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The effect of using electronic cigarettes on the blood gases in the blood of people addicted to smoking electronic cigarettes

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Abstract
The current study analyzed how addiction to vaping impacts individuals' health by measuring various blood gases and physiological variables. Data from 80 electronic cigarette users were collected and analyzed, with participants categorized based on nicotine percentage and years of vaping. Comparisons were made with 30 samples from healthy individuals and non-smokers acting as the control group.
The results of the study revealed that the levels of certain variables varied significantly based on the percentage of nicotine and the number of years smoking. For example, the percentage of monocarbon gas in the blood showed a clear increase, reaching 40% in those who smoked for more than 10 years compared to 16% in those who smoked for (1-4) years.
Similarly, oxygen levels decreased, with the highest decline of 73% in those with a 12% nicotine intake. Carboxyhemoglobin levels also varied, with the highest increase of 127% found in those with 12% nicotine intake and over 10 years of smoking. The acid function section saw the highest decrease of 2% in those smoking for more than 10 years compared to 1% in those smoking for (1-4) years.
Keywords: E-cigarette, ecigarette, vaping, nicotine vaporizer, secondhand vapor.

Introduction

The electronic cigarette is a battery-operated device designed to deliver nicotine to the smoker. It was first developed by Herbert Gilbert, who obtained a patent for a device described as a "cigarette without smoke and without tobacco," where tobacco and burning paper were replaced by hot, moist air with a variety of flavors in 1963 (Gilbert *et al*., 1965).
However, the invention of the electronic cigarette can be traced back to the Chinese pharmacist Hon Lik in 2003, and electronic cigarettes were marketed in the Chinese markets as a smoking cessation device in 2004 (Cummings *et al*., 2014). It is advertised that electronic cigarettes are safer than tobacco cigarette products, as it is believed that the chemical compounds, inhaled from electronic cigarettes are less toxic and harmful than those found in tobacco cigarettes. Electronic cigarettes contain many dangerous chemical compounds such as formaldehyde, acetaldehyde, and other harmful compounds (Bekki *et al*., 2014).Since they first appeared on the market over a decade ago, electronic cigarettes have been considered a less harmful alternative to traditional cigarette smoking. These devices are essentially electronic devices, consisting of a cartridge filled with e-liquid, a heating element essential for vaporizing the e-liquid to produce an inhalable vapor, a mouthpiece, and a rechargeable battery (Hiemstra and Bals, 2016).Cigarette smoke is considered a complex mixture of chemicals such as carbon monoxide (CO), hydrogen cyanide (HCN), nitrogen oxides (NOX), and others like formaldehyde, acrolein, benzene, and some nitrosamines (N). These volatile substances are present in the vapor phase of cigarette smoke, along with other chemicals like nicotine, phenol, polycyclic aromatic hydrocarbons (PAHs), and tobacco-specific nitrosamines (TSNAs) (Mohammed *et al*., 2022).
Electronic cigarettes have harmful effects on health as they cause respiratory diseases, increase the risk of heart and cardiovascular diseases, impair wound healing, and also lead to many cases of burn injuries (Moheimani *et al*., 2017).Exposure to secondhand smoke can result in negative effects or even death due to asthma, and it may be genetically linked to an increased risk of asthma in offspring (Liu *et al*., 2022).Smoking electronic cigarettes causes dysfunction of the blood vessel lining and an increase in oxidative stress, leading to effects on the heart and blood vessels (Daiber *et al*., 2023).

Materials and methods

Collecting blood samples

Blood samples were collected from smokers, with 10 ml of venous blood being taken. Hemolyzed blood samples were excluded to avoid inaccurate results. The blood was divided into three parts, with 1 ml of blood being placed in a tube. The tube was then washed with liquid heparin for testing the dissolved gases in the blood (CO2, O2, etc.) using the American-made radiometer gas analyzer, ABL800 FLEX, located at the Public Republican Hospital in Mosul, as shown in Figures(1-1).

