

Decompression Illness

Decompression illness, or DCI, is associated with a reduction in the ambient pressure surrounding the body. DCI encompasses two diseases, decompression sickness (DCS) and arterial gas embolism (AGE).

DCS results from bubbles in body tissues causing local damage.

AGE occurs when bubbles enter arterial circulation, traveling through the arteries and potentially causing tissue damage by blocking blood flow at the small vessel level.

1 Who Gets Decompression Illness?

Decompression illness affects scuba divers, aviators, astronauts and compressed-air workers. The main risk factor for DCI is a reduction in ambient pressure, but other risk factors will increase the likelihood of DCI occurring. The known risk factors for divers are deep or long dives, cold water, heavy exercise at depth, and rapid ascents.

Rapid ascents contribute significantly to the risk of AGE. Other factors that may increase DCI risk but lack conclusive evidence of association are obesity, dehydration, heavy exercise immediately after surfacing, and pulmonary disease. We don't yet fully understand possible individual risk factors. Some divers get DCI more frequently than others despite following the same dive profile.

Almost any dive profile can result in DCI, no matter how safe it seems. The risk factors, both known and unknown, can influence the probability of DCI in many ways. Evaluation of a diver for possible decompression illness is done on a case-by-case basis. The diver's signs, symptoms and dive profiles are all considered when making a diagnosis.

2 Decompression Sickness

DCS (also called the bends or caisson disease) results from inadequate decompression following exposure to increased pressure. In some cases, it is mild and not an immediate threat. In other cases, a serious injury occurs. The sooner the treatment of an injury begins, the better the chance for a full recovery.

During a dive, the body tissues absorb nitrogen (and/or other inert gases) 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, the nitrogen may come out of solution and form bubbles in the tissues and bloodstream. Bubbles may occur as a result of violating prescribed limits, but it can also happen even when following accepted guidelines.

Bubbles forming in or near joints are the presumed cause of joint pain (the bends). With high levels of bubbles, complex reactions can take place in the body. The spinal cord and brain are usually affected, causing numbness, paralysis, impaired coordination and disorders of higher cerebral function. If large numbers of bubbles enter the venous bloodstream, congestive symptoms in the lung, and eventually circulatory shock, can occur.

2.1 Manifestations of DCS

The most common manifestations of DCS are joint pain and numbness or tingling. The 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 apparent. However, most DCS manifests subtly with a minor joint ache or paresthesia (an abnormal burning or tingling sensation) in an extremity.

2.2 Signs and Symptoms

Signs and symptoms usually appear within 15 minutes or up to 12 hours after surfacing. In severe cases, symptoms may appear before surfacing or immediately afterward.

Delayed onset of symptoms is rare but can happen, especially if air travel follows diving. In many cases, these symptoms are ascribed to another cause such as overexertion, heavy lifting or even a tight wetsuit. Sometimes these symptoms remain mild and resolve by themselves, but they may increase in severity until it is obvious that something is wrong and help is needed.

Here are the signs and symptoms of DCS:

Unusual fatigue

Skin itch

Pain in joints or arm, leg or torso muscles

Dizziness or vertigo

Ringing in the ears

Numbness, tingling and/or paralysis

Shortness of breath

A blotchy rash

Muscle weakness or paralysis

Difficulty urinating

Confusion, personality changes or bizarre behavior

Amnesia

Tremors

Staggering

Coughing up bloody, frothy sputum

Unconsciousness or collapse

2.3 Prevention

Recreational divers should dive conservatively, whether they are using dive tables or computers. Experienced divers sometimes select a table depth (rather than actual depth) of 10 feet (3 meters) deeper than called for by standard procedure. This practice is recommended for all divers, especially when diving in cold water or under strenuous conditions. Divers should be cautious about approaching no-decompression limits, especially when diving deeper than 100 feet (30 meters).

Avoiding the risk factors described above will decrease the risk of DCS. Flying or other exposure to altitude too soon after diving can also increase the risk of decompression sickness as explained in Flying After Diving.

