

DECOMPRESSION ILLNESS

减压病

4.1 THE ONSET OF DECOMPRESSION ILLNESS

减压病的发生

Western Medicine

Decompression illness (DI) is one of the first disorders people think of when talking about diving medical problems, although they do not exactly know what it is. I have added basic information about it in this book to extend the knowledge about diving medicine in general and also to make clear that, for example, an ENT disorder like tinnitus can be seen as a sign of decompression illness as well. Acupuncture might help promote the general condition of the diver, which can contribute to preventing decompression illness. Of course it is of indisputable importance to follow all diving rules relating to the ambient pressure, the ascent rate and the release of nitrogen.

Decompression illness and drowning under and above the water surface are the most common diving accidents. They often occur through panic resulting from overconfidence. People can take on too much risk when they are in a holiday mood and think everything is possible. They dive deeper than they should, omit their safety stops or become panicked when they think they have lost their buddy. Either way: they don't think clearly any more and might ascend too fast.

Accidents under water like myocardial infarction are mostly accidents which would happen above the water surface as well and are not directly related to diving (except that in the beginning of the dive the blood pressure is higher). People might get myocardial infarction under water because of not being trained for the situation.

It's important to have knowledge about decompression illness when treating divers. The relation between health and decompression illness is a crucial factor. You can *not* treat decompression illness itself with acupuncture because the diver has to be treated in a decompression room and must be provided with 100 per cent

oxygen. But when you know about the causes of decompression illness your acupuncture treatment might help prevent it. Acupuncture can support the general condition, reduce stress and tiredness and improve the blood circulation, all very important factors when reducing the risk of decompression illness.

When a diver descends the body assimilates more nitrogen due to the increased pressure of the ambient surrounding (*on-gassing*). According to Henry's Law the partial pressure of nitrogen grows proportionally to the diving depth. Tissues that store nitrogen easily are blood and lung tissues. Tissues slow to absorb nitrogen are bones and fat. During the ascent the excess of nitrogen disappears by exhaling (*off-gassing*). The nitrogen needs a certain time to wash out, for which it is important to ascend with a certain speed and to make safety stops. When ascending too quickly the partial pressure of nitrogen in the tissues can't diminish sufficiently (*transcends ambient pressure*). When the overpressure exceeds a certain limit, the nitrogen is released into the body tissues and blood vessels as nitrogen *bubbles*. These bubbles are the cause of the onset of decompression illness. A nitrogen bubble may obstruct a blood vessel, cause a lot of damage in the surrounding of the obstruction and even lead to arterial gas embolism.

Decompression illness also may occur when the diving guidelines are followed well, caused by factors like dehydration, repeated dives and being in poor condition (see 'Risk Factors' below).

To prevent decompression illness there are *decompression tables*, which advise a certain time at a certain depth, a certain time in between several dives combined with safety stops (decompression stops), and an ascent rate of 10 metres per minute. When you dive to 30 metres depth or deeper you are obliged to make a safety stop of three minutes at 5 metres depth before you surface. It's recommended to make a safety stop for every dive less deep than 30 metres as well. When you exceed a depth of 40 metres you must ascend directly and make an urgency stop for eight minutes at 5 metres depth. Making a safety stop is part of the normal procedure of the dive. *During the safety stop the body can eliminate nitrogen before surfacing.*

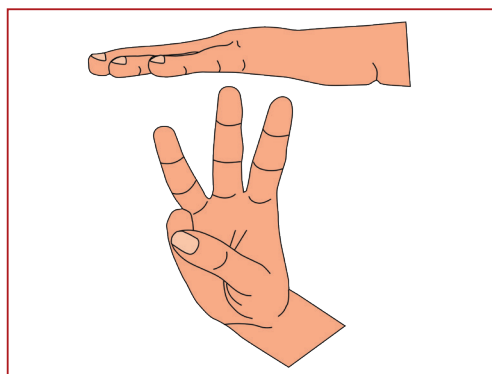


Figure 4.1.1 Diving hand signal to express the safety stop needed for off-gassing before surfacing
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Never cough, squeeze, clear or breathe in when ascending because that will make the lung tissues expand! When the elastic limit is exceeded the lung tissues will rupture. Even a small change in pressure can lead to a rupture, especially when taking a deep breath before ascending. *During the ascent you need to exhale so the lungs will not expand due to the decrease in ambient pressure.* Even when ascending from only 1.3 metres depth it is possible to damage the lungs due to the big volume change, and this can lead to mediastinal emphysema, neck emphysema, pneumothorax and arterial gas embolism. Arterial gas embolism (AGE) is the number-one of causes of death when there is pathology.

People mostly ascend too quickly:

- when there is fear or panic
- during an emergency ascent
- as a result of ignorance of the laws of physics that relate to diving
- due to bad dive instruction or poor supervision.

