MARINE CAVES OF THE EASTERN MEDITERRANEAN SEA BIODIVERSITY, THREATS AND CONSERVATION

Edited by
Bayram ÖZTÜRK

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Health problems in cave diving

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Introduction

Cave diving is an important part of different scientific fields, as diving is needed to collect many data from this closed environment. These disciplines are; aquatic sciences, archeology, geology, ecology, biospeleology, speleomorphology, anthropology, marine sciences and biology. Remnants of our ancestors and many animals, artifacts related to agriculture in ancient times have been discovered in caves all over the World (Zumrick 1988). That is why scientists have been willing to explore the caves accessible by the sea. Furthermore, many divers are willing to specialize in cave diving, and the reason of their interest rely on the individual preference and the level of training in dives. Cave diving is generally considered a good alternative to diving in open water. Some divers are interested in exploring underwater caves in order to make new discoveries and collect information about where no one can reach them.

If we describe the environment of these semi-closed spaces, it will be easier to understand the challenges of the cave diving. There are some difficulties in terms of physical, biological, physiological and psychological conditions. From the point of view of biology, divers should be prepared of occasional large fish such as nurse shark, grouper or moral eels in coral caves. Marine sea caves are home for sea life such as sea anemone, sea urchins, sea mammals, fish and shellfish. From the point of view of the physical environment, marine habitat, power of waves, absorption of the light and tidal effect must be carefully evaluated in caves. Furthermore, caves may also contain extensive amount of clay and silt that can reduce the visibility to zero if stirred up by a diver (Figures 1 and 2) (Zumrick 1988).

Figure 1. Divers should be aware of visibility may not be clear as shown in this picture due to the clay and silt in the cave.

Although divers have skills, competence and are given appropriate training in cave diving, they may also suffer diving related illness that is also common in all level of diving experience. Barotrauma, decompression sickness and drowning-related injuries were the most common morbidities associated with recreational scuba diving. The prevalence of incidents in scuba diving ranged from 7 to 35 injuries per 10,000 divers and from 5 to 152 injuries per 100,000 dives (Buzzacott 2012). Cave diving carries an inherent amount of risks, just as any other diving activity. These risks are; depth, breaking the safety rules in diving, lack of knowledge about the diving equipments, over-reliance on experience and discontinuance of prudence, lack of skills in first aid techniques and how to rescue the injured diver. Furthermore, buoyancy changes at depth, thermal protection loss, injuries with marine animals, restriction of environment may also accelerate the occurrence of the diving accidents (Lloyd 1967). Due to the limited physical conditions in caves, cave diving may not be recommended if the diver experience discomfort or fear as the dark environment restricts vision, if the basic skills and abilities for diving have not been developed, or if the idea of not being able to float on the water surface creates fear, stress and restlessness.

In this chapter, we describe main health problems that may occur during a cave dive, more particularly those that may be eliminated by training and knowledge.

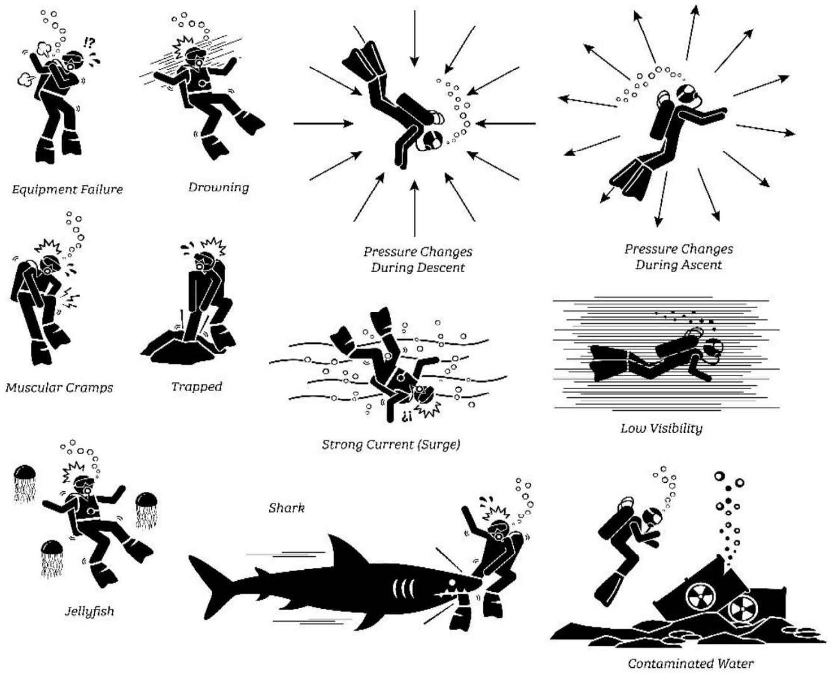

Figure 2. Divers may encounter various unpredictable risks in cave diving.

Physical trauma

Underwater caves may contain air sections that are home to animals such as seals, bats and spiders. In case of perception of threat to the living things, they may be disturbed and, the stone may fall from the ceiling of the cave and pose a danger to divers. In some conditions, there may be air pockets which are likely to be oxygen deficient or air inside the cave can be contaminated. As a result, inhalation of the air can be harmful to the body due to the toxic effects of the inhaled gases. Snowball effect may appear and even the experienced divers can get into difficult situation (Zumrick 1988; Palmer 1997).

