DAN RECOMPRESSION CHAMBER NETWORK

RCN Bulletin:

A Newsletter of the DAN Recompression Chamber Network

THE DAN RCN BULLETIN

Let us start this newsletter with a little bit of history.

The DAN Recompression Chamber Assistance Program (known to many as RCAP) was conceived in 1993 as a means of developing a network of safe and effective diver recompression chambers in our popular dive regions. Prior to the global advances in the provision of HBO, many of the chambers had safety, technical, operational and especially sustainability issues due to the relatively few treatments given. In fact, many were the products of passion – local service providers and benefactors establishing chambers that would not be used often but were essential in the treatment of injured divers. DAN launched this outreach program to help these chambers attain the level of safety in operations that benefitted all. RCAP is still very much in action.

The DAN Recompression Chamber Network, or RCN, developed out of this and included chambers that did not require much in the way of assistance but that were willing and able to accept and treat divers.

It might be of interest to note that the RCN now has 172 active and participating chamber facilities, with the number growing in areas that are fast becoming top recreational diving locations. This means that we have our work cut out for us and engaging with all makes for a busy department.

In 2001, DAN launched the Risk Assessment Guide for Recompression Facilities, to provide all facilities with the basic requirements to be able to operate safely and effectively. It was not intended as an audit or inspection tool, but rather as a resource for facilities to be able to use in better understanding their risks, and obtaining guidance on equipment, operations, education and maintenance of facilities. Since then, the guide has gone through several revisions to accommodate changes in some of our codes and standards, lessons learned from a variety of incidents, new operational techniques, and even the advancement of hyperbaric technology. Spanish and Portuguese versions were issued along the way.

In October of this year, we published Revision 4 of the Guide, with substantially more information, guidance and risk mitigation recommendations. While the hardcopy book is available in the various DAN regions, for a nominal fee, it is online as a free Acrobat (PDF) download. The website is https://apps.dan.org/Publication-Library/ and the QR code is below – for those of you who like to use your mobile devices. In short, you will receive over 100 pages of information, guidance and, we hope, education. Use this to identify your facilities actual risks so that you can mitigate these effectively and without needing significant investments. Use it if you are about to make changes to your facility or are about to set up a new facility – remember that a hyperbaric facility is much more than just a chamber. Use it if you are changing your operational procedures. And use it to inform and educate all your staff. This way we can all be safer, available and effective in dealing with injured divers – and HBO patients if this is part of your services.

In a similar vein, DAN published a Risk Assessment Guide for Dive Operators ad Dive Professionals in late 2018. Our vision is to not only be able to ensure effective treatments but to prevent accidents from happening in the first place. This Guide, now in Spanish too, is aimed at those putting divers into the water: prevention is better than cure, but we will of course always need a cure for those unintended, undeserved and unfortunate cases. You can download a free copy of this Guide on the same website. Feel free to let the dive centers and professionals that you work with know about this too.

Lastly, and in support of our risk assessment and mitigation work in our industry, we have produced two free eLearning courses for anyone to be able to take. One concerns dive boat safety best practices, but the other applies equally to chambers compressing their own gases. The Assurance of Breathing Gas Quality is as applicable to a chamber as it is to a diver. You can find these at https://dan.diverelearning.com – the QR code is provided too.

Risk Assessment guide

DAN eLearning courses

This is the 3rd in our series of newsletters: please be sure to let us know whether you find them useful, if you have questions and even if you just want to share your thoughts. Our email address is rcn@dan.org.

-Francois Burman and the DAN RCN Team.

DAN

RCN Bulletin:

A Newsletter of the DAN Recompression Chamber Network

WELCOME TO THE DAN RCN BULLETIN

What's Inside:

The Essential Attributes of Effective Emergency Action Plans

Francois Burman

One good definition of an emergency action plan, or EAP, is "a predetermined course of action intended to mitigate a potential emergency or damaging situation that might endanger or harm people, property or a facility's ability to function safely."

In this article we will explore the underlying purpose and essential elements of an EAP.

The needs of a hyperbaric treatment facility can be distilled into four primary areas:

1. The protection of staff, patients & public - hyperbaric exposures & pressurized systems are not without risk;
2. The protection of facilities & assets – including the building, facility, chamber and support equipment;
3. The mitigation of liability risks – from staff & patient exposure, compromised treatments and public safety; and
4. The ability to be able to provide essential services for injured divers or HBO patients.

An effective plan requires a detailed assessment of the risks and potential situations that can occur and an understanding of what mitigating actions may be necessary.

We start with a vulnerability assessment in which we consider the probable hazards and then decide which of these are real and which are purely theoretical.

At many hyperbaric treatment facilities and based on the scope of treatments given, we could find any of the following situations requiring rapid and well thought-through responses:

Chamber emergencies: examples of system situations include:

- Loss of primary air and/or oxygen supply
- Loss of back-up air and/or oxygen supply
- Contamination of air or oxygen
- Rapid increase or decrease in chamber pressure
- Fire inside or outside the chamber
- Fire inside or outside of the compressor or gas storage facilities
- Loss of electrical power
- Failure of any chamber systems (lighting, communications, etc.)
- Activation of deluge system (either accidental or intentional)
- Abandonment, trapped inside the chamber
- External threats (weather, unrest, criminal)

Then, as we are providing a medical treatment, examples of patient or attendant medical situations could include:

- Oxygen toxicity
- Arrhythmias, cardiac arrest (& defibrillation)
- Pneumothorax
- Barotrauma (middle ears, sinuses, teeth, lungs, intestinal)
- Emergency myringotomy
- Arterial gas embolism
- Respiratory distress or bronchospasm
- Suspected hypoglycemia
- Vomiting
- Loss of consciousness
- Claustrophobia
- Uncooperative or aggressive patient

Once the relevant hazards and their probability, frequency and severity are established, you will know where your risks exist. You then need to decide on how to respond immediately and without any doubt about what to do.

