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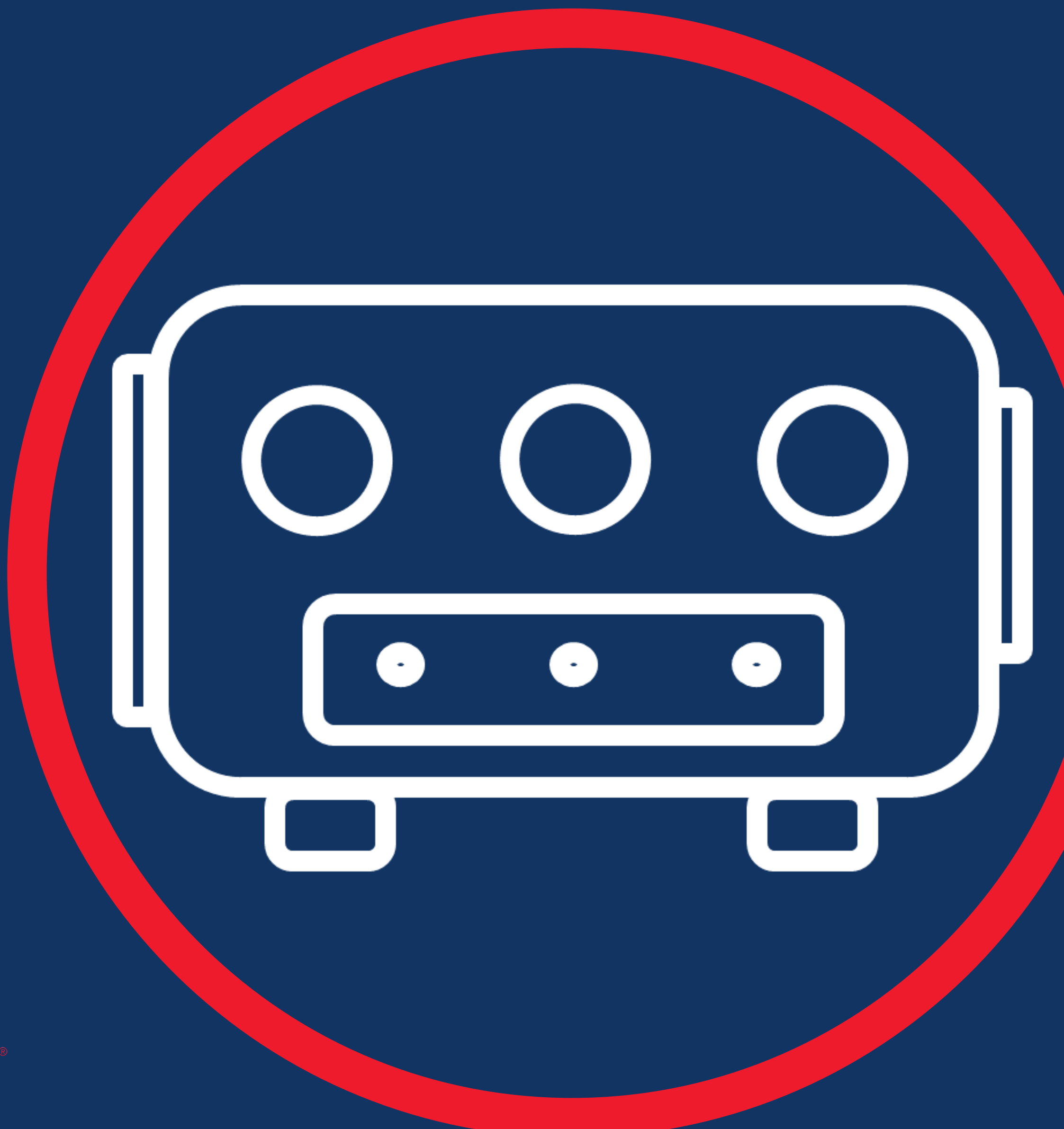
THE RCN BULLETIN

A Newsletter of the DAN Recompression Chamber Network



www.dan.org

rcn@dan.org

WHAT'S INSIDE:

THE RCN WELCOME LETTER:

COVID LEADS TO INNOVATIONS IN ONLINE INTERACTIONS

The COVID-19 pandemic remains with us and hence the number of diving injuries remains low – the DAN emergency hotline activity shows this very clearly too.

In response to this however, the hyperbaric medicine profession has been hard at work providing and updating requirements for chamber infection control. DAN and other organizations are researching the effects on divers who have contracted the virus: diving after COVID-19 is a concern to many.

Once the pandemic crisis has receded, we are expecting divers to return to their favorite dive-destinations and for recompression chamber facilities to be back to providing essential services to the recreational scuba industry.

Infection control will, however, remain a key element of all services provided to the public in the future. Now is the time to review your general disinfection procedures and investigate new products and systems that can be used to aid in these efforts.

One solution to this that has been suggested, and even studied at a few facilities, is the use of ultraviolet (UV) radiation – a very effective disinfectant under the correct circumstances.

However, please take great care in considering this– your acrylic windows will be harmed if exposed to any direct or even indirect UV light – the wavelength of UV that disinfects effectively can just as effectively cause permanent harm to your chamber windows.

We are learning of several new treatment centers being installed in the Middle East and Southeast Asia; exciting news in that it signifies growth in both diving and hyperbaric treatments. We have several significant gaps in diving regions where there are no suitable recompression chamber facilities.

