EDUCATION

Emergency Oxygen for Scuba Diving Injuries

DAN

STUDENT HANDBOOK

Emergency Oxygen for Scuba Diving Injuries

Student Handbook

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DAN would also like to thank all those individuals that assisted in the development, creation and testing of the training materials for this program.

This program is intended for anyone who might come in contact with divers or diving-related injuries. It meets the current guidelines from the U.S. Occupational Safety and Health Administration (OSHA) and the October 2010 Guidelines for Resuscitation issued by the International Liaison Council on Resuscitation (ILCOR)/American Heart Association (AHA).

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DAN Emergency Oxygen for Scuba Diving Injuries

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1 DAN Emergency Oxygen for Scuba Diving Injuries

Course Overview

Scuba diving injuries are rare and are often subtle when they occur. In the unlikely event of an injury, being able to recognize the problem and initiate appropriate action can speed the diver's recovery and minimize lasting effects. Oxygen first aid is the first response for diving injuries.

The DAN Emergency Oxygen for Scuba Diving Injuries course is an entry level training program that teaches participants common presentations of dive injuries and how to provide emergency oxygen first aid.

During this course, participants will become familiar with the signs and symptoms associated with decompression illness and nonfatal drowning and the proper administration of supplemental oxygen. Proper assembly, disassembly and use of all component parts found in the DAN Oxygen Unit are included in the skills section of this course.

The DAN Emergency Oxygen for Scuba Diving Injuries student handbook introduces medical terms that may be unfamiliar to some readers. Familiarity with basic medical terminology will enhance the quality of communication with emergency and health-care workers. A glossary of terms is provided in the back of this handbook.

Successful completion of the DAN Emergency Oxygen for Scuba Diving Injuries course includes demonstration of skill competency and passing a written knowledge assessment. The result is certification as a DAN Oxygen Provider.

Reading this handbook without instruction and practice will not make someone competent to use oxygen in a diving emergency.

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www.DAN.org/training/directory/default.aspx

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Emergency-response skills deteriorate with time. Retraining is required every two years to maintain DAN Emergency Oxygen for Scuba Diving Injuries Provider certification, and DAN encourages, when possible, regular practice to retain proficiency. All skills performed in an emergency should be within the scope of one's training.

First Responder Roles and Responsibility

First aid is the provision of initial care for an injury or illness. Striving to (1) preserve life, (2) prevent the condition from worsening and (3) promote recovery. The primary goal of medical care is to perform treatments or procedures without causing harm. The administration of supplemental oxygen is considered a very safe medical intervention. Provided the scene is safe and equipment is functioning properly, the trained rescuer can feel confident that oxygen provides benefits that may minimize injury and enhance recovery.

Course Prerequisites

A current certification in full cardiopulmonary resuscitation (CPR) is a prerequisite for this program. Certification is accepted from any recognized organization. There is no minimum age requirement to participate in this course. Some countries, states and local municipalities may have minimum age stipulations for the use of emergency oxygen.

Scuba Certification

Scuba diving certification is not a course prerequisite. This course teaches scuba divers and interested nondivers how to provide emergency oxygen first aid to injured divers. Familiarity with diving equipment and diving terminology will make understanding the material easier. However, interested and informed nondivers should be able to master the material.

Continuing Education

Continuing education is encouraged in the form of additional training courses, supervised practice sessions, reading current literature and refresher training. Your DAN Instructor can provide information about these programs. If you have further questions, contact the DAN Education department.

How to use this handbook

Each chapter in this student handbook contains 3 distinct features.

- The beginning of each chapter has a list of learning objectives. This is the information you should be watching for as you read the material, watch the video and participate in class discussions.
- Green boxes with the word "NOTE:" provide explanations that are important to understanding the material just presented.
- The yellow boxes under "Advance Concepts" contain additional information beyond what is required for this course. It is enrichment for those students who want to know more.

2 Overview of Atmospheric Gases

Chapter 2 Objectives

1. What is oxygen (O_2)?
2. How much oxygen is in both inhaled and exhaled air as we breathe?
3. How is oxygen transported to body tissues?
4. What is carbon dioxide, and how is it eliminated from the body?
5. What is nitrogen gas?
6. What is carbon monoxide, and why is it dangerous?

Oxygen (O_2)

Oxygen is a colorless, odorless, tasteless gas that comprises approximately 21 percent of the Earth's atmosphere. It is a vital element for survival and is needed for cellular metabolism. Essential for life, we may experience discomfort, unconsciousness or death within minutes when oxygen supplies are inadequate (hypoxia) or absent (anoxia).

Inhaled oxygen is primarily transported from the alveolar capillaries throughout the body by red blood cells (erythrocytes). Hemoglobin is the oxygen-carrying molecule within erythrocytes responsible for binding both oxygen and carbon dioxide. At rest, humans consume approximately 5 percent of the 21 percent oxygen in the air. Exhaled air therefore contains about 16 percent oxygen. These percentages will vary somewhat by individual and level of activity, but they provide a tangible example of oxygen utilization. This effect has practical importance for rescue breathing as our exhaled breath contains less oxygen than normal air.

*NOTE: *Although exhaled air has lower oxygen content than atmospheric air, this amount is still sufficient for effective rescue breaths.*

Advanced Concepts

During aerobic metabolism, our cells require oxygen to convert biochemical energy in the form of nutrients (sugar, proteins and fatty acids) into the energy-storage molecule called adenosine triphosphate (ATP). The production of ATP generates water, heat energy and carbon dioxide.

In health-care settings, blood oxygen levels are commonly measured with a pulse oximeter. This device, which is often placed over the end of a finger, measures hemoglobin saturation — the percent of hemoglobin binding sites occupied by oxygen — through a color shift between oxygenated and deoxygenated blood states. Normal values while breathing air are 95-100 percent at low to moderate altitudes. Values below this warrant medical attention. Hypoxemia (low levels of blood oxygenation) may necessitate prolonged supplemental oxygen therapy to maintain values within normal levels.

The role of oxygen for diving injuries is to promote inert gas washout and enhance oxygen delivery to compromised tissues. When providing supplemental oxygen to an injured diver, a pulse oximeter is not used as a measure of oxygen treatment effectiveness or as an assessment of inert gas washout.

Carbon Dioxide (CO_2)

Normal air contains very little CO_2, only about 0.033 percent. CO_2 is a waste product of cellular metabolism. Exhaled gas from respiration contains approximately 4-5 percent CO_2. Elevated levels of CO_2 in a breathing gas mixture can lead to drowsiness, dizziness and unconsciousness — this is especially true when diving or breathing under increased atmospheric pressure.

Advanced Concepts

CO_2 is heavily concentrated in blood as bicarbonate (HCO_3-) and serves a critical role in acid-base buffering. The remaining CO_2 is found either dissolved in plasma or bound to hemoglobin.

*NOTE: *Although exhaled air contains higher levels of CO_2 than air, rescue breaths — if performed correctly — should not result in significant elevations in the victim's CO_2 levels. In all cases where rescue breaths or other respiratory devices are used (bag valve mask or positive pressure device), supplemental oxygen is recommended.*

www.dan.org/training/eo2_atmosphere

Nitrogen (N_2)

Nitrogen exists in different chemical forms. As a gas, N_2 comprises about 78 percent of the Earth's atmosphere and in this form is physiologically inert — meaning it is not involved in cellular metabolism. In nondivers who remain at a constant ambient pressure, the concentration of N_2 in the exhaled air is also about 78 percent. In the case of divers who have been breathing inert gas under pressure, the percentage of exhaled nitrogen would be expected to rise above this level while offgassing. However, since nitrogen is an inert gas, it does not interfere with resuscitation efforts during rescue breathing.

2

Advanced Concepts

An elevation in exhaled CO_2 levels, relative to inhaled air, is an indication of metabolic activity. In some medical settings, CO_2 levels in exhaled air are monitored (capnography) and indicate cellular respiration and adequacy of airway management.

Inert gas absorption (nitrogen and helium) is associated with decompression sickness (DCS). Further discussion of DCS, and the role of oxygen, occurs later in this course.

Advanced Concepts

Ingested or organic nitrogen (taken in as a solid, liquid or supplement) is compounded with hydrogen and other ions to form amines — the foundation of amino acids, which make up proteins. These amine groups are broken down and absorbed by our digestive system but do not enter our tissues or bloodstream as absorbed gas (N_2). As a result, ingestion of amines does not pose a decompression risk or alter our propensity for DCS. The only form of nitrogen that plays a role in DCS is the inorganic gas molecule N_2.

Carbon Monoxide (CO)

Certain gases such as carbon monoxide (CO) interfere with tissue oxygen delivery. CO binds more fiercely to hemoglobin and inhibits both the uptake of oxygen and the delivery to tissues. CO poisoning can lead to fatal tissue hypoxia. Even small amounts of CO in the breathing gas of a diver can be hazardous. Inspired gas partial pressures increase with depth, so even small fractions of CO within a tank can become toxic when breathed under pressure.

The body requires a constant supply of oxygen to maintain cellular metabolism. In the absence of oxygen, the body's cells will rapidly deteriorate and die. Some cells are more sensitive than others to hypoxia. Nervous tissue (forming the brain, spinal cord and nerves) is typically very sensitive and will sustain irreversible damage within minutes of inadequate oxygen delivery.

Chapter 2 Review Questions

1. Oxygen is a clear, odorless gas essential to life.
a. True b. False

2. The atmospheric air we inhale contains ____ % oxygen.
a. 12
b. 16
c. 21
d. 27

3. The air we exhale contains ____ % oxygen.
a. 12
b. 16
c. 21
d. 27

4. Oxygen is carried throughout the body by _____ _____ cells.

5. Carbon dioxide is
a. A waste product of metabolism
b. A toxic gas
c. Essential for life
d. An inert gas

6. Nitrogen comprises ____% of atmospheric air.
a. 21
b. 27
c. 67
d. 78

7. Carbon monoxide is
a. A waste product of metabolism
b. A toxic gas
c. Essential for life
d. An inert gas

Review answers are on Page 72.

3 Respiration and Circulation

Chapter 3 Objectives

1. What is hypoxia?
2. Why is oxygen necessary for life?
3. Where does gas exchange occur in the body?
4. What body structures comprise the respiratory system?
5. What body structures are included in the cardiovascular system?

Oxygen is essential for life. Within minutes of experiencing severe oxygen deficiency (hypoxia) or the absence of oxygen (anoxia), we may experience severe discomfort (when associated with elevation in carbon dioxide ($C0_2$)), unconsciousness or death.

Under normal circumstances, breathing ensures an adequate oxygen supply to tissues. The respiratory system provides an effective interface between the bloodstream and the atmosphere and facilitates gas exchange (most critical to normal life is the intake of oxygen and removal of carbon dioxide).

Carbon dioxide (CO_2) results from cellular metabolism and is transported by blood to the lungs, where gas exchange across the alveolar-capillary membrane enables elimination in the exhaled breath. Elevated levels of CO_2 provide the primary ventilatory drive, not low levels of O_2. The rapid elevation of dissolved CO_2 during short periods of breath-holding provides quick insight into the power of its influence.

The Respiratory System

The respiratory system is comprised of the upper airways (mouth, nose and pharynx), the trachea (windpipe) and the lungs. Key supporting structures include the chest wall (ribs and intercostal muscles) and diaphragm (a muscle critical to respiration that separates the thorax from the abdomen). Surrounding the lungs and lining the inside of the chest wall is a thin membrane called the pleura. Although this is one continuous membrane, its coverage of both the lungs and chest wall forms a double layer. Between these two pleural membranes is a potential space that contains a thin layer of fluid that acts as a lubricant, allowing efficient movement of the lungs during breathing.

Air is drawn into the mouth and nose and passes into the pharynx. The pharynx divides into two distinct passages: the trachea and the esophagus. The opening to the trachea is protected from food (solids and liquids) during swallowing by a flexible flap of tissue called the epiglottis. The esophagus, located behind the trachea, is a conduit for food and fluids en route to the stomach.

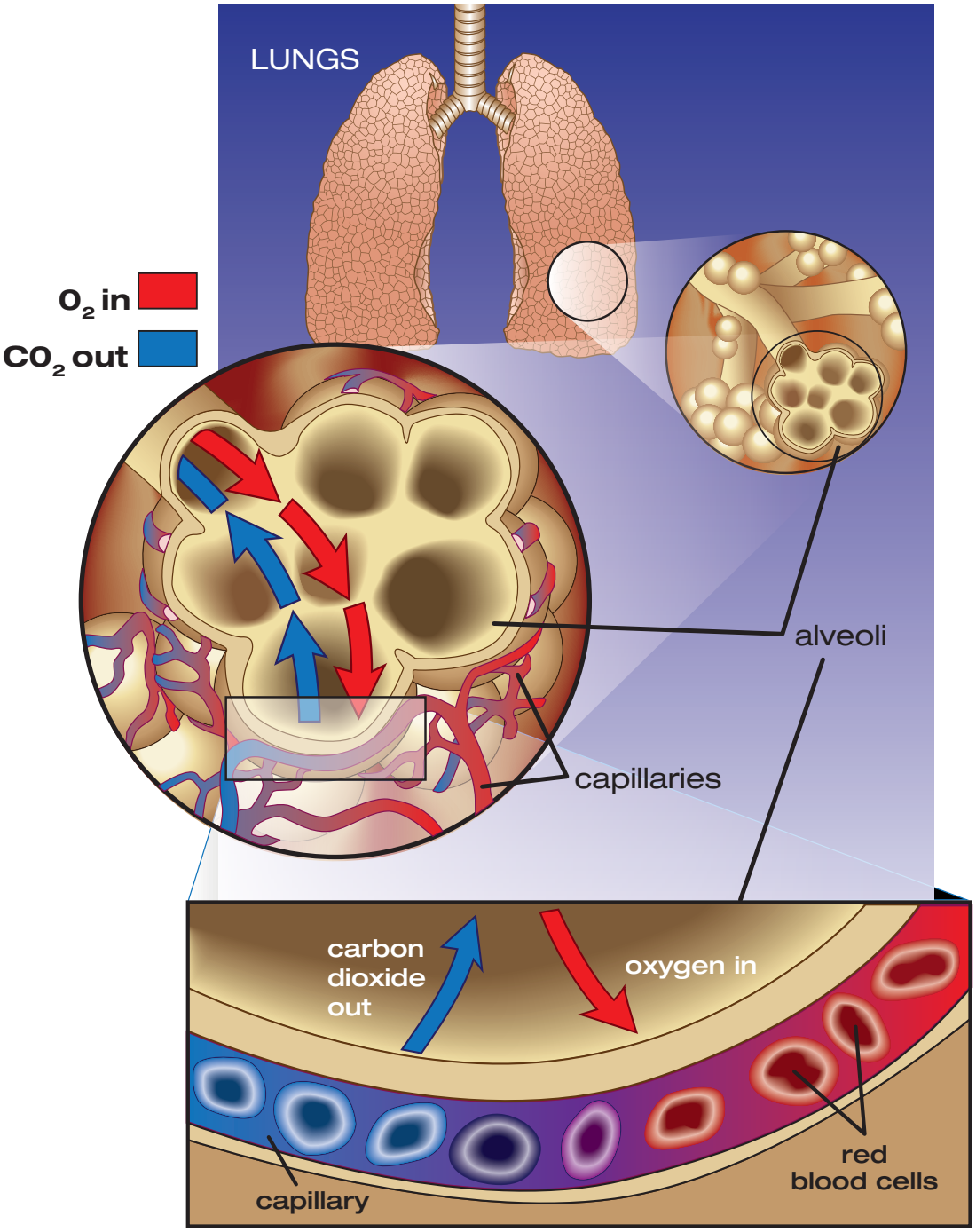
In contrast to solids and fluids, air travels from the pharynx through the larynx (voice box) and into the trachea. The trachea consists of a series of semicircular cartilaginous rings that prevent collapse. The trachea passes down into the chest cavity and branches into the right and left bronchi, which enter the right and left lungs, respectively. The bronchi progressively divide into smaller and smaller tubes and finally into the alveoli. This branching pattern is commonly referred to as the bronchial tree.