Figures: (1-1) Device for measuring dissolved gases in blood (Severinghaus, 1996)However, the second part of the blood deposited 2 ml of venous blood in clot-preventing plastic tubes containing Ethylene Diamine Tetraacetic Acid (EDTA). The tests included blood components such as packed cell volume (PCV), platelet count, red blood cells (RBCs), and hemoglobin concentration (HB).In the third stage, the remaining blood was placed in tightly sealed tubes free from anticoagulant substances called Jell tubes and dried. The tubes were then left at room temperature for 20 minutes before being centrifuged at a speed of 9000 x g for 15 minutes to obtain serum. The serum was

divided into parts, placed in dry and sterilized Eppendorf plastic tubes, and stored in a deep freezer at -20°C until the required biochemical tests for this study were conducted.

The Statistical Analysis

The data were analyzed according to the simple experiment using a completely randomized design. The different significant factors were marked with alphabetic letters using Duncan's multiple range test at the 0.05% probability level (Kirkwood and Sterne., 1988).

Results and Discussions

1-Determination of the Concentrations of Some Gaseous Pollutants in Blood Smokers

1-1The Carbon Monoxide (CO) Gas Concentration

The results in tables (1-1) and (1-2) showed a significant increase in CO2 concentration at a probability level of P≤0.05. The highest concentration of this gas was found after smoking for more than 10 years, followed by smoking for (10-5) years, and the lowest in smoking for(4-1) years, with percentages of 44%, 35%, and 31%, respectively.On the other hand, the highest concentration of nicotine percentage was 12%, 6%, and the lowest was 3%, respectively, with percentages of 40%, 20%, and 16% compared to the control group.The increase in the concentration of CO gas is attributed to the smoke emitted from cigarettes and inhaling it, as carbon monoxide gas is considered a major waste product of cigarettes (Stern et al., 2007).In addition to gases and vapors in the blood of smokers as a result of smoking, this leads to an increase in the levels of gases, including CO2 (Saleh, 2006; Van, 2002).Some of the most common air pollutants are CO, SO2, CO2, and NO gases, which are considered major sources of air pollution (Al-Hamad and Khan, 2008; Baltrenas et al., 2011).

The results of this study are consistent with other studies that have indicated an increase in the concentration of carbon monoxide (CO) gas when smokers inhale smoke from such environmental pollution cases. (Czogala et al,2014., Benowitz et al.,2022)

1-2 Measurement of CarboxyHemoglobin Levels (COHb)

The results of the current study, as shown in Tables (1-1) and (1-2), indicate a significant increase in the concentration of carboxyhemoglobin COHb.

The highest percentage was found in smokers who have been smoking for more than 10 years, followed by those who have been smoking for (5-10)years, and the lowest in those who have been smoking for (1-4)years, with percentages of 100%, 43%, and 17%, respectively. On the other hand, the results showed the highest concentration of nicotine at 12% and 6% and the lowest at 3%, with percentages of 127%, 77%, and 66%, respectively, compared to the control group.The results of the current study align with other studies, showing an increase in carboxyhemoglobin (COHb) levels and its harmful effects on the body (Febriyanto *et al*., 2022).The results of this study were in line with another study, showing the impact of smoking on health and its contribution to heart and cardiovascular diseases, as well as respiratory diseases. It also indicated an increase in levels of carboxyhemoglobin and carbon monoxide gas (Vámos *et al*., 2024).The reason for the increase in COHb levels is attributed to the fact that smoking electronic cigarettes increases the concentration of hemoglobin in the blood because it leads to a decrease in the blood's oxygen ratio and an increase in the concentration of carbon monoxide in the blood. The air inhaled by non-smokers contains 80% oxygen, 29% nitrogen, less than 1% carbon monoxide, and water vapor. However, in smokers, the inhaled air from smoke contains a high percentage of carbon monoxide, which is a toxic gas that binds to hemoglobin faster than oxygen, leaving less space on hemoglobin in red blood cells to carry oxygen. This is the reason for the elevated levels of this compound (Kahar *et al*., 2022).CO gas is considered one of the most dangerous gases as it rapidly combines with hemoglobin, exceeding oxygen's ability by about 240 times, forming the compound carboxyhemoglobin (COHb). This will affect the function of hemoglobin as a natural oxygen carrier, as CO gas is absorbed through the lungs. The concentration of COHb compound in the blood at any given time depends on various factors, including the concentration of inhaled CO gas, the duration of exposure, and the ventilation of the respiratory system (Horvath *et al*., 1988; Raub, 1999).Several studies have pointed out that the effects of varying concentrations of carbon monoxide are reflected in the concentration of COHb, thus impacting the cardiovascular system, nervous system, and hormonal secretions (Plumlee *et al*., 2004; Sherwood, 2004).