Cave diving has challenges in terms of environment such as flowing water, changes in water level, low visibility, restriction to the exits, entanglement, barrier that limits the divers to ascend to surface in case of emergency situation. Cousteau and Dumas documented the record of first scuba dive within a flooded cave in 1953. Death is an unpredicted event and may occur as a result of inappropriate behaviours during the dive. Researchers try to identify the causes of death which are reported from the autopsy findings, medical examiner reports, or death certificates. The main characteristic of divers who lost their lives were old age, without dive partner, further into the cave, and dives to deeper depths. Furthermore, divers deliberately or unintentionally may break rules that are the hard core of the dive plan directly resulting in death of the diver (Potts *et al.* 2016).

Panic and stress

Experts define stress as feeling of physical or emotional tension which can be caused by any event or thought that makes one angry or frustrated. The main causes of stress; 1) duty 2) responsibility 3) time 4) problems related to distance and direction 5) physical threats (fatigue, insomnia, decrease in body temperature, inexperience). It's a natural body reaction that helps one to avoid danger. Stress is necessary in daily life, but stress above a certain level is harmful, both physically and mentally. As a consequence, response to the stressful condition can be inappropriate and ineffective. Then, panic may appear with the uncontrolled behaviours. Therefore, recognition and control of stress is always crucial to protect human body from deleterious effects of threats (Edmonds 2005a). There are physiological and psychological symptoms/signs of stress which may create serious problems in diving. These are by and large lack of concentration, loss of attention, perceptual deficits, frustration, discordance of task related skills, increased heart rate and blood pressure, changes in breathing rate and so on (Morgan 1995; Anegg *et al.* 2002).

Panic reaction can be prevented by elimination of the reasons that created it. There are several factors that help to cope with panic reaction; knowledge, experience, safe materials and equipment, accurate and complete planning in diving. It is essential to be well trained diver or diving buddy and equipped with the suitable diving gears. If one is susceptible to panic, uneasy, tired, irritable and sleepy, not in shape, excited, the diver should stop diving. The signs of panic are increased breathing frequency, difficulty concentrating, eyes opened with fear, irregular swim, improper movements, and rapid ascent to the surface. In such cases, diver should force himself to think about other things, do things to be calm down (Edmonds 2005a).

Inert gas narcosis

Inert gas narcosis is a reversible alteration in consciousness that occurs while diving at depth. Because nitrogen has an anesthetic effect to the body while diving at higher partial pressure (Palmer 1997). It is also important to note that nitrogen is not the only gas with a narcotic effect on the diver, however it is the most common used gas. There are other gases that may have narcotic effects. For instance, argon, neon, krypton and xenon are other inert gases that associated with narcosis. Carbon dioxide (CO_2) may also exert narcotic effect itself (Clark 2015; Rocco *et al.* 2019). Even though there has been a lot of research done on the effect of nitrogen narcosis, the underlying mechanism is still not fully understood. There are several factors that increase the risk of narcosis such as cold temperature, anxiety, fast descent to the deep, drugs (sedatives), fatigue, alcohol, carbon dioxide excess (Plantz *et al.* 2019). Nitrogen narcosis can be difficult to identify, but a few symptoms may indicate that diver has had one. The most common symptoms of nitrogen narcosis are: vision changes, confusion, an altered level of consciousness, dizziness, over confidence. Altered mental status for mental judgment can even cause hallucinations while underwater (Figure 3 and Table 1) (Clark 2015; Melamed 1992).

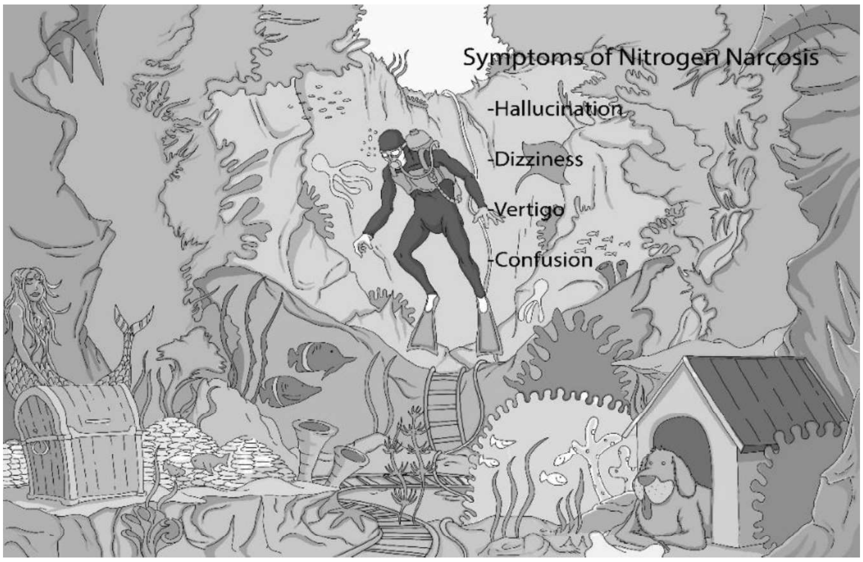

Figure 3. Inert gas narcosis with signs and symptoms. It commonly occurs deeper than 25-30 m in water (drawing by Ali Yiğit Ertan).