Advanced Concepts

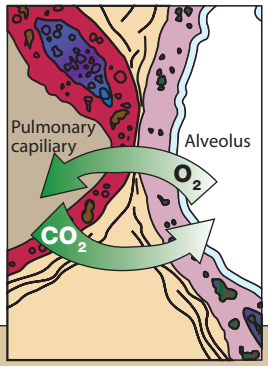
The double-layered pleural membrane is made up of the parietal layer, which lines the thoracic cavity, and the visceral layer, which coats the organs. These two layers normally remain closely adherent due to a slightly negative pressure that keeps them from separating. Because there isn't a separation between these membranes, this area is known as a potential space and only becomes a true space if the membranes are injured or rupture. A pneumothorax forms from the entry of air between these layers (intrapleural space) and may form from escaped alveolar air subsequent to pulmonary barotrauma.

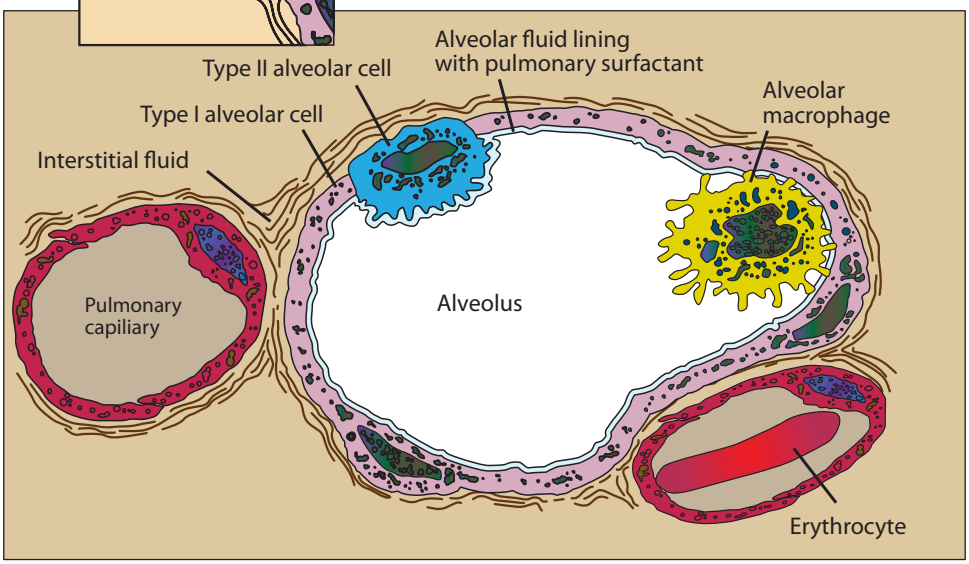
The alveoli, located at the end of the smallest branches of the respiratory tree, have extremely thin walls and are surrounded by the pulmonary capillaries. The alveoli have been likened to tiny balloons or clusters of grapes.

In both lungs, millions of alveoli cover a combined surface area of around 750 square feet (70 square meters) — or roughly the size of a tennis court.



A detergent-like substance, known as lung or pulmonary surfactant, coats the inner surface of the alveoli. Pulmonary surfactant decreases the surface tension of water within the alveoli and thus reduces its tendency to collapse at the end of expiration. If the surfactant is removed, as may occur in a submersion incident, the alveoli may collapse and remain collapsed after the inhaled water is removed (or reabsorbed), severely compromising gas exchange. Large areas of collapsed alveoli are known as atelectasis and may evolve into a pneumonic focus (pneumonia) if they become infected.

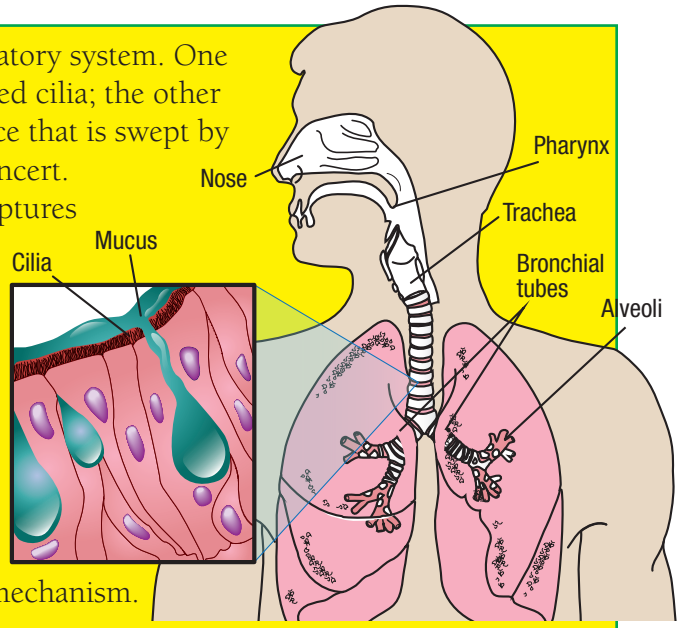




The average adult alveolus has an estimated diameter of 200-300 micrometers and is only a cell layer thick. Alveoli lie adjacent to capillaries that are also one cell layer thick, and this proximity enables the rapid exchange of CO_2 and O_2. The thin alveolar-capillary membrane separates the content of the lung from the bloodstream. If this membrane tears or becomes compromised due to trauma from a lung overexpansion injury (pulmonary barotrauma), it may enable gas to pass out of the alveoli and into the bloodstream. Gas entering the vascular system can travel throughout the body as an air embolism. This topic is discussed in more detail later in this course.

Advanced Concepts

Two types of cells line the respiratory system. One has small hairlike structures called cilia; the other cells produce a mucous substance that is swept by cilia. These two cells work in concert. The sticky mucous substance captures foreign particles, and the cilia move this mucus up into the pharynx, where it can be swallowed and digested together with any trapped foreign particles. In the case of smokers, the mucus is thicker and the cilia are damaged, which hinders the lungs' natural self-cleaning mechanism.



3

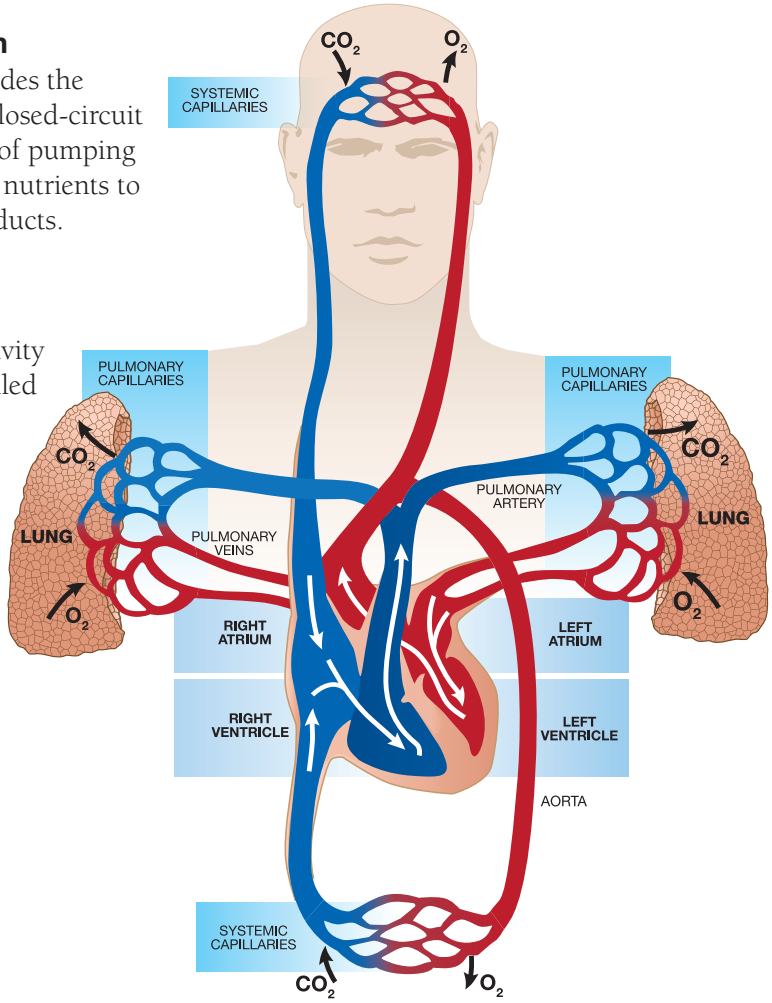
The Cardiovascular System

The cardiovascular system includes the heart and blood vessels. It is a closed-circuit system with a primary purpose of pumping blood, transporting oxygen and nutrients to tissues and removing waste products.

The Heart

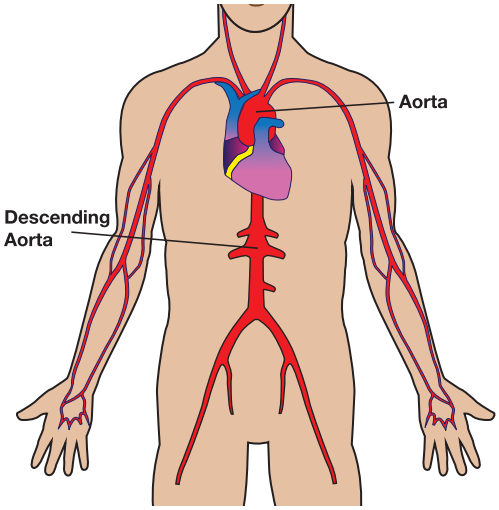
The heart is a hollow muscular organ situated in the thoracic cavity between the lungs in a space called the mediastinum. A thin connective tissue sac called the pericardium surrounds it. The pericardium — like the pleural linings of the lungs — reduces friction between the heart and surrounding structures.

The heart is a strong muscular pump that, in the average adult, has the capacity to beat spontaneously at a rate of about 70 times per minute (the normal resting heart rate is



60-100 beats per minute and may be as low as 40 beats per minute in athletes[7]). Every minute approximately 6 liters (about 1.5 gallons) of blood is pumped throughout the body. When exercising, this output may double or triple depending upon the amount of exertion.

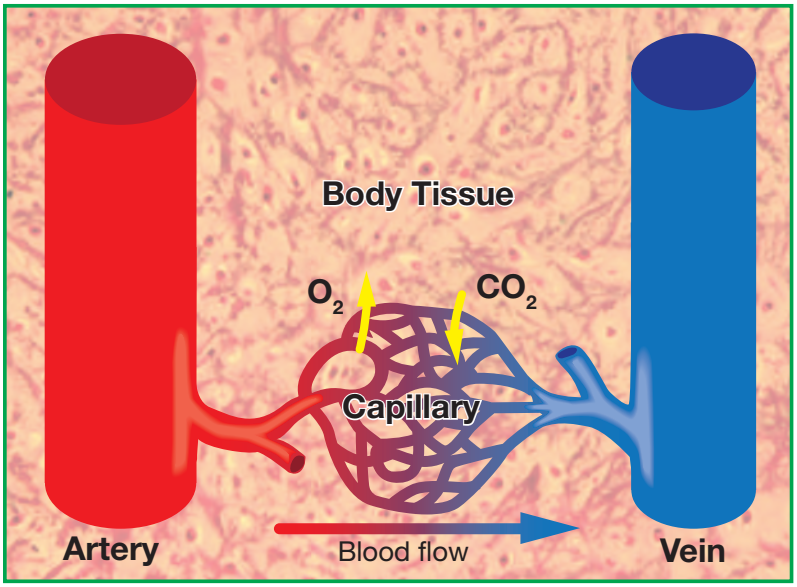
The heart is divided into a right and left pump system (also known as the right heart or pulmonary circuit and the left heart or systemic circuit). The right heart receives deoxygenated blood from the venous system and pumps it to the pulmonary circuit to exchange gases. Oxygenated blood is returned to the left heart, where it is pumped to the systemic circuit. Transportation of blood through both circuits completes a circulatory cycle.



Blood Vessels

Blood leaves the left ventricle via the aorta, which then branches into smaller arteries to supply the head, arms, torso and legs.

The blood vessels make up the vascular tree, with each branch leading to progressively smaller branches, which give rise to capillaries, the smallest of all blood vessels. Through these thin capillary walls, gases and nutrients are exchanged. Functionally, the heart and large blood vessels represent a pump-and-distribution system for the capillaries, responsible for supplying tissues with oxygen and nutrients and removing CO_2 and other metabolic waste products.

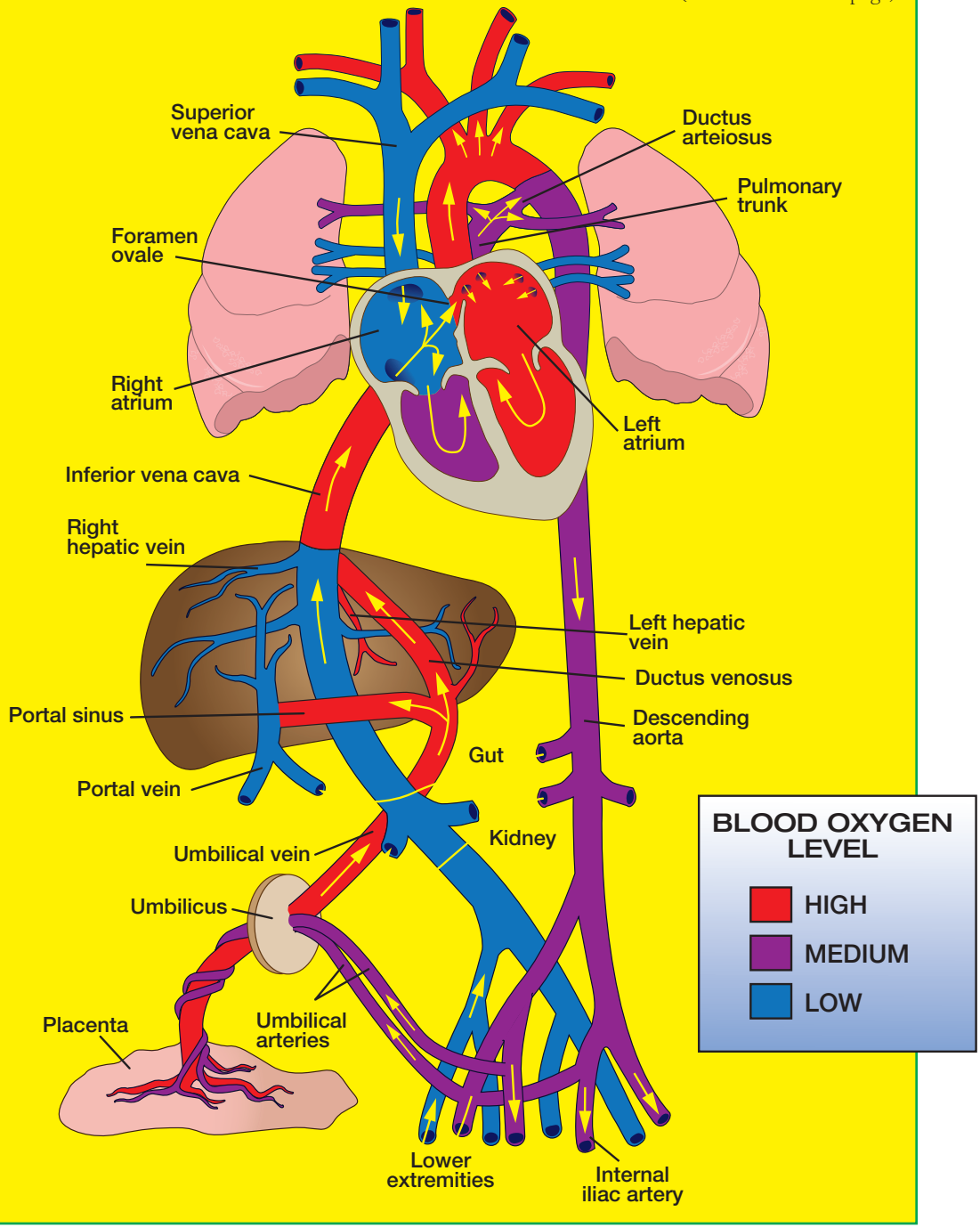


From the peripheral capillaries, the blood is gathered into small, thin-walled veins and returned via larger veins to the atria of the heart. Most veins direct blood flow by means of one-way valves that prevent blood from traveling in the wrong direction or pooling due to gravity.