In 50 per cent of DI cases the clinical signs and symptoms manifest themselves within one hour after the ascent, in 90 per cent after six hours. In the case of AGE due to ruptured alveoli the clinical signs and symptoms usually occur within 15 minutes after the ascent and often manifest themselves when reaching the water surface.¹

Risk Factors

- Ascending too quickly, which gives a pressure change that is too rapid. The sudden overpressure causes the nitrogen gas to release nitrogen bubbles.
- Dehydration leads to less circulating blood volume and blood that gets sticky (off-gassing is more difficult).
- Being in poor condition is a contributory factor because the blood circulation in the tissues is diminished.
- Repeated dives (the body stores nitrogen from previous dives).
- Not enough sleep, tiredness.
- Increasing age. The blood circulation is less good, the blood vessels are poorer quality and general condition becomes poorer.

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1 Brandt Corstius, J.J., Dermout, S.M. and Feenstra, L., *Duikgeneeskunde, Theorie en Praktijk*, second edition, Elsevier, Amsterdam, 2007.

- Temperature. Cold water leads to vasoconstriction. Ascending to the warmer water levels gives vasodilation, which triggers a release of gas bubbles, as does too rapid warming after the dive (sun, hot shower).
- Alcohol dehydrates the body and reduces sound judgement. For example, nitrogen narcosis may not be recognized.
- Patent foramen ovale (PFO): see Section 1.4 and Figure 1.4.2.
- *Obesity*: at the end of the diving holiday there will be more nitrogen stored in the fat tissues, which release it slowly. If overweight, it is necessary to stop diving one extra day before flying home. This means 48 hours of no diving before flying, as the rule normally is to stop diving 24 hours before flying.
- Hormonal influences might result in more chance of decompression illness during the second half of a woman's cycle due to fluid retention and tissue swelling and less ability to release nitrogen. DAN[®] (Divers Alert Network)² says it might be advisable to dive more conservatively when having PMS (premenstrual syndrome) and during menstruation, especially for women who use oral contraceptives. *Conservative diving* means fewer, shorter and shallower dives and longer safety stops.
- Physical effort such as during drift diving or heavy exercise after the dive may trigger decompression illness. Swimming against the current is quite strenuous and feels uncomfortable quickly in general, and puts increased pressure of the pulmonary arteries and capillaries.

Subdivisions of Decompression Illness³

Type I Skin and Joints

- Clinical signs and symptoms: skin
 - itching, burning sensation
 - cutis marmorata
 - exanthema, pain in skin and subcutis.
- Clinical signs and symptoms: joints
 - initially dull pain around the joint and later piercing pain

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2 Uguccioni, D.M., Moon, R. and Taylor, M.B., 'DAN explores fitness and diving issues in women', DAN: Divers Alert Network, www.diversalertnetwork.org/medical/articles/DAN_Explores_Fitness_and_Diving_Issues_for_Women (accessed 13 August 2017).

3 Brandt Corstius, J.J., Dermout, S.M. and Feenstra, L., *Duikgeneeskunde, Theorie en Praktijk*, tweede druk, Elsevier, Amsterdam, 2007.

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- pain increases on moving
- severe fatigue of the affected limbs
- eventually redness and swelling around the affected joint.

Type II Central Nervous System, Stomach and Intestines, Spine, Lungs and Heart

- Clinical signs and symptoms: CNS
 - headache (often first sign)
 - visual disorders
 - aphasia
 - agnosia
 - dizziness
 - disorientation
 - speech disorder
 - unconsciousness and death.
- Clinical signs and symptoms: stomach and intestines
 - nausea
 - decreased appetite
 - diarrhoea
 - abdominal cramps
 - eventually vomiting of blood or blood in diarrhoea.
- Clinical signs and symptoms: spine
 - para-/hemiplegia
 - back pain
 - micturition and defecation disorders.
- Clinical signs and symptoms: lungs
 - sudden dyspnoea
 - pain in thorax, especially when breathing deeply
 - coughing
 - rales (clicking, bubbling or rattling sound when breathing)
 - haemoptysis
 - eventually cyanosis, shock, unconsciousness and death.
- Clinical signs and symptoms: heart
 - angina pectoris
 - nausea and vomiting
 - perspiring
 - agony

- pallor
- irregular heartbeat
- eventually cardiac arrest and death.

Type III Arterial Gas Embolism in Combination with Type II DI

- Clinical signs and symptoms
 - pain in breast
 - dyspnoea
 - dizziness
 - tinnitus
 - sensory disorders
 - visual disorders
 - para-/hemiplegia
 - disorientation
 - convulsions
 - unconsciousness
 - respiratory arrest and sudden death
 - cardiac arrest and sudden death.

Treatment

The usual therapy for decompression illness is to give *100 per cent oxygen* and treatment of the diver in a *decompression room*. It is necessary to give 100 per cent oxygen to provide the area around the blood vessel that is obstructed by the nitrogen bubble as much oxygen as possible to prevent damage.

