# DOs and DON'Ts:

## *Defining Medical Fitness to Dive*

### DAN Addresses Diving and Cardiopulmonary Conditions

***If a diver has a medical condition that might affect his or her ability to dive safely, he/she must have a clear understanding of the specific limitations.***


Leslie Brix Photo

In an earlier article of this series*, we discussed the regulatory environment for establishing dive fitness as well as its evaluation process. Regulatory authorities can vary from region to region globally. For example, both commercial and recreational diving in the United Kingdom and Australia require specific medical clearance examinations. However, neither is officially regulated in the United States by an overseeing authority and the same is true in many other countries, especially developing countries, around the world.

Because of this lack of regulation in most places, the burden of responsibility for dive fitness rests with the diver. When divers consult physicians about their diving fitness, the evaluating physician should consider fitness requirements in the context of the dives each particular diver is planning.

A technical dive, for example, would be riskier and more challenging, both mentally and physically. It would also demand a different standard of physical as well as intellectual fitness. The spectrum of dive certifications, from novice to technical levels, as well as each individual's current health exemplify how fitness requirements should be tailored to the type of diving planned.

Any fitness-to-dive evaluation should have both an educational and evaluative function. The encounter should serve to inform and assist prospective candidates to become aware of potential health-related dive safety issues.

If a dive candidate has a medical condition that might affect his ability to successfully put into practice what he has learned during training, then he must understand his specific limitations in greater detail. This is important for divers with chronic diseases such as asthma, diabetes or cardiac conditions because they need to self-monitor to make an appropriate "go" or "no-go" decision for each dive.

Conditions like these can limit exertion and place divers at an increased risk of drowning. Cardiopulmonary disorders lead this category. This article discusses cardiovascular and pulmonary disease and additional medical issues that might be problematic in an evaluation of one's fitness to dive.

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As with all chronic diseases, dive physicians should assess to what degree heart or lung disease affects individuals' daily lives as well as their maturity and understanding of their particular condition. Physicians should then offer insight into the specific diseases of their patients, explaining the possible consequences of a diving accident.

## Cardiovascular disease

Many medical problems experienced during a dive are less related to the specific demands of the dive setting than to a diver's pre-existing medical condition. Cardiac problems illustrate the point.

We see cardiac complications in many diving deaths reported to DAN. Why is this happening? It is no doubt related to the fact that the average age of the diving population is now 43 years. Many divers continue to dive into their 70s and 80s, thereby establishing a slightly higher-than-normal risk of cardiovascular disease than that experienced in the general population.[1]

## Exertion requirements

Although routine recreational dives are not particularly strenuous, exercise requirements vary depending on the dive site, currents and expected sea conditions. Diving in rough seas or a current imposes a necessary exercise demand on the cardiovascular system. The energy required to swim against a current increases significantly. If the current speed doubles, the energy required to swim against it increases 4 times. A 1.8-knot current approaches the maximum speed even fit swimmers can swim against.[2]

Physiologists often measure an individual's maximal oxygen consumption, or aerobic capacity - abbreviated as $VO_2$ max - to describe peak exercise capacity. $VO_2$ max is defined as the maximum amount of oxygen in millilitres one can use in one minute per kilogram of body weight. Additionally, $VO_2$ max correlates with peak exertion, not endurance. According to diving cardiologist Dr. Fred Bove, a diver with a maximum oxygen consumption of 40 ml/kg/minute can tolerate swimming against a 1.3-knot current for only a few minutes.

At high workloads, such as those approaching 65 percent of a person's $VO_2$ max, an individual experiences fatigue accompanied by severe shortness of breath. This finding, Bove says, explains why currents greater than 0.8 knots are associated with an increased risk of panic and drowning,[3] further illustrating the wisdom of matching the requirements of your dive to your personal fitness level. This is particularly important for individuals with limited exercise capacity and those who have cardiovascular disease.

### *Can you dive after a heart attack?*

The answer is not a simple yes or no. Most dive physicians agree that many individuals can resume diving after a heart attack if they keep the demands of their exertion within reason. Although there are no accepted U.S. recommendations, most diving physicians recommend an 'exercise stress test'. Exercise stress testing will help determine whether an imbalance exists between the supply

of oxygen to the heart and the demands of the anticipated workloads.

METs, also known as metabolic equivalents, are defined as the ratio of a person's working metabolic rate relative to the resting metabolic rate. Measuring METs is another way of expressing exercise workload; 1 MET corresponds to an adult's assumed resting metabolic rate of about 3.5 ml of oxygen per minute per kilogram of body weight.

Bove states that most diving in warm water requires activity in the range of 3 to 5 METs with occasional excursions to 7 METs. He recommends that divers who plan to conduct "difficult dives" be able to tolerate a level of 40 ml/kg/minute, or about 13 METs as the lower limit for divers.[3] Treadmill testing can easily provide that information. "Less difficult dives," or dives with fewer physical demands, are evaluated accordingly.

