INDONESIAN JOURNAL OF ANESTHESIOLOGY AND REANIMATION
Volume 1 Number 2, 2019 : 58-63

Literature Review

TRANSPORTATION AND THE USE OF OXYGEN

Kun Arifi Abbas[1a]

[1] Department of Anesthesiology and Reanimation, Faculty of Medicine Universitas Airlangga, Dr. Soetomo General Academy Hospital Surabaya

[a] Corresponding author: kunarifi@gmail.com

ABSTRACT

Introduction: All living things need a certain amount of oxygen which is obtained from free air, which is continuous throughout life, but cannot be stored in the body as a reserve. Oxygen is distributed throughout the body to the mitochondria of cells which are used in metabolic processes along with glucose to produce ATP (energy source for cell activity) and remove carbon dioxide (CO_2). **Literature Review:** The exchange of oxygen as a metabolic material for the body and carbon dioxide as the end product of the body's metabolism is done through a process called respiration. Blood pumped by the heart carries oxygen from the lungs to all body tissues and brings back the blood containing carbon dioxide from the tissues back to the lungs for gas exchange. Oxygen transport in the blood takes two forms, namely bound to hemoglobin/Hb (the largest) and dissolved. Meanwhile, the transportation of carbon dioxide in the blood takes 3 forms, namely: carbonic ion (the largest), dissolved, and binds to Hemoglobin. **Conclusion:** The consumption of oxygen in the body requires processes and is associated with several organ systems. If one of the systems is not functioning properly, it can cause oxygen deficiency, thus the cells do not consume enough oxygen, which can cause anaerobic metabolism and if it becomes severe it will cause the death of cells, organs, and the individual.

Keywords: Oxygen Transportation; Respiration; O_2; CO_2; Hemoglobin

ABSTRAK

Pendahuluan: Semua mahluk hidup membutuhkan oksigen dalam jumlah tertentu yang didapatkan dari udara bebas, berlangsung terus menerus selama kehidupan, namun tidak dapat disimpan dalam tubuh sebagai cadangan. Oksigen didistribusikan ke seluruh tubuh hingga mitokondria sel yang digunakan dalam proses metabolisme bersama dengan glukosa untuk menghasilkan ATP (sumber energi aktifitas sel) dan membuang karbondioksida (CO_2). **Review Literatur:** Pertukaran gas oksigen sebagai bahan metabolisme tubuh dan carbondioksida sebagai hasil akhir metabolisme tubuh melalui proses yang disebut respirasi. Darah yang dipompa jantung membawa oksigen dari paru ke seluruh jaringan tubuh dan membawa kembali darah yang mengandung karbondioksida dari jaringan kembali ke paru untuk mengadakan pertukaran gas. Transportasi oksigen di dalam darah melalui 2 bentuk yaitu terikat hemoglobin / Hb (paling besar) dan terlarut. Sedangkan transportasi karbondioksida dalam darah melalui 3 bentuk yaitu : ion carbonic (paling besar), terlarut, dan berikatan dengan Hb. **Kesimpulan:** Konsumsi oksigen didalam tubuh memerlukan proses dan berkaitan dengan beberapa sistem organ tubuh. Jika salah satu sistem tidak berfungsi dengan baik bisa menyebabkan defisiensi oksigen sehingga sel tidak cukup mengkonsumsi oksigen, bisa menyebabkan metabolisme anaerob dan jika memberat akan menyebabkan kematian sel , organ dan individu itu sendiri.

Kata Kunci: Transportasi Oksigen; Respirasi; $O_{2;}$ $CO_{2;}$ Hemoglobin

INTRODUCTION

All living things need a certain amount of oxygen which is obtained from free air, which is continuous throughout life, but cannot be stored in the body as a reserve. Oxygen is distributed throughout the body to the mitochondria of cells which are used in metabolic processes along with glucose to produce ATP (energy source for cell activity) and remove carbon dioxide (CO_2). The tissues of the body require a constant supply of oxygen to be delivered to cells known as Delivery Oxygen (DO_2). Oxygen delivery in a minute is influenced by the amount of oxygen component in the arterial blood (Content