Chinese Medicine

Reducing tiredness, stress and (if overweight) weight, supporting the blood circulation and stopping smoking can contribute to lowering the risk of decompression illness. Therefore acupuncture can be an effective way to treat divers with physical and mental problems. It is supportive to increase the Qi level of the organs and to promote the smooth circulation of Qi and Xue.

I want to stress again that some acupuncture treatments are very useful before going on a diving holiday, especially when people are stressed and/or tired. The better they feel before they go for a long-distance flight the better they might arrive at the diving destination.

As well as being in good condition it's very important to follow all diving rules at any time! An uncontrolled and too rapid emergency ascent in combination with diving too long, too deep and/or making repetitive dives creates a big risk

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of getting decompression illness. *Of course acupuncture can't prevent decompression illness in the case of such uncontrolled actions!*

● Treatment Principle

- Check pulse, tongue, face and/or abdomen for your diagnosis.

In general:

- Spread Liver-Qi.
- Strengthen the Lung and promote the descending and diffusing of Lung-Qi.
- Strengthen the Spleen, Kidney, Heart.
- Promote the free flow of Qi and Xue.

● Acupuncture Points (select from)

LI-4 Hegu, **LIV-3** Taichong, **PC-6** Neiguan, **LU-7** Lieque, **LU-9** Taiyuan, **BL-13** Feishu, **SP-6** Sanyinjiao, **SP-4** Gongsun, **SP-3** Taibai, **BL-20** Pishu, **ST-36** Zusanli, **KI-3** Taixi, **KI-6** Zhaohai, **CV-4** Guanyuan, **CV-6** Qihai, **GV-4** Mingmen, **BL-23** Shenshu, **HT-7** Shenmen, **BL-15** Xinshu, **SP-10** Xuehai, **BL-40** Weizhong, **BL-17** Geshu, Ear Point: Shenmen.

● Explanation

- **LI-4–LIV-3** combination and **PC-6** spread Liver-Qi. **LI-4–LIV-3** combination promotes the free flow of Qi and Xue.
- **LU-7**, **LU-9** and **BL-13** strengthen the Lung and promote the descending and diffusing of Lung-Qi.
- **SP-6**, **SP-4**, **SP-3** and **BL-20** strengthen the Spleen.
- **ST-36** supports general tonification.
- **KI-3**, **KI-6**, **CV-4**, **CV-6**, **GV-4** and **BL-23** strengthen the Kidney (for their different actions see Table 1.7.5).
- **HT-7** and **BL-15** strengthen the Heart.
- **SP-10**, **BL-40** and **BL-17** move Xue.
- Ear Point: Shenmen supports general relaxation (release of endorphins).

Advice for the Diver

- Drink enough water during the flight to your diving destination as the air conditioning in the airplane (dry air) dehydrates your body. DAN[®] Europe advises drinking 240 ml water every hour of the flight time. Drink enough water before and in between the dives to prevent dehydration. DAN[®] Europe recommends drinking one glass of water every 15–20 minutes.
- Drink coconut water – which you can find at most tropical dive locations – because it is more hydrating than normal water and it contains electrolytes (magnesium, calcium, sodium, potassium and phosphorus).
- Take your time to recover from jetlag and don't jump in the water directly after arriving at your holiday destination. When you have had a long flight it's best to take one day of rest to recover and adapt to the new and – most of the time – tropical surrounding with higher temperatures.
- Put on your diving suit just before going in the water to prevent dehydration when it's warm. When you sweat a lot before the dive you will lose a lot of body fluids.
- Take care to have sufficient sleep during the whole diving holiday.
- In general eat healthy food and don't take too much coffee before diving because that causes dehydration as well. When you dive in tropical regions there are usually bananas, coconuts, mangos and pineapples which provide a lot of vitamins and minerals.
- Adding some vitamins such as vitamin C and minerals such as magnesium and Omega 3 may support your general well-being and/or the blood circulation in the muscles.
- Adjust the thickness of the diving suit to the temperature of the water so you will not unnecessarily lose body warmth. Wear a hood and/or gloves when the water is really cold or when making a night dive. A night dive is usually less deep (often a maximum of 10 m) and when done wisely is in an area the diver has been before so he or she can recognize the surrounding, but the water cools quickly when the sun goes down.
- After the dive have a freshwater shower as soon as possible so you can get rid of the salt crystals, which may dry on the skin and aggravate dehydration.

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- Only sit in the sun after a dive for a short time to dry your body; then it is better to look for a comfortable place in the shade and relax before the next dive.
- Protect your body well in cold diving surroundings as low temperatures also can induce decompression illness. Cold water can result in cold diuresis by which the body can dehydrate.
- After diving you need to wait for 24 hours before flying (back home after your holiday or to another location during your diving holiday). The additional nitrogen in the body – due to the diving – needs time to leave the body tissues. In the air cabin there is an artificially low air pressure of about 0.8 ATA. Because of the decreased air pressure there is still a risk for decompression illness as nitrogen bubbles might expand.