3 Arterial Gas Embolism

If a diver ascends without exhaling, air trapped in the lungs expands and may rupture lung tissue. This injury, called **pulmonary barotrauma**, involves release of gas bubbles into the arterial circulation. Circulation 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 organ in which bubbles may interrupt circulation if they become lodged in small arteries.

This circulation interruption is AGE, considered the more serious form of DCI. The diver may have made a panicked ascent or held their breath during ascent. However, AGE can occur even if the ascent was completely normal. Pulmonary diseases such as obstructive lung disease may increase the risk of AGE.

A diver may surface unconscious and remain so or lose consciousness within 10 minutes of surfacing. These cases are true medical emergencies and require rapid evacuation to a treatment facility.

AGE may involve minor symptoms of neurological dysfunction, such as sensations of tingling or numbness, weakness without obvious paralysis, or complaints of difficulty in thinking but no apparent confusion. In these cases, there is time for a more thorough evaluation by a diving medical specialist to rule out other causes.

Like DCS, mild symptoms may appear to be due to causes other than diving, which can delay treatment. Symptoms may resolve spontaneously, and the diver may not seek treatment. The consequences of this are similar to untreated DCS. Residual brain damage may occur, making it more likely there will be residual symptoms after a future AGE — even after treating the later instance.

3.1 Manifestations of AGE

Dizziness

Visual blurring

Areas of decreased sensation

Chest pain

Disorientation

Bloody froth from mouth or nose

Paralysis or weakness

Convulsions

Unconsciousness

Cessation of breathing

Death

3.2 Prevention

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 AGE. If you have any of these conditions, consult a physician with experience in diving medicine before you dive.

4 Flying After Diving

When flying after diving, the ascent to altitude increases the risk of decompression sickness (DCS) because of the additional reduction in atmospheric pressure. The higher the altitude, the greater the risk.

Cruising cabin pressure in commercial aircraft is usually maintained at a constant value regardless of the actual altitude of the flight. The equivalent effective cabin altitude generally ranges from 6,000 to 8,000 feet, though it varies somewhat with aircraft type. The maximum value is 8,000 feet, which equates to about 0.75 atmospheres absolute (ATA).

The following recommendations for recreational divers represent the consensus reached by attendees at the 2002 Flying After Recreational Diving Workshop. The attendees created the recommendations based on earlier published work and experimental trials. They apply to air dives followed by flights at

cabin altitudes of 2,000 to 8,000 feet (610 to 2,438 meters) for divers who do not have symptoms of DCS.

The recommendations should reduce the DCS risk associated with flying after diving but do not guarantee avoidance of DCS. Preflight surface intervals longer than the recommendations will further reduce DCS risk.

HOW LONG SHOULD YOU WAIT? SUGGESTED MINIMUM SURFACE INTERVALS

 Single day no-deco dive 12+ hours	 Multi-day or repetitive no-deco dives 18+ hours	 Mandatory deco dive 24+ hours
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Longer surface intervals further reduce DCS risk

These guidelines apply to divers who have no symptoms of decompression sickness (DCS) and will be flying at cabin altitudes of 2,000-8,000 ft (610 to 2,438 meters)

Dives Within No-Decompression Limits: For a single no-decompression dive, the recommendation is a minimum preflight surface interval of 12 hours.

For multiple dives per day or multiple days of diving, the recommendation is a minimum preflight surface interval of 18 hours.

Dives Requiring Decompression Stops: There is little experimental or published evidence on which to base a recommendation for decompression dives. A preflight surface interval substantially longer than 18 hours appears prudent.

Flying with DCS Symptoms: It is more common for divers to fly with DCS symptoms than to develop symptoms during or after a flight. Flying with symptoms may be a greater health problem than symptoms that arise during or after a flight.

Divers should seek medical advice and avoid flying if they note signs or symptoms that may indicate DCS.

5 Treatment

The treatment for decompression illness is recompression. Early management of AGE and DCS is the same. It is essential that a diver with AGE or severe DCS to be stabilized at the nearest medical facility before being transported to a chamber.