Most importantly you need to be able to mitigate the initial situation and this could include any or all of the following:

- Containing, controlling, extinguishing and reacting appropriately.
- Communicating the situation to rapidly obtain assistance.
- Taking care of any injured people.
- Accessing emergency equipment that is readily available and functional.
- Strictly following the plan, reacting appropriately and not overthinking your actions.

Other elements that can be considered to mitigate emergencies and help you defend yourself and your facility in the event of accusations, investigations or criminal hearings include following:

- Standard operating procedures – these help with prevention and at the very least, early warning in an emergency situation;

- EAP checklists, which provide structured reactions, reduce thinking & aid training;
- Incident forms and reporting documents, which provide learning opportunities and help reduce legal consequences;
- Training, which provides knowledge & awareness, and also aids in prevention; and
- Realistic drills, which ensure the ability to react correctly without panic and are the cornerstone of prevention, preparedness and competence.

Emergency actions plans are useless if not practiced. During all our chamber safety assessments, which include some 130 facilities to date, we have found that this is the most important and most poorly managed of all the risks facing a hyperbaric treatment facility.

It is through practicing these regularly that we can:

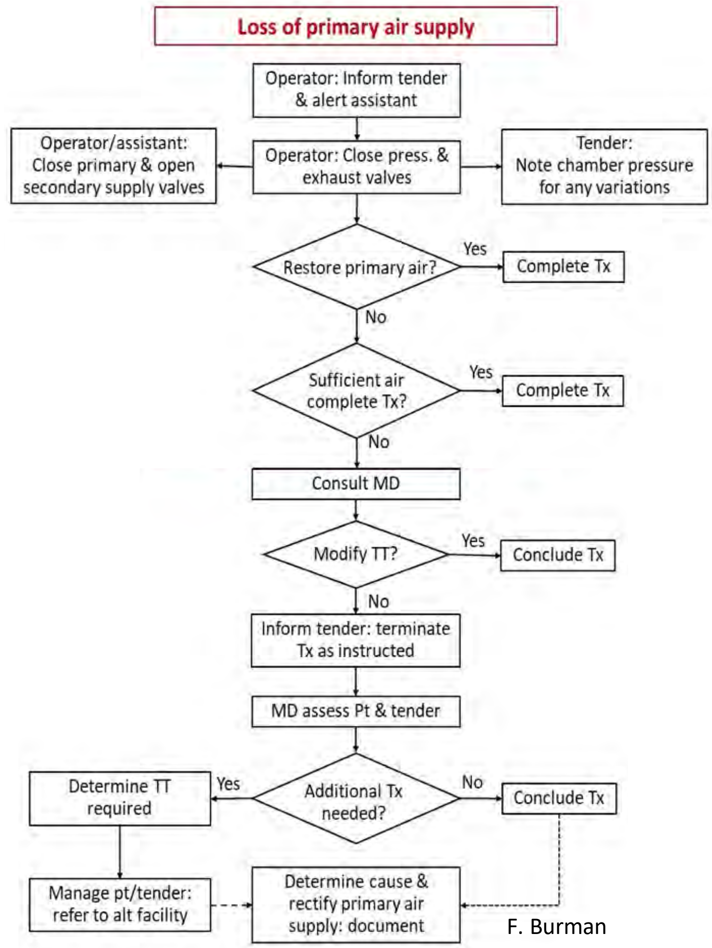
- Determine their effectiveness – do they achieve the required result?
- Iron-out any problems - we can ensure that all steps are able to be performed, we can think of alternate plans if plan A does not work, and we can review and adjust these plans as needed.
- Perform under pressure – making mistakes while your colleagues are watching is better than missing an essential step during a real emergency, and remember, this is a team effort.
- Build confidence and competence – not only will we know exactly what to do in what will be a very stressful situation, we will also know that the plan works.
- Skills diminish with time so determine an appropriate frequency for your drills and keep records of each one.

Take these seriously, ***every time***.

We have been asked by some of you to give a few examples of EAPs. The problem with this is that every facility is different – staff are different, the equipment and the building are different and the availability of emergency services varies greatly, especially in some more 'remote' areas.

Medical emergencies are less of a concern, as medicine is a very well-developed series of practices. We can provide some guidance as to the important elements of medical emergencies but remember that *skills have to be refreshed regularly*.

Operational or system emergencies require very system-specific plans. The one we dread the most is fire inside the chamber. The one more likely, and critical in the event of a seriously injured diver who cannot simply have their treatment terminated, is loss of air supply to the chamber.



F. Burman

We have provided a sample version for you to review and to adjust to fit your own air supply systems, common points of failure and available equipment. Remember: you may have two independent, non-power dependent, air supply systems. But you may have only one connection between these and the chamber. If the main valve fails, you will lose both your supply systems simultaneously.