Arterial O_2/CaO_2) and the volume of blood pumped in a minute (Cardiac Output/CO) (Figure 1). Any abnormality of one of these components results in disruption of oxygen supply to tissues/cells. Severe oxygen deficiency conditions result in anaerobic metabolism and can lead to cell death. (1,2)

Blood pumped by the heart carries oxygen from the lungs to all body tissues and brings back the blood containing carbon dioxide from the tissues back to the lungs for gas exchange. Cardiac output pumped by the heart depends on the volume of blood pumped once contracted (stroke volume) and the frequency of the heart's pump in a minute (heart rate) (Figure 1). Any interference with one of the components, for example heart rate or stroke volume, without adequate compensation for the other components, will cause a reduction of cardiac output and oxygen supply to tissues.

The amount of oxygen in arterial blood (CaO_2) is determined by the amount of hemoglobin (functions to bind oxygen), the fraction/percentage of oxygen bound to hemoglobin (SaO_2), and arterial blood-dissolved oxygen in small amounts affected by oxygen partial pressure (PaO_2) (Figure 1). Any disturbance in one of the components, such as low hemoglobin or a decrease in arterial blood saturation (desaturation), will result in reduced oxygen supply to the tissues. (1,2)

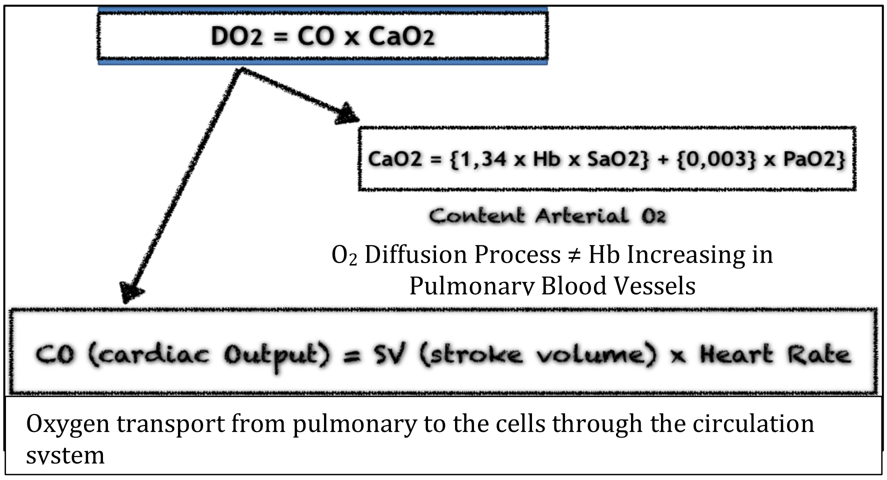

Figure 1. Oxygen Delivery

LITERATURE REVIEW

The exchange of oxygen as a metabolic material for the body and carbon dioxide as the end product of the body's metabolism is done through a process called respiration. Respiration is divided into two, namely external respiration (the exchange of O_2 and CO_2 with outside air) and cellular respiration (intracellular metabolism consumes oxygen and produces CO_2) (Figure 2). Free air contains 20-21% oxygen, the rest is nitrogen (78%), and other gases in very small amounts (CO, CO_2, etc). The air pressure at 1 atmosphere is 760 mmHg and the partial pressure of oxygen (PaO_2) in free air is about 160 mmHg. The largest component of free air that is inhaled during inhalation is 21% oxygen and 78% nitrogen. Whereas the gas content during exhalation is 17% oxygen, 78% nitrogen, and 4% CO_2. Oxygen used for metabolism is about 4-5% of the inhaled air. (3)