As breathing gas at depth increases its partial pressure, narcotic effect may be induced. The rule of thumb is Martini effect may occur where every 15 meter (50 feet) of compressed air is approximately equal to drinking one glass of Martini that varies by the individual tolerance (Lowry 2005). Nitrogen is a very weak anesthetic gas but if one breathes at around 100 meters the diver will become unable to respond to stimuli and appears to be sleepy. Given the fact that CO_2 builds up to 10% of breathing gas, diver will lose consciousness unexpectedly. CO_2 is usually retained in lungs during deep diving, when there is heavy exercise and when there is resistance in the breathing equipment. Consequently, Nitrogen and CO_2 in the breathing gas can add up and accelerate the appearance of sudden loss of consciousness. This condition is named as deep water blackout. The combined effect of the carbon dioxide and nitrogen is responsible for the deep water blackout (Palmer 1997; Arthur and Margulies 1987). Divers usually aren't aware of one of the hazards about having to do heavy work at deep depth. That is why it is really good practice to maintain as low at work as possible during deep dive. The only way to avoid nitrogen narcosis is to avoid deep air diving and adhere to the guidelines. Alcohol in the blood, carbon dioxide level, increased stress level, medications being taken, may induce the narcotic effects (Lowry 2005).

Although new gas mixtures such as trimix is highly recommended in deep dives, high costs, thermal properties are the reasons why compressed air is mostly preferred in most diving operations.

Avoidance of deep diving to prevent inert gas narcosis is essential in diving (Melamed 1992). If the diver suffers from the complaints of nitrogen narcosis, resting and being calm down will reduce the symptoms, then dizziness may disappear after several deep breaths. Immediately, the diver should descend safely to the shallower depths in order to get rid of these symptoms (Lowry 2005).

Table 1. Symptoms and signs of nitrogen narcosis

Light headedness	Dizziness	Overconfidence
Uncontrolled laughter	Hallucination	Memory loss/post-dive amnesia
Perceptual narrowing	Impaired sensory function	Loss of consciousness
Loss of manual dexterity	Euphoria	Vision changes
Confusion	Decreased coordination	Impaired mental performance

Hypothermia

If the human body looses too much heat and the body temperature reaches unsafe levels, the condition is called as "hypothermia". In normal physiological state, a body functions best between 36.5-37.5 degree Celsius (°C). A drop in the core body temperature less than 35°C is defined as hypothermia. It is a life-threatening condition which deteriorates the normal metabolism and body function and may result in death (Pennefather 2005). The body's thermo-regulation mechanism adjusts to environmental temperature changes. Given that the body is exposed to cold and the thermo-regulation mechanism is unable to preserve the heat, a drop in the core body temperature will occur.

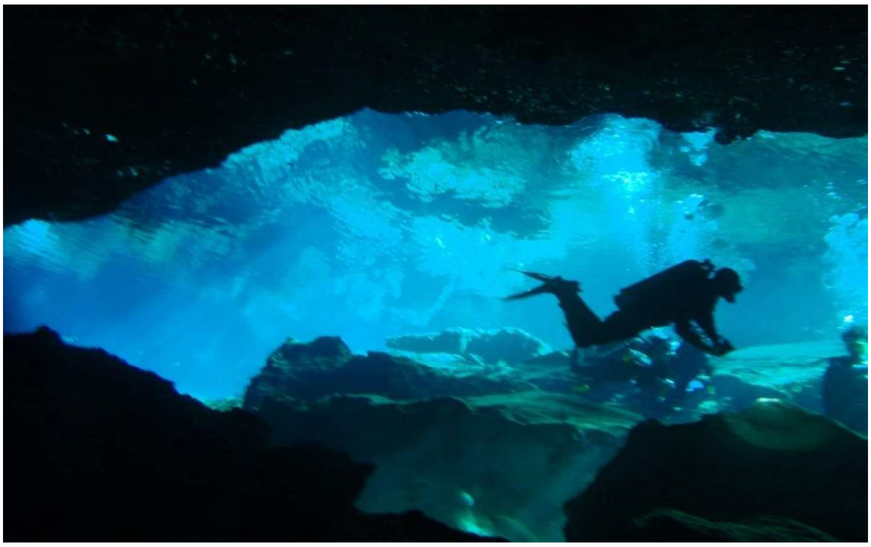

Figure 4. Water temperature decreases due to the spring water in caves. As a result, hypothermia is a serious problem and may result from unprotected clothing.

Hypothermia occurs after the exposure to low water temperatures and may be precipitated by alcohol consumption, poor clothing, excessive fluid loss, older age, poor nutrition, hypoglycaemia (Figure 4). In addition to that, hypothermia may result from breathing cold helium oxygen gases even if the diver's skin is warm (Lloyd 1979). Main symptoms and signs include shivering, cold and pale skin, fast breathing, tiredness, altered mental status such as confusion and poor judgment. The ailment is categorized mild, moderate, severe hypothermia. Symptoms of hypothermia depends on the degree of hypothermia, so the victim may slowly lapse into an unconscious state (Table 2). A diver's response to immersion in cold water depends on the degree of thermal protection worn and water temperature. Responses to falling core body temperature are individual. Eventually, mental confusion, irrational actions or responses will develop resulting in a diver who is unable to complete basic tasks such as handling diving gear or swimming normally. Furthermore, shivering, collapse, unconsciousness, dangerous rhythm of the heart, depressed respiration may result in death (Pennefather 2005). Knowing limitations of the body individually, comfort range and taking necessary precautions will decrease the deleterious effects of hypothermia.