Early oxygen first aid is essential and may reduce symptoms, but this should not change the treatment plan. Symptoms of AGE and severe DCS often resolve after breathing oxygen from a cylinder, but they may reappear later.

Always contact DAN or a physician trained in dive medicine in cases of suspected decompression illness — even if the signs and symptoms appear resolved.

Delays in seeking treatment elevate the risk of residual symptoms. Over time the initially reversible damage may become permanent. After a delay of 24 hours or more, treatment may be less effective, and symptoms may not respond. Even if there has been a delay, consult a diving medical specialist before making any conclusions about possible treatment effectiveness.

6 After Treatment

There may be residual symptoms after treatment. Soreness in and around an affected joint is common and usually resolves in a few hours. If the DCI was severe, there could be significant residual neurological dysfunction. Follow-up treatments, along with physical therapy, can help. The usual outcome is eventual complete relief from all symptoms with prompt treatment.

With severe DCS, you may have a permanent residual effect such as 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 injury may decrease the likelihood of recovery from a subsequent bout of DCS.

Untreated joint pain that subsides could cause small areas of bone damage (osteonecrosis). If this happens through repeated instances of DCS, there may be enough damage to cause the bone to become brittle, or for joints to collapse or become arthritic.

7 Responding to DCI

7.1 *Determine the Urgency of the Injury*

Make an initial evaluation at the dive site. You can suspect decompression illness if you notice any of the signs or symptoms listed above within 24 hours of surfacing from a dive. While waiting for professional medical care or evacuation, take as detailed a history as possible and try to evaluate and record the diver's neurological status. Base your response on one of these three categories depending upon the symptoms: emergency, urgent or timely.

If necessary, you can administer first aid within the scope of your training, as described below.

7.1.1 *Emergency*

Symptoms are severe and appear within an hour or so of surfacing. The diver may lose consciousness. Symptoms might progress, and the diver is obviously ill. The diver may be profoundly dizzy or have trouble breathing. Neurological symptoms may manifest as altered consciousness, abnormal gait or weakness.

If necessary (e.g., if the diver isn't breathing and has no pulse), begin CPR and take immediate action to have the diver evacuated. Check for foreign bodies in the airway. If they need ventilatory or cardiac resuscitation, the injured diver should be lying on their back. Vomiting in this position is dangerous; if it happens, turn the diver to the side until the airway is clear and resuscitation can resume in the supine position. While awaiting evacuation, take as detailed a history as possible and try to evaluate and record the diver's neurological status.

Use supplemental oxygen while administering breaths to increase the percentage of oxygen breathed by the injured diver. Even if CPR is successful and the diver regains consciousness, continue administering 100 percent oxygen until the diver arrives at a medical facility and health care professionals assume care.

7.1.2 *Urgent*

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

Administer 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.

7.1.3 Timely

Symptoms are either not visible or have progressed slowly for several days. The main signs or symptoms are vague complaints of pain or an abnormal sensation, which could indicate something other than DCI. Obtain as complete a diving history as possible and do a neurological evaluation. Then go to the nearest medical facility for evaluation.

7.2 Get the Dive History

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

- All dives (depth, time, ascent rates, surface intervals, breathing gases) for 48 hours preceding the injury. Also note problems or symptoms at any time before, during or after the dive.
- Symptom onset times and progression after surfacing from the last dive
- All first aid measures (including times and method of emergency oxygen delivery) and their effect on symptoms
- Results of an on-site neurological examination
- All joint or other musculoskeletal pain including location, intensity and changes with movement or weight-bearing maneuvers
- Description and distribution of any rashes
- Any traumatic injuries before, during or after the dive.

7.3 On-Site Neurological Examination

Information regarding an injured diver's neurological status will be useful to medical personnel not only for 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 their treatment. The examination may help diagnose decompression illness, which can have neurological components. The On-Site Neurological 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.

Perform the following steps in order, and record the time and results.

7.3.1 Orientation

Does the diver know their own name and age?

Does the diver know the present location?

Does the diver know what time, day and year it is?

Note: Even though a diver appears alert, the answers to these questions may reveal confusion. Do not omit them.