The DAN Risk Assessment Guide for Recompression Facilities contains useful information to aid you in assessing your real risks and mitigating emergency situations. The guide is available at the link provide in the introduction to this newsletter.

Inherent Weakness in Some Decompression Models- Dive Tables

WAJ Meintjes

The case:

A young, fit diver was on a two-week diving holiday where he performed two or three dives per day. His dives were always conservative and within no-decompression limits. On day 5 of his diving holiday he experienced pain in his left shoulder, which he described as having a deep character and movement of the shoulder did not affect the pain much. After discussion with the DAN Hotline, the diver was diagnosed with musculoskeletal decompression sickness at a local clinic, and chamber treatment resulted in immediate and complete resolution of his symptoms.

His question:

Why would I get decompression sickness if I never exceeded no-decompression limits, and no unfavorable events happened during the dive?

The explanation:

Inert gas exchange during a dive follows similar dynamics to how medication is absorbed and eliminated by the body. In technical terms, we refer to this as "tissue half-times." A "tissue half-time" is the time it takes a tissue compartment to reach 50% of its saturation capacity. This way, when diving, in one half-time a tissue would be 50% saturated. After two half-times it would be 75% saturated and so forth.

If we do the math, we can say for practical purposes that a tissue would be fully saturated after six half-times. For instance, if we consider a "fast tissue,"

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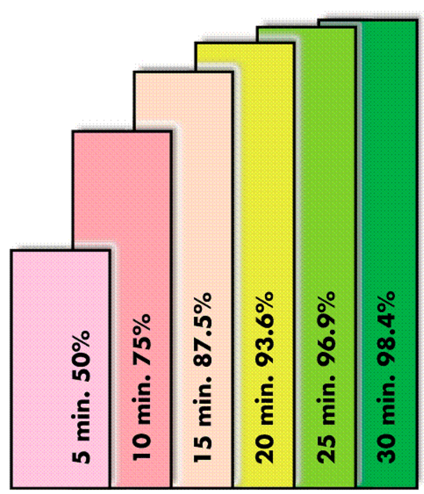
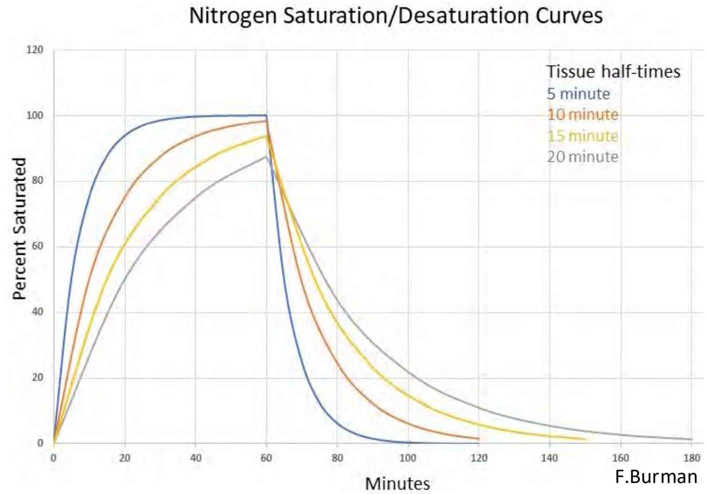


Tissue Halftimes



such as neurological tissues, we can (for argument's sake) hypothesize a tissue half-time of 10 minutes. This means that this tissue will be fully saturated at a specific depth if you have spent one hour (60 minutes, or 6 half times) at that depth. Likewise, desaturation (off-gassing inert gas) will also take 6 half times (60 minutes in this example).

However, it is important to notice that even if the tissue is not fully saturated when desaturation begins, it will still take 6 half-times to fully desaturate. Therefore, if a "slow tissue compartment" is only partially saturated in the case ofthe same 60-minute dive, a 30-minute tissue will be 75% saturated.

It is important to note that this same tissue that has absorbed gas for 60 minutes, will take 6 half-times (3 hours) to fully desaturate… After one hour it will only be 75% desaturated.

With this concept in mind, it is important to notice that most diving tables consider a person a "new diver" (not performing a repetitive dive) after a period of 12 hours. If this constitutes 6 half-times, it means that the slowest tissue considered in the diving tables has a tissue half-time of 2 hours (2 hours x 6 = 12 hours). This is, of course, a mathematical formula, but research[2] has shown that the actual slowest tissue half-times (for nitrogen) is somewhere between 320 to 480 minutes (5h20min to 8 hours!). This implies that most diving tables currently in use do not consider the slowest tissue compartments adequately when calculating decompression profiles. This

[1] (n.d.). Retrieved from https://www.idc-guide.com/recreational-dive-planner/

[2] Sicko Z, Kot J, Doboszynski T. The maximum tissue half-time for nitrogen elimination from divers' body. Int Marit Health. 2003;54(1-4):108-16

means that according to physiological principles, a "repetitive dive" (where residual nitrogen in the tissues may impact a subsequent dive) should be defined as "a dive performed somewhere between 1,920 and 2,880 minutes after a previous dive." This is 32 to 48 hours following the previous dive!

Fortunately, decompression sickness is not a frequent event and the body can tolerate a certain amount of supersaturation without experiencing decompression sickness. However, this is one explanation as to why a person can suffer decompression sickness – even if they dive within no decompression limits.