Table 2. Symptoms and signs of hypothermia in mild, moderate, severe cases

Severity of the Hypothermia	Symptoms and Signs
Mild Hypothermia (32-35°C)	Increase in heart rate Increase in respiratory rate Changes in speech, gait, judgment, motor skills Shivering
Moderate Hypothermia (28-32°C)	Decrease in heart rate Decrease of cardiac output Atrial fibrillation Decrease level of consciousness Ataxia
Severe Hypothermia (<28°C)	Decrease in respiratory rate Ventricular fibrillation Asystole Unresponsiveness

Treatment should be started promptly in doubtful cases. If the diver begins to shiver during exposure to cold water, this is the point where diver should get out of water and warm up. Prolonged exposure to the cold beyond this point can be dangerous resulting in fatalities. In severe cases, the main approach is to remember the victim needs to be handled gently. The diver should be removed from the water and to a safe and dry place. The treatment of hypothermia consists of rewarming the diver (Sward and Bennett 2014). A simple indicator that rewarming is complete, is the onset of sweating. In case of mental confusion or unconsciousness, medical emergency and rewarming must be started instantly. Recommendations are listed below in case of hypothermia in diving (Pennefather 2005).

1. Bring the diver out of the sea handle gently the diver, not allow to walk
2. Restore body temperature by rewarming techniques; using warm water (38-44°C) either in a bath or directed under the diver's suit
3. Remove the wet clothing and wrap the diver with a warm, dry blanket
4. Alternative to hot water is to dry the diver and provide warm clothes, a sleeping bag or blankets and a warm room
5. Fluid re-hydration with warm beverages free of alcohol or caffeine
6. Loosen the tight fitting wet suit in order to prevent constricting peripheral circulation
7. Do not massage the diver
8. Give warm humidified % 100 oxygen, if the oxygen is available
9. Transport horizontally to prevent heart arrhythmia
10. If the diver does not response and is without pulses, one should immediately start lifesaving cardiopulmonary resuscitation (CPR). It should be done consistently until the diver is warmed to at least 30 to 32°C.

Barotrauma

Barotrauma (BT) is a physical damage to body tissues caused by a difference in pressure between an air space inside or beside the body and surrounding environment. Barotrauma typically occurs in air filled spaces within the body because gases are compressible, fluid filled tissues are not compressible during an increase in ambient pressure. Barotrauma may occur during ascend or descend of the dive (Melamed 1992). The human body has several different gas spaces. The lungs are the most obvious of these. But one also has assorted sinus passages, the middle ears and gastrointestinal system as well in. In addition, other gas space is inside masks each of these gas spaces must be equalized to the surrounding pressure at depth.

Divers mostly do not notice the equalization process in the case of the lungs where it happens by normal breathing or they are taught to manually equalize the air-filled spaces to surrounding pressure by using various techniques as in the case of the middle ear spaces. When the diver is unable to equalize these gas spaces the potential for trauma exists in diving (Raymond and Cooper 2019). A change in altitude may also induce barotrauma if one is flying in an airplane, diving in the mountains. Middle ear barotrauma is the most commonly observed in the diving society (Mirasoglu and Aktas 2017). The primary symptoms are related to the tissues mostly effected.

Middle/Inner/Outer Ear Barotrauma
Common symptoms of ear BT include; pain, a feeling of fullness or pressure in the ears, moderate to severe hearing loss, dizziness. Treatment for ear BT includes chewing gum and yawning to relieve the pressure. Medications such as decongestants, antihistaminics, painkillers may also help to relieve the symptoms. Damage can also be produced if the hood fits too tightly over the ears, so as to produce an airtight seal over the external ear (Glazer and Telian 2016).

Pulmonary Barotrauma-Pulmonary Overinflation
Pulmonary barotrauma may develop with the symptoms of coughing, pink & blood stained sputum chest pain, hypotension, changes in breath rate, and cyanosis. Manifestations of lung barotrauma may appear in different clinical conditions; pneumothorax, mediastinal emphysema, subcutaneous emphysema, arterial gas embolism (Table 3, Figure 5). Pneumothorax is defined as the presence of air in the cavity between the lungs and the chest wall causing collapse of the lung. As the collapsed lung is not functional if more gas leaks into the chest cavity or if the gas expands further like during an ascent, the pressure in the chest can increase to such an extent that it also compresses the other lung (Figure 6). This situation is called a tension pneumothorax and is deadly in minutes as the increased pressure in chest prevents blood from returning to the heart (Sümen 2019).

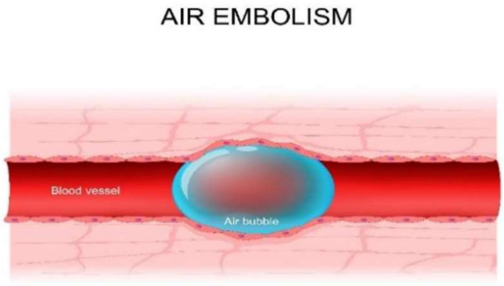

Figure 5. As air bubble blocks the circulation in blood vessels, the perfusion of the tissues deteriorates.

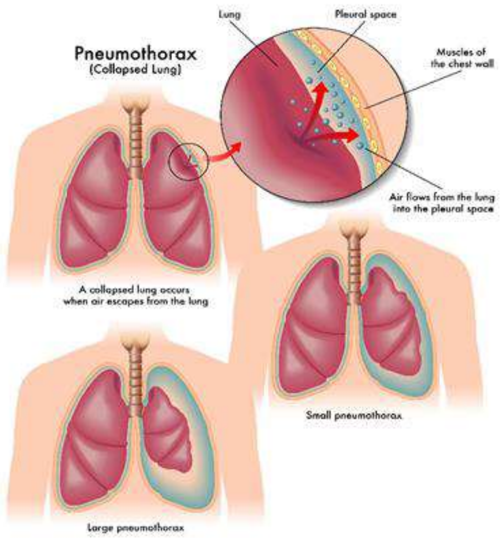

Figure 6. Pneumothorax may develop soon after the rupture of air sacs of lungs.