Finally, we have noticed greater participation from around the diver-treatment world in hyperbaric safety training. Online, real-time courses have allowed greater attendance as there are no associated travel costs or immigration hurdles. This is excellent news for the safety of all treatment centers.

Once again, this 5th edition of the RCN newsletter contains a series of articles submitted specifically for your interest and education. Please do contact us if you'd like to share something with your colleagues within our profession.

Remember to send your questions to us at rcn@dan.org. We are here to help all facilities treating injured divers.

- Francois Burman and the DAN RCN Team

Case Study: Ocular DCS?

MATIAS NOCHETTO

A 65-year-old male technical diver did a single day, single dive to a maximum depth of 193ft (59m) for 60 minutes in a cold freshwater environment. During his decompression, at around 60ft (18m), he noticed that he could not see part of his computer face. The diver described this partial loss of visual field as approximately the "right upper quadrant of the [his] right eye".

The call came in after he arrived at the dock, where he reported feeling otherwise normal. When asked for specifics of his loss of field of vision, he said that when he got to the surface, the visual loss was becoming transient rather than steady and that when looking at someone's face, he could "not see their nose or the upper right part of their face".

He denied any history of visual problems, reported having no known medical problems and was asymptomatic.

An example of a scotoma

The injured diver was reportedly able to walk normally and was always calm and very articulate. He did not seem to feel any problems with basic coordination tasks, no pains, no sensory changes, and no history of altered level of consciousness since symptom onset.

The diver was instructed to begin first aid with oxygen while en route to the closest medical facility that conveniently had a hyperbaric complex and vast dive medicine experience. About one hour and twenty minutes later, the treating physician contacted DAN to report that the diver was received with no changes from what was initially reported, began a USNTT6, and reported full resolution of symptoms within 10 minutes at 60ft (18m).

At follow-up the next morning, the diver was discharged with recommendations to follow up with a dive medicine specialist.

Ocular decompression sickness is a relatively rare event that can manifest with blind spots and it is not easy to decipher what type of change in the field of vision the diver was experiencing. However, the diver's description could also be interpreted as a scotoma or even a quadrantanopia. With some of the differential diagnoses having a far more concerning prognosis than DCI, the diver was recommended immediate medical evaluation at the closest medical facility. Fortunately, they were very close to a robust medical center with advanced diagnostic capabilities. After ruling out a vascular event or glaucoma and as the diver had received recompression therapy at 60ft (18m) with a very positive effect early on, the case was interpreted as ocular decompression sickness.

Case Study: Bent in Komodo

MATIAS NOCHETTO

A 30-year-old female diver called the DAN hotline by recommendation of her instructor, concerned about DCS. The group was in Komodo National Park in Indonesia, and she wanted to know if it would be ok for her to take a series of flights back home in about 18 hours. The diver had completed a series of nine dives over a four-day period. On days 1, 3, & 4 she had completed 3 dives a day.

The last day of diving included:

1. 33 fsw (10 msw)/71min on AIR; SIT=3h;
2. 92 fsw (28 msw)/50min on AIR; SIT=6h;
3. 79 fsw (24 msw)/52min on AIR: out of the water at around 19:30 local time.

The diver denied experiencing any unusual problems or complications with any of her dives. She describes experiencing an unusual moderate pain throughout the lateral aspect of her bilateral thighs - onset was approximately 1.5 hours following her final dive, which she attributed to a tight-fitting wetsuit. The diver stated that she fell asleep that evening and awoke 1 hour later with more intense pain on her thighs and numbness in the surface of her skin that extended to her buttocks and lower back. She fell back asleep and awoke with improvement of her symptoms but noticed a small "blotchy" rash (6cm x 3cm) on the lateral side of her left thigh.

She decided to discontinue diving when her dive instructor mentioned that she might be experiencing DCS. The crew started her on NBO2 for about 2 hours, after which she felt better and noticed a reduction in the size of the rash.

The diver declared having an unremarkable past medical history, took ASA PRN, was certified three years prior, and had 20-lifetime dives and was not a DAN member.DAN's recommendation was for her not to fly until after medical evaluation to determine possible causes, including Type 2 DCS.

Later that day, DAN received a call from a Travel Assistance company, whose Medical Director was inquiring about recommendations regarding a flight to a nearby dive medicine facility in reference to this same case.

DAN's recommendation was first to seek medical evaluation locally, and that if DCS was suspected, then a commercial flight was generally inadvisable. DAN's experience flying symptomatic DCS cases was limited to mild & stable patients with non-progressive symptoms but expressed concern for deterioration of pre-existing symptoms during the flight and a reduced efficiency of a first treatment.

Unfortunately, the local medical facility did not consider this case to be DCS, and the diver did not receive recompression therapy. DAN was not able to directly follow-up with the patient, as she was an insured with a different organization.

DAN was reasonably confident this case was indeed DCS. Although the case initially appeared to be Type 1 DCS (pain, skin manifestations including mild cutaneous sensory changes and a "blotchy" patch), in which mild and stable cases are generally deemed low risk, the L4-L5 dermatomal distribution of the reported paresthesias necessitated further workup. With this hypothesis, DAN deemed that it was safer to assume the case did not fit the definition of "Mild or Marginal DCI" as stated in the 2004 DAN/UHMS workshop titled "Management of Mild or Marginal Decompression Illness in Remote Locations", and delay a hypobaric exposure until professional neurological evaluation could be performed.