This makes sense, since the only factors taken into account when developing the mathematical decompression model (using diving tables) are the maximum depth of the dive and the time spent at that depth. There are a number of other physiological factors that are not considered, such as age, sex, exercise (before and during the dive), hydration status, any medications being used, temperature, body composition (fat percentage), hormonal changes, etc. The bottom line being that mathematics does not yet fully predict our physiological responses to a dive.

The implications:

Tissue saturation has not yet been fully investigated and, as such, we don't have a "mathematical model" to guide our actions during a diving holiday. However, we do know that divers performing 2-3 dives per day could potentially present with (slow-tissue) pain-bends around the fifth day of diving. Conservative divers should therefore consider taking a 24-hour break from diving every three days or so. This will increase the safety margin and make a diving holiday less painful. Likewise, dive operators may plan packages for their clients that include non-diving activities to increase the safety margin of their clients.

Case Study: Skin DCS

Matias Nochetto

A 52 year old woman and her husband had been diving on a Caribbean island. They did 7 dives over 3 days, with 3 dives on the last day of diving.

The maximum depth in the dive series was 108fsw on day 2, and the average depth for all dives was 75fsw. All dives were performed on air, within no-decompression limits and were reported as uneventful. After a third dive on the final day of diving, the female diver noticed blueish mottling and tenderness across her abdomen. This sensation was followed by vague constitutional symptoms, including generalized soreness and tiredness, dizziness, lightheadedness and mild nausea.

The diver was evaluated at a local clinic by a knowledgeable dive medicine physician who diagnosed her with Type 1 DCS with cutaneous manifestations consistent with cutis marmorata. The doctor confirmed no neurological abnormalities and prescribed a USN TT6 and intravenous hydration with positive results but incomplete resolution. The next morning the diver reported feeling much better but was still experiencing some persisting deep tissue soreness in the abdominal area and mild constitutional symptoms, to which the doctor prescribed a subsequent USN TT5, after which all symptoms resolved. A follow-up 24 hours later confirmed no relapse.

Skin DCS

This case illustrates a classic case of cutaneous decompression sickness. The description of abdominal mottling was perfectly described, with a bluish marbled pattern on all 4 quadrants and associated deep tissue soreness on palpation, all in the context of a series of 3 days of diving. The divers provided downloaded dive profiles, which did not seem to be indicate aggressive dives other than a few final rapid ascents from the safety stop to the surface.

It is important to emphasize that it is not uncommon for divers to develop classic cases of decompression sickness without any apparent deviation from what is commonly considered to be a "safe and uneventful dive." These cases only confirm that decompression stress should always be regarded as a physiological insult of a magnitude that is proportional to the magnitude of the dive profile itself. But what turned a moderate and uneventful dive series into one that triggered decompression sickness has yet to be deciphered.

The Recompression Chambers of the Red Sea

Guy Thomas

The Red Sea has always been an extremely attractive destination for European divers because of its close proximity to Europe and the great deals on offer despite past political problems in some of the countries. Typical dive destinations around the Red Sea can be found in Djibouti, Egypt, Israel, Jordan, Saudi Arabia and Sudan.

The most popular dive destination i is without a doubt Egypt, both for the beauty of the underwater life as well as for the relatively low price of a 1-week dive holiday. In fact, for European divers it is often cheaper to travel to Egypt for a week of diving than to another European country, or even to another location in their own country. Diving occurs mainly from smaller dive boats that offer day trips or from larger liveaboard vessels. The huge number of divers in the Egyptian part of the Red Sea has led to a larger number of diving accidents when compared to other "European-preferred" diving destinations. The first available hyperbaric recompression chamber in the area was established in Sharm El Sheikh in the 1990's, but over the years a network of multiplace chambers with 24/7 availability has developed through-outthe region (Marsa Alam, Safaga, Hurghada, El Gouna, Dahab and Sharm El Sheikh). This has made it possible for DCI cases to be treated within a maximum of 6-12 hours, including the time needed to reach the shore. The recompression chambers are located either in or hospitals or clinics. With exception of the Marsa Alam area, search and rescue services are active within the entire region which further reduces transportation times. Generally speaking, all Egyptian treatment facilities are very collaborative and open to discuss the treatment of injured divers with DAN and other dive insurance companies in real-time.

Israel's city of Eilat is another favored dive destination although most visitors are from within Israel. Diving is typically done from shore and DCI cases are treated in a multiplace chamber (24/7 availability) that is situated inside the Joseftal hospital. Obtaining medical reports and discussing the real-time treatment of injured divers is however sometimes problematic.

Aqaba in Jordan is a "young" dive destination and the local government is investing significantly in recreational diving activities to attract divers to the region. They are adding interesting dive sites by sinking boats to create artificial reefs and wrecks to dive on, but also have made sure that an up-to date multiplace chamber and hyperbaric team is available 24/7 in the city's modern military hospital. Although collaboration is excellent, the hospital does not accept payment for treatments and visitors from foreign countries which complicates medical and insurance assistance.

Saudi Arabia is a less popular dive destination and accidents rarely happen in this part of the Red Sea. A chamber is however available at the Dr. Soliman Fakeeh Hospital in the city of Jeddah.

Hyperbaric chamber in Eilat, Israel

In Djibouti a US Navy hyperbaric chamber is located at the harbor. However, communication is often problematic and medical evacuations to Europe or Egypt are often required.