Mediastinal emphysema is defined as gas filled areas around the heart. Subcutaneous emphysema refers to gas tracking upwards out of the chest in the tissue layers. Arterial gas embolism appears on ascent and manifestations develop soon after the rupture of air sacs of lungs always after surfacing in the sea. Some cases present with neurological complaints which may change from slight mood alterations to loss of consciousness (Adir and Bove 2016; Oh *et al.* 2003; Muth and Shank 2000; Arthur and Margulies 1987).

Table 3. Symptoms and signs of pulmonary barotrauma (pulmonary over-inflation)

Pneumothorax	Mediastinal emphysema	Subcutaneous emphysema	Arterial gas embolism
Breathing faster than normal	Increase in the breathing rate	Feeling of fullness around the throat	Impairment of breathing
Chest tightness	Feeling faint	Change in voice	Failure of cardiac functions
Chest pain	Chest pain & tightness	Difficulty swallowing	Changes in mood
Breathing shallow	Shortness of breath	Feeling the gas in the tissues around the base of the throat on palpation	Loss of consciousness
Bluish discoloration of the lips and tongue	Change in the diver's voice	Crackling sound	Sudden cardiopulmonary arrest

Treatment includes, refrain from diving, breathing 100 % oxygen and the diver should be transferred to a fully equipped hospital. Pneumothorax does not require recompression treatment in a hyperbaric chamber unless there are signs of arterial gas embolism or decompression sickness (Arthur and Margulies 1987).

Sinus Barotrauma

There are four pairs of sinuses and named as frontal sinus, ethmoid sinus, sphenoid sinus, maxillary sinus. They are arranged around the nasal cavity. When the sinus cavity is blocked it can't be equalized properly. Pain occurs immediately. Then it follows by bleeding in nostrils. This is often seen after the dive or blood appears in the mask during the dive. The frontal sinus is the most affected and pain behind the eye is one of major symptoms (Raymond and Cooper 2019; Livingstone and Lange 2018). There are less commonly seen types of barotrauma which include the following (Melamed 1992; Bowman, *et al.* 2019; Livingstone and Lange 2018).

Face mask barotrauma

Mask may also act like a partial vacuum, resulting in conjunctival hemorrhages. This develops when the diver does not exhale through the nose into the dive mask while equalizing.

Gastrointestinal barotrauma
This refers to the expansion of the gas in the bowels during ascent. It is manifested by the symptoms of colicky pain and abdominal fullness, nausea, epigastric discomfort, flatus expulsion, anorexia, malaise.

Suit squeeze
This occurs mostly in divers using dry suit. It tightly compresses the body surface and red or bluish discoloration, slight edema, hemorrhagic lesions may appear on the skin.

Dental barotrauma
Air may get trapped quite close to the pulp at the base of a carious lesion. Diving will then cause a partial vacuum and affect the nerve of the pulp. Due to the unfilled holes in teeth, some divers may suffer from toothache. The pain may persist for some time. Rarely, a filling can be dislocated or a tooth can explode during ascent due to the air trapped in a filling cavity (Sümen 2019).

Decompression sickness

This is a serious health problem for professional divers, but does rarely affect cave divers, unless one does repeat dives or deep dives. Decompression sickness refers to the ailment that occur after the pressure differences between the body and the environment forming bubbles in blood stream or tissue. It is manifested by joint pain, impairment of motor and sensory functions, shortness of breath, coughing, or visual disturbances after scuba diving or decrease in environmental pressure (Buzzacott 2012) (Melamed 1992). When the diver descends the partial pressure of the nitrogen in breathing air gets higher, because the environmental pressure increases. Body does not use nitrogen it dissolves into tissues. As the partial pressure increases more and more nitrogen dissolves into tissues until they are saturated. The pressure gradient of nitrogen in breathing air and the nitrogen dissolved in the tissues becomes higher and higher as diver goes up. If the pressure gradient stays low enough, nitrogen comes out of the body without causing any problem. If the diver ascends rapidly to the surface, stays longer at depth, or performs repeated and deep dives, air bubbles form both in tissues and in the blood which are responsible for the disease (Glazer and Telian 2016; Aktaş 2019; Aktaş 2000; Aktaş *et al*. 1990).

Usually these micro-bubbles do not cause blockages/problems as they diffuse into the alveoli without problem. These bubbles are called "silent bubbles". If the diver exceeds the safe limits of pressure and time, these bubbles may cause a problem. In case of accumulation of a lot of nitrogen, by staying too long at depth or come up too fast to the surface, more nitrogen has to leave the tissues as the diver ascend. As bubbles increase in size, larger bubbles can block blood flow in narrow blood vessels (Hall 2014). Signs and symptoms of decompression sickness do usually appear immediately or a few hours after a dive (Table 4). They can arise up to 48 hours later. There are two types of decompression sickness (DCS). DCS type I is the least dangerous and 3/4 of cases are of this type. Decompression sickness type II is rare but serious and can lead to death (Arthur and Margulies 1987). The chance of getting DCS on a recreational dive is 1 in 10,000. In a study conducted in cave diving, the incidence of DCS in Australian cave divers was estimated to be 2.8:10,000 (Harris, *et al.* 2015). Most cases of decompression sickness are caused by diver error. As the professional divers dive deeper and longer, the majority of cases of DCS occur after technical dives. Signs and symptoms of decompression sickness can be categorized as mild or serious symptoms. Mild symptoms can progress to the serious symptoms (Glazer and Telian 2016). Although, the majority of symptoms arise within 12 to 24 hours (Pendergast, *et a.l* 2015).