Fetal Circulation

Within the uterus, the fetus lives in a fluid-filled environment. As such, the lungs are not used for gas exchange, and circulating blood is largely shunted away from pulmonary tissue. In the fetus, gas exchange takes place in the placenta, drawing available oxygen from the mother's blood.

(continued on next page)



There are two unique passages in the fetal circulation that allow blood to bypass the lungs. These two portals, known as the ductus arteriosus and foramen ovale, usually close soon after birth with the baby's first breaths.

The ductus arteriosus (a duct between two arteries) enables blood coming from the right ventricle to directly enter the aorta and thus bypass the lungs. Once this passage closes, blood is transported to the lungs, which are now needed for blood oxygenation. A vestige (remnant) of the ductus will remain as a ligament bonding the aorta and the pulmonary artery (ligamentum arteriosum or arterial ligament).

The foramen ovale (an oval-shaped hole) is a passage between the atria that allows blood to shunt from the right atrium to the left, thus bypassing the nonfunctional lungs. At birth, when the pressures in the left atrium increase, this passage usually closes, too, leaving only a depression in the wall known as the fossa ovalis. Closure of the foramen is incomplete in approximately 25-30 percent of the population, thus leaving a patent (open) foramen ovale (PFO). The PFO is not physiologically relevant in many persons, but it may predispose a small number of people to certain medical issues.

Advanced Concepts

Blood

Blood is a specialized fluid (actually a distinct organ system) that links the respiratory system to the rest of the body. Approximately 55 percent of our circulating blood volume is comprised of plasma, the visible fluid fraction of blood. While mostly water, plasma also contains proteins, glucose, minerals, nutrients, waste products and dissolved gases. The cellular constituents of blood include erythrocytes (red blood cells; RBC), which transport oxygen and carbon dioxide, and leukocytes (white blood cells; WBC), which play a critical role in infection control and inflammatory responses. The third constituent is platelets, cell fragments responsible for initiating the clotting process.

Chapter 3 Review Questions

1. Hypoxia is a condition of low oxygen supply.

a. True b. False

2. An absence of oxygen

a. May cause cell death
b. Is known as anoxia
c. May cause unconsciousness
d. All of the above

3. Gas exchange takes place at the

a. Vein-artery interface
b. Long bone joints
c. Alveolar-capillary membrane
d. Muscle-nerve junctions

4. The respiratory system includes: (Mark all that apply.)

a. Nose
b. Mouth
c. Trachea
d. Lungs

5. The circulatory system includes: (Mark all that apply.)

a. Mouth
b. Veins
c. Arteries
d. Heart

Review answers are on Page 72.

Decompression Illness (DCI)

4

Chapter 4 Objectives

1. What are the most important initial actions in responding to diving accidents?
2. What is decompression illness (DCI)?
3. What is the primary cause of decompression sickness (DCS)?
4. What are the primary symptoms of DCS?
5. What is arterial gas embolism (AGE)?
6. What is the primary risk factor for AGE?
7. Why is it important to seek medical evaluation when DCI is suspected?
8. What are the most prevalent symptoms of DCI?
9. What are the typical onset times of DCS and AGE symptoms?

The term decompression illness (DCI) describes signs and symptoms arising either during or subsequent to decompression, and it encompasses two different but potentially linked processes:

- Decompression sickness (DCS)
- Arterial gas embolism (AGE)

While the underlying cause of these two conditions may be different, their initial medical management (first aid) is the same.

The most important initial actions performed in diving accidents are early recognition and the use of supplemental oxygen.

Decompression Sickness

DCS results from bubbles formed within tissues or blood from dissolved inert gas (N_2 or helium). The size, quantity and location of these bubbles determine the location, severity and impact on normal physiologic function. Besides the anticipated mechanical effects that can cause tissue distortion and blood-flow interruption, bubble formation may trigger a chain of biochemical effects. These include activation of clotting mechanisms, systemic inflammation, leakage of fluids out of the circulatory system and reactive vasoconstriction. These effects may persist long after bubbles are gone and may play a significant role in the duration and severity of clinical signs and symptoms.

While the effects of bubbles impact us on a systemic level, specific signs and symptoms are thought to result from either bubble accumulation or its impact on specific areas. Examples include joint pain, motor or sensory dysfunctions and skin rash.

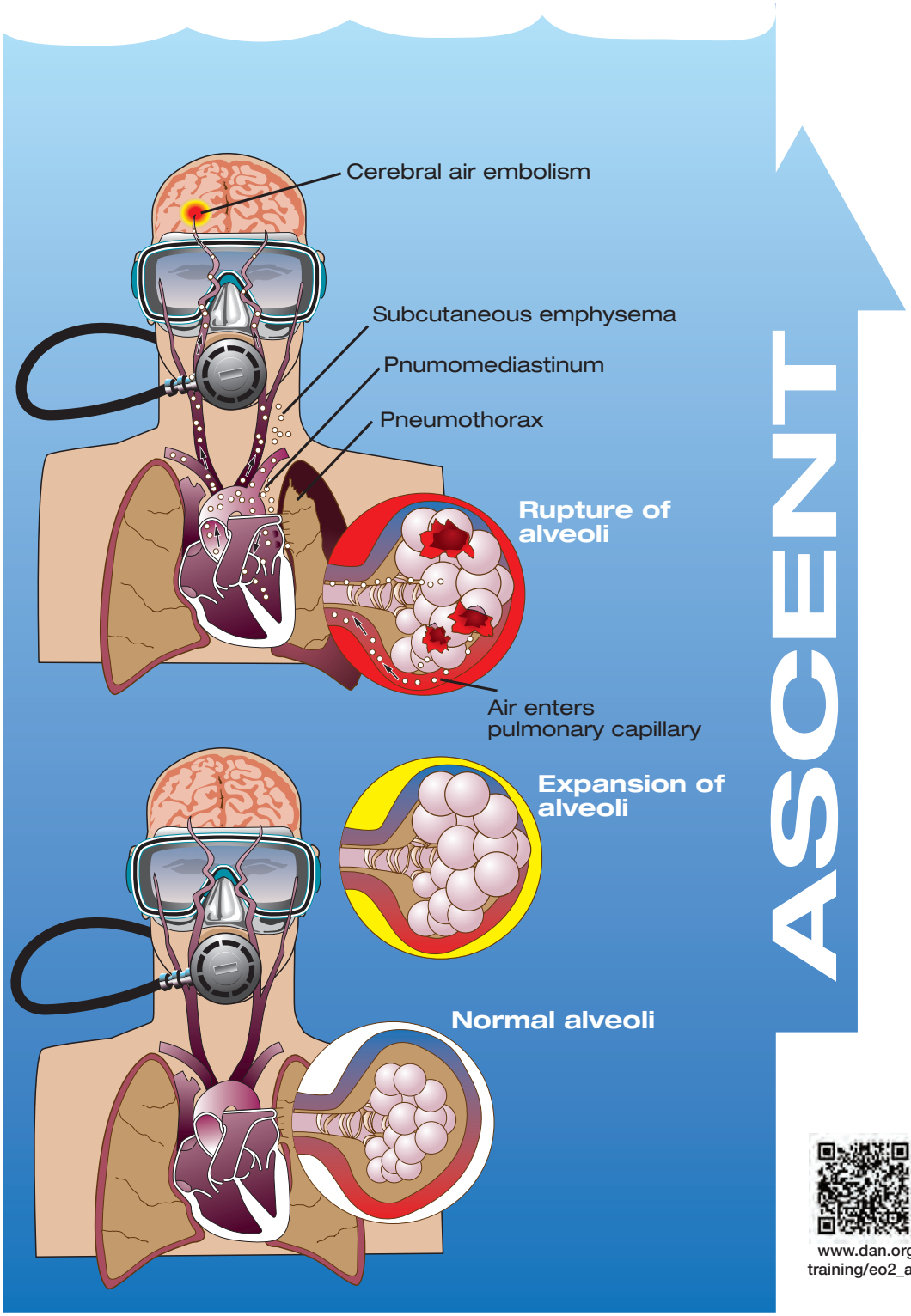
DCS is rarely life-threatening. Early treatment with high concentrations of O_2 (as close to 100 percent as possible) has been shown to speed symptom resolution and optimize the impact of recompression therapy.[8] Though symptom resolution is a desired effect of oxygen first aid, it is important to emphasize that it should not be considered a definitive treatment or arbitrarily stopped when symptoms resolve.

Arterial Gas Embolism (AGE)

Arterial gas embolism in divers typically results from a lung-overexpansion injury. The greatest risk for this injury occurs in shallow water and may result from breath-holding in as little as 4 feet (1.2 meters) of sea water. Lung-tissue trauma can allow the entrance of breathing gas into the blood vessels returning to the heart (pulmonary veins). These bubbles, if transported to the brain, can cause rapid and dramatic effects.

The primary risk factor for AGE is breath-holding during ascent. Other potential risk factors include underlying conditions like lung infections and preexisting diseases like asthma that may increase the risk of air trapping.

It is important to state that not all pulmonary tissue injuries result in AGE (this includes lung-overexpansion injuries in divers). Pulmonary trauma from stab wounds, projectiles or blunt force can also lead to lung-tissue damage and enable the escape of intrapulmonary (within the lungs) air without causing arterial bubbles. Signs of pulmonary barotrauma include extra-alveolar air (air outside the lungs) such as pneumothorax, subcutaneous emphysema (air beneath the skin), mediastinal emphysema (air in the mediastinum) and pneumopericardium (air trapped around the heart). Depending on the location of gas collection, signs and symptoms may include chest pain, changes in voice pitch, difficulty breathing or swallowing, gas bubbles felt under the skin (typically around upper thorax, neck and/or face) and cyanosis (bluish coloration of the lips).



www.dan.org/training/eo2_age

Pulmonary barotrauma with subsequent arterial gas embolism and representation of brain (cerebral) injury. Recreated by the Divers Alert Network from Lancet 2011; 377: 154

Advanced Concepts

A separate but related concern is AGE that occurs secondary to venous bubbles bypassing the pulmonary filter and entering the arterial system directly. The process through which blood passes from the right side of the circulatory system to the left and bypasses the "pulmonary filter" is called shunting — in this case, right-to-left shunting. Shunting may occur through a physiologically relevant PFO or passage through the lungs (transpulmonary shunt). Regardless of the method, problems can occur when bubbles enter the arterial circulation. Bubbles may impact the central nervous system (CNS) and cause acute neurological symptoms. Symptom onset in this scenario could develop after a longer interval than the 10-15 minutes typically described in cases of AGE since the source of the arterialized bubbles is from the venous system and not pulmonary barotrauma. It is important to note that while bubbles in the systemic system are undesirable, their presence does not automatically cause symptoms. Bubbles have been visualized in the left heart following decompression in subjects who have not gone on to develop symptomatic DCI.

Oxygen and the Importance of Proper Medical Evaluation of DCI

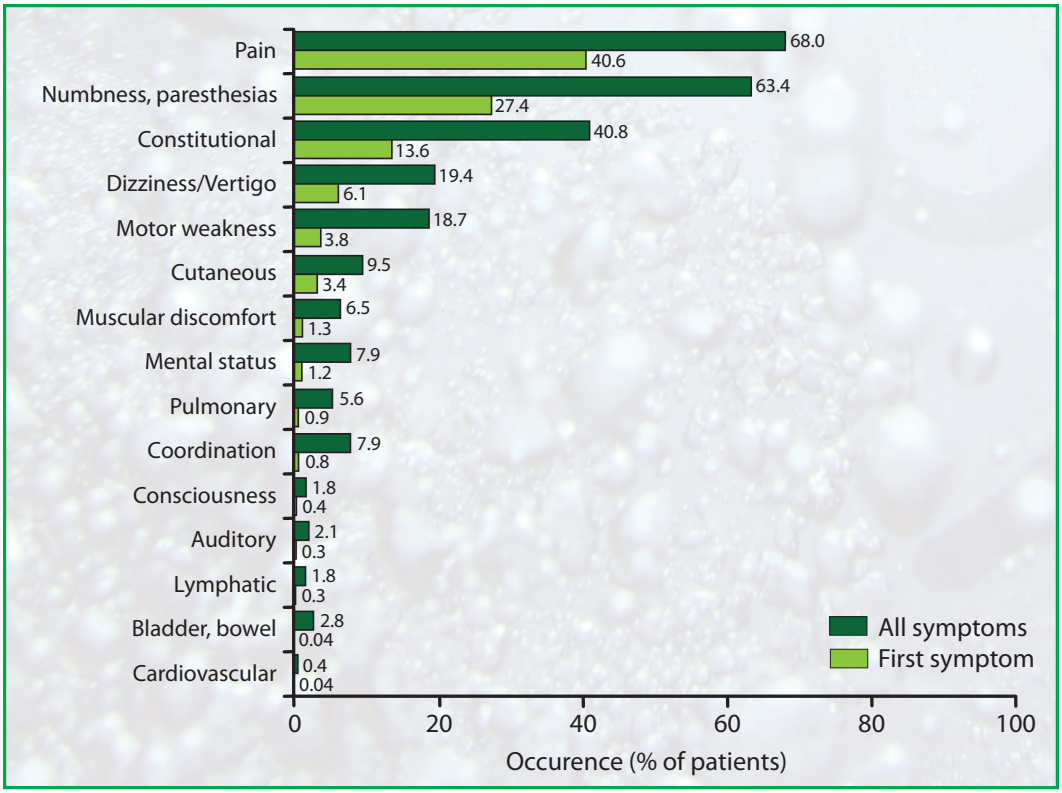
The diagnosis of DCI is based on history and clinical findings — there is no diagnostic test. Symptoms can range from very mild to severe and, particularly in the former case, may be dismissed by divers or appear to resolve by the time medical care is sought.

In some cases the use of oxygen leads to symptom resolution, which may prompt the decision to forego medical assessment. DAN recommends seeking prompt medical evaluation in all cases of suspected DCI regardless of the response to oxygen first aid. For those tempted to avoid medical assessment, be advised that symptoms may recur, and the risk of recurrence may be reduced with hyperbaric treatment.

Common Signs and Symptoms of DCI

While providing emergency oxygen to an injured diver, you may see their condition change with time. In the case of complete symptom resolution, continue oxygen administration, and seek medical attention regardless of perceived improvement.

Injured divers may have one or more of the following signs and symptoms. The list is ranked in order of presentation frequency based on Project Dive Exploration (PDE) data from 2,346 recreational dive accidents reported to DAN from 1998 to 2004.



Classification and frequency distribution of initial and eventual manifestations of decompression illness in 2,346 recreational diving accidents reported to Divers Alert Network from 1998 to 2004.

Pain (Initial symptom in 41 percent of cases)

Commonly associated with neurological symptoms, it has been characterized as a dull, sharp, boring or aching sensation in or around a joint or muscle. It may begin gradually and build in intensity or be so mild that it is disregarded.

- Movement of the effected joint or limb may or may not make a difference in the severity of the pain. The pain may be out of proportion to the amount of work or exercise performed and may be referred to as unusual or just "different."
- DCI pain can be difficult to distinguish from normal aches and pains. Symptoms can mimic other illness such as viral infections, muscle or joint pain, fatigue from exertion and other nonspecific discomforts.

Neurological: Numbness/Paresthesia (Initial symptoms in 27 percent of cases)

- Paresthesia /anesthesia/dysesthesia are terms that refer to altered sensations and may present as abnormal feelings (paresthesia), decreased or lost sensation (anesthesia) or hypersensitivity (dysesthesia). Paresthesia is commonly characterized as a pins-and-needles sensation. These altered sensations may only affect a small patch (or patches) of

skin and may go unnoticed by the diver until they are revealed by a thorough medical evaluation. A diver may complain that an extremity has "fallen asleep" or a "funny bone" has been hit. Numbness and tingling most often occur in the limbs and may be associated with complaints such as a cold, heavy or swollen sensation.