Oxygen Cascade

Oxygen is inhaled from free air and is sent to the mitochondria in the cells through the body's ventilation and circulation systems. The partial pressure of oxygen in free air will gradually decrease up to the mitochondria. During inhalation with free air, the oxygen pressure of about 160 mmHg will drop because it is humidified by the air in the respiratory tract to 150 mmHg. After passing through the airway, the partial pressure of oxygen again drops in the aveoli because there is a carbon dioxide component in the alveoli of about 100 mmHg. Then the oxygen will undergo diffusion, increasing the partial pressure of oxygen from the veins, which was originally 40-45 mmHg, in the arteries the partial pressure of oxygen will be 90-95 mmHg (taking into account the physiological shunt of the body containing CO_2). Oxygen will be sent with blood to the arterioles, to the interstitial cells, the oxygen pressure becomes 40-45mmHg. In cell plasma, oxygen pressure becomes 20-25 mmHg and the partial pressure of oxygen in the mitochondria becomes 1-10 mmHg. In venous blood system, the partial pressure of oxygen is around 40-50 mmHg which will return to the lungs and begin the diffusion process and return to the initial cycle (Figure 3). (3)

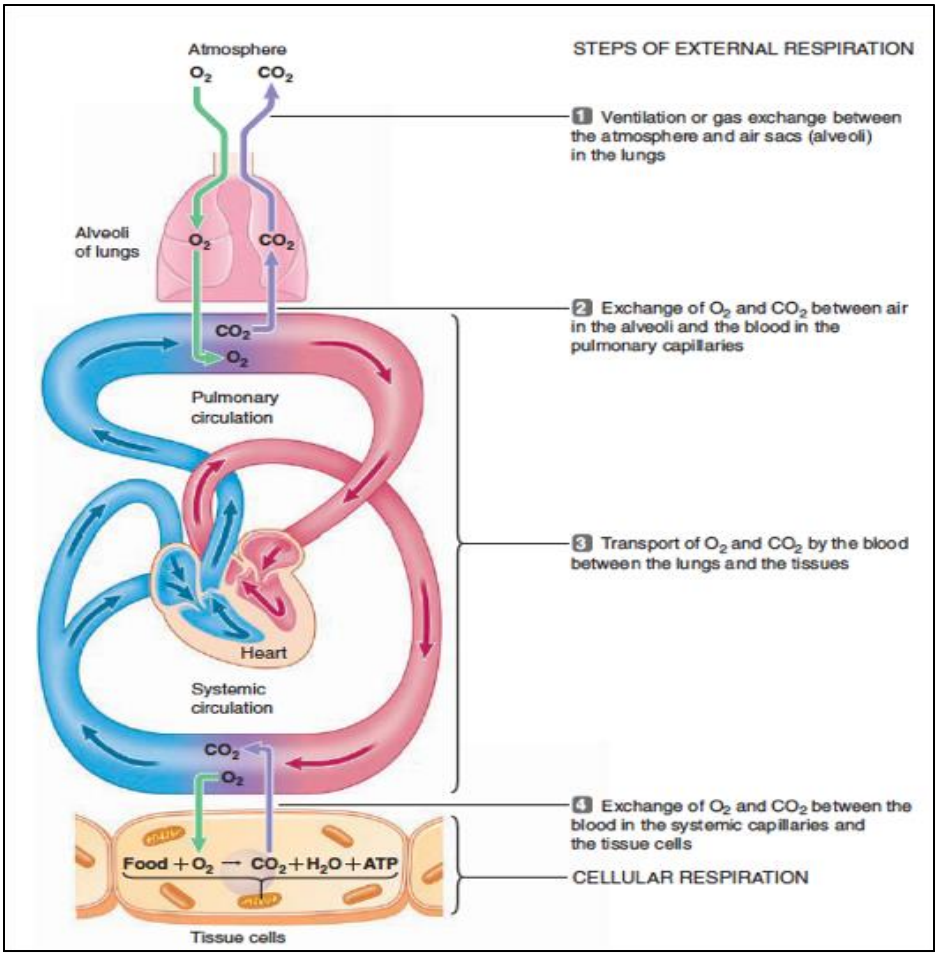

Figure 2. Steps of External Respiration

CO_2 as a result of metabolism has a partial pressure of CO_2 from the veins about 40-45 mmHg is sent to the lungs where it will diffuse and is excreted through the exhaled air around 35-40 mmHg.(3)