Table 4. Severity scores of symptoms in Decompression Sickness

Mild Symptoms	Fatigue Rash "Skin bends" Joint pain Nausea
Serious Symptoms	Numbness and tingling Motor weakness Altered mental status Confusion Abnormal mood or behaviour Visual changes Loss of balance and coordination Paralysis Urinary retention/incontinence Seizure Coma Cardiopulmonary symptoms Death

Treatment should be administered immediately, as waiting until the occurrence of more severe symptoms may deteriorate the clinical conditions of the diver resulting in perminant neurological sequelae. Diver should be transported to the hyperbaric treatment center in order to be treated with recompression therapy (Bennett *et al.* 2012; Sward and Bennett 2014; Toklu *et al.* 2014). The main initial treatment includes oxygen (through a nonrebreathable face mask with reservoir bag) and administration fluid (Ashken *et al.* 2015).

The treatment algorithm follows;

I. 100 % Oxygen inhalation
II. Fluids (Oral/Intravenous)
III. Pain/anti-inflamatory medications
IV. Hyperbaric oxygen therapy
V. Don't wait to see what happens, call Hyperbaric Oxygen Treatment Center available 24 hours.

Drowning

Drowning denotes the death of an air breathing victim as a result of oxygen deprivation due to immersion in fluid environment. (Edmonds 2005b). Drowning is the most common cause of death. The exact number of incidents related to drowning are difficult to estimate. Divers can drown, as a result of loss of mask or mouthpiece, running out of air, or inhalation of small quantities of water. This may occur from the failure of the air supply with the panic reaction in a hazardous situation. The most serious problems may happen due to the effect of oxygen deprivation of the brain. Oxygen deprivation is directly related to the duration of immersion until resuscitation is started. Furthermore, pulmonary edema and pneumonia due to inspiration of mud, sand and vomit will exacerbate the symptoms of the ailment. Main symptoms of drowning are blue discoloration of the skin, irregular heartbeats, decrease in breathing, loss of conscious, chest pain, hypotension (Buzzacott 2012).

The treatment of drowning falls into two phases; 1) maintain breathing and circulation 2) call for help from qualified medical personal. Proper first aid attempt saves human lives (Figure 7). The diver's vital signs regarding breathing rate, blood pressure, pulse and temperature should be recorded. As the complications such as pulmonary edema, pneumonia may occur many hours after the incident, proper medical observation is essential. Regardless of the severity of a drowning case, all victims should be transported to a medical facility for follow-up care immediately. 100 % oxygen should be administered in the transport vehicle (Edmonds 2005b). An attempt to remove water from the airway of the diver by any means of other than suction is usually unnecessary and dangerous, because it could eject gastric contents and cause aspiration into the lungs. Patients may suffer late effects of the incident and die days later at the health care center. So, the medical care specialists should consider the clinical consequences and management of near drowning. The prevention of drowning is best ensured through training in safe diving practices and qualified diving personal. A trained diver should not easily fall victim to drowning.

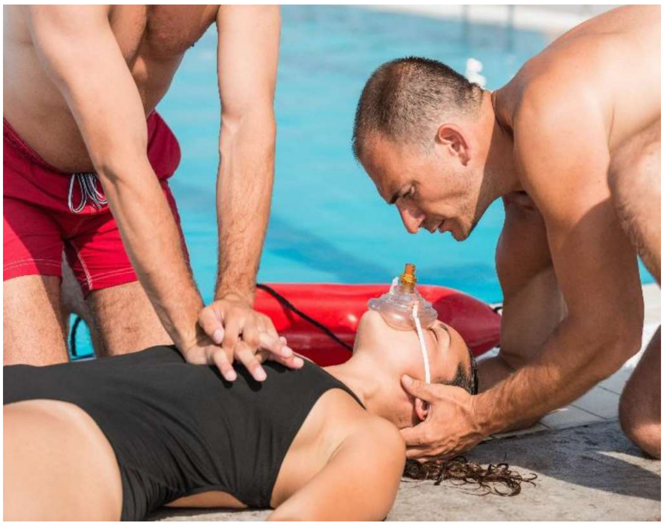

Figure 7. Proper first aid attempt saves human life.

Problems related to rebreather use

The use of closed-circuit ‘rebreather’ devices has become more preferred in technical or cave diving as re-breathers have many advantages over other diving equipments. These devices help to decrease gas consumption by means of recycle exhaled gas. Chemical damage and accumulation of CO_2 are the major problems that may arise from these high-tech devices can threaten the health of the cave diver (Mitchell and Doolette 2013; Edmonds 2015c; Sümen 2015).