Constitutional Symptoms (Initial symptoms in 14 percent of cases)

- These are generalized symptoms that do not impact a particular part of the body. Examples include extreme fatigue, general malaise and nausea.

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- Extreme fatigue: It is not unusual to be fatigued after a scuba dive or other physical activity. The fatigue associated with DCI is typically more severe and out of proportion with the level of exertion required by the dive. The diver may want to lie down, sleep or ignore personal responsibilities such as stowing gear or cleaning equipment.

Balance and Equilibrium (Initial symptoms in 6 percent of cases)

- Vertigo (spinning sensation): Vertigo presenting during or after the dive should be considered a serious symptom suspicious of inner ear/vestibular involvement.
  - There are several non-DCI-related causes for such symptoms, and these include round- or oval-window rupture, alternobaric vertigo and caloric vertigo.
- Dizziness: A feeling of unsteadiness, which may also be characterized as light-headedness, is commonly associated with nausea.

Muscular Weakness (Initial symptom in 4 percent of cases)

This symptom may present as difficulty walking due to decreased muscular strength or limb paralysis.

Cutaneous (Skin) Symptoms (Initial symptom in 3 percent of cases)

Skin signs are often located on the chest, abdomen, back, buttocks or thighs. Rashes commonly migrate (move to different parts of the body). Effected areas may be tender or itch and are thus often confused with allergies or contact dermatitis.

Altered Mental Status (Initial symptom in 1.2 percent of cases)

Symptoms may include confusion, personality changes or speech disturbances (slurring of words or nonsensical speech).

Bowel and Bladder (Initial symptom in 0.04 percent of cases)

Spinal cord DCS may injure the nerves responsible for bladder and bowel control. Sometimes people will require urinary catheterization.

***Any suspicion of neurological symptoms should prompt immediate oxygen therapy and transportation to a medical facility.**

Other Signs and Symptoms of DCI

- Altered level of consciousness: Identified as initial symptom in 0.4 percent of cases.
- Audiovestibular or inner-ear DCS: This relatively rare manifestation is associated with deep heliox diving.
- Lymphatic DCS: Identified as an initial symptom in 0.3 percent of cases. This symptom is often characterized as localized swelling affecting the trunk and shoulders.
- Visual disturbance: Loss or blurring of vision or loss of visual fields
- Difficulty breathing: This may be the result of pulmonary barotrauma or a severe form of DCS known as the chokes (a rare but life-threatening condition caused by an overload of venous gas emboli that severely impacts cardiorespiratory function). There are also many other causes of respiratory compromise not necessarily related to or associated with DCI — all of which should prompt medical evaluation.
- Convulsions are rare.

Epidemiology of Decompression Illness

DCI is an uncommon event, which nonetheless warrants attention and concerted efforts to prevent. Based on 441 confirmed or possible incidents of DCI referenced in the 2008 *DAN Annual Diving Report*, 3.9 percent were classified as possible AGE.[1]

The occurrence of DCS varies by population. Based on DAN data, the per-dive rate among recreational divers is 0.01-0.019 percent; among scientific divers it's 0.015 percent; for U.S. Navy divers it's 0.030 percent; and for commercial divers it's 0.095 percent.[1,2]

Previously published per-dive DCS rates based on 135,000 dives by 9,000 recreational divers were 0.03 percent. This rate was higher in those who performed deep cold-water wreck dives versus the group aboard warm-water liveaboards. The incidence of DCS from warm-water liveaboards was: 2/10,000 (0.0002) and among cold-water wreck divers in the North Sea 28/10,000 (0.0028).[3]

http://www.DAN.org/medical/report/index.asp

DCI Symptom Onset

While the timing of symptom onset varies, the majority of people complain of DCS symptoms within six hours following a dive. Symptom onset may be delayed by as much as 24 hours, though beyond this time frame the diagnosis becomes increasingly questionable.

In contrast to DCS, AGE will typically show a more dramatic array of neurological symptoms, most of which will show up immediately upon surfacing or within 15 minutes from the time of injury. As one might expect, sudden neurological injury that leads to unconsciousness may result in drowning.

Recompression Therapy

An injured diver may feel better or experience reduced symptom severity after receiving emergency oxygen. Despite symptom improvement, and in some cases resolution, divers should still seek medical evaluation. The primary medical concern is that symptoms (especially neurological symptoms) may recur when supplemental oxygen therapy is stopped. This is one of the reasons DAN recommends transportation to the nearest medical facility for evaluation. DAN is always available to provide information to emergency medical staff regarding diving injuries and the potential benefit of hyperbaric treatment. DAN also provides evacuation assistance and care coordination with treating facilities.

Prolonged treatment delays, usually measured in days, may reduce the effectiveness of treatment and may extend the time needed to achieve optimal symptom resolution. It should be understood, however, that in the majority of less severe cases, minor delays of a few hours rarely impact the final treatment outcome.

Residual Symptoms

Residual symptoms following hyperbaric oxygen treatment are not uncommon, especially in severe cases or when considerable delays (sometimes measured in days) in treatment initiation have occurred.

Divers who experience persistent symptoms following hyperbaric oxygen therapy should remain under the care of a hyperbaric physician until symptoms have resolved or further therapy is deemed either unnecessary or unlikely to provide further benefit. A decision to return to diving should be made in consultation with a physician knowledgeable in dive medicine.

Chapter 4 Review Questions

1. Decompression illness (DCI) includes:

a. Decompression sickness (DCS)
b. Arterial gas embolism (AGE)
c. Both of the above

2. The most important initial actions in responding to diving accidents are to recognize there is a problem and administer 100 percent oxygen.

a. True b. False

3. DCS is caused by:

a. Breath-hold during descent
b. Breath-hold during ascent
c. Inert gas bubbles in the body

4. The primary risk factor for AGE is

a. Breath-hold during descent
b. Breath-hold during ascent
c. Inert gas bubbles in the body

5. Describe why it is important to seek medical evaluation when DCI is suspected.

_____
_____
_____
_____

6. List the five most frequent symptoms of DCI.

_____
_____
_____
_____
_____

7. Initial DCS symptoms

a. Occur within 15 minutes of the time of injury
b. Typically occur within six hours of surfacing
c. May be delayed up to 24 hours
d. Both b and c

8. AGE symptoms

a. Occur within 15 minutes of the time of injury
b. Typically occur within six hours of surfacing
c. May be delayed up to 24 hours
d. Both b and c

9. Returning to diving following decompression illness should be done in conjunction with a physician knowledgeable in dive medicine.

a. True b. False

Review answers are on Page 72.

5 Oxygen and Diving Injuries

Chapter 5 Objectives

1. What are the benefits of providing a high concentration of oxygen to an injured diver?
2. How does establishing a gas gradient help the injured diver?
3. What is the primary goal of emergency oxygen for injured divers?
4. What critical factors impact the percentage of oxygen delivery when using a demand valve?
5. What is the initial flow rate for constant-flow oxygen delivery systems?
6. What is the priority for oxygen delivery in remote areas?
7. What are the concerns for oxygen toxicity when delivering emergency oxygen first aid?
8. What are the symptoms of nonfatal drowning?
9. What is the first responder's role in a nonfatal drowning?

The most common diving injuries for which oxygen use is recommended are arterial gas embolism (AGE) and decompression sickness (DCS). In the case of AGE, bubbles may enter the arterial system secondary to lung overexpansion and lung-tissue rupture. In the case of DCS, problems arise when gas dissolved in body tissues during a dive comes out of solution in the form of bubbles during or following decompression. Bubbles may cause tissue disruption, compromise blood flow and/or trigger inflammatory responses, which may result in symptoms.

Though most cases of DCS are mild and do not pose an immediate risk to life, impaired circulation or function of vital areas like the brain and spinal cord can result in severe neurological symptoms. These can range from mild tingling and pain to weakness, paralysis, difficulty breathing, unconsciousness and even death.

In contrast to DCS, AGE is commonly associated with lung-overexpansion injury and can result in acute neurological symptoms including unconsciousness. Bubbles entering the arterial system through damaged lung tissue can quickly travel to the brain and interrupt circulation. The goal of first responders is to enhance blood oxygen levels and speed bubble size reduction by establishing a gas gradient.

Oxygen administration in the setting of a suspected diving injury creates a partial pressure gradient that helps in two key ways. The first is an acceleration of inert gas (nitrogen and/or helium) elimination. This process may reduce bubble size and improve circulation. The gradient also enhances oxygen delivery to injured or ischemic tissues (areas with poor circulation), which can reduce pain and limit or reverse hypoxic injury. Oxygen administration may also reduce edema (swelling), which can further improve the efficiency of tissue oxygen delivery.

The DAN Oxygen Provider course emphasizes the use of oxygen for diving injuries and nonfatal drowning but does not address other indications for oxygen treatment.

Oxygen Flow Rates

The primary goal of emergency oxygen for injured divers is to deliver the highest percentage of inspired oxygen possible. Keeping this goal in mind is key to delivering optimal care.

There are two variables that impact delivered oxygen concentrations: mask fit and flow rate (measured in liters per minute or lpm). In the case of demand valves, proper fit and seal are critical as flow rate is not adjusted. When using constant-flow systems, mask fit is still crucial as leaks result in decreased inspired fractions of oxygen (FiO_2). Enhanced flow rates are an inefficient way to compensate for a poor fitting mask.

Delivery Device	Flow Rate	Inspired Fraction+
Nasal cannulae	2-4 lpm	≤ 0.3 (30%)*
Oronasal mask (no reservoir bag)	10 lpm	≤ 0.5–0.6 (50%–60%)*
Nonrebreather mask	10-15 lpm	≤ 0.8 (80%)**
Bag valve mask	15 lpm	≤ 0.9–0.95 (90%–95%)
Demand valve	N/A	≤ 0.9–0.95 (90%–95%)

*May vary with respiratory rate

**Less variation with changes in respiratory rate

+ Delivery fractions vary with the equipment and techniques used. This table summarizes various oxygen-delivery systems and potential values of inspired oxygen with their use.

Nasal cannulae are generally operated at relatively low flow rates of 2-4 lpm. Nasal cannulae are the least efficient method of oxygen delivery, typically delivering fractions no greater than 0.3 (30 percent). Simple face masks may deliver fractions of 0.5-0.6 at flow rates between 10-15 lpm.

Nonrebreather masks can deliver a higher fraction but probably still no greater than 0.8. Demand valves are appropriate for conscious and spontaneously breathing divers and with careful mask management may deliver fractions up to 0.9-0.95.

Accidents frequently occur in remote locations or far away from medical services, and oxygen supplies are generally limited. Rescuers face the dilemma between maximizing inspired fractions and limiting flow rates in an attempt to conserve oxygen supplies. The priority should always be to maintain the highest inspired fractions possible.

As shown in the above table, the best solution is the demand valve (or manually triggered ventilator being used as a demand valve). If continuous-flow delivery is required or the only method available, start at 10-15 lpm and increase or decrease in increments based on the needs of the diver, ensuring that the reservoir bag remains full.

Flow rates above 10 lpm will not cause harm but will deplete oxygen supplies faster. If the next level of care is accessible before the supply is exhausted, higher flow rates can be used to maintain optimal oxygen fractions and enhance patient comfort. Any perceived or suspected worsening in a diver's condition should prompt reassessment.

Hazards of Breathing Oxygen

Oxygen toxicity can occur when one breathes high concentrations of oxygen for prolonged periods or while under pressure. Oxygen toxicity occurs in two forms: central nervous system (CNS) and pulmonary (lung) toxicity. In CNS oxygen toxicity, seizures may develop when someone breathes oxygen at greater than 1 atmosphere absolute (ATA) pressure. The risk of acute toxicity increases with elevations in partial pressure. For this reason, the accepted safe recreational limit for oxygen partial pressures while underwater is 1.4 ATA.

Breathing high concentrations of oxygen for prolonged periods at the surface can cause pulmonary oxygen toxicity, which is quite distinct from CNS toxicity. In this setting, lung tissue may become irritated when breathing elevated oxygen concentrations. The underlying mechanism for this is the production of oxygen free radicals in a quantity that overwhelms our cellular antioxidant defenses. Initial symptoms may include substernal (behind the sternum) irritation, burning sensation on inspiration and coughing. The most severe symptoms may occur after about 12 to 16 hours of exposure at 1 ATA.[4] The time

Advanced Concepts

Chemical oxygen systems deliver neither sufficient flow rates nor sufficient oxygen volume to be effective. The average measured flow rates were 3 lpm (Pollock and Hobbs, 2002) and less than 2 lpm (Pollock and Natoli, 2010) with total flow durations of little more than 15 minutes for one reactant set.

to initial symptom onset is expected to reduce at higher partial pressures (greater than 1 ATA). Symptoms may be seen from 8 to 14 hours at 1.5 ATA[5] and from 3 to 6 hours at 2 ATA.[4,5] At higher pressures, symptoms may occur more quickly but are often less severe due to limited exposure times. The prevailing concern with PO_2 levels greater than 2.5 ATA and 3 ATA is CNS toxicity.[4,5,6]

CNS toxicity is **not** a concern for the oxygen provider rendering first aid. Pulmonary oxygen toxicity is also not a significant concern for first responders delivering oxygen at maximal concentrations at ground or sea level for less than 12-24 hours.

Nonfatal Drowning

Nonfatal drowning refers to a situation in which someone almost died from being submerged underwater and was unable to breathe. In the case of prolonged asphyxia (not breathing) or reduced cardiac and lung function due to submersion, oxygen therapy may be crucial. While nonfatal-drowning victims may quickly revive, lung complications are common and require medical attention. In addition, fluid and electrolyte imbalances may develop with the potential for delayed symptom onset.[8]

Symptoms of nonfatal drowning may include difficulty breathing, bluish discoloration of the lips, abdominal distention, chest pain, confusion, coughing up pink frothy sputum, irritability and unconsciousness. Victims may also be anxious or cold and would benefit from removal of wet clothes and possible treatment for hypothermia.[8]

As a first responder, your primary role is to monitor vital signs, provide supplemental oxygen and transport to the nearest medical facility as soon as possible.

NOTE: Keep yourself safe. Avoid in-water rescue unless trained and properly equipped.

www.dan.org/training/eo2_drowning

Chapter 5 Review Questions

1. Providing a high concentration of oxygen to an injured diver may provide these benefits: (Mark all that apply.)

a. Acceleration of inert gas elimination
b. Reduce bubble size
c. Enhance oxygen delivery to tissues
d. Reduce swelling

2. The primary goal of the highest concentration of oxygen possible to an injured diver is to facilitate inert gas washout and improve oxygen delivery to compromised tissues.

a. True b. False

3. Percentage of oxygen delivered when using a demand valve is influenced by

a. Flow rate
b. Mask fit
c. Mask seal
d. Both b and c

4. The initial flow rate for constant-flow oxygen delivery is

a. 2-4 lpm
b. 10-15 lpm
c. 20-25 lpm
d. The rate the injured diver will tolerate.

5. In remote areas, the priority in oxygen delivery is

a. To conserve oxygen supplies
b. To maximize highest inspired fraction of oxygen
c. Limit the flow of oxygen

6. Oxygen toxicity, whether CNS or pulmonary, is not a concern for oxygen first aid to an injured diver.

a. True b. False

7. List eight symptoms of nonfatal drowning.

_____
_____
_____
_____
_____
_____
_____
_____

8. As a first responder to a nonfatal drowning, your primary role is to

a. Monitor vital signs
b. Provide supplemental oxygen
c. Transport to the nearest medical facility
d. All of the above

Review answers are on Page 72.