Chamber Air Supply Requirements

FRANCOIS BURMAN

A question often asked of us is how much air is needed for a recompression chamber facility or in other words, how do I size my chamber air supply system correctly? Chambers vary in size and intended operation but let us focus this question on a typical multiplace chamber used for recompression treatments.

When we review the many codes and standards that provide instruction on minimum capacity requirements, we will see that this is usually calculated as the ability to:

1. pressurize the treatment (main) lock to depth in an appropriate period of time, plus
2. provide for at least two pressurizations of the transfer (entry) lock, plus
3. provide sufficient gas to ventilate the chamber in order to assist in maintaining temperature, humidity and odor, to be able to keep the chamber at a safe oxygen level, and to control the build-up of carbon dioxide.

The first two items are obviously determined by the actual size of the chamber locks, the deepest treatment that is offered, and the time required to get to pressure at a minimum rate of 0.1 atmospheres (atm) or 8 fsw (2.4 msw) per minute[1].

The third item or ventilation rate depends on the maximum number of occupants, at depth, at an acceptable flow rate. This is where we see a lot of variation. However, a great rule of thumb is 2.3 acfm (65 alpm) multiplied by treatment pressure – usually 2.8 ATA (60 fsw or 18 msw), multiplied by the maximum number of occupants. This would apply to most chambers to keep the various comfort and contaminant levels within an acceptable range.


Francois Burman

Where using a low-pressure compressor with the appropriately sized air receiver[2], the required compressor flow rate is determined by the maximum ventilation rate plus a factor of say 1.5 to allow for peak demands (say for very anxious occupants). A 4-occupant chamber would require 2.3 acfm x 2.8 ATA x 4 plus 50%. This equates to about 40 scfm (1,100 lpm), or about 10 scfm (300 lpm) per occupant.

High pressure storage banks are somewhat more complex, especially if you consider treating during a power outage. The supply system requires enough gas to complete pressurization to maximum treatment depth, allow for two transfers-under-pressure, and provide enough air to ventilate the chamber for the entire duration of the longest likely treatment table (a fully extended USN TT6 for example would take more than 8 hours to complete).

Chamber size and number of occupants determine the size of the high-pressure bank. A basic 60" (1.5m) diameter chamber, for 2 occupants, could theoretically require 15 K (50 liter by 200 bar) filled cylinders for the longest-case situation. Each additional patient could require up to 4 additional filled cylinders. Remember though that while the patients are on oxygen, the ventilation rate can be significantly reduced except where there is an oxygen leak resulting in elevated chamber environment oxygen levels - remember that the maximum safe limit is 23.5%. This could reduce the number of cylinders where careful attention is paid to the actual chamber conditions.

Cylinder banks of 16 cylinders would be sufficient for most typical recompression chambers treating up to 3 patients plus 1 attendant where careful air management is conducted during a power outage. It remains imperative that you consult with the compressor supplier to select the correct compressor for your application. This brief analysis will guide the supplier to determine the appropriate compressor size.

Determining exact requirements can be daunting. Please feel free to contact us at rcn@dan.org if you have a specific question relating to your exact chamber configuration and prior to ordering any compressors or air banks

Notes

1. The industry average is 1 atm (33 fsw or 10 msw) per minute but pressurization is often usually slowed down to alleviate any patient distress or discomfort. The US Navy states 0.6 atm (20 fsw or 6 msw) per minute.
2. The receiver should be large enough so that the chamber can be pressurized to maximum treatment depth in the right amount of time (no less than 7.5 minutes to 2.8 ATA) with the compressor running continuously.

Essential Supplies for a Remote Chamber Setting

JULIO GARCIA

When assessing needs in a remote setting to care for an injured diver at a recompression center, of course emphasis should be placed on the basics. The primary focus must be Airway, Breathing and Circulation*****, and is essentially a primary survey; in other words, what do I need to keep my patient stable?

Naturally, one would want to recompress an injured diver with DCI, but they could also present with trauma, bleeding or cardio-pulmonary arrest that may need to be addressed prior to or during recompression. With this in mind, a wish list should include the following:

- Oropharyngeal Airways (OPAs)
- Bag Valve Mask (BVM)
- Suction
- Pneumothorax kits
- Combat Application Tourniquet (CAT Tourniquets)
- Automatic External Defibrillator (AED)
- IV access devices and fluids

Of course, many other niceties exist that could be on many a wish list, but the above items can get you a long way towards stabilizing a critical patient. The above list should not be considered all-inclusive, and some may place different values on different interventions or modalities. In general, these items would serve you well to have on hand in a remote setting. Let us discuss these items further.

** In 2010 the American Heart Association changed the focus from ABC to CAB (circulation, airway and breathing).*

OPAs are simple devices that assist in maintaining an open airway. They are easy to use, easy to deploy, and a set of 6 different sizes will run less than twenty US dollars. There are many on the market to choose from and training is readily available. In addition, OPAs should be coupled with a BVM. This self-inflating bag acts as a reservoir to deliver the tidal volume for respirations, a non-rebreather valve and a mask. The bag can be connected to an oxygen source for enhanced oxygenation. If you have ever had to give mouth to mouth resuscitation, you know how valuable these devices are to have on hand.