Oxygen transport in the blood takes two forms, namely bound to hemoglobin/Hb (the largest) and dissolved. Meanwhile, the transportation of carbon dioxide in the blood takes 3 forms, namely: carbonic ion (the largest), dissolved, and binds to Hb (Figure 4). Most of the diffused oxygen will be bound by Hb and each Hb molecule binds 4 O_2 molecules. The amount/fraction in percent of

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oxygen bound to Hb is represented in oxygen saturation, if all hemoglobin binds to 4 molecules causes the saturation to be 100%. (3,4)

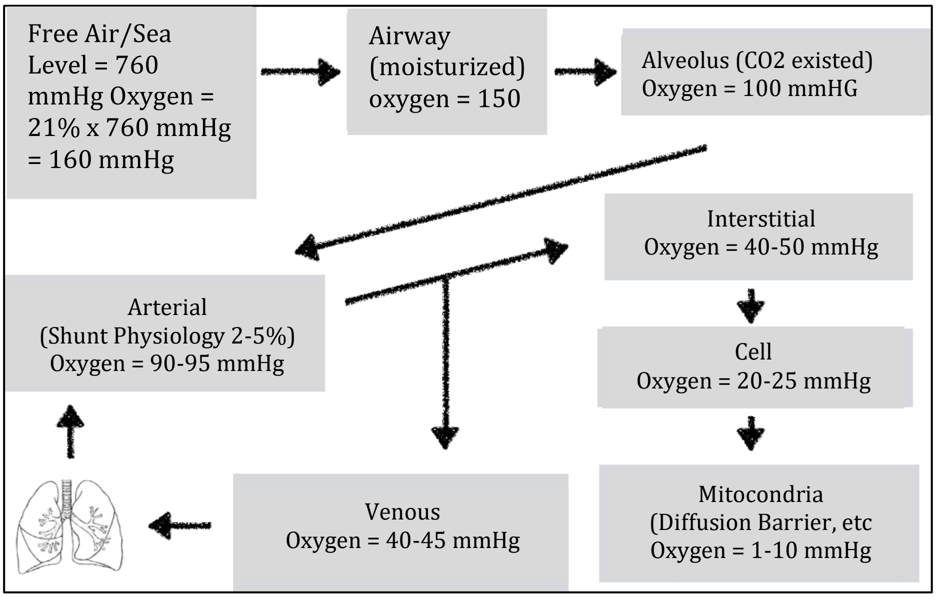

Figure 3. Oxygen Cascade

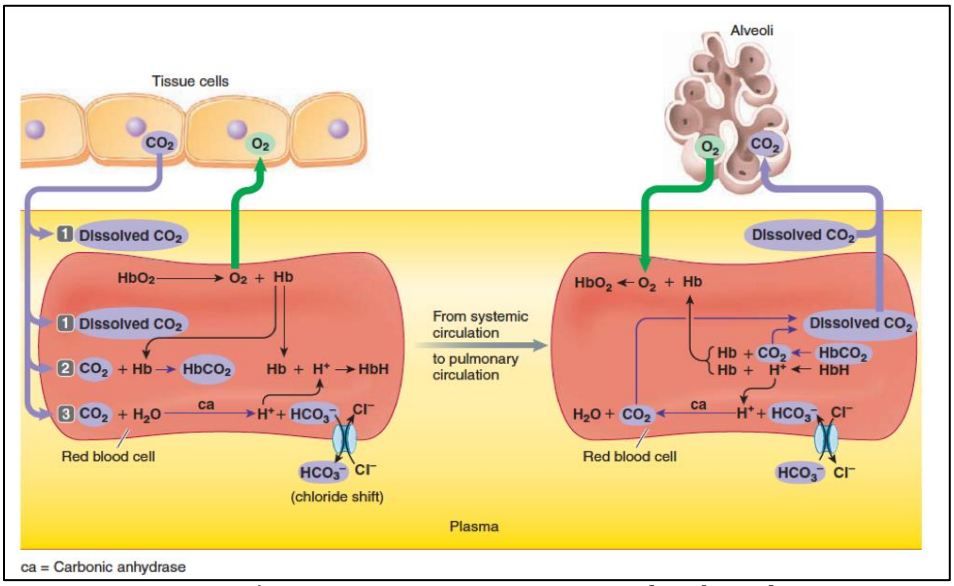

Figure 4. Transport Oxygen & Carbondioxyde

In body tissues, the oxygen released to the tissues causes the oxygen bound to hemoglobin to decrease thus the blood saturation in the veins will decrease. The tendency of hemoglobin to bind or release oxygen is influenced by several factors. This is reflected in oxygen dissociation curve. The oxygen curve shifts to the right under conditions of acidosis, hypercarbia, febris, and an increase in blood levels of 2,3 DPG. This causes oxygen to be released more easily from hemoglobin. The oxygen curve shifts to the left under conditions of alkalosis, hypocarbia, hypothermia and a decrease in 2,3 DPG. This makes it difficult for oxygen to escape from hemoglobin (Figure 5). (1,3,4)

