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A Review of Barotrauma from Diving: A Narrative Literature Review

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A B S T R A C T

Barotrauma is a trauma or wound that occurs in the organs of the body due to sudden changes in air pressure around either change in pressure in the air or underwater. This literature review aimed to describe barotrauma from a traumatology perspective. In the case of barotrauma, the pathophysiology will follow Boyle's law. Namely, there is a relationship between the volume of gas in a closed room and the surrounding environment. Barotrauma that occurs when the pressure drops are called a squeeze. Squeeze events occur when there is a space filled with air and a membrane with a supply of blood flow from arteries and veins and experience a sudden change in pressure. Manifestations of barotrauma can also occur in the teeth, spine, and joints due to sharp and rapid changes in pressure. Damage to the teeth can occur because air is trapped in the teeth or because the teeth are sensitive to pressure. Damage to the spine and joints can occur because the pressure causes the vertebral discs to shift or damage the joint tissue. In conclusion, barotrauma is damage caused by pressure differences in the body, especially in the ears, lungs, and sinuses. Deaths from barotrauma are commonly associated with diving, especially freediving and gear diving.

1. Introduction

Barotrauma is a trauma or wound that occurs in the organs of the body due to sudden changes in air pressure around either change in pressure in the air or underwater.[1,2] Cases of barotrauma are often found in the community, especially in coastal areas.[3,4] This is related to the diving activities of coastal communities that do not use the equipment according to safety standards in diving. That effect is generated When exposed to very strong pressure and occurs suddenly. It damages the lining of the eustachian tube or eardrum so that it will damage hearing function.[5,6] Victims due to barotrauma are easier to identify because the victims are found after diving activities in the deep sea. This literature review aimed to describe barotrauma from a traumatology perspective.

Definition and pathophysiology of barotrauma

Barotrauma is damage caused by pressure differences in the body, especially in the ears, lungs, and sinuses.[4-6] Deaths from barotrauma are commonly associated with diving, especially freediving and gear diving. In addition, barotrauma can also occur in flights or other activities that involve significant changes in altitude and air pressure.

In the case of barotrauma, the pathophysiology will follow Boyle's law. Namely, there is a relationship between the volume of gas in a closed room and the surrounding environment. Barotrauma that occurs when the pressure drops are called a squeeze.[7] Squeeze events occur when there is a space filled with air and has a membrane with a supply of blood flow from arteries and veins and experiences a sudden change in pressure. When the body is under high pressure, such as during a dive, the air in the body cavities, such as the ears, sinuses, and lungs, must

flow in or out so that the pressure in these cavities balances the pressure in the environment.[8-11] If the air in the cavity cannot flow quickly and in balance, then the pressure difference can cause tissue damage.

Ear barotrauma can occur when changes in pressure produce a difference in pressure between the inner ear and the surrounding environment.[8,9] This can cause pain, difficulty hearing, tinnitus (ringing in the ears), or even permanent damage to the inner ear. This can put pressure on the eardrum and cause damage to the eardrum or ossicles. Sinus barotrauma occurs when pressure differences cause headaches, pain in the sinus area, or nasal congestion.

Lung barotrauma occurs when a person dives too fast or too deep, causing an imbalance in the air pressure in the lungs. This can lead to lung damage, including pneumothorax (air leakage into the chest cavity), air embolism (blockage of a blood vessel by air bubbles), and pulmonary edema (fluid buildup in the lungs).[11]

Manifestations of barotrauma can also occur in the teeth, spine, and joints due to sharp and rapid changes in pressure. Damage to the teeth can occur because air is trapped in the teeth or because the teeth are sensitive to pressure. Damage to the spine and joints can occur because the pressure causes the vertebral discs (spinal pads) to shift or damage the joint tissue.[12]

Barotrauma-related pressure concept

Barotrauma can be classified into two types, namely, barotrauma due to water pressure (in diving) and due to air pressure (in flight).[13] Pressure in diving can be grouped into five types, namely atmospheric pressure, hydrostatic pressure, absolute pressure, gauge pressure, and partial pressure. Atmospheric pressure is the pressure in the ocean, which is 1 atmosphere (atm). At 1 atm pressure in the sea, it is estimated that it is close to 10 meters of sea depth.

Hydrostatic pressure is the pressure generated by the water above the diver. This pressure is different from atmospheric pressure, which is generated by the air pressure around us. In diving, hydrostatic pressure is an important factor because the deeper a person dives, the greater the hydrostatic pressure they are exposed to. When a person dives into the water, the hydrostatic pressure increases with depth. Every 10-meter increase in water depth increases the hydrostatic pressure by about one atmosphere or 14.7 psi. Therefore, at a depth of 10 meters, the hydrostatic pressure will be twice the atmospheric pressure at sea level.

Absolute pressure is the pressure experienced by a diver when he is at sea depth which is the sum of atmospheric pressure and hydrostatic pressure. Absolute pressure is usually measured in psi (pounds per square inch) or bars and is important in dive planning, in the selection of dive equipment, and in measuring the safety of a dive. For example, when a diver is at sea level, the absolute pressure is equal to atmospheric pressure, which is about 1 bar or 14.7 psi. As the diver descends, the absolute pressure increases in proportion to the hydrostatic pressure generated by the water column above him. Therefore, when the diver reaches a depth of 10 meters, the absolute pressure is about 2 bar or 29.4 psi.[14,15]

Gauge pressure is the pressure measured relative to atmospheric pressure. In gauge pressure measurement, atmospheric pressure is considered as zero or "zero gauges", so gauge pressure always represents the difference between the measured pressure and atmospheric pressure. For example, if gauge pressure reads as 10 psi, this means the actual pressure is 10 psi higher than the current atmospheric pressure. Gauge pressure is typically used in applications where small changes in pressure are critical, such as in measuring pressure in a closed gas or liquid system or in measuring pressure in a pressure gauge such as a manometer.[14,15]

Partial pressure is the proportion of the total pressure that each gas has. For example, air at 1 ATA contains 21% oxygen, so the partial pressure of oxygen is 0.2 ATA. Partial pressure is an important concept in scuba diving or rebreather diving. Basically, partial pressure refers to the partial pressure of a particular gas in a given mixture of gases, in this case, air, under total pressure. In diving, when a person descends to a greater depth, the water pressure increases and causes the air pressure in the breathing tube to increase. Because the air mixture in the cylinder consists of several gases, each gas has a different partial pressure. The partial pressure of oxygen (PO_2) is the most critical because it is very dangerous if it is too high or too low.[14,15]

Determining mortality in barotrauma while diving

In disclosing cases of death due to barotrauma during diving, there are several components that must be assembled into a sequence of events. These components are the results of investigator and witness reports (characteristics of the area where the diving victim was found), history of the victim's diving (frequency and experience of the victim's dives, diver certification), medical history of the diver, examination of the equipment used by the victim (how much air remains in the tank and its composition, presence of carbon monoxide, regulator and tank are still in standard test fit), dive computer log downloaded which is looking for the best evidence of the speed when the diver ascends to land and measures the load carried by the diver.[16,17] Before the autopsy, a CT scan of the lungs should be done to see gas bubbles and signs of decompression. The CT-scan examination was carried out under 8 hours of death.

2. Conclusion

Barotrauma is damage caused by pressure differences in the body, especially in the ears, lungs, and sinuses. Deaths from barotrauma are commonly associated with diving, especially freediving and gear diving.

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