Along with managing the airway, the airway should be kept free of fluids or obstruction. This is where either a suction machine with battery backup or a manual suction device is beneficial to handle secretions or emesis.

When dealing with injuries that occurred in a hyperbaric environment like diving, trauma or over-pressurization of the lungs can lead to pneumothorax. A tension pneumothorax is always an at-risk complication, and a way to intercede should always be available. Needle decompression kits are available at low cost, providing a quick and effective intervention in this life-threatening scenario. Numerous manufacturers produce these kits worldwide. The technique requires advanced training under the supervision of a physician or allied health professional.

After considerations for airway and breathing, as discussed above, the next step is to consider circulation. In order to have circulation, there must be blood and something to pump it. The first consideration here is to keep blood inside the body. A lot has been learned from the extended conflicts in the Middle East in terms of the utilization of CAT tourniquets. Once thought to be a treatment of last resort, it is now deployed rapidly in any type of hemorrhaging event where there is profuse blood loss, pooling of blood or continuous bleeding. Again, there are many models to choose from but the most recognized and recommended are probably the following:

- Combat Application Tourniquet Gen 6 (CAT-6)
- Combat Application Tourniquet Gen 7 (CAT-7)
- Ratcheting Medical Tourniquet (RMT) Tactical
- SAM Extremity Tourniquet (SAM-XT)
- SOF Tactical Tourniquet–Wide (SOFTT-Wide)
- Tactical Mechanical Tourniquet (TMT)
- TX2 Tourniquet (TX2)
- TX3 Tourniquet (TX3)

The American College of Surgeons in conjunction with the US Department of Defense and the Committee on Trauma has developed a training course for civilians and medical personnel alike, which can be found at www.stopthebleed.com.

The final consideration for circulation is the use of AEDs and IV access.

AEDs have become commonplace and can be found in airports, shopping malls, and other public places, and have become part of front-line treatment in Basic Life Support classes. A basic AED costs from $600 - $1,500 USD depending on the model. These are valuable in the resuscitation of a common cardiac event called ventricular fibrillation. When a victim is suspected of having a cardiac event with loss of consciousness, the AED can be deployed to analyze the cardiac rhythm and deliver a corrective “shock” to convert the fibrillation of the ventricles into a rhythm that can support life. These devices are easy to use and can potentially save a life, making them essential in today’s world.

After all is said and done from the hair raising, adrenaline-pumping, anxiety inducing events listed above… it would be great to get IV access to be able to give fluids as needed. Some simple IV access needle kits of multiple sizes and a couple of bags of routine fluids such as 0.9% normal saline, D5W or Lactated Ringers can make your patient feel a whole lot better.

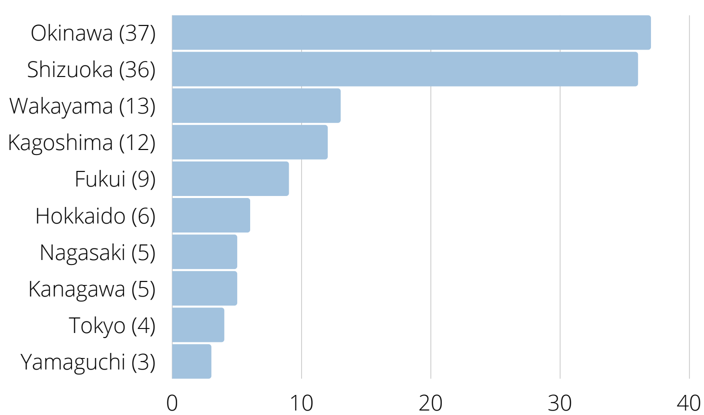
Take a moment to consider the wish-list items discussed above and formulate your own needs. What would you like? What would you need in your setting? It is better to plan ahead for emergencies than to wait and “wish” you had more.

Multiplace Hyperbaric Chambers of Japan

YASUSHI KOJIMA
AKIKO KOJIMA

Japan is an archipelagic country with islands covering over 1,864 miles (3,000km), offering a wide variety of diving opportunities throughout the year. In Southern islands such as Okinawa, the water is warm all year round with colorful fish, white sand and crystal clear water. In Northern islands such as Hokkaido, the ocean tends to be cool or cold even in summertime, and the floating ice diving in winter is quite famous. Also, Japan is volcanic with a unique underwater topography such as caves, steep walls, and rock formations.

Dive sites are scattered all around Japan—among them, the Izu Peninsula (near Tokyo and a weekend dive site for Tokyo residents), Kii Peninsula (near Osaka), and Okinawan islands are the major spots most often visited by divers.



The number of diving accidents in Japan is unknown; however the number of diving fatalities is known and shown in the graph above.

Most treatments for decompression illness are provided in multiplace chambers, compliant with the safety standards of the Hyperbaric Oxygen Treatment Safety Association which belongs to the Japanese Society of Hyperbaric and Underwater Medicine (JSHUM), and utilizing US Navy treatment tables.

Treatment in a monoplace chamber is supplemental where a multiplace chamber is not available.

The JSHUM conducts surveys of chambers across the country once every two years. According to the most recent survey conducted in 2019, there are 28 multiplace chambers among 204 healthcare facilities. 17 multiplace chambers are 24/7 for diving accidents, with poor regional distribution. Specifically, there are 8 facilities in the Kanto area (including Tokyo), and 3 facilities in the Okinawa area while other regions are medically vulnerable.