CO_2 retention

There are two main causes of CO_2 retention in the body of diver. 1) difficulty to exhale from the lung 2) inhalation of excessive amount of gas due to the faulty or inefficient CO_2 absorbants (canister). Ventilation of the diver can be limited due to the effect of breathing gas density and dynamic airway compression (Edmonds 2005c). Eventually, diver can’t increase the airflow to the lungs and tries as hard as he likes, but that puts more pressure on the outside of the airway. As a result, he hardly breaths more and implications that have for exercising in CO_2 retention. Diver can find himself in a situation where he is producing more CO_2 than he is capable of exhaling it even if he wants to. Increase in partial pressure of CO_2 in body may also result from re-breather with faulty canister. As the CO_2 build up in the body, the effects are clear within a couple of minutes. Main symptoms are flushing of the skin, sweating, tremor, increase in breathing rate, difficulty in breathing. These symptoms may result in drowning in depth. It is a key issue that diver doesn’t attempt to work hard when he does deep dive (Pendergast *et al.* 2015).

Chemical Injury

The term ''chemical injury'' refers to the burn of the upper airway of a diver by the introduction of a caustic alkaline solution from the scrubber of the re-breather. As the chemical trauma injures the air passage it requires immediate hospitalization. Due to the thermal injury of caustic material inhaled by the diver, the victim may present with the symptoms of laboured breathing, burning of sensation of the mouth and throat, headache, choking, gagging, foul taste and so on. Treatment should include rinsing the mouth with fresh water, if only sea water is available, rinse the mouth but diver should not swallow and not attempt to induce vomiting, transport to a medical facility (Edmonds 2005c).

Accident analysis and fatalities in cave diving

Analyzing accidents provide to identify the causes of the casualties and to determine all the precautions that should be taken. Due to the lack of sufficient information or network regarding the total number of dives yearly, and the exact number of diving accidents and the causes of deaths in cave diving, there is uncertainty on exact statistical number of incidents. As a result, we learn more from the assumptions of the diving society and from news on the social media. It is not possible to say if the recent number of diving casualties in cave dives is less that previous years. Diver Alet Network (DAN) has been collecting the data of diving casualties annually by means of digital network with limited information of some countries (Buzzacott and Denoble 2018).

If we search in scientific literature, we may find some published case reports from different countries. In history, the causes of fatalities were discussed for the first time and published in the book *"Basic Cave Diving: A Blueprint for Survival"* in 1979. The book also covered the suggestions on taking preventive measures. It was also concluded that guidelines should be prepared, air supply system should comply with the third rule in planning, the importance of not violation of maximum operating depths in caves (Exley 1986). Although the author of the book ''Basic Cave Diving'' is widely appreciated with his contribution to the educational part of cave diving, he unfortunately died of the accident during a cave expedition. In 1990's, it was strongly recommended that proper training should be required in cave diving. Divers should be equipped with proper lighting with minimum three lights. Furthermore, in another research new items were inserted in the analysis of causes of diving accident; age of the diver, new technologies (side mount dive gears, re-breathers, e.g.), inappropriate breathing gas mixtures, solo diving, equipment and skill maintenance.

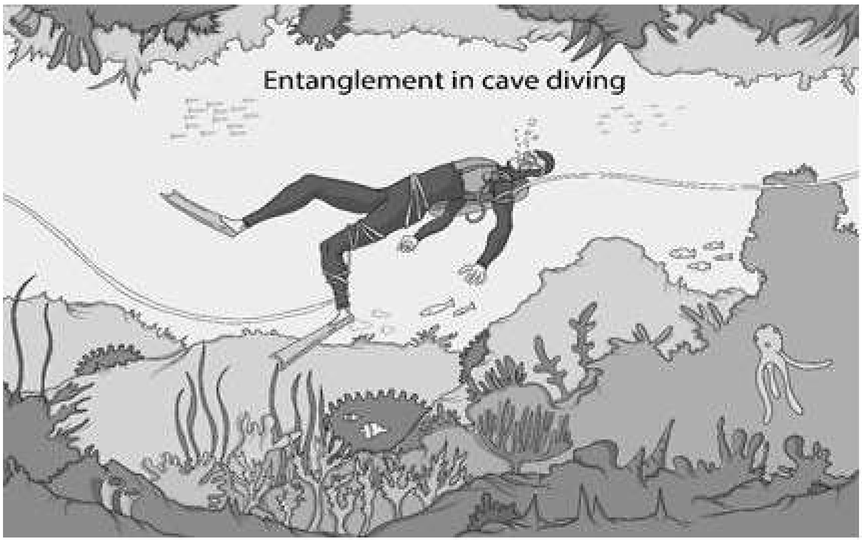

Figure 8. Entanglement in cave diving causes to run out of air and led to drowning (Drawing by Ali Yiğit Ertan).

Data including 287 cases have been analyzed the potential causes of cave diving fatalities in 1997, and results indicated that the majority of causes of death was related to drowning (93%). The chief contributing factor was the lack of training skills and improper use of guideline back to safety. Running out of air (72%), losing the exit (44%) of the cave and entanglement (9%) were the primary preceding events for drowning (Figure 8). Poor gas planing was the primary reason of diving with insufficient gas (Table 5) (Byrd and Hamilton 1997).

According to the results of cave diving fatality report between 1969-2007, it was stated that the most common cause of deaths remains drowning due to the lack of breathing gas. The majority of divers (more than 2/3) ran out of air and the main reasons are poor planning with insufficient gas supply and unable to find the way out of the cave. Additionally, most divers appear to be untrained (Buzzacott *et al.* 2009). In consistency with the cave diving fatalities report published in 2016, the most common cause of death was asphyxia due to drowning. Drowning was introduced by running out of breathing gas, by and large after getting lost in the cave preceded by poor visibility due to stirred silt (Potts *et al.* 2016).