After Egypt, Sudan has probably the best underwater environment, but there is no local hyperbaric chamber and medical facilities in Port Sudan are limited in their abilities, necessitating evacuation to a larger, better equipped hospital 500 miles (800 km) away. In reality, all medical evacuations are made to Europe.

Throughout this region, where there may be political unrest at times and to some extent complex visa requirements, evacuations to Europe are often the preferable solution.

Dive Sites and Recompression Chambers of Argentina

Gustavo Mauvecín

Argentina has an extensive maritime coastline of more than 2,900 miles (4,700 kilometers) on the Atlantic Ocean. Argentina has a great Continental Platform, that is to say, the extension of the continent below sea level.

Diving usually takes place in two different areas: the waters of the Atlantic Ocean and the lake sectors. Both of these preferred dive locations lie in the Patagonian region thanks to the transparency of its waters.

The most outstanding sites in Patagonia include:

- Puerto Madryn, which is considered the nation's capital of diving. There are both natural areas and artificial parks or shipwrecks, especially populated with boats or sunken vehicles, to create an environment suitable for the proliferation of marine species.

Map of Argentina

- San Antonio Bay, located on the coast adjacent to the Río Negro has several beaches: Playa las Grutas, Playa Orengo, Isla de los Mejillones, Banco de Almejas and Puerto de Ultramar, that are optimal places to enjoy diving. There is varied marine fauna and the temperature of the water is comfortable.
- The Beagle Channel in Ushuaia, with its cold water where diving becomes an extreme activity. With temperatures below 40ºF (5ºC), special preparation and equipment is required for diving here. When underwater, the spider crabs and the algae forests constitute a peculiar underwater landscape. Also part of the Beagle Channel are Lake Traful in Neuquén and Lake Nahuel Huapi in Bariloche. Among the lake sectors these two are the most popular.

Hyperbaric medicine facilities in Argentina are mainly private or belong to the armed Forces, with only a single public hospital equipped with a hyperbaric chamber. Almost all hyperbaric medicine services are provided in multiplace chambers suitable for treatments up to a pressure of 3 bars (100 FSW or 30 MSW). Availability is 24/7. According to the records of the Argentine Society of Hyperbaric Medicine and Underwater Activities (SAMHAS), there are 16 registered hyperbaric medicine facilities in the country.

In Patagonia, the area where diving is most practiced, the availability of hyperbaric chambers is scarce, with large distances between treatment facilities.

- Mar del Plata: CMH Hyperbaric Medicine: Multiplace chamber
- Escuela de Submarinos y Buceo, Armada Argentina: Multiplace Chamber
- Hospital Naval Puerto Belgrano: Multiplace Chamber
- Puerto Madryn (public) Hospital: Multiplace Chamber
- Hospital Naval Ushuaia: Multiplace Chamber

An important aspect here is the availability of human resources and adequate training of doctors and paramedics in the management of decompression accidents. Most of the doctors, paramedics, and recompression chamber operators are trained in the Armed Forces and are familiar with the use of the US Navy's therapeutic tables.

Zanzibar's 2010 Hyperbaric Chamber Attendant and Operator Course

Tammy D. Holter

Note: This article was originally written for the Autumn 2011 issue of DAN Southern Africa's Alert Diver magazine.

Since my first Zanzibar diving experience more than a decade ago, I was overwhelmed with the diversity of marine life in the waters off this idyllic island less than 6˚ from the equator. Over the years, I have become more and more involved not only with our dive centre, Scuba Do Zanzibar, but with the industry as a whole.

The dive centres in Tanzania formed aconsortium in late 2005. The concept wasoriginally to overcome the difficulties of importing PADI training products into a remote destination. The idea of working together has grown and now it not only gives us added buying power from PADI, but also from many diving industry suppliers. This consortium of diving companies is now working together on important marine conservation initiatives with our Department of Fisheries and Environment. Currently, the Zanzibar diving industry is working even closer together by promoting diving safety through the Hyperbaric Chamber Support Programme which our diving doctor, Dr Henrik Juhl, has recently resuscitated.

Diver recompression chamber at Matemwe, Zanzibar

Zanzibar has been very fortunate over the past four years to have the guidance of top diving doctors such as Dr Isabel, Dr Bruce, Dr Luba and now Dr Henrik. Their guidance has taken us from the old school thinking that DCS happens only to the "dodgy divers" who do not follow safe diving practices, to our current understanding that a diver can get bent – even without doing anything wrong! Although diving is one of the safest adventure activities, as the Zanzibar diving industry grows and more people of all ages and fitness levels get involved, statistics show there will be a greater need for an operational chamber with the support of medically trained personnel.

Having taught over 400 people to dive and being a certified diver for more than 15 years, I only recently witnessed my first diver with an undeserved case of DCI. A healthy female diver in her early 30s experienced a skin bend after two very conservative dive profiles. I was personally acting as dive master on the dive and can attest as to how conservative her dives were as I slowly ascended with her, making safety stops on each ascent.

Hearing about the concept of an undeserved case of DCI and actually seeing it are two different things. It was this one incident which encouraged me to educate myself even further on recognising the signs and symptoms of DCI – far beyond what is taught in standard dive theory. This experience also heightened my interest in hyperbaric medicine and motivated me into getting more involved with our Chamber Support Programme.