Handling Oxygen Safely

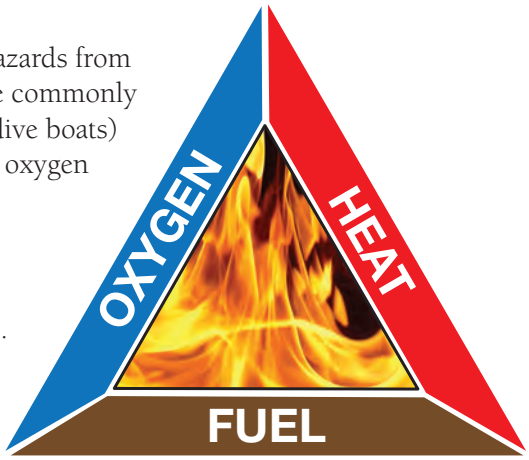
6

Chapter 6 Objectives

1. What is the fire triangle, and how is oxygen involved?
2. What two steps should be implemented to reduce the risks of handling oxygen?
3. What are the safety precautions that should be implemented when using oxygen equipment?
4. What grade of oxygen should be utilized for diving first aid?
5. What documentation is required to receive an oxygen fill?

Oxygen is not flammable, but all substances need oxygen to burn and may burn violently in an environment of pure oxygen. Problems associated with the use of properly maintained emergency-oxygen devices are rare. Three elements — heat, fuel and oxygen — are required for a fire to exist. This is commonly called the fire triangle. Emergency-oxygen systems will always have at least one element, and that is oxygen.

DAN Oxygen Providers should reduce the risks of handling oxygen. Be sure that the hazards from both the fuel (oil deposits and hydrocarbons are commonly used as lubricants for diving and are found on dive boats) and heat from the sun and rapid opening of the oxygen cylinder valve are minimized.



Where Does Pure Oxygen Come From?

Fractional distillation of air yields pure oxygen. Air is first filtered to remove any debris and dirt. Compressed to very high pressures, it is dried to remove water vapor. To liquefy the gas, it

is cooled to very low temperatures and allowed to slowly rewarm. As it is rewarming, various components of air (primarily oxygen and nitrogen) are captured and stored in separate containers as they reach their particular boiling points.

There are many grades of oxygen, but the three primary ones that DAN Oxygen Providers need to consider are:

- Aviator-grade oxygen
- Medical-grade oxygen
- Industrial-grade oxygen

Each grade must be 99.5 percent pure oxygen; however, differences exist in how the cylinders are filled, affecting the overall purity of the oxygen. For example, to prevent freezing at high altitudes aviator-grade oxygen has a lower moisture content than medical-grade oxygen.

The filling procedures for medical-grade oxygen require that an odor test is conducted and the cylinder contents be evacuated before the fill. When odors are detected or damage to the valve or cylinder is observed, medical-grade oxygen cylinders are cleaned before returning them to use.

Industrial-grade oxygen is not recommended for use with dive injuries. Industrial-grade oxygen guidelines allow for a certain percentage of impurities and other gases to be contained within the cylinder. While both aviator- and medical-grade oxygen are suitable for breathing, industrial-grade oxygen may not be. The procedures for filling industrial oxygen cylinders do not ensure that the oxygen is free of contamination.

Safety Precautions When Using Oxygen

Oxygen cylinders require the same care as scuba cylinders with a few additional precautions:

- Do not allow the use of any oil or grease on any cylinder or device that comes in contact with oxygen. The result may be a fire.
- Oxygen cylinders should not be exposed to temperatures higher than 125°F (52°C) in storage (for example, in a car trunk).
- Do not allow smoking or an open flame around oxygen and oxygen equipment.
- Remember to provide adequate ventilation when using oxygen. In a confined, poorly ventilated space (the cabin of a boat, for example), the oxygen concentration may build up and create a fire hazard.
- Use only equipment (cylinders, regulators, valves and gauges) made to be used with oxygen. Avoid adapting scuba equipment for use with oxygen.
- Visually inspect the condition of valve seats and oxygen washers, and make sure the materials are compatible for oxygen use.

- Keep the valves closed with the system purged when the unit is not in use. Close valves on empty cylinders. Empty cylinders should be refilled immediately after use.
- An oxygen cylinder should always be secured so that it cannot fall. When carrying an oxygen cylinder by hand, carry it with both hands, and avoid holding it by the valve or regulator. When transporting an oxygen cylinder in a car, secure and block the cylinder so it does not roll.

Oxygen Cylinder Filling

In many areas, medical-grade oxygen is considered a prescription drug, and that can make it difficult to refill your emergency oxygen cylinder. The most common method of documenting the need for oxygen is a prescription; however, prescriptions are for diagnosed medical conditions. The prescription allows for use only by the individual who was given the prescription.

The other method of obtaining an oxygen cylinder fill is by providing documentation of training in the use of emergency oxygen. Like your scuba diving certification card, your DAN Oxygen Provider card is your documentation of appropriate training. Since retraining is required every two years, you will need to maintain your skills by taking an oxygen refresher program. Ask your DAN Instructor about retraining opportunities.

Some countries, states and local governments have regulations that require that oxygen supply companies document all medical-grade oxygen distillation, cylinder transfills and sales. These governmental agencies routinely inspect the facility's operations and documentation to verify compliance with these regulations. Other areas have few or no regulations regarding the distribution of oxygen.

If you have any questions regarding oxygen refills or if you have difficulty obtaining an oxygen cylinder fill, contact the International DAN office in your region for assistance.

Chapter 6 Review Questions

1. Oxygen is one element of the fire triangle.

a. True b. False

2. The risks of handling oxygen can be reduced by

a. Keeping the oxygen units free of hydrocarbons found in oils and lubricants often found on dive boats
b. Opening the oxygen cylinder slowly
c. Keeping the unit away from the heat of the sun
d. All of the above.

3. Safety precautions to implement when using oxygen cylinders include (mark all that apply):

a. do not allow any oil or grease to come in contact with oxygen cylinder
b. do not expose oxygen cylinders to high temperatures or allow smoking/ open flames around oxygen
c. provide adequate ventilation when using oxygen
d. only use equipment made for use with oxygen.
e. always secure the oxygen cylinder so it cannot fall or roll.

4. With what grade of oxygen should an oxygen cylinder for diving first aid be filled?

a. Aviator grade
b. Medical grade
c. Industrial grade
d. Either a or b

5. Methods for obtaining oxygen fills may include:

a. Prescription
b. Documentation of training in oxygen delivery
c. Both a and b

Review answers are on Page 72.

Oxygen Delivery Systems and Components

7

Chapter 7 Objectives

1. What are the components of an oxygen delivery system?
2. What two factors influence what cylinder is appropriate?
3. When should the oxygen provider switch to a full cylinder?
4. Which oxygen regulator is preferred for diving first aid?
5. Why is a demand valve the first choice for delivering oxygen to an injured diver?
6. What are the advantages and disadvantages of the following?
   a) Manually triggered ventilator
   b) Bag valve mask

Oxygen Delivery Systems

The oxygen delivery system consists of an oxygen cylinder, a pressure-reducing regulator, a hose and a face mask. There are many oxygen equipment options. Note the following specific guidelines for the use of oxygen equipment for scuba diving injuries.

Oxygen cylinders. Enough oxygen should be available to allow for continuous delivery to an injured diver from the time of injury at the farthest possible dive site to the next level of emergency response. The duration of common portable oxygen cylinders varies based on the size of the oxygen cylinder, the oxygen flow rate and the type of delivery device. However, it is common for a single portable oxygen cylinder to last from 15 minutes to 60 minutes. Nonportable oxygen cylinders can last up to eight hours or more.

Oxygen regulators. Oxygen delivery occurs via three common types of regulators. One type is a constant-flow style, which can deliver a fixed or adjustable flow of oxygen. Another is the demand regulator; it functions like a scuba regulator and delivers oxygen when the demand valve is activated. The third style is the multifunction regulator, which combines the features of both the demand and constant-flow regulators.

A multifunction regulator is preferred over the other styles because it will allow a rescuer to provide as close to 100 percent oxygen as possible to two injured divers simultaneously and permits various mask options. All DAN Oxygen Units come equipped with multifunction regulators.

Hoses and tubing. Certain types of constant-flow masks provide oxygen-safe, clear plastic tubing to connect the mask to the regulator. Since an oxygen demand valve requires approximately 50 psi (3.5 bar), an intermediate pressure hose attaches to the threaded outlets on both the regulator and valve.

Oxygen masks. An oxygen mask held to the face permits the inhalation of higher concentrations of oxygen. Using a demand valve with an oronasal mask can deliver optimal oxygen concentrations while also preserving supplies for as long as possible.

Common constant-flow masks provide from 35 to 75 percent oxygen. For diving injuries, it is recommended that oxygen be delivered by a demand valve and oronasal mask to provide as close to 100 percent inspired oxygen as possible.

Oxygen System Components

Common oxygen cylinders. Portable oxygen cylinders come in a variety of sizes. As a DAN Oxygen Provider, you are primarily concerned with capacity. Remember, you should have enough oxygen available to transport an injured diver to the nearest appropriate medical facility.

If you conduct shore diving where there is an emergency medical service (EMS) in place, you may need only a 15-minute supply. When you dive off a boat close to shore, you may need a one- or two-hour supply. If you dive far offshore and assistance is hours away, you may want to consider carrying a nonportable oxygen cylinder or multiple portable oxygen cylinders.

Consult your DAN Instructor about which cylinder size is most appropriate for your use. The duration of a cylinder's oxygen content depends on the consumption of gas. An oxygen cylinder should be changed to a full one when the pressure drops below 200 psi (14 bar). However, if only one cylinder is available, it should be used until the oxygen supply is depleted. When using a constant-flow oxygen regulator, it is easy to estimate how long a cylinder will last.

To approximate how long an oxygen cylinder will last with a constant-flow regulator, use this easy formula:

Capacity in liters ÷
flow in liters per minute =
approximate delivery time

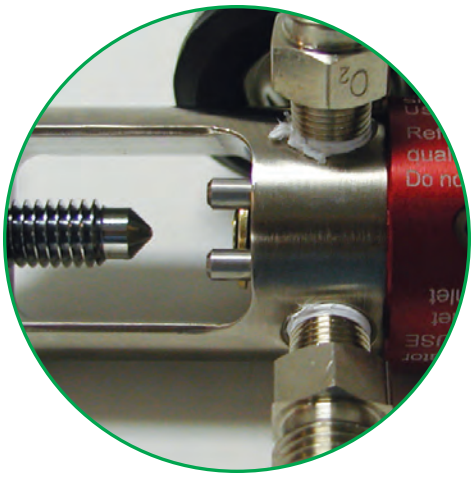
For example, if a cylinder holds 640 liters and the oxygen flow rate is 15 liters per minute, the cylinder will last approximately 43 minutes. At 10 liters per minute, the same cylinder will last 64 minutes.

When a diver uses a demand inhalator valve, it is more difficult to determine an exact time of supply. The rate at which the oxygen is used will depend on the injured diver's breathing rate and volume. Generally, the average oxygen use on a demand valve is equivalent to 8 to 10 liters per minute. Demand-style is preferred because no oxygen is wasted, and usually the oxygen supply lasts longer.

Cylinders are made of either aluminum or steel and are subject to periodic visual and hydrostatic testing. Testing times are generally established by law or regulations, and requirements vary. Common hydrostatic testing intervals range from two to 10 years. In the United States, the hydrostatic testing requirement is five years.

For easy identification and to minimize the risk of using cylinder contents for an unintended purpose, oxygen cylinders are color coded. Common oxygen cylinder color combinations include green (United States), black with a white shoulder (Australia, New Zealand, United Kingdom and others) and white (Canada and Europe). Ask your DAN Instructor for the color-coding requirements of your region. Oxygen cylinders also should be clearly labeled.

Pressure regulators. The pressure regulator reduces the cylinder pressure to a safe working pressure compatible with a demand valve or constant-flow equipment. All regulators must attach to the oxygen cylinder. Various methods of attachment are available.



In some areas, pins engage matching holes on the cylinder valve. This pin-indexed valve is called a CGA 870 medical oxygen valve.

These pins are aligned to prevent an oxygen regulator from being used on a cylinder that may contain another gas. This system is important in locations where there are various gases in use, and each requires its own regulator and cylinder. Pin placement is specific for each gas.

In other areas, oxygen cylinders may have threaded gas-outlet valves (CGA 540 medical oxygen valve and bull-nose valve that will accept regulators intended only for medical oxygen use.

Ask your DAN Instructor which connection systems are used in your region for oxygen cylinders and regulators.

Adapters. In some regions, oxygen-compatible adapters accommodate various regulators with other oxygen cylinders. These adapters provide flexibility when one travels to other areas where different cylinders and valves are used. Adapters also let you use regulators designed for portable oxygen cylinders with nonportable large ones.

Oxygen system adapters are available commercially. To minimize the risk of fire and explosion, they should be oxygen cleaned. Avoid homemade adapters and the use of scuba regulators with high oxygen concentrations.

Flow meter. The flow meter, an integral part of the pressure regulator, indicates the oxygen flow rate delivered through the barbed outlet to the constant-flow device (nonrebreather mask or oronasal resuscitation mask with supplemental oxygen inlet).

Oxygen flow is measured in liters per minute (lpm). The control valve regulates the flow rate on the regulator, with the flow-rate indicator window located on the front.

The DAN multifunction regulator is designed to deliver up to 25 lpm. DAN recommends an initial flow rate of 10 lpm when used with either a nonrebreather mask or oronasal resuscitation mask. The goal of such systems is to deliver the highest concentration of oxygen possible to the injured diver.

7

Oxygen Delivery Devices

DAN demand inhalator valve. DAN Oxygen Units contain a demand inhalator valve (similar to a scuba regulator second stage). When an injured diver begins breathing through the mask and a proper seal between the mask and the injured diver's face is maintained, the injured diver will receive as high a concentration of oxygen as possible.

With the demand inhalator valve, oxygen flows only when the injured diver inhales, and the available oxygen supply will often last much longer than with a constant-flow system. You may use either an oronasal mask or an oronasal resuscitation mask to fit the demand valve to the injured diver's face.

www.dan.org/training/eo2_oxygendelivery

Nonrebreather mask. The nonrebreather mask, which may be used to assist a breathing injured diver, allows an injured diver to inhale oxygen from the reservoir bag positioned below the oronasal mask. The nonrebreather mask consists of a mask with three nonreturn valves — one on either side of the mask and one separating the mask from the reservoir bag. Oxygen tubing, located on the side of the mask where the reservoir bag is attached, connects the mask to the regulator.

During inhalation, oxygen flows through the mask from the reservoir bag into the injured diver's lungs. The nonreturn valves on the sides of the mask prevent air from being inhaled, which would dilute the oxygen.

During exhalation, the one-way valve prevents exhaled air from flowing back into the bag, but it is released to the outside by the one-way valves on the sides of the mask. Additionally, during exhalation, the reservoir bag refills with pure oxygen.

The nonrebreather mask is an effective way to deliver a high concentration of inspired oxygen using the constant-flow feature of the regulator. However, this mask requires a large supply of oxygen because of the constant flow. Unless the mask completely seals around the face, air will leak past the mask and valves and dilute the oxygen. Thus, this method of oxygen delivery is the second choice, after the demand valve, for a breathing injured diver.

A nonrebreather mask is recommended for the breathing, injured diver who does not tolerate the demand inhalator valve or when multiple diving injuries require oxygen.

With a good fit and proper technique, the nonrebreather mask may deliver inspired oxygen concentrations up to 80 percent.

Caution: If the oxygen supply to the nonrebreather mask is interrupted and the injured diver has a good seal, the injured diver faces some risk of suffocating. Therefore, one should never leave an injured diver unattended and should always monitor breathing while providing emergency oxygen first aid using a nonrebreather mask. Remove any mask before turning off the gas supply.

Several other oxygen delivery devices, such as the partial rebreather mask, the simple face mask and the nasal cannula, are available. Since these devices do not deliver sufficient percentages of oxygen or require additional training, they are not discussed in this course.

Bag valve mask (BVM). The BVM is a self-inflating bag that aids rescuers in providing ventilations to a non-breathing or inadequately breathing injured diver. It is connected to a mask by means of a mechanism with several one-way valves. When the bag is compressed, air or oxygen is directed through the mask into the injured diver's lungs.

The BVM can also be connected to an advanced airway device such as an endotracheal tube used by EMS personnel.