Table 5. Summary of some cave diving fatalities
(year, country, number of victims, causes)

Year	Country	Total number of deaths /Causes
1980	United Kingdom	11/ 8 of death overrunning the air[1]
1980	South Australia	11and 3 running out of air as a result of either deep-diving with inadequate gas reserves or getting lost in silty, low visibility conditions [2]
1997	USA	287 Drowning[3]
1985-2015	USA	161 asphyxia due to drowning, running out of breathing gas, getting lost owing to a loss of visibility caused by suspended silt
1946-2006	United Kingdom	20 drowning[4]

[1] Churcher and Lloyd, 1980, [2]Horne, 1981-1987, [3]Byrd and Hamilton, 1997, [4]Brock, 2006

When the database of cave diving accidents is searched in Turkey, it is not possible to access the records of all casualties. The main restriction of the planning research is the difficulty to clearly estimate the exact number of divers lost their lives in cave diving due to the limited access to the continuous systematic monitoring system of scuba divers. The total number of accidents related to cave diving is unknown and unattainable to calculate. Because this activity is not regularly recorded and controlled by regulations. After searching in the scientific database regarding fatality reports of cave diving published in Turkey, we found only one case record in the thesis covering diving accidents published in 2019 (Koca *et al.* 2019). In this study, the deaths of the 52 fatal diving accidents were evaluated retrospectively in the archive scan of the death reports. 20 of the accidents were found to be associated with scuba diving and only one diver's body was recovered in cave diving. Drowning was found as the primary cause of death in the study. Due to the lack of adequate information we aimed to search other victims and review the descriptive analysis of fatality cases associated with cave diving. Thus, we aimed to obtain additional information in order to find the numbers and the causes of the cave diving accidents in Turkey. Both electronic database and website of news were searched and information was collected face to face from the reference of some fisherman or diver. As a result, we reached the limited information of 7 fatal cases. The detailed information of these cave diving fatalities in Turkey summarized in Table 6. In accordance with the previous reports, drowning was the main cause of the death in these seven fatalities.

Table 6. The descriptive analysis of cave diving fatalities in Turkey between 1990's and 2019

No	Year	Gender Age	Diving type	Nationality	Diving gear	Diving depth (m)	Name of Cave	Depth of Cave (m)	City	Cause of Death
1	1994 a	M	Scuba	Foreign	Air diving	60	Suluin	122	Antalya	Drowning Nitrogen narcosis
2	1994 a	M	Scuba	Foreign	Air diving	60	Suluin	122	Antalya	Drowning Nitrogen narcosis
3	2006 b	M 18	Free diving	Turkish	Spearfishing	20	Kargı	20	Bodrum Muğla	Drowning
4	2011 c	M 40	Scuba	Turkish	Air diving	11	Küçük Pınar	60	Kemalpaşa İzmir	Drowning Lost of the entrance
5	2015 d	M 33	Scuba	Foreign	Air diving	*	Fosforlu	*	Alanya Antalya	Drowning Lost of the entrance Turbid water
6	2015 e	M	Scuba	Turkish	Air diving	41	Antrum	26-52	Kekova Antalya	Drowning Entaglement
7	2015 e	M	Scuba	Turkish	Air diving	41	Antrum	26-52	Kekova Antalya	Drowning Running out of air

*Unknown

Abbreviations; a, b, c, d, e indicate the website access of the news in reference list.

a. https://www.haberturk.com/yasam/haber/170051-magara-dalisina-akademik-tepki (accessed 04 Sept 2019).
b. http://arsiv.sabah.com.tr/2004/07/14/gun102.html (accessed 27 Jan 2019).
c. https://www.trthaber.com/haber/turkiye/magaraya-dalis-yapan-dalgica-ne-oldu-20744.html(accessed 04 Sept. 2019).
d. https://www.turkiyegazetesi.com.tr/yasam/320425.aspx (accessed 04 Sept. 2019).
e. http://www.milliyet.com.tr/2-nefesi-daha-olsa-kurtulacakti-gundem-2075967/ (accessed 27 Jan 2019).

Conclusion

Cave diving has challenges and the majority of accidents are associated with relatively few potential causes. Divers should follow the guidelines remembering the Pareto principle, named after economist Vilfredo Pareto. It states that 80 percent of consequences come from 20 percent of the causes. In cave diving, divers should focus on preliminary research, detailed planning, special equipment, turn around after using one third of the gas rules technical knowledge and experience, keep track of the use of a guideline that must be followed and to have adequate health conditions. Divers ideally should maintain a reasonable level of cardiovascular condition, display strength and flexibility. So, periodic physical examination of diver getting older is essential in order to find and prevent problems before the cave dive.

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Recommendations for safety to prevent health problems in cave diving

- ✓ Always use a single continuous guideline from the entrance of the cave throughout the cave
- ✓ Limit the dive's penetration to 1/3 of the starting air volume
- ✓ Avoid deep diving in caves
- ✓ Diving not beyond a safe depth for the type of gas being used
- ✓ Avoid stirring up silt
- ✓ Proper technical and first aid training
- ✓ Avoid panic by building up experience slowly and being prepared for emergencies
- ✓ Always use at least three lights per diver, each capable of outlasting the dive
- ✓ To comply with the permission of local authorities regarding the access to the cave
- ✓ Diver should not break cave diving safety rules
- ✓ Plan adequately for one's gas needs to avoid running out of air and drowning
- ✓ Stick to follow closely all rules and guideline
- ✓ Practice emergency procedures with your partner before going cave diving, and review them often