## Diving after cardiac surgical procedures

*But what about divers who have undergone heart surgery or those who have had angioplasty or another type of revascularization or blood vessel repair surgery? Can they dive?*

Recommendations vary globally. Although there are no universally accepted rules in the United States for returning to diving after heart surgery, rules in the United Kingdom stipulate that if a bypass grafting or angioplasty is required, a previously trained diver may return to diving, but training of a new diver should not begin. *DAN advises any beginning diver with any degree of heart disease to consult a cardiologist before begining dive training*. (Ed's note: It is preferable that the cardiologist has knowledge of diving and an understanding of the stressors of the diving environment.) If the diver, personal physician or specialist needs additional information, the DAN office can be contacted during office hours. (Such a call should not be made to the emergency hotline).

## Other cardiac stressors

In addition to the expected demands exercise places on the heart, diving can also stress the cardiovascular system simply through immersion: This increases the volume of blood that returns to the right side of the heart by supporting the usually gravitationally-dependent blood vessels of the lower extremities and abdomen. This results in a blood volume shift to the thorax and heart, increasing central blood volume by about 700 ml.[4] Such a volume increase may be dangerous in people who have medical conditions that require them to carefully control their fluid intake. This applies particularly to persons with a history of congestive heart failure or renal disease.

In addition to immersion, cold water can make matters worse by causing blood vessels in the skin, legs and arms to contract; this peripheral vasoconstriction significantly increases the resistance against which the heart must pump.

Finally, the elevated gas density at depth increases the work of breathing. In some circumstances, these phenomena may combine to cause unexpected cardiopulmonary complications, such as acute shortness of breath or immersion pulmonary oedema, even in otherwise healthy divers who do not have a history of cardiac disease.

Of course, other vascular problems such as hypertension, may increase these problems, although in most routine diving circumstances hypertension is not a problem as long as it is under control and the medications do not overly limit exercise capability. (Ed's note: some anti-hypertension medications, such as beta blockers, have been implicated in certain diving accidents and many dive physicians prefer to recommend alternatives.)

## Patent foramen ovale

It has been known for some time that in retrospect, case control studies indicate that a patent foramen ovale, an interatrial defect in the heart, is associated with decompression illness (DCI), particularly the neurological variety.[5, 6]

Case control studies do not imply a direct cause and effect, however, and although the increase in relative risk is technically statistically significant, the increase in absolute risk is likely trivial. In other words, a twofold increase in a small risk is not as meaningful as a twofold increase in a larger risk. The U.S. Navy, NASA and commercial diving companies do not routinely test their divers or astronauts for PFO: What to do about divers with PFOs remains a controversial topic nonetheless.

Rules in the United Kingdom suggest that right-to-left shunts, such as PFO, be tested to determine whether an unexpected neurological bend has occurred. If a PFO is discovered, dive physicians usually recommend the diver maintain depth limits of 15 metres and consider surgery to close the opening.

There may be good reasons to surgically correct a PFO in non-diving individuals, but there is controversy about the advisability of surgically closing PFOs to prevent DCI in divers. This author opposes the practice for the following reasons:

1. The risk of contracting DCI, even in divers with PFO, is much smaller than the risk of surgical complications.

2. While the severity of almost all DCI in recreational divers is extremely mild, surgical complications associated with operating on the heart can be severe.

3. There is no convincing evidence that closing a PFO will prevent DCI. Many people without PFOs still experience decompression illness.

4. The service half-life and the long-term durability of the patch material used to close the PFO are unknown.

In a young person, it will need to last many years without breaking down; the track record is not yet established. This is a question that will require additional careful study.

### Pacemakers and other cardiac equipment

If they are used within the manufacturer's operating depths, pacemakers may be acceptable for diving. There are depth limits to observe, however.

A team of doctors recently reported on testing of cardiac pacemakers, carried out independently of the manufacturers, to depths of up to 60 metres. None of the devices failed electrically at the tested depths, but more than half of the containers were deformed at the 60-metre mark. No containers were deformed at depths of 30 metres; this falls in line with most recommended depths for these devices.[7]

Diving with an automated implantable defibrillator is not recommended. These devices are used on individuals whose underlying condition put them at risk for recurrent, sustained ventricular tachycardia or fibrillation, both possible life-threatening conditions. Such conditions can cause loss of consciousness, never a safe prospect in diving.

Although prosthetic heart valves are not in themselves a contraindication for diving, the chronic anticoagulation (blood thinners) required for mechanical valves rules them out. A diver who has been prescribed an anticoagulant, e.g., Coumadin[R] or warfarin, should be warned of the potential for bleeding: Excessive bleeding can occur from even a seemingly benign ear or sinus barotrauma.

In addition, there is a potential risk that, if decompression illness occurs, it may then cause significant bleeding in the brain or spinal cord. Finally, if bleeding occurs for any reason, the diver being treated with anticoagulants might experience greater than normal blood loss and simple, yet lifesaving, treatment may not be available because blood-banking facilities are usually not found in remote dive locations.