I had the fortunate experience of attending the November 2010 Hyperbaric Chamber Attendant and Operator Course, sponsored by DAN-SA, with our instructor, Morné Christou. It was an amazing personal learning opportunity as well as an important event for the diving industry of Zanzibar. The Zanzibar Hyperbaric Chamber facility gives peace of mind to all divers who visit and enjoy the wonderful diving here in Zanzibar and the whole of East Africa. The first part of the week's training covered the Hyperbaric Chamber Attendant Course.

The attendant's role involves being inside the chamber with the injured diver. This person has the responsibility of monitoring the patient's signs and symptoms and communicating with the doctor to assist the patient with the oxygen mask, and to be familiar with operating the chamber from the inside in case of emergency and be familiar with all emergency procedures. We are also in a position to brief the injured diver on chamber procedures, check that they are adequately dressed with no flammable clothing, jewellery, etc., and assist them in and out of the chamber. Together with Morné, we followed each pipe to and from the chamber and learned to problem solve anything that could potentially go wrong. We were taught how to bring the chamber online as well as take it offline after a treatment, always leaving it in a state of readiness.

On my first chamber dive, I knew very little and had no idea that I could control it from the inside. As a diver, I know that when I am diving I can control my descent and that I will not hurt my ears if I experience a squeeze. Therefore, on this first chamber dive I had an overwhelming feeling that I was not in control which, combined

with the sounds of the chamber being pressurised and the changes in temperature, was quite an intimidating experience. This has given me insight as to what it might be like for an injured diver to go into a chamber for their first time while most likely experiencing pain from the injury. As the chamber attendant, it is my job to try to put the injured diver at ease and prepare them for what they are going to experience. By my second chamber dive, I had learned how to control the chamber from the inside and Morné and Dr Henrik repeatedly presented challenges for us to solve which not only built our confidence, but also made the experience of being inside the chamber much more manageable!

Once we mastered being on the inside, we learned to control all aspects of the chamber from the outside. We were really put to the test and given example treatment tables to follow while our instructor and doctor were throwing many, many scenarios at us. Overall, the course was very intense; we learned a tremendous amount and were left feeling confident to operate the chamber if and when needed.

About a month after our training, just around sunset, I received a call from Dr Henrik. He was at the chamber with a patient. As I had been in the office all day and our other instructors who are operators had been diving, it was my turn to go. On my 30 minute drive to the chamber, I was reviewing all of my training in my head and getting myself prepared. I arrived at the chamber and it was decided that I would be the attendant on the inside with the patient. Once inside, everything we had learned in training came back to me. It was amazing to see the patient get relief as soon as we reached our treatment depth.

Dr. Henrik Juul instructing new staff

The team of chamber operators and attendants from Zanzibar is made up of volunteers, mostly dive masters and instructors working on the island. When treating an injured diver, Dr Henrik relies on his team of attendants and operators who are on call to come and assist. As most dives are during the day, initial chamber treatments are likely to happen from late in the afternoon to the middle of the night, so it is important to have quite a few of us trained up to ensure we can support Dr Henrik. At Scuba Do Zanzibar, four of our instructors trained as operators and attendants so that we are in a position to assist. Currently, we have a team of 14 trained operators and attendants from One Ocean, Bahari, Peponi and Buccaneer Dive Centres, as well as a few independent divers not working in the industry who volunteer their time. The overall safety of diving in Zanzibar, as well as our ability to handle any sort of diving emergency, is an asset to the whole industry and a clear benefit resulting from the co-operation of the diving operators in the industry.

I invite you to come and experience the beautiful, diverse diving we have in the Indian Ocean off the East African coast. In addition to our magnificent marine life, we can offer you the peace of mind that, in the unlikely event you or your buddy have a diving accident, our diving doctor and his chamber support team, together with DAN-SA, will be there to help! I am very happy to be part of the team of Zanzibar chamber operators and attendants.

Karibu Zanzibar!

Case Study: Dizziness Following a Dive

Jim Chimiak

A 44-year-old woman flew to the south pacific and began diving the following day. She described herself as an experienced diver. She was overweight with a history of well controlled depression for which she took sertraline for over three years without problems. She was otherwise healthy. She was a non-smoker, consumed alcohol socially and exercised regularly. Her air dives were conservative and consisted of 5 days of diving with a day off on day three. Her diving days began with her deepest dives first and consisted of 2-3 dives per day. Her dives ranged from 85 fsw to 45 fsw and were all no decompression dives. Safety stops were performed on each dive.

Twenty minutes after the third dive, which was otherwise uneventful, extreme fatigue and a powerful sensation that the room was spinning was relayed to the divemaster. She had one episode of vomiting and persistent nausea that also began following this last dive. She was quite anxious with an elevated breathing rate and a mild tingling of both fingertips and around her lips. She was immediately placed on high flow surface level oxygen, oral hydration was initiated, a neurologic exam conducted, diving operations ceased, and she was immediately transported to a local medical clinic for evaluation. Her dizziness and nausea persisted but her breathing rate slowed and her tingling resolved.

At the clinic, oxygen administration was continued along with intravenous hydration with a balanced salt solution without glucose. A neurologic exam was normal except for noted right nystagmus, a positive Romberg and altered gait. She stated that the sensation of spinning persisted. Her initial nausea had improved. Motor and sensory exams were normal. Normal bladder function with the production of clear dilute urine was seen. She denied any ear congestion, hearing difficulties and her otoscopic exam was completely normal.