7.3.2 Eyes

Have the diver count the number of fingers you display, using two or three different numbers.

Check each eye separately and then together.

Have the diver identify a distant object.

Tell the diver to hold head still, or you gently hold it still, while placing your other hand about 18 inches (0.5 meters) in front of their face. Ask the diver to follow your hand. Now move your hand up and down, then side to side. The diver's eyes should follow your hand and should not jerk to one side and return. Check that the pupils are equal in size.

7.3.3 Face

Ask the diver to purse their lips. Look carefully to see that both sides of the face have the same expression.

Ask the diver to grit their teeth. Feel the jaw muscles to confirm that they are contracted equally.

Instruct the diver to close the eyes while you lightly touch your fingertips across the forehead and face to be sure sensation is present and the same everywhere.

7.3.4 Hearing

Hearing can be evaluated by holding your hand about 2 feet (0.6 meters) from the diver's ear and rubbing your thumb and finger together.

Check both ears moving your hand closer until the diver hears it.

Check several times and compare with your own hearing.

Note: If the surroundings are noisy, the test is difficult to evaluate. Ask bystanders to be quiet and to turn off unneeded machinery.

7.3.5 Swallowing Reflex

Instruct the diver to swallow while you watch the "Adam's apple" to be sure it moves up and down.

7.3.6 Tongue

Instruct the diver to stick out their tongue. It should come out straight in the middle of the mouth without deviating to either side.

7.3.7 Muscle Strength

Instruct the diver to shrug shoulders while you bear down on them to observe for equal muscle strength.

Check diver's arms by bringing the elbows up level with the shoulders, hands level with the arms and touching the chest. Instruct the diver to resist while you pull the arms away, push them back, up and down. The strength should be approximately equal in both arms in each direction.

Check leg strength by having the diver lie flat and raise and lower the legs while you resist the movement.

7.3.8 Sensory Perception

Check on both sides by touching lightly as was done on the face. Start at the top of the body and compare sides while moving downwards to cover the entire body.

Note: The diver's eyes should be closed during this procedure. The diver should confirm the sensation in each area before you move to another area.

7.3.9 Balance and Coordination

Note: Be prepared to protect the diver from injury when performing this test.

First, have the diver walk heel to toe along a straight line while looking straight ahead.

Have the diver walk both forward and backward for 10 feet or so. Note whether movements are smooth and if they can maintain balance without having to look down or hold onto something.

Next, have the diver stand up with feet together and close eyes and hold the arms straight out in front — with the palms up. The diver should be able to maintain balance if the platform is stable. Your arms should be around, but not touching, the diver. Be prepared to catch the diver who starts to fall.

Check coordination by having the diver move an index finger back and forth rapidly between the diver's nose and your finger held approximately 18 inches/0.5 meters from the diver's face. The diver should be able to do this, even if you move your finger to different positions.

Have the diver lie down and instruct them to slide the heel of one foot down the shin of the other leg, while keeping their eyes closed. The diver should be able to move their foot smoothly along the shin, without jagged, side-to-side movements.

Check these tests on both right and left sides and observe carefully for unusual clumsiness on either side.

7.4 Medical Evaluation

Call local EMS to get the diver to the nearest medical facility.

8 Returning to Diving after DCI

For recreational divers, whose livelihood is something other than diving, a conservative approach will help minimize the chance that a diving injury will recur.

After pain-only DCI without neurological symptoms, you can consider a return to diving after a minimum of two weeks.

With minor neurological symptoms, consider returning after six weeks.

If you had severe neurological symptoms or have any residual symptoms, you should not return to diving.

You should always consult with a physician before returning to diving. Even if symptoms were not severe and they resolved completely, if you have had multiple instances of decompression illness, you must make special considerations. If you are getting DCI when other divers who dive the same profile are not, you may have elevated susceptibility. In these cases, consult a dive medicine specialist to determine if you can safely resume diving.

Source: DAN, Ed Thalmann, M.D. [Dan Article 1](#) [Dan Article 2](#) [Flying After Diving](#)