In the lungs, O_2 is easier to bind to Hb because of uptake H^+ by HCO_3^- to reform CO_2

(expelled on exhalation) causes alkalosis, thus shifting the oxygen dissociation curve to the left. This process causes an increase in oxygen produce CO_2 which reacts with H_2O is then broken into H^+ and HCO_3^- thus making the condition slightly acidotic, causing the oxygen dissociation curve to shift to the right (oxygen is more easily released by hemoglobin). uptake and a decrease in CO_2 affinity, thus CO_2 is easier to remove. This is known as Haldan effect. In contrast, in tissues, cells Moreover, CO_2 which binds to hemoglobin reduces the affinity of hemoglobin for oxygen, thus O_2 is easier to release into the network. This is known as Bohr effect.(4)

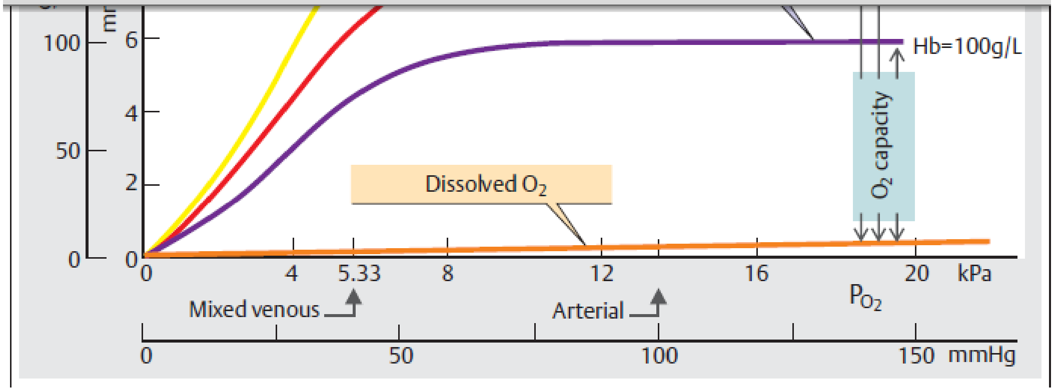

Figure 5. Oxygen Discociation Curve

When it reaches the cellular level, oxygen is taken up by the mitochondria for use in aerobic metabolic processes. Oxygen, along with glucose, produces 36 ATP, carbon dioxide (CO_2), and water (H_2O). If the body's metabolism does not use oxygen, anaerobic metabolism will occur which only produces 2 ATP and lactic acid. (1,5) Normally, the body needs O_2 250 ml/minute and produces CO_2 200 ml/minute. Produced CO_2 divided by consumed O_2 is called respiratory quotion. Respiratory quotion differs in the use of different energy sources (carbohydrates/fat/protein), overall respiratory quotion range is 0.8. (4)