The results were discussed with the DAN physician and the decision was made to proceed with a recompression on a US Navy treatment table 6. Due to some improvement, extensions were conducted. Upon completion her nausea had resolved, and her vertigo was mild. The following day, a US Navy treatment table 5 was conducted with near resolution of her vertigo. A second treatment table 5 resulted in full resolution of her vertigo and a normalization of her neurologic exam including her gait.

She complied with the physician's recommendation to wait a minimum of 3 days (she left on day 4 following her last treatment) before flying home where she followed up with a diving medical physician who documented a normal exam. She was perplexed that her series of dives were much more conservative than those she had completed in the past. The diving medical physician discussed her diagnosis of inner ear decompression sickness risk and detailed practical conservative diving techniques to help mitigate the risk of repeat episodes. She stated she was considering cardiology consultation for a bubble contrast echocardiogram to rule out PFO.

Recompression Chambers in the Pacific Island Region

Johan Olivier

The Pacific Island region can be broken up into the following main regions: Asia, Micronesia, Melanesia, Polynesia and Australasia. The diving environment varies from warm tropical waters in the northern Micronesian region to colder sub-tropical waters in the Australasian area. Popular dive destinations include Guam, Indonesia, Fiji, and Papua New Guinea, just to name a few. These sites are sometimes very remote and offer tropical sea-life in abundance. Most of the popular dive destinations and associated operations are on smaller islands well away from main cities and airports, so there is normally a fair amount of travel required to get to these exclusive or exotic areas.

Hyperbaric chamber in Makassar, South Sulawesi, Indonesia

Medical treatment and chambers are sometimes located very far away, and transporting an injured diver to the nearest appropriate recompression chamber facility may be restricted by weather and often flights are only available during the day.

Divers are therefore encouraged to raise this issue with the resort or dive operator at the time of booking so that they can better understand the emergency action plan for their trip.

Hyperbaric chamber in Manado, North Sulawesi, Indonesia

Here are a few chamber locations in what is a truly vast area:

- Australia – most major cities
- Borneo – Kota Kinabalu
- Chuuk
- Fiji – Suva
- Malaysia – Kuala Lumpur, Ipoh
- Indonesia – Jakarta, Manado, Bali, Kota Palu
- New Zealand – Auckland and Christchurch
- Palau
- Philippines – Manila, Batangas, Cebu, Subic Bay
- Singapore
- Solomon Islands
- Vanuatu

It should be noted however, that the quality of chamber services and the level of care available differs significantly between the various health-care facilities.

Part of the challenge in remote diving regions where there is a locally established recompression chamber is financial sustainability. Funding and utilization are often very limited in remote areas where the primary need is the treatment of an injured diver.

While larger centers are often managed by healthcare facilities offering hyperbaric oxygen therapy (HBO), others that were initially established by the local diving industry, or donated by a concerned benefactor, struggle to maintain their operating status. The reality is that treating injured divers alone does not make for a feasible business plan, unless the chamber is funded by companies concerned with costly evacuations. Associated with this is the availability of trained staff. A chamber may be in good operating condition, but with a staff complement so low that should one of the key members be ill, be off island, or have even resigned, this would potentially render the facility unavailable from between a few days, to potentially months.

There have also been cases where the region's hyperbaric and recompression chambers are all owned by a single entity, and either due to internal politics, or the lack of contract to operate these, they remain out of service until the issues have been resolved.

Bethesda hospital chamber in Jakarta, Indonesia

Technically, there are a wide range of potential issues including advanced age and a lack of appropriate certification of the chamber as a pressure vessel. Another issue of specific concern is the lack of air conditioning in thechamber location, making a treatment uncomfortable for both the injured diver as well as the operating staff.

In general, however, services in most cases are more than sufficient – one just has to manage the expectations of divers, some of whom expect what is available back home. Wait times, language barriers and an absence of physicians with specific dive medicine training may add to their concerns.

Without saying more than is necessary, it is still worth stating that DAN has working experience with many of these chambers, the local physicians, transport and other challenges in the area. This is part of the critical service rendered by our hotline staff, available to any diver in need.

Case Study: IEDCS and Residual Dizziness

Matias Nochetto

The caller in this case was an RN consulting for an ER physician on the US east coast, on behalf of a 50-year-old male who presented with vertigo 2 hours after a two-tank dive, single day of diving.

The diver reported no issues with the dives and was doing “very well” on the 2.5-hour ride back to shore, “joking and laughing” with fellow divers. The diver mentioned that upon reaching the dock, he bent over to collect his gear and lunch box, and while stepping onto the dock he experienced a sudden onset of vertigo, staggered to get to a bench to lay down, and began vomiting. He denied any problems with equalization and claimed to be a very experienced diver (~5,000 dives lifetime), with no prior adverse events experienced.

	Dive 1	SI	Dive 2
Time	45 min (air)	2 hours	45 min (air)
Depth	137 fsw	----	84 fsw
Deco stop	10 min @ 33 FSW (EAN65)	----	11 min @ 33 FSW (EAN 65)
GF	95	----	95

Upon examination, the ER physician reported a positive and "impressive" bilateral nystagmus and vertigo, but no other neurological deficits were noted. His patient was reclining in bed with eyes closed due to an unbearable spinning sensation and said "I feel like I am drunk.” MD also noted an O_2 saturation of 98% on room air, so the need for oxygen was not seen. DAN recommended normobaric oxygen at the highest inspired fraction possible, since inner ear decompression sickness (IEDCS) could be a reasonable explanation for the patient’s condition, to which they only agreed after some basic rationalization.