Transportation of injured divers is mostly managed by EMS and the Japan Coast Guard. In some areas, such as remote island of Okinawa and Ogasawara (Bonin Islands), the Maritime Self-Defense Force provides emergency transportation with special protocols.

A language problem often arises for divers from overseas. Many facilities now provide medical treatment with multilingual medical personnel, however in especially remote places, dive centers are requested to assist the accident divers who do not speak Japanese.

Figure 1:
Distribution of 24/7 multiplace chambers that can treat DCI in Japan

Unexpected Twists

EDUARDO GARCIA

A 61-year-old Canadian female Open Water diver with more than 100 dives in the last ten years was on vacation scuba diving in Cozumel and presented with vertigo, nausea, vomiting, and inability to walk one hour after finishing her dives for the day and taking a hot bath. In the four days prior to the accident, the diver made eight dives.

On the day of the accident her dive profiles were as follows: Dive 1: 75 fsw (23 msw)/:60 min on AIR, made a safety stop, her computer alarm warned her she went into DECO but she did not make decompression stops; SIT=1h Dive 2: 50 fsw (15 msw)/:60 min, with a safety stop. On her second dive, the computer indicated a rapid ascent.

Upon direct interrogation, she denied any history of decompression sickness (DCS) or hyperbaric treatment but declared she had four episodes of vertigo associated with diving, two of which required medical attention. These ranged from hours to days to resolve.

Other history included an episode of atrial fibrillation that apparently reversed with no anti-arrhythmic treatment, open-angle glaucoma of the left eye under treatment, and bilateral total hip replacement surgery.

Upon the diver's arrival at the emergency department, physical examination found normal vital signs, a Glasgow Coma Scale (GCS) of 15, normal pupils, a persistent lateral and rotational nystagmus to the right, and an inability to keep her eyes open due to the sensation of vertigo. Her muscular strength, tendon reflexes and sensitivity were normal.

However, her Romberg test was abnormal and she was unable to walk. Additionally, her hearing was normal but the external auditory canals showed a barotrauma of the left middle ear classified as a TEED score of 2. She denied any difficulties equalizing, ear discomfort during diving, or forceful ear equalization maneuvers.

To summarize, the diver presented with an episode of vertigo that began one hour after two dives with at least one identified significant stressor: an omitted decompression stop. In addition to the severe vertigo, she presented with a mild left middle-ear barotrauma with no evident adverse effect in the auditory system.

Differential diagnoses of vertigo associated with diving include alternobaric vertigo (ABV), inner ear barotrauma (IEBT), and inner ear decompression sickness (IEDCS). Alternobaric vertigo typically manifests during diving, but for the diver in question this was not the case. IEBT is usually associated with a significant barotrauma of the middle ear, mainly from ascent or forced equalization maneuvers, and vertigo starts during diving or towards the end of it. IEDCS was initially described in technical divers with mixed gases, however in the last 30 years there has been greater documentation of cases in recreational divers. Symptoms usually begin in the first 90 minutes after the dive.

The diver was treated with a USN TT6. A 12-lead electrocardiogram and a brain CT scan were also performed and reported to be normal. After initial treatment, there was little improvement in vertigo, gait and nystagmus. The diver was hospitalized and managed with hyperbaric oxygenation sessions and physiotherapy every day.

On the second day of treatment, transthoracic echocardiography (TTE) with bubble test was performed to rule out the presence of a right-to-left shunt (RLS), usually recommended for divers who experience “undeserved” vestibular, skin, or brain DCS. The result was positive, detecting bubbles in the left heart, which may be associated with a medium-sized Patent Foramen Ovale (PFO).

The diver reported decreased visual acuity in the right eye on the third day of treatment, and evaluation by an ophthalmologist reported an exacerbation of her preexisting glaucoma. The diver received 8 days of hyperbaric treatments, and was discharged from the hospital walking without assistance, mild vertigo associated with rapid head movements, and vision changes[1].

IEDCS is a real challenge for the hyperbaric doctor to accurately diagnose, and sometimes this can create confusion whether to treat with hyperbaric oxygen or not. However, with a good analysis of diving history, time of evolution, a good clinical otological and neurological examinations, the hyperbaric doctor can be supported in making this decision.

Current Scientific Postulation:

Several research studies touch on this same subject. Mitchell postulates that DCS involves the vestibulocochlear apparatus, commonly known as IEDCS. Symptoms attributable to inner ear involvement such as nausea, vertigo, and hearing loss may appear in association with other manifestations of decompression sickness or as an isolated clinical entity. This type of decompression sickness has been associated in multiple investigations with the presence of RLS[1].

Germonpré and Ballestra describe the clinical presentation of divers with decompression sickness, with lesions located in the upper cervical spinal cord, cerebellum, inner ear or brain and a significantly higher prevalence of PFO than divers with DCS locations in the lower spinal cord[2].

Cantais describes in his study of 101 divers who presented decompression sickness, 58% of thecases had RLS being more frequent in divers with cochleo-vestibular disorder first and second with cerebral manifestations, Cantais describes in his study of 101 divers who presented decompression sickness, 58% of the cases had RLS being more frequent in divers with cochleo-vestibular disorder first and second with cerebral manifestations, which suggests a paradoxical embolism as a potential mechanism[3]. Klingmman in a specific study of IEDCS and RLS refers that the causal mechanism in these cases may have been intravascular bubble embolism and that IEDCS may be more common among recreational divers than is currently recognized. Failure to treat IEDCS with recompression therapy can result in permanent disability. Because the differential diagnosis between IEBT and IEDCS may be impossible, the authors suggested that divers with inner ear symptoms after a dive should have recompression immediately[4].