These devices are intended for ventilating nonbreathing or inadequately breathing injured divers in situations where physical contact is not desired. BVMs are also a good choice when two rescuers are available as it is less fatiguing than providing rescue breaths. Since BVMs ventilate with air, they provide oxygen at concentrations of 21 percent, compared with the 16-17 percent delivered through rescue breathing. BVMs can provide much higher oxygen

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concentrations if connected to an oxygen cylinder. The concentrations of oxygen are substantially reduced when the mask seal is poor. The bag and the mask are available in sizes suitable for adults, children and infants. Most adult self-inflating bags have a volume of 1600 mL. A system for an adult should never be used on a child since the bag can overexpand a child's lungs. In addition to having a smaller bag, some systems for children include a system for preventing lung overexpansion.

Note: When providing emergency oxygen with a BVM, it is recommended that a tidal volume of 400-600 mL be given for 1 second until the chest rises. These smaller tidal volumes are effective for maintaining adequate arterial oxygen saturation, provided that supplemental oxygen is delivered to the device. These volumes will reduce the risk of gastric inflation.

Current BVMs incorporate a connection for oxygen and a reserve bag (or tube), which is usually connected to the base of the resuscitation bag. Oxygen passes into both of them every time the reservoir is compressed.

To ventilate a nonbreathing or inadequately breathing injured diver, rescuers should ensure that the airway is open and clear while ensuring a good mask seal. Many studies have clearly shown that the technique applied by a single rescuer in general produces very poor ventilations, even though the rescuers may be well trained and conduct it perfectly. Therefore, it is recommended that the bag-valve unit be used by a minimum of two trained rescuers to guarantee the optimal ventilation. One manages the airway and keeps the mask sealed well, and the other compresses the bag.

Note: Achieving a good seal while lifting the jaw with one hand and using the other to compress the bag is difficult as a single rescuer. The injured diver's mouth sometimes stays partially closed beneath the mask, requiring a high flow of gas to counterbalance nasal obstruction. Leaks are difficult to prevent. The problem of potential leaks can be minimized by regular practice and a good knowledge of the various techniques, such as using the knees to keep the head tilted.

On the other hand, if a good seal is obtained on the injured diver's face, the BVM can produce enough pressure to expand the stomach and/or damage the lungs. Hence the earlier recommendation to limit tidal volume to 400-600 ml.

Newer versions of the bag valve mask have a stop valve to help prevent overinflation. It restricts air flow from the bag to the injured diver if resistance, such as may be encountered if the lungs are overfilled, is met during ventilations. The stop valve may also be activated if too much pressure is being used to operate the system. Either way, the stop valve then prohibits further air volume from being administered.

Despite the potential problems, the BVM can be very effective if used by properly trained rescuers.

Description and Function of a Typical BVM Device

Even though different models of the BVM have differing design details or characteristics, the operating principles are the same. You should become familiar with the model you use.

Ventilation bag. This bag is designed to reinflate after it is compressed. It refills with air or oxygen through a suction valve at the end of the bag. The suction valve also functions as a nonreturn valve, preventing the gas from escaping from the bottom of the bag and preventing strain around the neck of the bag.

Ventilation bag

Tolerance valve. Depending on the manufacturer, this assembly contains two one-way valves. The first is the "lip valve," which opens when the gas exits from the ventilation bag and closes when the gas goes in the opposite direction. This allows the gas contained in the ventilation bag to be directed toward the injured diver and prevents the expired gas from reentering the bag. The expired gas is directed from the assembly through a separate membrane or through the lip valve, which rises to allow the gas to be dispersed. This membrane also prevents the air from returning to the injured diver.

Oxygen reserve bag. The majority of BVM devices have a reserve bag of some type. The reserve bag is designed to collect the oxygen during the expiration cycle so that it is available for the inspiration cycle.

Oxygen reserve bag

The BVM should include a system for preventing excess pressure in the system and/or in the reserve bag caused by the introduction of unused gas. Some systems have slits in the reserve bag that open under pressure and allow excess gas to escape. Other devices use an outlet valve or a membrane.

In addition, the BVM requires an inlet that allows a certain amount of air to reenter when the reserve bag is used if there is insufficient gas to allow the ventilation bag to refill.

Manually Triggered Ventilators

The manually triggered ventilator, also known as a flow-restricted oxygen-powered resuscitator, is a dual function regulator. It allows the rescuer to provide emergency oxygen to a nonbreathing or inadequately breathing injured diver with optimal oxygen levels. The user can start or stop the oxygen flow immediately by activating a button similar to the purge button of a scuba regulator.

It can also function as a demand valve that can deliver maximum oxygen concentrations to the breathing diver and minimizes the gas waste.

Note:

Lower tidal volumes are recommended with manually triggered ventilators. These smaller tidal volumes are effective for maintaining adequate arterial oxygen saturation and will reduce the risk of gastric inflation. Ventilations are given over 1 second until the chest rises. Two rescuers are recommended when using the manually triggered ventilator. One rescuer should maintain the airway and mask seal, while the second rescuer activates the ventilator.

Manually triggered ventilators offer several advantages. They deliver higher concentrations of oxygen than rescue breathing with supplemental oxygen and are less tiring for the rescuers delivering care. The high concentration of oxygen available compensates for any loss that arises as a result of a poor mask seal.

Manually triggered ventilators can deliver a flow greater than 40 lpm to a breathing injured diver, an amount that is significantly more than what is required to satisfy the breathing requirements of an individual.

The MTV-100, one model of manually triggered ventilators, automatically reduces the flow rate to 40 lpm, thereby reducing the risk of introducing gas into the stomach and subsequent regurgitation. This corresponds with current American Heart Association recommendations that a lower flow rate be used to reduce complications. To correct some of the problems that could occur using the first oxygen-powered ventilators, the MTV-100 is designed to terminate either the flow or the pressure if excessive pressure is detected in the airways. In addition, a redundant valve was added for use in the event that the first one failed.

Some older versions of oxygen-powered ventilators exceeded 160 lpm in delivered oxygen. Previously it was thought that this amount was necessary to ventilate an injured diver. However, such a high flow rate can very easily cause expansion of the stomach, which can lead to regurgitation and the aspiration of the contents of the stomach. Moreover, a high flow rate can potentially damage the lungs.

Some other units terminate the flow but do not allow the pressure to be released, which could impede the injured diver's exhalation. When used on an adult, the safety valve should prevent pulmonary injuries but might not prevent distension of the stomach (which normally occurs when the esophagus pressure is greater than 15-20 cm H2O). To prevent the outward pressure from exceeding the expected limits, the MTV-100 has a safety valve. The oxygen flow terminates when this valve detects mounting pressure of greater than approximately 60 cm H2O.

Some devices can stop providing gas prematurely without alerting the operator. This can happen when the lungs of the injured diver present resistance or when there is a poor response from the lungs, as can happen when ventilating an individual with asthma or an injured diver who has experienced a submersion incident. The MTV-100 has an acoustic alarm that alerts the operator of excessive levels of pressure in the airways. If the device does not signal an acoustic alarm, the operator may not become aware of the resistance during resuscitation, and therefore an obstruction in the airway or an overexpansion of the lungs may not be detected.

As with all oxygen-assisted ventilation techniques, when the oxygen supply is exhausted, these units can no longer be used.

www.dan.org/training/eo2_mtv

DAN Oxygen Units

DAN Oxygen Units were specially designed with divers in mind. Each unit is capable of delivering high concentrations of inspired oxygen to injured divers.

Rescue Pak. The Rescue Pak is an affordable and compact oxygen system, ideal for areas where emergency medical services exist nearby or the distance to the nearest medical facility is short. It includes the following:

- Brass multifunction regulator
- Demand valve with hose
- M9 oxygen cylinder (248 liters)
- Nonrebreather mask with 6-foot tubing
- Oronasal resuscitation mask
- Tru-Fit silicone mask
- DAN *Dive and Travel Medical Guide*
- Pelican® 1450 waterproof case
- Optional MTV-100 with hose

Rescue Pak Extended Care. The Rescue Pak Extended Care, a popular choice among divers, is a self-contained kit that has all the necessary equipment to provide first aid for both breathing and nonbreathing injured divers. It includes the following:

- Brass multifunction regulator
- Demand valve with hose
- Jumbo-D oxygen cylinder (636 liters)
- Nonrebreather mask with 6-foot tubing
- Oronasal resuscitation mask
- Tru-Fit silicone mask
- DAN *Dive and Travel Medical Guide*
- Pelican® 1600 waterproof case
- Optional MTV-100 with hose

Dual Rescue Pak Extended Care. DAN's dual-cylinder unit is ideal for offshore diving or for divers who desire a greater oxygen supply. It includes the following:

- Brass multifunction regulator
- Demand valve with hose
- Two Jumbo-D oxygen cylinders (636 liters each)
- Nonrebreather mask with 6-foot tubing
- Oronasal resuscitation mask
- Tru-Fit silicone mask
- DAN *Dive and Travel Medical Guide*
- Pelican® 1600 waterproof case
- Optional MTV-100 with hose

Soft-Sided Oxygen Unit. The DAN Soft-Sided Oxygen Unit provides the same components as the Rescue Pak Extended Care in a compact, water-resistant nylon case designed exclusively for the unit.

Charter Boat Oxygen Unit. DAN's Charter Boat Oxygen Unit allows the use of larger oxygen cylinders, which provide for extended oxygen treatment if required. It includes the following:

- Brass multifunction regulator with CGA-540 connector
- Demand valve with hose
- Oronasal resuscitation mask
- Nonrebreather mask with tubing
- Wrench for CGA-540 connector
- DAN *Dive and Travel Medical Guide*
- Pelican® 1400 waterproof case

First Aid Backpack with Oxygen Option. Not only is this backpack fully stocked with first aid supplies, it also includes an adjustable padded pouch with Velcro backing, designed to fit a standard M9 oxygen cylinder. This is a portable, durable and practical unit with reflective strips and D-rings featured on the shoulder straps, and the waterproof cover is stored in the bottom compartment of the backpack. It includes the following items:

- Brass multifunction regulator
- M9 cylinder (248 liters)
- Demand valve with hose
- Oronasal resuscitation mask
- Nonrebreather mask with 6-foot tubing
- Tru-Fit silicone mask
- DAN *Dive and Travel Medical Guide*
- Dive safety slates
- Nitrile gloves
- Medications/Tools Pack
- Stop Bleeding/Shock Pack
- Wounds (Cuts) Care Pack
- Fractures/Sprain/Strain Pack

Chapter 7 Review Questions

1. Oxygen delivery systems are comprised of which of the following? (Mark all that apply.)

a. Oxygen cylinder
b. Pressure-reducing regulator
c. Oxygen hose
d. Face mask

2. Name two considerations when choosing an oxygen cylinder.

_____
_____

3. A multifunction regulator is preferred in emergency oxygen for scuba diving injuries because it can provide emergency oxygen to two injured divers at the same time.

a. True b. False

4. An oxygen cylinder should be switched during care when the pressure drops below 200 psi if another cylinder is available or, if there is not another cylinder available, use the cylinder until it is empty

a. True b. False

5. Oxygen cylinders are subject to periodic visual and hydrostatic testing.

a. True b. False

6. Oxygen cylinders are color-coded for easy identification. Match the color markings with the region where they are used. (Colors may be used more than once.)

a. Green	___Australia
b. Black with white shoulder	___Europe
c. White	___Canada
	___United States
	___New Zealand
	___United Kingdom

7. Oxygen regulators are fitted with a pin indexing system to prevent use on other cylinder valves that may not contain oxygen.

a. True b. False

8. A demand valve flows only when the injured diver inhales, allowing the oxygen to last longer

a. True b. False

9. A bag valve mask

a. Is a self-inflating bag with a mask that aids in rescue breathing
b. Has a manual trigger that initiates oxygen flow
c. Is best used by two rescuers working together
d. a and c

10. Manually triggered ventilators

a. Allow rescuers to deliver high concentrations of oxygen to non-breathing or inadequately breathing divers
b. Can also function as a demand valve
c. Is best used by two rescuers
d. All of the above

11. Match the following:

non-rebreather mask _____
multifunction regulator _____
oronasal resuscitation mask with inlet oxygen _____
demand inhalator valve _____
bag valve mask _____
MTV _____

a. Will deliver 100 percent oxygen
b. Provides both a demand valve and a manual ventilation options
c. Will provide the highest concentration of oxygen to more than one injured diver
d. Constant-flow mask that is recommended for performing rescue breathing as part of CPR
e. Constant-flow mask that is recommended when treating more than one breathing injured diver
f. Manual ventilation mask with reservoir

Review answers are on Page 72.

8 Oxygen Provider Skills Development

Chapter 8 Objectives

For the skills included in this course, the oxygen provider will be able to:

1. Oxygen equipment identification, disassembly and assembly
   - Identify the component parts of the DAN Oxygen Unit
   - Disassemble and reassemble with minimal assistance the DAN Oxygen Unit or equivalent
2. S-A-F-E
   - List the steps in performing a scene safety assessment
   - Perform a scene safety assessment in a scenario
   - Use appropriate first aid barrier devices in a scenario
   - Demonstrate a caring attitude toward a simulated diver who has become ill or injured
3. Initial assessment with basic life support (review only)
   - Establish responsiveness of a simulated injured/ill diver
   - Demonstrate current sequence of providing care with proper ventilations and compression rates
4. Demand inhalator valve
   - Provide emergency oxygen to a responsive breathing injured diver using the demand inhalator valve and oronasal mask
5. Nonrebreather mask
   - Provide emergency oxygen to an unresponsive breathing injured diver using the nonrebreather mask

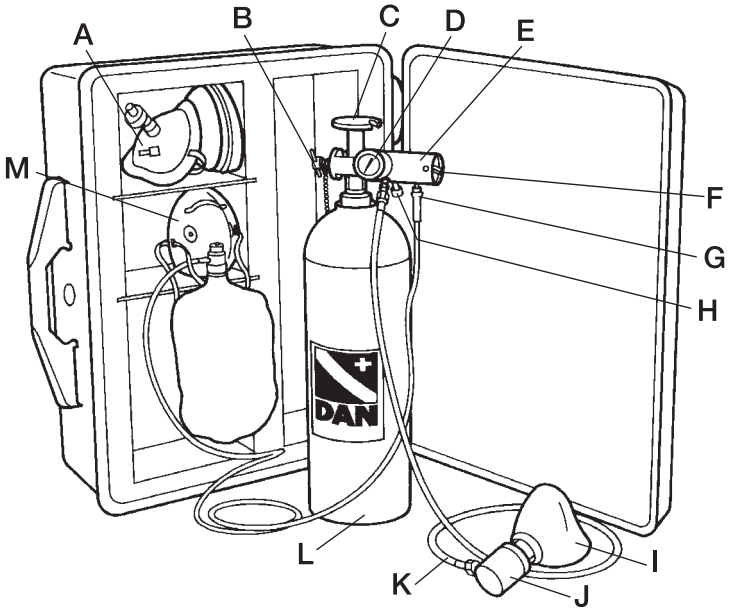
- Discern when options for oxygen delivery are not working adequately, and switch to another as appropriate

6. Bag valve mask
   - Provide emergency oxygen to a nonbreathing or inadequately breathing injured diver using the bag valve mask
7. MTV
   - Provide emergency oxygen to a nonbreathing or inadequately breathing injured diver using an MTV and oronasal mask
8. Emergency assistance plan
   - List the components of an emergency assistance plan
     - Develop an emergency assistance plan for the local diving area

Being able to provide emergency oxygen to an injured diver is more than just knowing what to do, it is being able to do it. The following skills are essential elements to oxygen delivery. Your DAN Instructor will guide you through this skill development section.

Oxygen Equipment Identification

DAN Oxygen Unit components:



A. Oronasal resuscitation mask with oxygen inlet
B. T-handle
C. Handwheel wrench
D. Pressure gauge
E. Multifunction regulator
F. Constant-flow controller
G. Barbed constant-flow outlet
H. DISS threaded outlet
I. True-fit® mask
J. Demand inhalator valve
K. Intermediate pressure hose
L. Oxygen cylinder and valve
M. Nonrebreather mask

Oxygen Equipment Assembly and Disassembly

Objectives:

- *Identify the component parts of the DAN Oxygen Unit.*
- *Disassemble and reassemble with minimal assistance the DAN Oxygen Unit or equivalent.*

Follow these simple steps to assemble and disassemble the DAN Oxygen Unit.

