for the diver

6. What are the limits of the information provided by the system?

It is important to clearly define the area of application of the product, which, it should be noted, does not fall within the category of medical devices. Some information, such as medical information, is voluntarily not considered by the system.

The consideration of medical information or observations that are part of the regulatory visit process remains essential and must be separated from the use of the product.

The objective of the O'Dive system is, it should be reminded, to assess the quality level of a practice with regard to a quality index QI that considers:

- the severity index SI of the dives carried out, a risk factor directly related to diving parameters;
- the level of vascular microbubbles detected after diving, which is similar to a risk amplification factor.

Studies carried out using some of the best documented databases (see article in note 6) illustrate the relevance and meaning of this approach to DCS prevention[7].

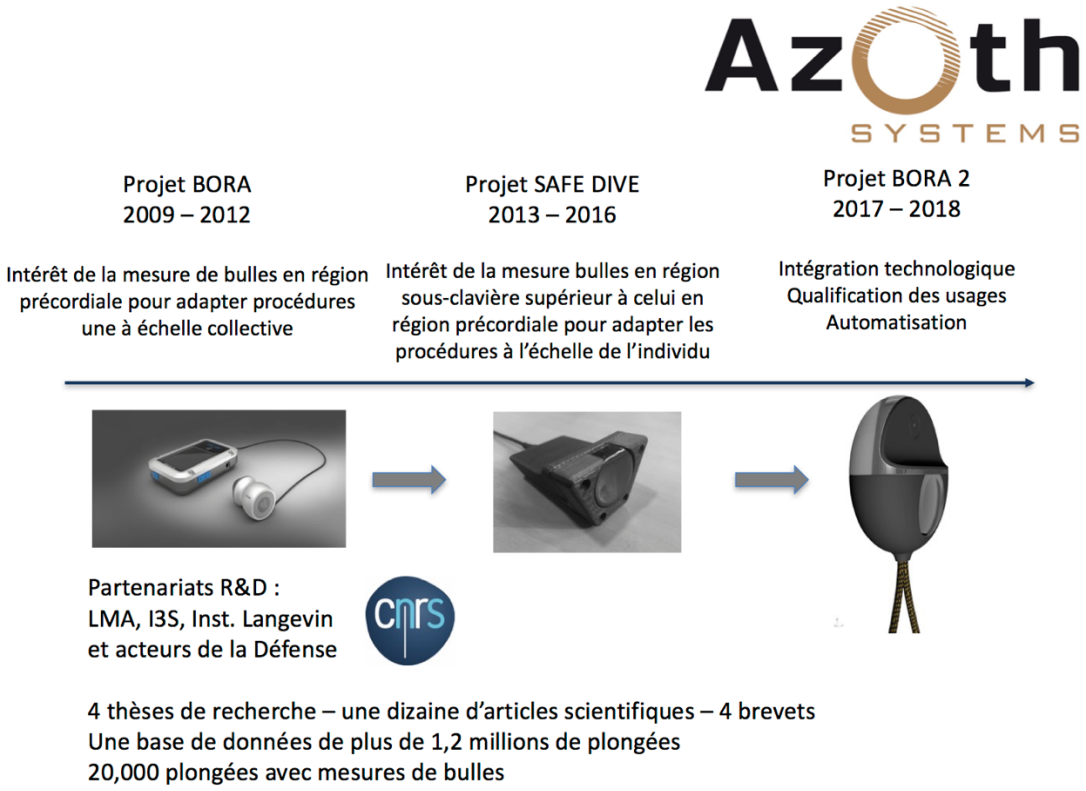
O'Dive is therefore a very useful tool, allowing divers to get to know themselves better and to improve their practice with regards to the risk of decompression sickness.

If, for example, a diver suspects or knows of the presence of a PFO or any other risk factor, he or she will have a strong interest in a diving practice that tends to minimise microbubble production and the O'Dive system will help him or her to do so.

If, on the other hand, he or she is not subject to any known risk factor, minimising his or her bubble production will give him or her an increased margin of safety.

7. A technology resulting from research and development and shaped by the field

O'Dive technology is the result of a multidisciplinary research and development program; it has undergone many stages of maturation before reaching the current level of performance; it is the subject of several patents.



[7] An unpublished part of the logic behind the O'Dive TEK application is the result of several decades of experience in international professional diving (including COMEX).

Conclusion & perspectives

O'Dive is an innovation that opens up entirely new perspectives for divers.

Being aware of the quality level of their diving practice, measuring the suitability of diving procedures to their person in terms of their own production of vascular microbubbles and calculating, from a personal model, the safety contribution of different practice options are all new possibilities the diver can now have access to through the O'Dive system.

O'Dive is the missing link for dive computers to take the step of personalised decompression and several leading brands are now working with Azoth Systems to further enhance user experience.

With this tool and the new insights, it already provides, the primary ambition of Azoth Systems is to significantly reduce the occurence of decompression sickness in the coming years.

Références scientifiques et techniques d'Azoth Systems

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