A more relevant consideration, however, is the underlying condition necessitating any cardiac device: Is it a contraindication in itself? This is a question best answered by a medical professional on hand.

## Pulmonary Disease

Pulmonary conditions such as asthma and chronic obstructive lung disease have a twofold risk: They can limit exertion, and they present a risk of barotrauma. However, respiratory limitations on exercise capacity may be more important than gas-trapping considerations. Here again, however, we see some global differences in recommendation.

### Asthma

For example, practitioners in the United Kingdom, United States and Australia approach asthma very differently. The U.K. recommend-ations are more liberal: They allow diving by individuals treated for asthma as long as they are asymptomatic.

By contrast, Australia recommends a more extensive workup with pulmonary function tests, including a saline or methacholine challenge, medical tests used to assist in the diagnosis of asthma.*

The U.S. recommendations vary within these test limits. At Duke University, we recommend that one meets the following criteria:

1. no current symptoms attributable to asthma;
2. a normal physical exam without active wheezing;
3. normal spirometry before and after provocative exercise testing.

Because asthma is a heterogeneous disease - that is, it has a great variety of dissimilar constituent triggers - the decision about whether to dive must be made on a case-by-case basis.

### The many faces of pneumothorax

Pneumothorax, or collapsed lung, appears in several forms. A simple pneumothorax usually occurs with only partial collapse of a lung; the pressure buildup in the lung cavity is not sufficient for cardiovascular complications. Individuals with a simple pneumothorax may not have noticeable signs and symptoms.

If a diver experiences a spontaneous pneumothorax, on the other hand, this is considered a medical emergency and a contraindication to scuba diving. A recent study showed that individuals with a previous spontaneous pneumothorax had a 19 percent chance of recurring within one year.[8] Spontaneous pneumothorax can occur without any trauma to the chest. Or it can be caused when a bleb, an imperfection in the lining of the lung, bursts and causes the lung to deflate. Other causes for this condition include these diseases:

- chronic obstructive pulmonary disorder
- tuberculosis
- pneumonia
- asthma
- cystic fibrosis
- lung cancer
- interstitial lung disease
- Marfan syndrome
- lymphangioleiomyomatosis

Blebs (or bullae) are abnormal balloon- or blisterlike extensions of air sacs in the lungs. They are responsible for the most common lung condition that predisposes an individual to pulmonary barotrauma. Scientists believe these sacs are caused by degradation of elastic fibers in the lung due to inflammation.

Blebs are most frequently found in smokers, but they can also occur in non-smokers. Because these sacs are thin-walled and during exhalation tend to empty their air slowly, pressure can build up during ascent, and they may rupture. Dive physicians recommend specific testing for divers who have experienced pulmonary barotrauma before they return to scuba diving. The evaluation may include a set of breathing tests, a chest X-ray or computed tomography of the chest (CT or "CAT" scan).

A significant step beyond simple pneumothorax, tension pneumothorax is a life-threatening condition that prevents adequate exhalation to push the air back out into the pleural cavity. This condition can result in an accumulation of air that puts pressure on the mediastinum, compressing the heart and decreasing cardiac output. In addition, it can put enough pressure against the trachea to deviate it from the midline. The increased thoracic pressure can decrease venous return to the heart, causing a backup of blood into the venous system.

The grave possibility of developing a tension pneumothorax at depth prevents most dive physicians from recommending certification for individuals who have had a pulmonary barotrauma unless they have had medical or surgical treatment to reduce the probability of a recurrence.

Traumatic (iatrogenic) pneumothorax, a type of pneumothorax caused during the routine course of a surgical procedure, are not thought to have the same risk of recurrence as the spontaneous variety.

Restrictive lung disease, which results in decreased pulmonary elasticity, may also predispose someone to pneumothorax. It is associated with an increased work of breathing as well as the potential to trap gas, retention of carbon dioxide and collapsed lung. In addition, anecdotal reports suggest that restrictive lung disease may predispose someone to decompression illness.

The best treatment to prevent recurrence of pneumothorax is a topic of much discussion and will not be discussed here. Those with questions may contact the DAN office.

## Finally …

Although good health is important to safe diving, there's a little wiggle room with some conditions. Many conditions once thought to be incompatible with recreational diving are now considered generally acceptable, with some caveats: The diving must be performed with the proper preparation, the appropriate consultation with your diving physician, and the diver must, at all times, exercise caution.

Different diving environments require varying levels of individual fitness. The dedicated medical professionals at DAN are always happy to help you find the information - and medical help - you need.

*In either test, the patient breathes in nebulized methacholine or saline, which provokes narrowing of the airways. Airway constriction is detected when the patient performs spirometry, a pulmonary function test that measures lung function, specifically the volume and/or speed (flow) of air that can be inhaled and exhaled. People with asthma react to lower doses of inhaled methacholine or saline.

### About the Author

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