Venous inert gas bubbles are commonly formed during or after decompression of dives, and the only plausible link between RLS and IEDCS is the transfer of these bubbles to arterial circulation; something described by Germonpré, Klingmann et. al. and Cantais et. al.

It has been interpreted to suggest that in divers with such a shunt, IEDCS may be caused by arterial bubbles that act as emboli. This logic is sound, but a purely embolic cause does not explain why, in many cases, the inner ear can be affected while the brain appears to not be.

As postulated by Mitchell et. al. the inner ear derives its blood supply from the labyrinthine artery, a small branch of the anterior inferior cerebellar artery, itself a branch of the basilar artery. The basilar artery is distributed only to the brain, so if venous gas emboli (VGE) are entering the labyrinthine artery from the basilar artery, they should also be widely distributed in the brain, however in isolated cases of IEDCS we do not see evidence of cerebral manifestations.

It is not clear why the inner ear can be injured under these circumstances while the brain is apparently unaffected.

One possible explanation for this discrepancy arises from work on the kinetics of inert gas in the inner ear and our subsequent ability to predict conditions of gas supersaturation in the inner ear after diving. "Supersaturation" refers to the fact that the sum of the tissue gas partial pressures is greater than the ambient pressure, a necessary condition for bubble growth. Bubbles introduced into tissue supersaturated with inert gas have been shown to grow. It follows that small arterial bubbles, which pass through a right-to-left shunt, would grow and be more likely to cause microvascular obstruction and mechanical disruption if transported to a tissue that was significantly supersaturated with inert gas. The mean time to nitrogen removal from the inner ear after decompression has been shown to be slower than that from the brain.

All of these factors must be taken into account to understand the pathophysiology of inner ear decompression sickness. In this case, the patient had a slow and favorable evolution, although she was left with sequelae. At present she is not recommended to return to diving due to vestibular sequelae, possible previous episodes of DCS and the presence of a medium sized PFO[1].

References

1. Mitchell, S. J., & Doolette, D. J. (2009). Selective vulnerability of the inner ear to decompression sickness in divers with right-to-left shunt: the role of tissue gas supersaturation. Journal of applied physiology (Bethesda, Md. :1985), 106(1), 298–301. https://doi.org/10.1152/japplphysiol.90915.2008
2. Germonpré, P., Dendale, P., Unger, P., & Balestra, C. (1998). Patent foramen ovale and decompression sickness in sports divers. Journal of applied physiology (Bethesda, Md. : 1985), 84(5), 1622–1626. https://doi.org/10.1152/jappl.1998.84.5.1622
3. Cantais, E., Louge, P., Suppini, A., Foster, P. P., & Palmier, B. (2003). Right-to-left shunt and risk of decompression illness with cochleovestibular and cerebral symptoms in divers: case control study in 101 consecutive dive accidents. Critical care medicine, 31(1), 84–88. https://doi.org/10.1097/00003246-200301000-00013
4. Klingmann, C., Benton, P. J., Ringleb, P. A., & Knauth, M. (2003). Embolic inner ear decompression illness: correlation with a right-to-left shunt. The Laryngoscope, 113(8), 1356–1361. https://doi.org/10.1097/00005537-200308000-00017

