

# Decompression Illness:

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***D***ecompression illness, or DCI, is a term used to describe illness that results from a reduction in the ambient pressure surrounding a body. A good example is what happens to your body when you're surfacing after a dive.

DCI encompasses two diseases, decompression sickness (DCS) and arterial gas embolism (AGE). DCS is thought to result from bubbles growing in tissue and causing local damage, while AGE results from bubbles entering the lung circulation, traveling through the arteries and causing tissue damage at a distance by blocking blood flow at the small vessel level.

## **Who Gets DCI?**

Decompression illness affects scuba divers, aviators, astronauts and compressed-air workers. It occurs in approximately 1,000 U.S. scuba divers each year. Moreover, DCI hits randomly. The main risk factor for DCI is a reduction in ambient pressure, but there are other risk factors that will increase the chance of DCI occurring. These known risk factors are deep / long dives, cold water, hard exercise at depth, and rapid ascents.

Rapid ascents are closely linked to the risk of AGE. Other factors thought to increase the risk of DCI but for which evidence is not conclusive are obesity, dehydration, hard exercise immediately after surfacing, and pulmonary disease. In addition, there seem to be individual risk factors that have not yet been identified. This is why some divers seem to get DCI more frequently than others although they are following the same dive profile.

Since DCI is a random event, almost any dive profile can result in DCI, no matter how safe it seems. The reason is that the risk factors, both known and unknown, can influence the probability of DCI in myriad ways. Because of this, evaluation of a diver for possible decompression illness must be made on a case-by-case basis by evaluating the diver's signs and symptoms and not just based on the dive profile.

## **Decompression Sickness**

Decompression sickness (DCS, also called the bends or caisson disease) is the result of inadequate decompression following exposure to increased pressure. In some cases, the disease is mild and not an immediate threat. In other cases, serious injury does occur; when this happens, the quicker treatment begins, the better the chance for a full recovery.

During a dive, the body tissues absorb nitrogen from the breathing gas in proportion to the surrounding pressure. As long as the diver remains at pressure, the gas presents no problem. If the pressure is reduced too quickly, however, the nitrogen comes out of solution and forms bubbles in the tissues and bloodstream. This commonly occurs as a result of violating or approaching too closely the diving table limits, but it can also occur even when accepted guidelines have been followed.

Bubbles forming in or near joints are the presumed cause of the joint pain of a classical "bend." When high levels of bubbles occur, complex reactions can take place in the body, usually in the spinal cord or brain. Numbness, paralysis and disorders of higher cerebral function may result. If great amounts of decompression are missed and large numbers of bubbles enter the venous bloodstream, congestive symptoms in the lung and circulatory shock can then occur.

## **Symptoms of DCS**

- Unusual fatigue
- Skin itch
- Pain in joints and / or muscles of the arms, legs or torso
- Dizziness, vertigo, ringing in the ears
- Numbness, tingling and paralysis
- Shortness of breath

## Signs of DCS

- Skin may show a blotchy rash
- Paralysis, muscle weakness
- Difficulty urinating
- Confusion, personality changes, bizarre behavior
- Amnesia, tremors
- Staggering
- Coughing up bloody, frothy sputum
- Collapse or unconsciousness

**Note:** Symptoms and signs usually appear within 15 minutes to 12 hours after surfacing; but in severe cases, symptoms may appear before surfacing or immediately afterwards. Delayed occurrence of symptoms is rare, but it does occur, especially if air travel follows diving.

## Denial and Recognition

The most common manifestations of DCS are joint pain and numbness or tingling. Next most common are muscular weakness and inability to empty a full bladder. Severe DCS is easy to identify because the signs and symptoms are obvious. However, most DCS manifests subtly with a minor joint ache or a paresthesia (an abnormal sensation like burning, tingling or ticking) in an extremity.

In many cases these symptoms are ascribed to another cause such as overexertion, heavy lifting or even a tight wetsuit. This delays seeking help and is why it is often noted that the first symptom of DCS is denial. Sometimes these symptoms remain mild and go away by themselves, but many times they increase in severity until it is obvious to you that something is wrong and that you need help.

What happens if you don't seek treatment? In severe DCS, a permanent residual handicap may result: this can be a bladder dysfunction, sexual dysfunction or muscular weakness, to name a few.

In some cases of neurological DCS, there may be permanent damage to the spinal cord, which may or may not cause symptoms. However, this type of damage may decrease the likelihood of recovery from a subsequent bout of DCS.