1-3 Concentration of lactic acid.

The results in Tables (1-1) and (1-2) showed a significant increase in the concentration of lactic acid in the blood of electronic cigarette smokers compared to the control group. The highest percentage was found in smokers of electronic cigarettes for more than 10 years, followed by those who smoked for (5-10) years, and the lowest in those who smoked for (1-4) years, with percentages of 106%, 99%, and 53%, respectively. The results also showed the highest concentration at a nicotine percentage of 12% and the lowest at 3%, with percentages of 76% and 28%, respectively, compared to the control group. Studies have shown that when oxygen levels are very low, it cannot quickly reach the mitochondria for oxidation and the production of the reduced enzyme nicotinamide adenine dinucleotide (NADH) from the glycolysis pathway. In this case, the enzyme lactate dehydrogenase (LDH) in muscles performs its function in the formation of lactic acid in the absence of oxygen, leading to anaerobic glycolysis or lactate fermentation. However, in the presence of oxygen, lactic acid is not formed, and pyruvate oxidation continues in the citric acid cycle to produce carbon dioxide and water (Sameeh *et al.,* 2009).

The results of the current study are in line with previous studies (Essamy *et al*., 2012; Ahmad-Qasem *et al*., 2013), which indicated that an increase in lactic acid leads to various damages in different body organs.

1-4 The oxygen gas concentration(O_2).

The results in tables (1-3) and (1-4) showed a significant decrease in the oxygen levels in the blood of smokers using electronic cigarettes compared to the control group. The highest significant decrease in O2 concentration was found in smokers with more than 10 years of smoking history, followed by those with (5-10) years, and the lowest decrease was observed in smokers with (1-4) years of smoking history, with percentages of 67%, 60%, and 58%, respectively. As for the nicotine levels, the highest decrease was 12% and 6%, while the lowest decrease was 3%, with percentages of 73%, 67%, and 54%, respectively, compared to the control group.The results of this study were consistent with other studies, which showed a decrease in the oxygen levels in the blood of smokers compared to non-smokers (Chatterjee *et al*., 2021; Thirión-Romero *et al*., 2019). The reason for the decreased oxygen levels in the blood of smokers is attributed to electronic cigarettes due to the rapid binding of hemoglobin with carbon monoxide, forming the compound carboxyhemoglobin (COHb), which affects the process of oxygen transport in the blood (Vámos *et al*., 2024).

1-5 Potential Hydrogen value(PH) .

The results in tables (1-3) and (1-4) indicated that the values of the acidic function showed a slightly non-significant decrease in the blood of electronic cigarette smokers compared to the control. The highest non-significant decrease was observed in smokers with a smoking duration of more than 10 years, while the lowest was in those with a smoking duration of (4-1) years, with a decrease rate of 2% and 1%, respectively. The decrease in nicotine levels was similar in all concentrations at a rate of 1% compared to the control group.The results of this study were consistent with another study that demonstrated the impact of the acidic function of direct contact with electronic cigarette aerosol on tissues in the respiratory system and other body organs through the circulatory system. There is an inverse relationship between the acidity level and nicotine, as the higher the pH, the higher the concentration of nicotine, and the lower the pH, the lower the concentration of nicotine (Shao and Friedman, 2020).

1-6 bicarbonate concentration(HCO_3) .

The results in tables (1-3) and (1-4) showed a significant decrease in bicarbonate concentration in the blood of smokers of electronic cigarettes compared to the control group. The highest significant decrease was observed in smokers with a smoking duration of more than 10 years, followed by (5-10)

years, and the lowest decrease was seen in smokers with a smoking duration of (1-4) years, with percentages of 12%, 10%, and 8%, respectively. The highest decrease in nicotine percentage was 12.6%, with the lowest at 3%, with percentages of 9%, 8%, and 5% compared to the control group.The findings of this study align with previous research, which showed a decrease in bicarbonate concentration in the blood of e-cigarette smokers (Kadiyala et al., 2013; Csekő et al., 2022).