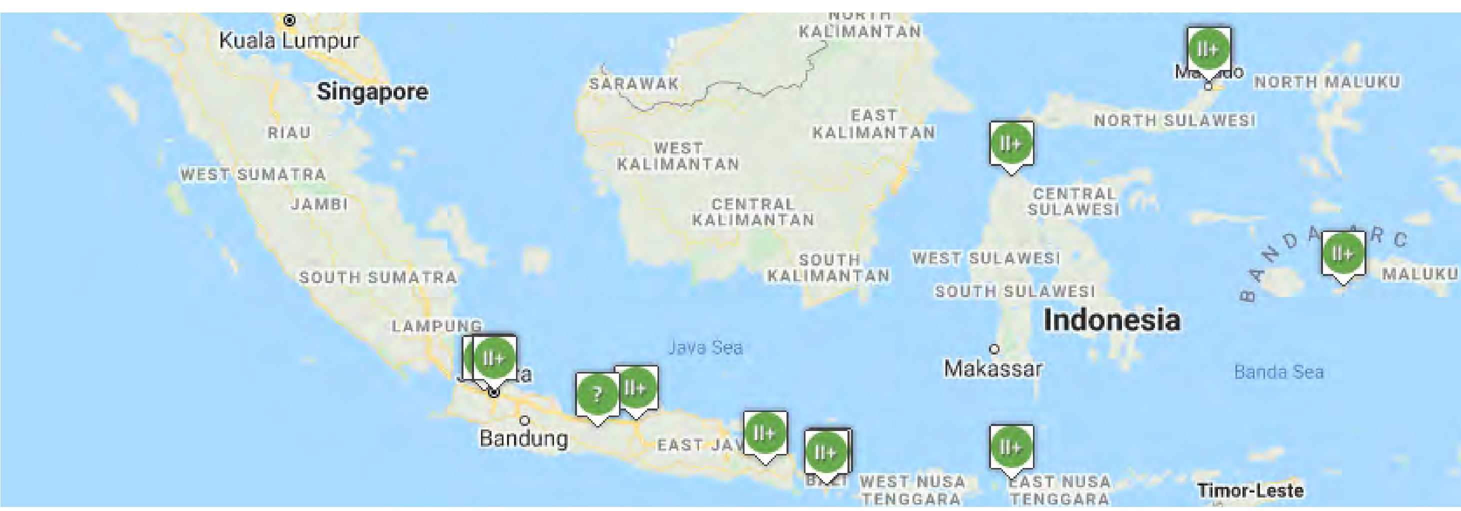
Diving Chambers in Indonesia

SHERYL SHEA

Indonesia is a prime diving destination, one of whose main attractions is the abundance of remote dive destinations, far from civilization and medical care, where reefs are pristine and diving conditions superb. There are many remote popular dive resort areas that may take days to reach, such as Wakatobi in Southeast Sulawesi, Misool in Raja Ampat and Manado in North Sulawesi. Liveaboard dive vessels are numerous and visit, for example, Raja Ampat, the Banda Sea and Alor. These destinations are very popular with serious divers who go to dive, dive, dive. A typical dive trip to these locations consists of multiple consecutive days of diving, with up to 4-5 dives per day. Due to the cost of these types of dive trips, the average age of divers tends to be older and while generally healthy, many have medical conditions which increase the risk of needing medical care. If a diver develops any medical complications requiring advanced care in these locations, reaching an adequate care facility – such as a recompression chamber - is usually complex and can result in a significant delay in treatment, often 24 hours or more.

A plethora of dive sites surround Bali and adjacent islands, which are popular with all ages, for opposite reasons; easy accessibility, with numerous daily international flights and the availability of land-based tourist attractions, especially cultural. Medical care on Bali is readily available, including three adequate recompression chamber facilities. While divers on and around Bali don't usually plan numerous consecutive days of diving such as in the remote destinations, shore diving is popular and some areas are accessed by roads that pass over mountains, which present an increased risk of decompression sickness. Alcohol consumption is popular, which also puts divers at an increased risk.

There are many multiplace hyperbaric chambers in Indonesia, but few that have been assessed by DAN and are considered operationally safe. To be considered so, they must have a local medical director with dive medicine knowledge and staff trained in chamber and emergency procedures, the capability to carry out a USN TT6, a fire suppression system, backup gas supplies, regular maintenance performed and a 24/7 availability to treat diving emergencies. At present there are 10 recompression facilities in Indonesia that DAN refers divers to, 3 of them on Bali, the others spread out over a vast area from Jakarta to Manado. This number can change as chambers can go on and off-line, have maintenance issues or staff changes.



Hyperbaric Chambers in Indonesia

However, the number of DAN-assessed chambers in Indonesia has gradually increased over the past few years, from two; one in Bali and one in Manado. Although the newer chambers tend to be larger, more attractive, have easier access due to large rectangular doors, and comfortable seats, the older round deck-style chambers are also quite adequate, although access is a bit more difficult, especially with an incapacitated patient. The more important factor is not the age, comfort or appearance of the chamber, but the factors previously mentioned. There are no diving chambers in Indonesia that DAN is aware of that can treat a critical patient. They would have to be evacuated to Singapore.

Manado- one of the original two diving chambers in indonesia

Some issues with Indonesia chambers that DAN has experienced which have resulted in avoiding referring diving patients to them are the lack of a local dive medical director, and treatment regimens for DCS that are not in line with international standards. Some chambers have medical directors that are based in other cities and even other countries, who are therefore not available to oversee chamber operations and treatment of patients. In some locations, the initial treatment for DCS, on both Type 1 and Type 2 cases, is a USN TT5, rather than the standard USN TT6 with or without extensions, which can result in inadequate resolution of DCS.

It is generally accepted that a USN TT5 may be adequate for the initial treatment of mild type 1 DCS cases, but for moderate to severe Type 1 or for Type 2 cases, the initial treatment should at a minimum be a USN TT6 or equivalent. Also, there are multiplace chambers that lack an entry lock, so are not suitable for treatment of divers with DCS, due to the inability of medical staff to enter the chamber during a treatment to attend to patient emergencies.

One of the new chambers in Bali, Indonesia

The recompression chambers that are used most for recreational diving patients in Indonesia are the chambers in Bali, due to the (somewhat) centralized location of Bali, 24/7 chamber availability for diving emergencies, a good airport, and experience in treating diving patients. As diving in Indonesia increases in popularity, and with the anticipated control of the Covid-19 pandemic with the arrival of the vaccine, the need for DAN-assessed operationally-safe diving chambers in Indonesia will increase.

DAN Diving and Hyperbaric Safety welcomes the opportunity to help you work though these issues to become a DAN operationally-safe chamber. For more information, please contact us at rcn@dan.org.

FREQUENTLY ASKED QUESTIONS

Q: How often do I need to calibrate my chamber depth gauges?

A: This question is asked frequently, and some confusion exists with how it needs to be done. There is more to just 'calibration' though, so let us break this down into a few respective parts.