- Ensure oxygen unit is depressurized.
- Open constant-flow control.
- Check pressure gauge.
- Remove multifunction regulator from the oxygen cylinder valve.
- Secure oxygen cylinder.
- Remove oxygen washer from multifunction regulator.
  — *Note: Washer is different from standard scuba O-ring.*
- Remove oxygen hose from multifunction regulator.
- If the fitting is too tight, use handwheel/wrench to unscrew the hose.
  — *Note: Check valves; ensure oxygen does not flow from threaded ports.*
- Remove oxygen hose from demand inhalator valve.
  — *Note: Both ends of the oxygen hose are identical.*
- Unscrew the plastic mask adapter from the demand inhalator valve.
- Remove inhalation/exhalation assembly.
- To assemble, repeat steps in reverse.

Scene Safety Assessment

Objectives:

- *List the steps in performing a scene safety assessment.*
- *Perform a scene safety assessment in a scenario.*
- *Use appropriate first aid barrier devices in a scenario.*
- *Demonstrate a caring attitude toward a simulated diver who has become ill or injured.*

Follow these simple steps to perform a scene safety assessment.

Remember S-A-F-E.

S — Stop.

- Stop.
- Think.
- Act.

A — Assess scene.

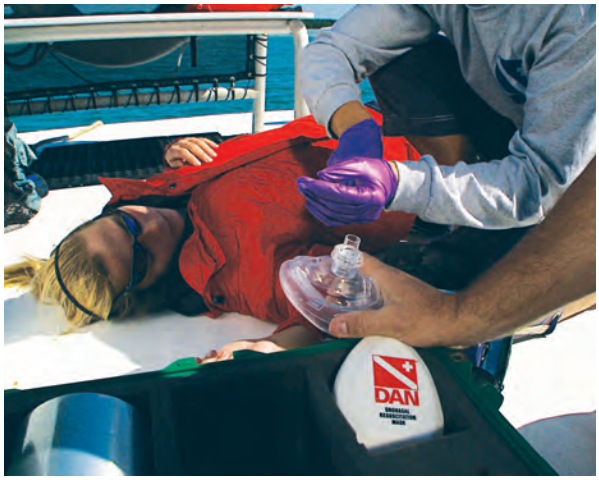
- Is the scene safe?
- Is it safe to approach the injured diver?
- Is the ventilation adequate for oxygen?
- Any other hazards present?

F — Find and secure oxygen, first aid kit and AED unit.

- First aid kits contain critical supplies such as barriers.

E — Ensure exposure protection.

- Use barriers such as gloves and mouth-to-mask barrier devices.



Initial Assessment with Basic Life Support

Objectives:

- *Establish responsiveness of a simulated injured/ill diver*
- *Demonstrate current sequence of providing care with proper ventilations and compression rates*

Follow these simple steps to assess responsiveness and provide basic life support.

Remember S-A-F-E.

Assess responsiveness.

- State your name, training and desire to help.
- Ask permission to help.
- If unresponsive,
  - — Tap on the shoulder.
  - — Shout, "Are you OK?"
  - — If no response, call for help and activate emergency medical services (EMS).

Assess breathing.

- While you assess responsiveness, determine if the diver is breathing normally. If he is unresponsive and not breathing normally, initiate CPR, beginning with 30 compressions.

If the diver is breathing normally and you suspect a diving emergency, initiate oxygen first aid, and put your emergency action plan into motion.

- CPR is not generally taught as part of this course, although your instructor may offer it as an additional module. If an AED unit is available, deploy it. Discuss other training opportunities with your DAN Instructor.

Demand Inhalator Valve

Objective:

- ***Provide emergency oxygen to a responsive breathing injured diver using the demand inhalator valve and oronasal mask***

8

Follow these simple steps to provide emergency oxygen to a responsive or unresponsive breathing injured diver with the demand inhalator valve. This is the preferred method of providing emergency oxygen to any breathing injured diver.

Remember S-A-F-E.

Deploy the oxygen unit.

- Open cylinder valve with one complete turn.
- Check cylinder pressure.
- Ensure that there are no leaks in the system.
- Constant-flow setting should be in "off" position.
- Take a breath from the demand inhalator valve and exhale away from it.
- Inform the injured diver that oxygen may help. State: "This is oxygen, and it may make you feel better. May I help you?"

  — If the diver is unresponsive, permission to help is assumed.

Place the mask over the injured diver's mouth and nose.

- Check the mask for any leaks around the injured diver's face.

Instruct the injured diver to breathe normally from the mask.

- Reassure and comfort the injured diver.

Instruct the injured diver to hold the mask to help maintain a tight seal.

Monitor the injured diver and the oxygen pressure gauge.

- Listen for the demand inhalator valve to open during inspiration.
- Observe mask fogging during exhalation and clearing with inhalation.
- Watch the chest rise during inhalation and fall with exhalation.

Activate emergency action plan.

- Call EMS or other appropriate medical facility.
- Contact DAN for consultation and coordination of hyperbaric treatment.

8

Nonrebreather Mask

Objectives:

- *Provide emergency oxygen to an unresponsive breathing injured diver using the nonrebreather mask.*
- *Discern when options for oxygen delivery are not working adequately, and switch to another as appropriate.*

Follow these simple steps to provide emergency oxygen to a responsive or unresponsive breathing injured diver with the nonrebreather mask. The nonrebreather mask is ideal when you have two injured divers or an injured diver who will not tolerate the demand inhalator valve.

Remember S-A-F-E.

Ensure airway and breathing.

Deploy the oxygen unit.

- Remove nonrebreather mask from bag.
- Stretch oxygen tubing to avoid kinks.
- Attach oxygen tubing to barbed constant-flow outlet on multifunction regulator.

Set constant-flow control to an initial flow rate of 10-15 liters per minute (lpm).

Prime mask reservoir bag.

- Place a thumb or finger inside the nosepiece, closing the nonreturn valve until the reservoir bag fully inflates.

Inform the injured diver that oxygen may help.

- State: "This is oxygen, and it may make you feel better. May I help you?"
  - — If the diver is unresponsive, permission to help is assumed.

Place the mask over the injured diver's mouth and nose.

- Check the mask for any leaks around the injured diver's face.
- Adjust the elastic band around the head to hold the mask in place.
- Squeeze the metal clip over the nose to improve the seal and prevent oxygen leakage.

Instruct the injured diver to breathe normally.

- Adjust flow rate (increase or decrease) to meet the needs of the injured diver.
  - — Ensure that the reservoir bag does not collapse completely during inhalation (some deflation is normal and expected).
- Reassure and comfort the injured diver.
- Place the injured diver in the proper position.
- If responsive, instruct the injured diver to hold mask to maintain a tight seal.
- Monitor the injured diver and the oxygen pressure system.
- Look for the reservoir bag to slightly inflate and deflate and for movement of the nonreturn valves.
- Observe mask fogging during exhalation and clearing with inhalation.
- Watch the chest rise during inhalation and fall with exhalation.
- Activate the emergency action plan.
- Call EMS and DAN.

Resuscitation with a Bag Valve Mask

Objective:

- *Provide emergency oxygen to a nonbreathing or inadequately breathing injured diver using the bag valve mask*

Follow these steps to resuscitate a nonbreathing or inadequately breathing injured diver using a BVM. Ventilating a nonbreathing or inadequately breathing injured diver using the BVM requires two rescuers.

Remember S-A-F-E.

Rescuer One

The first rescuer begins single-rescuer CPR as soon as possible and continues while the second rescuer prepares the oxygen equipment. When the oxygen equipment is ready, Rescuer One ventilates the injured diver by compressing the bag about one-third of the bag volume.

- Bag compressions should be slow and gentle lasting about one second for the ventilation phase. Allow the chest to fall completely before beginning each new ventilation.
  - — Watch the stomach for signs of distension to prevent regurgitation.
- Each ventilation should last about one second. Deliver two ventilations.
- Delivers chest compressions between ventilations.

Rescuer Two

The second rescuer prepares the oxygen equipment while the first rescuer performs CPR. When the equipment is ready, the second rescuer should do the following:

- connect the BVM tubing to the constant flow barb on the oxygen regulator;
- turn on constant flow to initial setting of 15 lpm and allows the reservoir bag to inflate.
- seal the mask in place using head tilt chin lift method, pulling the diver's jaw up and into the mask
- maintain the airway
- Monitor the oxygen supply.
- Activate your emergency action plan
- Call EMS and DAN

Using an MTV

Objective:

- *Provide emergency oxygen to a nonbreathing or inadequately breathing injured diver using an MTV and oronasal mask.*

Follow these steps to resuscitate a nonbreathing or inadequately breathing injured diver using an MTV. Two rescuers are required for this skill.

8

Remember S-A-F-E.

Rescuer One

The first rescuer begins single-rescuer CPR using an oronasal resuscitation mask as soon as possible and continues while the second rescuer prepares the oxygen equipment.

When the oxygen equipment is ready, Rescuer One ventilates the injured diver by pressing the resuscitation button carefully while observing the chest and releasing the button quickly.

- Watch for the chest and abdomen to rise.
  - o Ventilations should take about 1 second.
- Release the resuscitation button as soon as the chest begins to rise. Deliver two ventilations.
  - o Leaving one hand gently on the center of the chest can help to assess that ventilations are adequate and not excessive.
- Watch for distension of the stomach.
- Delivers chest compressions between ventilations

Rescuer Two

When the equipment is ready, the second rescuer should do the following:

- Test the safety valve to ensure that it functions properly.
- Press the ventilation button then block the oxygen outlet of the MTV with his hand. The oxygen flow should stop and the gas should be released.

NOTE: If the safety shut off does not work, do not use the MTV.

- Connect the oronasal mask to the MTV adapter.
- Position the mask over the mouth and nose of the injured diver.
- seal the mask in place using head tilt chin lift method, pulling the diver's jaw up and into the mask
- Maintain the airway and hold the mask in place, while the first rescuer pushes the ventilation button on the MTV and delivers chest compressions.
- Monitor the supply of oxygen attentively, and be prepared to resume rescue breathing if the supply is exhausted.
- Activate your emergency action plan

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- Call EMS and DAN

Emergency Assistance Plan

Objective:
- *List the components of an Emergency Assistance Plan.*
- *Develop an Emergency Assistance Plan for the local diving area.*

The following information is critical in managing scuba diving injuries and illnesses.

Diver information

Name:_____ Age: _____

DAN Member #_____

Address: _____

_____

Emergency contact phone: _____

Current complaint: _____

_____

Significant past medical history (medications, allergies, previous injuries, etc.):

_____

Dive Profile (including S.S./deco) Depth Time Surface Interval

Dive #1 _____

Dive #2 _____

Dive #3 _____

Dive #4 _____

Dive #5 _____

Exit water time: AM/PM Breathing gas: air/nitrox/mix _____%

Emergency assistance plan

Initial contact information: _____

Emergency medical assistance: _____

Nearest medical facility directions: _____

_____

Phone: _____

Diving medical consultation information:

Divers Alert Network (DAN): +1-919-684-9111*

** This number may be called collect in an emergency.*

Other important information: _____

_____

Phone: _____

9 Recommendations and Reminders for Oxygen Providers

Chapter 9 Objectives

1. When should an oxygen unit's contents and cylinder pressure be checked?
2. How should an oxygen unit be stored?
3. How often should the oxygen regulator be serviced?
4. How often does law require an oxygen cylinder to be tested?
5. When and how should reusable oxygen masks be cleaned?
6. What should be considered when positioning an injured diver?

Oxygen Unit Storage and Maintenance

Before every dive outing, check the oxygen unit's contents and cylinder pressure. Keep the cylinder filled with oxygen at all times.

The emergency oxygen unit should remain in the case, fully assembled and turned off. This allows for rapid deployment. Never store an oxygen system with the valve open and/or the regulator pressurized. The oxygen may be accidentally drained if there is a leak that goes undetected.

Storing the oxygen unit in its protective case also reduces the likelihood of damage to component parts and prevents exposure to the corrosive properties of sea water. Never allow oxygen equipment to come in contact with any grease or oils; they can cause an explosion or fire.

For extended delivery and to assist several injured divers, carry extra cylinders, washers and masks.

Have the oxygen regulator professionally serviced every two years by a trained and authorized service representative or the oxygen equipment manufacturer. Oxygen cylinders require periodic hydrostatic testing. In the United States, this is mandated by law every 5 years.

When turning on an oxygen cylinder valve, always turn it slowly to allow the system to pressurize. This will reduce the possibility of an oxygen fire if combustible contaminants have been introduced into the system. Once the system is pressurized, open the valve at least one full turn.

Clean reusable oxygen masks thoroughly after use. Soak the masks in a mild bleach solution of 1 part bleach and 9 parts water for at least 10 minutes. Rinse with fresh water and allow to air dry thoroughly. Harsh detergents or other chemical cleaning agents may cause deterioration the masks and cause skin irritations when they come in contact with the injured diver's skin. Other cleaning recommendations include the use of chlorhexidine or alcohol.

Recommendations for Oxygen Providers

Basic life support. Learn CPR before you are trained to provide emergency oxygen. Proficiency in CPR is not difficult, but it does require training and practice under the supervision of a qualified instructor. This manual is not intended as a resource in learning CPR.

Maintain your CPR certification so you are prepared in the unlikely event of a dive accident or any life-threatening incident. Recertification is required every two years by most agencies. Your DAN Instructor can assist you with retraining when the time comes. Skills deteriorate with time, so practicing and refreshing your skills are essential to being prepared.

Dive accident positioning. Place the injured diver in the proper position. The diver's responsiveness and breathing status determine the best position for providing basic life support and oxygen.

- **Responsive, breathing injured diver**

  If an injured diver is responsive and fully alert, he may be placed in a position of comfort — seated, supine position (lying flat on the back) or in the recovery position. It is important not to obstruct blood flow by crossing the injured diver's arms or legs. Inert gas elimination is still occurring, and obstructed blood flow to an extremity may interfere with efficient offgassing.

- **Unresponsive, breathing injured diver**

  An injured diver who is unresponsive but breathing should be placed in the recovery position. This minimizes the risk of airway obstruction by the tongue for the injured diver with a reduced level of consciousness.

- **Unresponsive, nonbreathing injured diver**

  When an injured diver is not breathing, place him on his back (supine) so CPR may be initiated. Vomiting in this position is extremely dangerous, and if it occurs, the injured diver should be quickly turned to the side until the airway is cleared so that aspiration (inhaling) of vomitus does not occur. Once the airway is cleared, resuscitation efforts can resume, with the diver in the supine position.

- **Turning the injured diver**

  Care should be taken when turning an injured diver from the supine into the recovery position. Avoid excessive movement, and remember to protect the head, neck and spine.

- **If vomiting or seizures occur**

  If an injured diver vomits, temporarily discontinue oxygen use. After vomiting has ended, evaluate the airway, clear if necessary, and resume providing emergency oxygen at the earliest possible moment.

  If the injured diver has a seizure, the rescuer may have to remove the oxygen. Seizures occurring during surface oxygen administration are usually the result of a hypoxic event to the brain. Resume oxygen delivery as soon as possible after seizure ceases.

- **Fluids**

  Administer fluids orally to the alert and oriented injured diver who has no risk of vomiting. Water is preferred because it is rapidly absorbed by the body, and it presents a lower risk of inducing vomiting. Other noncarbonated, noncaffeinated beverages are acceptable if water is unavailable.

Oxygen Safety Reminders

- Use oxygen only in well-ventilated areas.
- Extinguish all burning materials before using oxygen.
- Never combine oxygen and flammables, such as petroleum products. In the presence of high-pressure oxygen, the combination of these materials may support spontaneous combustion.

Understand Legal Considerations

There are no medical contraindications for providing emergency oxygen to an injured scuba diver. International laws are not well-defined for oxygen use and for filling oxygen cylinders.Understand misconceptions about oxygen and its use; read up-to-date literature, take other courses, and learn from others.