Untreated joint pains that subside are thought to cause small areas of bone damage called *osteonecrosis*. Usually this will not cause symptoms unless there are many bouts of untreated DCS. If this happens, however, there may be enough damage to cause the bone to become brittle or for joints to collapse or become arthritic.

## Prevention of DCS

Recreational divers should dive conservatively, whether they are using dive tables or computers. Experienced divers often select a table depth (versus actual depth) of 3-4 meters deeper than called for by standard procedure. This practice is highly recommended for all divers, especially when diving in cold water or when diving under strenuous conditions. Computer divers should stay well inside no-decompression limits, especially when diving deeper than 30 metres.

Avoiding the risk factors noted above (deep / long dives, exercise at depth or after a dive) will decrease the chance of DCS occurring. Exposure to altitude or flying too soon after a dive can also increase the risk of decompression sickness. DAN has published updated guidelines for flying after diving.

## Arterial Gas Embolism

If a diver surfaces without exhaling, air trapped in the lungs expands with ascent and may rupture lung tissue - called *pulmonary barotrauma* - which releases gas bubbles into the arterial circulation. This distributes them to body tissues in proportion to the blood flow. Since the brain receives the highest proportion of blood flow, it is the main target organ where bubbles may interrupt circulation if they become lodged in small arteries.

This describes an *air embolism*, which is a form of *arterial gas embolism*, or AGE, considered the more serious form of DCI. In some cases, the diver may have made a panicked ascent, or he may have held his breath during ascent. However, AGE can occur even if ascent appeared completely normal, and pulmonary disease such as obstructive lung disease may increase the risk of AGE. Another form of arterial gas embolism can occur if venous bubbles pass through or bypass the lungs filters, as can happen if the diver has a *patent foramen ovale* (see Alert Diver SEAP, Oct-Dec 2003).

The most dramatic presentation of arterial gas embolism is the diver who surfaces unconscious and remains so, or the diver who loses consciousness within 10 minutes of surfacing. In these cases, a true medical emergency exists, and rapid evacuation to a treatment facility is paramount. On the other hand, arterial gas embolism may cause less spectacular symptoms of neurological dysfunction, such as sensations of tingling or numbness, a sensation of weakness without obvious paralysis, or complaints of difficulty in thinking without obvious confusion in individuals who are awake and easily aroused. In these cases, there is time for a more thorough evaluation by a diving medical specialist to rule out other causes of symptoms.

Like DCS, mild symptoms may be ascribed to causes other than the dive, which only delays treatment. Sometimes symptoms may resolve spontaneously and the diver will not seek treatment. The consequences of this are similar to untreated DCS:

residual damage to the brain may occur, making it more likely there will be residual symptoms after a future bout of AGE, even if the later bout is treated.

## Symptoms of AGE

- Dizziness
- Visual blurring
- Areas of decreased sensation
- Chest pain
- Disorientation

## Signs of AGE

- Bloody froth from mouth or nose
- Paralysis or weakness
- Convulsions
- Unconsciousness
- Cessation of breathing
- Death

Currently cerebral gas embolism is responsible for approximately 10 percent of all DCI cases annually (Ed: in DAN America statistics - it is similar in the Asia-Pacific Region). AGE has decreased significantly over the past decade, however, moving from 18 percent of all cases in the late 1980s and early 1990s to much lower numbers. By 1997, the fraction had fallen to 7-8 percent.

In 2001, AGE was still cited in 7-8 percent but by 2002 it had fallen to 6.6 percent of the total diving population reporting DCI. It has been speculated that one of the reasons for this decrease is the advent of dive computers, which help chart the rate of ascent, thus reminding divers to slow down.

## **Prevention of AGE**

Always relax and breathe normally during ascent. Lung conditions such as asthma, infections, cysts, tumors, scar tissue from surgery or obstructive lung disease may predispose a diver to air embolism. If you have any of these conditions, it warrants an evaluation by a physician knowledgeable in diving medicine.

## **Treatment - Call DAN!**

The treatment for DCI is recompression. However, the early management of arterial gas embolism and decompression sickness is the same. Although a diver with severe DCS or an gas embolism requires urgent recompression for definitive treatment, it is essential that he be stabilized at the nearest medical facility before transportation to a chamber.

Early oxygen first aid is important and may reduce symptoms substantially, but this should not change the treatment plan. Symptoms of decompression illness (ie. either arterial gas embolism and decompression sickness) often clear after initial oxygen breathing, but they may reappear later. Because of this, always contact DAN or a dive physician in cases of suspected DCI - even if the symptoms and signs appear to have resolved.