1. We all use the term 'calibration' but in reality, all we can really do to test the gauge accuracy is zero the gauge and then compare the readings with some form of master, or pre-calibrated gauge. Let us therefore accept the word 'checking' rather than 'calibration', which will indicate if the gauge works and reads correctly.
2. Accuracy is a relative term. For deep diving, which decompression must be done very carefully, the standard requirement is ±0.25% of full scale. For a 0 – 450 fsw (0 – 130 msw) gauge, this would imply that each reading needs to be within ±1 fsw (±0.3 msw). However, for the treatment of injured divers to typically no more than 100 fsw (30 msw), this degree of accuracy is not required to ensure the best outcome. Here an accuracy of ±0.5% of full scale is accepted practice.
3. The frequency of testing depends on a variety of factors, such as the actual location and situation. Here are the guidelines:
   a. In the event of any visible discrepancy between different gauges reading the same pressurized compartment (say the Caisson and main lock gauges); or
   b. In the event of any gauge malfunction, such as not returning to zero, sticking, hunting around the expected pressure level; or
   c. In the event of any mechanical damage, such as the gauge being dropped or something striking the gauge; or
   d. Where regulatory requirements dictate (some countries and some operating standards have specified requirements;
   e. The original manufacturer's instructions; or failing any of these
   f. At least once a year. This is the general international standard; the ASME PVHO-2 standard for example requires annual testing.
4. The final consideration is how to check gauges. Here we have a few options.
   a. Comparing all the gauges fitted to the chamber: at least the treatment (main) lock and the transfer (entry) lock gauges; the Caisson gauge if fitted; or
   b. Using a master, calibrated gauge to check each depth gauge at a pre-selected set of pressures going up and down in pressure; or
   c. Removing the gauge and sending it to an accredited laboratory. However, unless this is required by the inspection authority, this is not the best way to do this as the transporting and then re-installing of the gauge can lead to changes in the readings. The ASME-PVHO-2 standard accepts the first option, as long as it is done thoroughly and recorded.

About The Authors

Francois Burman

Francois is a registered professional engineer and Director of Underwater and Hyperbaric Safety at Divers Alert Network, based in Durham, NC (USA). He is the author of the Risk Assessment Guide for Recompression Facilities, first published in 2001, and has performed over 150 on-site recompression chamber safety assessments around the world. He has over 35 years' experience in designing, manufacturing, installing, supporting and providing training in recompression chambers, has been with DAN since 1996 and is very active in supporting recompression chambers, especially through education and training.

Eduardo Garcia

Eduardo Garcia is a diving medical specialist based in Cozumel, Mexico. He qualified as a medical doctor in 1997 and then pursued a specialty in Internal Medicine, completing his studies in 2005. In the same year, he attended the NOAA Diving Medical Officer course in Seattle, USA. After this he went on to complete a Masters in Hyperbaric and Subaquatic medicine in 2015 in Barcelona. Eduardo has worked as a diving and hyperbaric doctor since he completed his first medical degree in 1997.

Julio Garcia

Julio has been a program director for both monoplace and a multiplace facilities since 1996. In 1999, he became the Program Director for the Center for Wound Care and Hyperbaric Medicine at Springhill Medical Center in Mobile, Alabama. In this position, with the assistance of his team that includes two physicians and five CHRNs, they provide 24/7 critical care hyperbaric services for over 200 miles of the central gulf coast. He is the incoming Nurse Representative on the UHMS board of directors, serves on the APWCA international education committee, and sits on the editorial board of Wounds magazine.

Akiko Kojima

Akiko is a passionate diver and has been certified as a Master Scuba Diver Trainer for more than 25 years. She is a former Manager of DAN Japan and has assisted many divers during emergencies as a case manager. She was certified as a Diving Safety Officer in 2019.

Yasushi Kojima

Yasushi is a medical doctor who specializes in orthopedics and diving medicine. He is the former Medical Officer of DAN Japan and now belongs to the of Tokyo Medical and Dental University Hyperbaric Medical Center, which houses the largest multiplace chamber in Japan. He is also a Director of the Japanese Society of Hyperbaric and Undersea Medicine.

Matias Nochetto

Dr. Nochetto is DAN's Director of Medical Services and Programs. He received his medical degree in 2001 at Universidad de Buenos Aires (UBA) and completed a 3-year clinical and research fellowship in hyperbaric and diving medicine from National Autonomous University of Mexico (UNAM). At DAN, Dr. Nochetto runs the Medical Services Department where a team of paramedics, nurses and doctors handle calls on the Emergency Line and medical inquiries, as well as assisting with development and implementation of DAN medical programs worldwide.

Sheryl Shea

Sheryl is a registered nurse, a certified Clinical Hyperbaric Technologist and works in the Medicine Department at Divers Alert Network. She has worked as a chamber operator and attendant, trained chamber personnel, worked for many years at a dive shop, has received extensive training in hyperbaric facility safety and technology, performed chamber safety assessments, and serves as both the chamber medical resource and diving medicine information specialist.

Contact Information

- Divers Alert Network .... +1-919-684-2948
- Recompression Chamber Network technical and operational assistance .... rcn@dan.org
- DAN Recompression Chamber Assistance Program .... rcap@dan.org
- Recompression chamber medicine enquiries .... medic@dan.org
- General diving safety enquiries .... riskmitigation@dan.org
- Chamber Operation Safety website .... https://dan.org/safety-prevention/chamber-operation-safety