One of the evaluations of tissue use of oxygen is by counting oxygen extraction ratio/O_2 ER. O_2ER is obtained by calculating the ratio uptake of O_2 (VO_2) with oxygen delivery (DO_2) with the equation $O_2ER = VO_2/DO_2$. In this equation, the same values for Hb, CO and 1.34 are obtained, then the equation $O_2ER = (SaO_2\text{-}SvO_2)/SaO_2$ will be obtained. At SaO_2 100% (full saturated) then O_2 ER = SaO_2 - SvO_2. Venous saturation is taken from the pulmonary artery or central venous catheter. The result of this equation shows the level of oxygen consumption by the cell. Normally the value of O_2ER is 20-30%. If O_2ER is over 30%, it indicates a decrease of oxygen delivery (e.g. anemia or low cardiac output), thus oxygen debt can occur. Oxygen debt causes anaerobic metabolism. If the increase is more than 50%, it indicates inadequate tissue oxygenation and is in a dangerous stage. If O_2ER is less than 20%, it indicates that oxygen cannot be used by cells. This can occur in cell dysfunction e.g. in sepsis and septic shock.(1)

Causes of oxygen deficiency/hypoxia can occur from the lung level (airway disturbance and ventilation), decreased transport capacity (anemia), heart pump failure, vasoconstriction/vasodilation, abnormal tissue diffusion (edema), and use of abnormal O_2 e.g. mitochondrial poisoning, sepsis). All of the above can cause impaired tissue oxygenation and lead to anaerobic metabolism (Figure 6). (6)

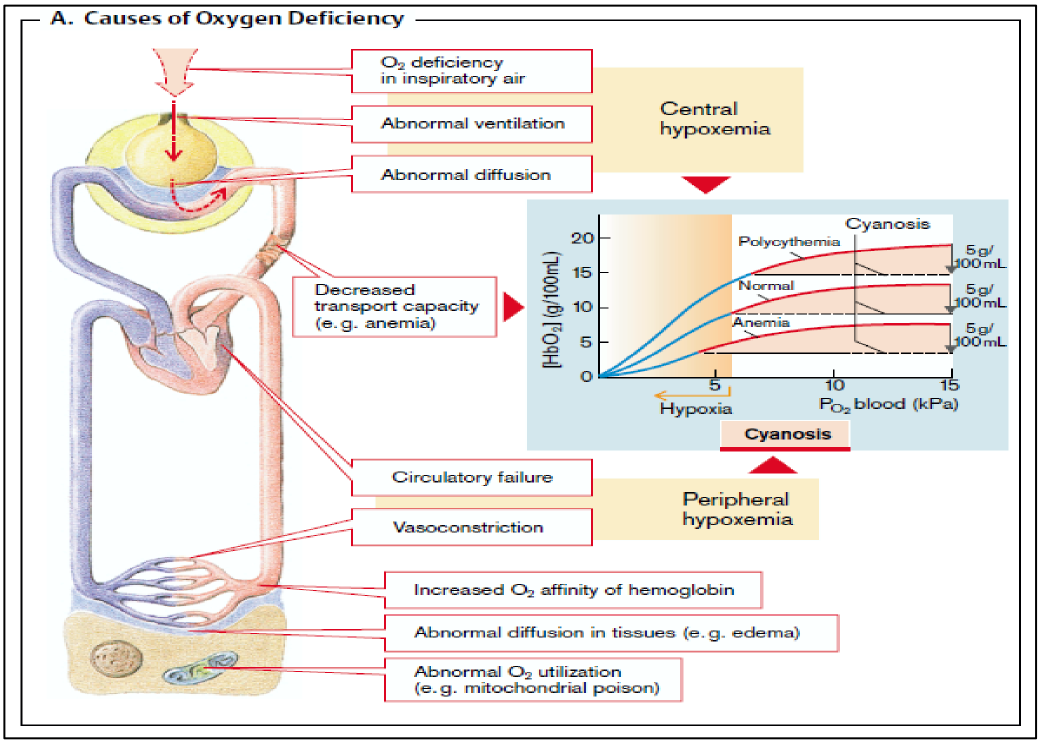

Figure 6. The Cause of Oxygen Deficiency

CONCLUSION

The consumption of oxygen in the body requires processes and is associated with several organ systems. If one of the systems is not functioning properly, it can cause oxygen deficiency, thus the cells do not consume enough oxygen, which can cause anaerobic metabolism and if it becomes severe it will cause the death of cells, organs, and the individual.

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