Treatment involves compression to a treatment depth, usually 18m, and breathing high oxygen fraction gases at an oxygen partial pressure of between 2.8 ata (atmospheres) and 3.0 ata. Delays in seeking treatment have a higher risk of residual symptoms; over time, the initially reversible damage may become permanent. After a delay of 24 hours or more, treatment may become ineffective and symptoms may not respond to treatment. Even if there has been a delay, however, consult a diving medical specialist before drawing any conclusions about possible treatment effectiveness.

In some cases, there may be residual symptoms after a treatment. Soreness in and around a joint that was affected by DCI is common and usually resolves in a few hours. If the DCI was severe, significant residual neurological dysfunction may be present, even after the most aggressive treatment. In these cases, there may be follow-up treatments, along with physical therapy. The good news is that the usual outcome is eventual complete relief from all symptoms, provided treatment was begun promptly.

## **Care Of The Diver With Decompression Illness**

### ***I. Determine the Urgency of the Injury***

Make an initial evaluation at the dive site. Suspect decompression illness if any of the signs or symptoms previously described occur within 24 hours of surfacing from a dive. The initial state of the affected diver will determine the order and urgency of the actions taken. Based on a classification used by the U.S. Navy, the diver can be placed in one of three case categories:

- emergency
- urgent
- timely

### **Category A - Emergency Cases Of DCI**

Symptoms are severe and appear rapidly, within an hour or so of surfacing. Unconsciousness may occur. Symptoms may be progressing and the diver is obviously ill. The diver may be profoundly dizzy, have trouble breathing or have major abnormalities in consciousness. Obvious neurological injury is seen in altered consciousness, abnormal gait or weakness.

These divers are obviously very sick, and a true medical emergency exists. If necessary (e.g. if the diver is unconscious), begin resuscitation as necessary and take immediate action to have the diver evacuated. Check for foreign bodies in the airway. If ventilatory or cardiac resuscitation is required, the injured diver must be

supine (lying on the back). Vomiting in this position, however, is extremely dangerous; if it occurs, quickly turn the diver to the side until the airway is cleared and resuscitation can resume in the supine position.

*If available, use supplemental oxygen while administering breaths to increase the percentage of oxygen received by the injured diver. Even if CPR is successful and the diver regains consciousness, 100 percent oxygen should be provided and continued until the diver arrives at a medical facility.*

### **If Trained Healthcare Personnel Are Available . . .**

... then an intravenous (IV) infusion using isotonic fluids without dextrose should be started. An initial rapid infusion of 1 litre over 30 minutes should begin to correct any dehydration and reduce haemoconcentration. Once this is accomplished, then the rate of administration should be reduced to a 100-175 cc / hour maintenance rate.

Additional 1-litre boluses may be required to further correct dehydration and maintain blood pressure but should only be given by trained healthcare personnel capable of weighing the need for further fluid with possible complications. These would include fluid overload problems and discomfort from urinary retention in divers with abnormal bladder function due to spinal cord decompression sickness. If trained personnel are available, a urinary catheter should be placed in all unconscious divers and in those who cannot urinate.

### **Call a DAN-supported Hotline**

After stabilization and arrangements for evacuation, contact a DAN-supported diving emergency hotline for advice on the nearest chamber location. DAN medical experts can get in touch with the receiving facility to assist in diagnosis and, if necessary, treatment. Do this even if the diver appears to be improving on oxygen. While awaiting evacuation, take as detailed a history as possible and try to evaluate and record the diver's neurological status. These facts are useful to the receiving medical facility. If air evacuation is used, cabin pressure should be maintained near sea level and not exceed 240 meters unless aircraft safety is compromised.

Place the diver in the recovery position. This puts the person on one side with head supported at a low angle and the upper leg bent at the knee. If vomiting occurs in this position, gravity will assist in keeping the airway clear.

### **Category B - Urgent Cases Of DCI**

Here, the only obvious symptom is severe pain that is unchanging or has progressed slowly during the past few hours. The diver does not appear to be in distress except for the pain, and the neurological signs and symptoms are not obvious without a careful history and examination.

Immediately place the injured diver on 100 percent oxygen and give fluids by mouth. Do not attempt to treat the pain with analgesics until advised to do so by medical personnel. Continue providing oxygen until arrival at the medical treatment facility.

Contact DAN or the nearest medical facility for advice on what sort of transport is necessary and where the diver should be evacuated to, even if symptoms improve or are relieved with oxygen. Emergency air transport may not be necessary in all cases.