Mmol\L Lactic acid ratio			CO ratio			COHb ratio			studied variable
% High	%	Average ± error Standard*	% High	%	Average ± error Standard*	% High	%	Average ± error Standard*	studied groups
-	100	0.83±1.76* D	-	100	4.56±40.93* b	-	100	0.35±1.16 ab	**control**
106	206	0.37±3.63 a	44	144	1.50±58.80 a	100	200	1.30±2.33 ab	**(more than 10(Yr.**
99	199	0.36±3.50 a	35	135	12.78±55.10 a	43	143	0.32±1.66 ab	**(5-10) Yr.**
53	153	0.26±2.70* b c	31	131	3.70±53.66 a	17	117	0.10±1.46* b	**(1-4) Yr.**

Table (1-1): The impact of vaping on the levels of carbon monoxide (CO), lactic acid, and carboxyhemoglobin (COHb). *Numbers followed by different letters vertically indicate the presence of significant differences between them at the probability level (P≤0.05) and vice versa according to the Duncan test.

Lactic acid ratio Mmol\L			CO ratio			COHb ratio			studied variable
% High	%	Average ± error Standard*	% High	%	Average ± error Standard*	% High	%	Average ± error Standard*	studied groups
-	100	0.83±1.76* d	-	100	4.56±40.93* b	-	100	0.35±1.16 a b	**Control**
76	176	0.26±3.10* ab	40	140	1.57±57.30* a	127	227	1.25±2.63 a	**Nicotine percentage 12%**
28	128	0.15±2.26* bc	20	120	9.21±49.36 a b	77	177	0.25±2.06 a	**Nicotine percentage 6%**
28	128	0.41±2.26* cd	16	116	1.47±47.50 ab	66	166	0.95±1.93 ab	**Nicotine percentage 3%**

Table (1-2): The impact of vaping on the levels of carbon monoxide (CO), lactic acid, and carboxyhemoglobin (COHb). *Numbers followed by different letters vertically indicate the presence of significant differences between them at the probability level (P≤ 0.05) and vice versa according to the Duncan test.

Table (1-3) shows: The effect of smoking electronic cigarettes on the percentage of oxygen gas, Potential Hydrogen value(PH), and the concentration of bicarbonate

HCO_3 ratio			ratio PH			O_2 ratio			studied variable
% Low	%	Average ± error Standard*	% Low	%	Average ± error Standard*	% Low	%	Average ± error Standard*	studied groups
-	100	0.50±26.50* A	-	100	0.06±7.43 a	-	100	0.76±83.83* a	**Control**
12	88	0.26±23.30 b	2	98	0.05±7.31 a	67	33	0.92±28.06* cd	**(more than 10(Yr.**
10	90	0.90±23.73 b	1	99	0.03±7.34 a	60	40	4.56±33.93* bc	**(5-10) Yr.**
8	92	1.25±24.46* ab	1	99	0.14±7.36 a	58	42	6.07±34.96* b	**(1-4) Yr.**

Table (1-3) shows: The effect of smoking electronic cigarettes on the percentage of oxygen gas, Potential Hydrogen value(PH), and the concentration of bicarbonate

***Numbers followed by different letters vertically indicate the presence of significant differences between them at the probability level (P≤ 0.05) and vice versa according to the Duncan test.**

HCO_3 ratio			ratio PH			O_2 ratio			studied variable
% low	%	Average ± error Standard*	% low	%	Average ± error Standard*	% Low	%	Average ± error Standard*	studied groups
-	100	0.50±26.50* A	-	100	0.06±7.43 a	-	100	0.76±83.83* a	**Control**
9	91	0.81±24.10* b	1	99	0.02±7.32 a	73	27	1.95±22.73* d	**Nicotine percentage 12%**
8	92	1.04±24.50 a b	1	99	0.03±7.35 a	67	33	4.52±28.10* cd	**Nicotine percentage 6%**
5	95	2.38±25.03 a b	1	99	0.02±7.37 a	54	46	1.82±39.03* b	**Nicotine percentage 3%**

Table (1-4) shows: The effect of smoking electronic cigarettes on the percentage of oxygen gas, Potential Hydrogen value(PH), and the concentration of bicarbonate

***Numbers followed by different letters vertically indicate the presence of significant differences between them at the probability level (P≤ 0.05) and vice versa according to the Duncan test**

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