The DAN Medic conferenced-in the DAN doctor with the ER physician as the other differential diagnosis to consider was inner ear barotrauma (IEBT). The patient was examined by an ENT specialist who noted a slightly reddened tympanic membrane, but otherwise normal function. The ENT specialist concluded that there was no evidence of barotrauma to the inner ear. The lack of clinical or otoscopic evidence of IEBT, the absence of difficulty equalizing, together with a significant decompression stress and a symptom onset of 2.5 hours post-surfacing was found to be highly suggestive of IEDCS. The patient was transferred to a hospital-based hyperbaric facility where he received 5 treatments over 4 days, as follows:

- Day 1 - USNTT6 (x1)
- Day 2 - 2.0 ATA for 2 hours (x2)
- Day 3 - 2.0 ATA for 2 hours (x1)
- Day 4 - 2.0 ATA for 2 hours (x1)

The patient experienced complete resolution of symptoms except for some minor residual dizziness. He was advised this would likely resolve over time. Before being discharged, a final MRI was ordered with no abnormal findings. The patient was given a series of PT exercises to do at home, and a follow-up consultation was scheduled for a week later.

A DAN follow-up call a week after discharge revealed the diver was still experiencing some mild dizziness, but that it was “getting better every day,” however, he reported that he was starting to worry about his vision and that he was having trouble focusing his sight and feeling dizzy after quickly turning his head right or left. A second follow-up call 2 weeks after discharge confirmed he had been seen by a physician about his vision and no issues were found, and his vision and dizziness kept improving on a daily basis.A third follow-up call 3 weeks after being discharged revealed that the diver had still not recovered completely, but was “95% normal.” The patient was lost to follow-up after that.

While discerning between IEDCS and IEBT is probably the most iconic diagnostic challenge for the dive medicine physician, the lack of clinical or otoscopic evidence of IEBT, the absence of difficulty equalizing, together with a significant decompression stress and a symptom onset of 2.5 hours post-surfacing was found to be highly suggestive of IEDCS. This being a clinical diagnosis, the receiving HBO physician agreed with the assessment and prescribed recompression therapy with successful results.

Two things are remarkable in this case:

1) It is not uncommon for DAN staff to have to convince EMS personnel or ER physicians to consider administering a high FiO_2 despite normal SAT readings on room air. It is important to remind them that this is not intended to reverse hypoxia but to wash-out residual inert gas.
2) IEDCS is a serious form of decompression illness that often requires multiple treatments. Convalescence might be long and full recovery may or may not be achieved. Incomplete recovery of an inner ear injury may have a negative impact on the diver’s life.

FAQ Frequently Asked Questions

The following are some frequently asked questions that DAN receives.

How often do we need to oxygen clean our hyperbaric system?

To answer this question, we first need to understand what is considered as the oxygen-enrichment level at which oxygen cleaning is require from a safety aspect.

There are many different points of view in this respect. However, the generally accepted 'consensus' or 'ASTM' limit is 25% - not to be confused with the safe operating limit in an air-filled chamber of 23.5%.

The important aspect here is that the pressure of gases in the compression and gas delivery systems may well exceed 125 psi (0.86 MPa), which is the limit at which one may use ball valves in oxygen systems. This points to a clear message: we need systems free of any form of fuel in order to prevent catastrophic fires.

All gas systems that convey an oxygen-enriched mixture with more than 25% enrichment, per volume, should therefore be regarded as oxygen systems. This means that no hydrocarbons (oil especially), dust, particles or any other potential sources of fuel should be present in the complete system.

Oxygen cleaning equipment

So, what then is the cleaning frequency of an oxygen system? Here good practice states that oxygen cleaning should be done on any oxygen-enriched gas system:

1) Before the system is put into service for the first time;
2) When-ever any contamination occurs or is suspected (such as when disallowed fluids or lubricants or even oil-lubricated compressor air is used);
3) When-ever a line (pipe, hose or component) is opened without being handled in an oxygen-clean manner;
4) When-ever a replacement part or new item of equipment is installed that is not certified as oxygen-clean;
5) When-ever a system is disassembled, serviced or overhauled;
6) When-ever any brazing or welding is done on any pipe; or
7) When-ever any unauthorized work is done on any part of the system;

If none of these activities occurs, then the system should be left intact and periodic cleaning is not required. In fact, as a piping system can be complex, if all the parts are properly cleaning before initial use, we are more likely to contaminate it than to clean it effectively.

If repairs, servicing, modifications, component replacement and/or system disruptions are required, remember to work cleanly to maintain oxygen-cleanliness integrity at all times.

There is one remaining concern:

What happens when we switch from oxygen to air on our breathing systems, and then back to oxygen from air: oil-lubricated compressor air will not be free of oil unless specifically filtered for this flammable impurity. The air purity limit for oil is ≤ 0.1 mg/m^3.

If you are unsure of your air quality, then take a sample immediately after use and preferably before oxygen is put back into the system. This may contaminate your piping system from where the air enters the oxygen lines until the breathing apparatus.

We will be publishing a FAQ on how to perform oxygen-cleaning in a future edition of this newsletter.