While awaiting evacuation, take as detailed a history as possible and try to evaluate and record the diver's neurological status. This information will be useful to those at the receiving medical facility. If air evacuation is used, cabin pressure should be maintained near sea level and not exceed 240 metres (800 feet) feet unless aircraft safety is compromised.

### **Category C - Timely Cases Of DCI**

Symptoms are either not obvious or have progressed slowly for several days. Usually the main signs or symptoms are vague complaints of pain or an abnormality of sensation; the diagnosis of DCI may be in question. Obtain as complete a diving history as possible and do a neurological evaluation. Then call DAN or the nearest medical facility for advice or go to the nearest medical facility, if nearby, for evaluation.

## **II. *Get the Dive History***

If possible, obtain and document the following information for all suspected cases of DCI:

- For 48 hours preceding the injury, get a description of all dives: depths / times, ascent rates, intervals between dives, breathing gases, problems or symptoms at any time before, during or after the dive;
- Ask for symptom onset times and progression after the diver has surfaced from last dive;
- Get a description of all first aid measures taken (including times and method of 100 percent oxygen delivery) and their effect on symptoms since the injury;
- Record the results of the on-site neurological examination (described below);
- Make a description of all joint or other musculoskeletal pain including: location, intensity and changes with movement or weight-bearing maneuvers;
- Get a description and distribution of any rashes; and
- Provide a description of any traumatic injuries before, during or after the dive.

## **III. *Conduct an On-Site Neurological Examination***

Information regarding the injured diver's neurological status will be useful to medical personnel in not only deciding the initial course of treatment but also in the effectiveness of treatment. Examination of an injured diver's central nervous system soon after an accident may provide valuable information to the physician responsible for treatment.

The On-Site Neuro Exam is easy to learn and can be done by individuals with no medical experience. Perform as much of the examination as possible, but do not let it interfere with evacuation to a medical treatment facility. DAN is soon to release a short training program to teach divers how to perform this examination.

## **IV. *Get the Diver to the Nearest Medical Facility & Call DAN***

Call for local emergency services first; then call the appropriate DAN-supported hotline. Depending on the severity of the injury (see above), take immediate care for the diver's Airway, Breathing and Circulation and contact local emergency services. After making contact with the emergency services, then call the DAN-supported hotline.

## **A Perspective**

The above tries to paint an accurate picture of DCI and its consequences; you should not conclude, however, that recreational diving is likely to cause injury. In fact, DCI is relatively uncommon: researchers estimate between three and four cases of dive injuries reported for every 10,000 dives - approximately 1,000 cases per year in the USA (Ed: around 500-600 known cases per year in the Asia-Pacific Region, excluding Japan). In addition the vast majority of the DCI cases are minor and treatment results in complete resolution with no impact on future diving activity.

Like any sport, scuba diving does have injuries, and knowing how to recognise DCI will ensure that in the unlikely event it does occur, the outcome will usually be favorable. DAN is available 24/7 to assist in getting treatment for any dive injury and has access to world-class experts in the diagnosis and treatment of DCI. Not many other sports can boast of that kind of immediate support.

DAN is not resting on its laurels, though. We're continuing to look for ways to reduce the number of diving accidents even further. Project Dive Exploration (PDE) is a study designed to do just this. This study trains observers to recognise DCI, and they then collect dive profile data and compile information on behavioral and health aspects. The principal goal of PDE is to establish a recreational dive database that will serve as resource research in dive safety.

## **Returning to Diving after DCI**

The U.S. Navy has set down rules for returning to diving after treatment. For pain-only DCI where there are no neurological symptoms, divers may begin diving two to seven days after treatment, depending on the treatment table used.

If there are neurological symptoms, the diver may resume diving two to four weeks after treatment, depending on symptom severity. For very severe symptoms, the diver must be reevaluated three months after treatment and cleared by a Diving Medical Officer.

The Navy's guidelines are for professionals, where time off must be minimized so operations are not compromised.

## **Guides For Sport Divers**

For recreational divers, where diving is not a livelihood, a more conservative approach is called for to further minimize the chance that a diving injury will recur.

- After pain-only DCI where there are no neurological symptoms, a minimum of two weeks without diving is recommended.
- If there are minor neurological symptoms, six weeks without diving is recommended.
- If there are severe neurological symptoms or any residual symptoms, no further diving is recommended.

Even if symptoms were not severe and they resolved completely, a diver who has had multiple bouts of DCI must take special considerations. If DCI is occurring where other divers on the same profile are DCI-free, the diver may have an increased susceptibility to DCI. In these cases, a Diving Medical Specialist must be consulted to determine if diving can be resumed safely.

Remember, your good health needs to last as long as you do.