Remember:

- Except to call for assistance with an unresponsive diver, never leave an injured diver alone or unattended while emergency oxygen is being provided.
- Provide injured breathing divers with the highest possible concentration of oxygen by demand inhalator valve or nonrebreather mask. An initial flow rate of 10-15 lpm is suggested when using the nonrebreather mask. Adjust the flow rate to the nonrebreather mask so that the reservoir bag does not completely deflate during inhalations. If the reservoir bag is continually deflated, check the seal of the mask, and adjust the flow rate accordingly, or switch to a demand valve.
- Continue oxygen use until the injured diver has reached a definitive care facility or until the oxygen supply is depleted. Do not reduce oxygen flow to the injured diver to make the supply last. High concentrations of inhaled oxygen, even if delivered over a shorter period of time, will be more beneficial to the injured diver. It creates a higher pressure gradient that results in a more effective washout of nitrogen. Lower concentrations of inspired oxygen may not be as effective, even though the rescuer can deliver oxygen for a longer period of time.

Dive Accident Solution

Throughout this manual you have reviewed several factors that may contribute to the dive accident. Now that you are informed as oxygen first aid providers, you are part of the dive accident solution.

As a prepared diver, you can do this by recognizing the warning signs of scuba diving injuries and illnesses.

Prepare a comprehensive emergency assistance plan with a backup. Facets of the plan include:

- Using communications equipment
- Knowing the location of the nearest medical facility
- Accessing the DAN Emergency Hotline for medical consultation and assistance in locating an appropriate hyperbaric facility
- Assisting in transportation

Activate your plan, and contact the local emergency medical services as soon as possible. Provide as much accident information as you can to medical personnel.

Remember to go to the nearest, most appropriate medical facility and not necessarily to the nearest hyperbaric chamber. This is advised for several reasons.

- Only a small number of hospitals are equipped with hyperbaric chambers.
- Many hospitals with hyperbaric chambers are not equipped to treat diving injuries 24 hours a day. It takes time to assemble a chamber crew for the treatment of a diving injury.
- Before accepting the transfer of an injured diver, many hospitals require a referral from DAN or a physician.
- Some chambers are open only when they have patients.
- Some chambers are not equipped to treat divers.

Hyperbaric chamber status continually changes, and it is nearly impossible for any individual to maintain accurate daily information. This situation may create unnecessary delays if a dive team relies on obsolete information.

DAN and most training agencies consider it unwise for dive instructors to advise students to go directly to the nearest chamber. DAN advises divers to call the DAN Emergency Hotline or the DAN-supported emergency number for your area, day or night, if you suspect a diving injury. Every dive injury is unique, and crucial medical decisions must be made individually by a physician trained in dive medicine. The decision on where to treat an injured diver can be made only after a thorough medical evaluation and appropriate consultation.

Final Thoughts

Upon completion of this course, you may question your ability to perform in a real situation. When someone is injured, anxiety is a natural reaction for both the injured diver and rescuers. Expect to have a pounding heart and breathless feeling if you are suddenly confronted with an emergency of any kind. These feelings generally do not interfere with your ability to use your skills, and your knowledge and training should reduce the level of your anxiety.

There are other concerns, including the fear of making a mistake, harming an injured diver or causing death. Although unlikely, these concerns are real. However, it is more important to make the effort since the person who needs assistance may be in worse shape without your help than with a possibly imperfect effort to provide assistance.

Rescuers may have concerns about liability and the possibility of being sued. However, if you act in good faith, as a reasonably prudent person would do, and perform appropriately within your realm of training and expertise, you have little fear of liability. Although an injured diver may not improve, this is not evidence that you were responsible or that you performed below standards.

Our responsibility as a first aid provider is to treat the injured diver, family and friends with respect during an emotionally difficult situation. You should act in a decisive manner and perform according to your knowledge and skill level. You should also see that the injured diver is referred to medical care or to someone whose ability is equal to or greater than yours. You are not obligated to start a first aid procedure, but once you do you must continue until you are relieved by someone with equal or greater skill and/or qualifications.

Chapter 9 Review Questions

1. The emergency oxygen unit contents and cylinder pressure should be checked before every dive.

a. True b. False

2. The emergency oxygen unit should be stored

a. In its protective case
b. Fully assembled
c. Turned off
d. Away from grease and oils
e. All of the above

3. Oxygen regulators should be serviced

a. Annually
b. Every two years
c. Every five years
d. Every 10 years

4. Oxygen cylinders should be hydrostatically tested

a. Annually
b. Every two years
c. Every five years
d. Every 10 years

5. Oxygen masks should be cleaned after every use.

a. True b. False

6. The positioning of an injured diver receiving emergency care is based on

a. Level of consciousness
b. Breathing status
c. Both a and b.

7. Never leave an injured diver alone except to call for emergency assistance if no one else is available.

a. True b. False

8. Injured divers should be taken to the nearest, most appropriate medical facility for evaluation rather than directly to a hyperbaric chamber.

a. True b. False

9. In the event of a dive accident, as a first aid provider your responsibility is to

a. Treat the injured diver, family and friends with respect
b. Act in a decisive manner
c. Perform according to your knowledge and skill level
d. See that the diver is referred to medical care
e. All of the above

Review answers are on Page 72.

Glossary

alveoli — microscopic air sacs in the lungs where gas exchange occurs with the circulatory system

anoxia — absence of oxygen in the circulating blood or in the tissues

aorta — the largest vessel of the systemic arterial system, from which the main arteries carrying oxygenated blood branch out and subdivide into smaller and smaller vessels

arterial gas embolism (AGE) — gas bubbles in the arterial system generally caused by air passing through the walls of the alveoli into the bloodstream

arteriole — small artery

atelectasis — the collapse of all or part of a lung

atrium — chamber of the heart that provides access to another chamber called the ventricle

bronchi — plural of bronchus, which is a division of the trachea

bronchiole — small branch of the bronchus that carries air to and from the alveoli

bronchospasm — bronchoconstriction, or the sudden narrowing of the smaller airways, of a spasmodic nature

capillary — microscopic blood vessels where the gas exchange takes place between the bloodstream and the tissues or the air in the lungs

carbon dioxide — a waste gas produced by the metabolism of oxygen in the body

carbon monoxide — a highly poisonous, odorless, tasteless and colorless gas formed when carbon material burns with restricted access to oxygen. It is toxic by inhalation since it competes with oxygen in binding with the hemoglobin, thereby resulting in diminished availability of oxygen in tissues.

cartilaginous — pertaining to or composed of cartilage

cilia — long, slender microscopic hairs extending from cells and capable of rhythmic motion

CPR — cardiopulmonary resuscitation

decompression illness (DCI) — dysbaric injuries related to scuba diving; DCI includes both decompression sickness (DCS) and arterial gas embolism (AGE).

decompression sickness (DCS) — a syndrome caused by bubbles of inert gas forming in the tissues and bloodstream that can evolve from too rapid an ascent from compressed-gas diving

dehydration — an abnormal depletion of water and other body fluids

Diameter Index Safety System (DISS) — intermediate pressure port where a hose attaches, leading to demand valve or other apparatus

EMS — emergency medical services

epiglottis — thin structure behind the tongue that shields the entrance of the larynx during swallowing, preventing the aspiration of debris into the trachea and lungs

erythropoietin — a hormone that is synthesized mainly in the kidneys and stimulates red blood cell formation

esophagus — portion of the digestive tract that lies between the back of the throat and stomach

fossa ovalis — oval depression in the wall of the heart remaining when the foramen ovale closes at birth (See patent foramen ovale.)

gradient — the difference in pressure, oxygen tension or other variable as a function of distance, time or other continuously changing influence

hypoxemia — inadequate oxygen content in the arterial blood

hypoxia — inadequate oxygen content

incontinence — absence of voluntary control of an excretory function, especially defecation or urination

inert — having little or no tendency to react chemically

intercostal muscles — the muscles between the ribs that contract during inspiration to increase the volume of the chest cavity

ischemia — inadequate blood flow to a part or organ

larynx — the organ of voice production, also known as the voice box; the opening from the back of the throat into the trachea (windpipe)

lpm — liters per minute; a measurement of a flow rate of gas or liquid

mediastinum — the space within the chest located between the lungs, containing the heart, major blood vessels, trachea and esophagus

metabolism — the conversion of food into energy and waste products

nystagmus — spontaneous, rapid, rhythmic movement of the eyes occurring on fixation or on ocular movement

oblique — an indirect or evasive angle

occlude — to close off or stop up; obstruct

oxygen — a colorless, odorless, tasteless gas essential to life, making up approximately 21 percent of air

patent foramen ovale — a hole in the septum (wall) between the right and left atria of the heart

pericardium — a double-layered membranous sac surrounding the heart and major blood vessels connected to it

pharynx — portion of the airway at the back of the throat, connecting mouth, nasal cavity and larynx

platelet — a round or oval disk found in the blood of vertebrate animals that is involved with blood clotting

pleura — membranes surrounding the outer surface of the lungs and the inner surface of the chest wall and the diaphragm

prescription — a written order for dispensing drugs signed by a physician

primary assessment — assessment of the airway, breathing and circulation (pulse) in an ill or injured person; also known as the ABCs

psi — pounds per square inch; a measurement of pressure

respiratory arrest — cessation of breathing

sign — any medical or trauma condition that can be observed

supine — lying face up

surfactant — a substance produced in the lungs to reduce surface tension in alveoli and small airways

symptom — any nonobservable condition described by the patient

thorax — the upper part of the trunk (main part of the body) between the neck and the abdomen that contains the heart, lungs, trachea and bronchi

trachea — the air passage that begins at the larynx and ends as the beginning of the principal right and left bronchi

Valsalva maneuver — the forced inflation of the middle ear by exhaling with the mouth closed and the nostrils pinched

venous gas emboli — inert gas bubbles in venous blood (that return to the heart and lungs)

ventilation — the exchange of gases between a living organism and its environment; the act of breathing

ventricle — thick-walled, muscular chamber in the heart that receives blood from the atrium, pumping it through to the pulmonary or systemic circulation

venules — small veins

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Review Answers

Chapter 2 Page 7

1. a
2. c
3. b
4. red blood
5. a
6. d
7. b

Chapter 3 Page 16

1. a
2. d
3. c
4. a, b, c, d (all apply)
5. b, c, d

Chapter 4 Page 25

1. c
2. a
3. c
4. b
5. symptom resolution does not mean DCS is not present; symptoms may return without hyperbaric treatment
6. pain, neurological (numbness), constitutional (fatigue, nausea), balance/ equilibrium (dizziness), motor weakness
7. d
8. a
9. a

Chapter 5 Page 30

1. a, b, c, d (all apply)
2. a
3. d
4. b
5. b
6. a
7. difficulty breathing, bluish colored lips, abdominal distention, chest pain, confusion, coughing up frothy pink sputum, irritability, unconsciousness
8. d

Chapter 6 Page 34

1. a
2. d
3. a, b, c, d, e (all apply)
4. d
5. c

Chapter 7 Page 49

1. a, b, c, d, (all apply)
2. capacity, distance to medical aid
3. a
4. a
5. a
6. b - Australia
   c - Europe
   c - Canada
   a - United States
   b - New Zealand
   b - United Kingdom
7. a
8. a
9. d
10. d
11. e - Non-rebreather mask
    c - Multifunction regulator
    d - Oronasal resuscitation mask
    a - Demand Valve
    f - Bag Valve Mask
    b - Manually triggered ventilator

Chapter 9 Page 66

1. a
2. e
3. b
4. c
5. a
6. c
7. a
8. a
9. e

Emergency Oxygen for Scuba Diving Injuries

OXYGEN

Scene Safety Assessment

S	Stop
A	Assess Scene
F	Find and take Oxygen Kit, First Aid Kit, AED and take to injured person
E	Exposure Protection

Initial Assessment

- Assess responsiveness and normal breathing
  - Tap the individual's collar bone and loudly ask "**Are you OK?**"
  - State your name and desire to help
- If the individual responds, have them remain in the position found
- If unresponsive but breathing normally, place in recovery position
- If not breathing normally, begin CPR
  - Use log roll to turn individual onto their back if not already supine
  - Shout for help or send a specific person to call EMS

Steps to Initiate Oxygen Delivery

- Turn the unit on with one full turn
- Check the pressure gauge on the tank to assure cylinder is full
- Ask the injured diver for permission to assist:
  - "This is oxygen. It may help you feel better. May I help you?"
  - If the diver is unresponsive, permission is assumed

Breathing Diver – Demand Valve

- Constant flow setting should be in the OFF position
- Place an oronasal mask on the demand valve
- Take a breath from the oronasal mask and exhale away from the mask
- Place the mask over the injured diver's mouth and nose
- Instruct the injured diver to breathe normally from the mask
- Instruct the injured diver to hold the mask to help maintain a seal
  - Assist with elastic strap for good seal

Breathing Diver – Non-Rebreather Mask

- Stretch oxygen tubing to remove kinks
- Attach tubing to constant flow outlet
- Set constant flow control at 10-15 lpm
- Prime mask reservoir bag
- Place mask over injured diver's mouth and nose
- Adjust nose clip and elastic strap to endure a (snug) seal
- Adjust flow up or down to meet the needs of the injured diver
  - If reservoir bag deflates completely, increase flow
  - If flow has been increased to 25 lpm and bag still deflates, switch to demand valve

Emergency Hotline (+1-919-684-9111)

DAN®

Emergency Oxygen for Scuba Diving Injuries

OXYGEN

Non-Breathing Diver – Bag Valve Mask (BVM)

First rescuer begins CPR

Second rescuer prepares oxygen equipment then maintains airway & seal

- Stretch tubing to remove kinks
- Connect tubing to constant flow outlet
- Set constant flow to 15 lpm; allow reservoir bag to fill
- Position mask over injured diver's mouth and nose
- Open airway using head tilt-chin lift, lifting jaw into mask and creating seal
- First rescuer ventilates injured diver by gently squeezing the bag about one-third of volume causing chest to rise
  - Each ventilation should last 1 second
  - Watch for chest to rise then fall between ventilations
- Continue CPR cycles of 30:2

If oxygen supply runs out, continue to ventilate using room air

Non-Breathing Diver – Manually Triggered Ventilator (MTV)

First rescuer begins CPR

Second rescuer prepares oxygen equipment then maintains airway & seal

- Check MTV Safety valve to ensure proper function
  - Press resuscitation button, block outlet – flow should stop
  - Do not use if it does not function properly
- Connect oronasal resuscitation mask to MTV
- Open airway using head tilt-chin lift, lifting jaw into mask and creating seal
- First rescuer ventilates injured diver by pressing resuscitation button
  - Deliver 2 breaths for 1 second each
  - Watch for chest to rise then fall between ventilations
- Continue CPR cycles of 30:2

If oxygen supply runs out, switch to another ventilation method

General Guidelines

- Monitor oxygen supply
- Monitor injured diver for signs of circulation
- Never leave injured diver alone

Emergency Hotline (+1-919-684-9111)

DAN®

Divers Alert Network

Divers Alert Network (DAN) is an international nonprofit dive safety organization. DAN's Mission is to improve diving safety through research, education, medical information, evacuation support, products and services.

DAN provides the diving community with several nonprofit resources such as the DAN Emergency Hotline (+1-919-684-9111). The hotline is available to divers 24 hours a day, 7 days a week. Divers suspecting a diving injury, requiring assistance, or needing to activate DAN TravelAssist (a benefit of DAN Membership) can call the DAN Emergency Hotline, and our medical services department can facilitate medical consultation with diving medicine specialists and coordinate evacuation to ensure appropriate care.

DAN also provides information via non-emergency resources, including the DAN Medical Information Line (+1-919-684-2948), FAQs on www.DAN.org, online seminars and video lectures and Alert Diver magazine.

DAN's nonprofit efforts are supported by membership and insurance. DAN Members enjoy such benefits as Alert Diver magazine, access to the DAN Dive Accident Insurance Program, free online seminars and more.

By taking this DAN Education course, you've already demonstrated a commitment to diving safety. Continue your education and your commitment by supporting the industry's only organization dedicated solely to improving diving safety. Join DAN!

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