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Smoking Effects on Common Carotid Arteries Resistivity and Pulsatility Indices in Current Sudanese Smokers

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Abstract: This study intended to evaluate the effect induced by the number of cigarettes consumed per day in the resistance index (RI) and pulsatility index (PI) of the common carotid arteries, in Sudanese current smokers. A prospective study was performed with a group of 900 healthy adults who categorized after scanning to (26.7% smoked 1-4 Cigarettes/day, 16% smoked 5-9 Cigarettes/day, 53.3% smoked 10 and more Cigarettes/day and 4% were non smokers) and aged from 18 to 50 years (12 women, 888 men; mean age of all patients, 28±11 years). The common carotid arteries were examined using spectral Doppler ultrasonography to measure resistive index (RI), and pulsatility index (PI) values in the vessels. Increase cigarettes' consumption per day in current Sudanese smokers significantly increases the RI (P-value < 0.0001) and PI (P-value < 0.0001) for the right and left common carotid artery respectively. Findings report that increasing the number of cigarettes smoked per day in current smokers; significantly influence common carotid arteries RI and PI with a linear positive correlation manner.
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1. Introduction

Smoking harms nearly every organ of the body by reducing the health of smokers in general and specifically causing some diseases. The adverse health effects from the cigarette smoking account nearly one of every five deaths each year in the United States (Mokdad et al., 2004). The products of tobacco combustion are absorbed into the systemic circulation that leads to injure the arterial endothelium and promote atherogenesis and this in turn will affect the common carotid artery which supplies the head and neck with oxygenated blood (Powell, 1998) and (Ashrafian, 2007).

Doppler ultrasound is widely used as a noninvasive method for the assessment of blood flow both in the central and peripheral circulation. It may be used to estimate blood flow, to image regions of blood flow and to locate sites of arterial disease as well as flow characteristics and resistance of internal carotid arteries (Evans et al., 1989) and (Muller et al., 2001).

Problems of this study were the increase number of mortality rates among the youth due to serious diseases caused by cigarette smoking in addition to the absence of experimental information that determines the duplex waveform changes in the blood flow among Sudanese smokers.

Obtained results from this study was supported by Barutcu et al., 2004 who have studied the acute cigarette smoking-induced hemodynamic alterations in the common carotid artery a transcranial Doppler study, out of which they revealed that: the smoking of one cigarette shown to temporarily alter cerebral flow velocity and vasomotor reactivity as well as the heart rate and blood pressure significantly increased but the diameter of common carotid artery (CCA), flow volume and area of each CCA were unchanged, while the RI and PI were significantly altered after smoking.

Edoardo et al., 2007, Jiang et al., 2000 and Jiang et al., 1998 stated that: “stiffer arteries have been also shown to be associated with reduced blood flow velocity in diastole, which is reflected by an increase in the RI which was confirmed in the results of this research where the mean value of PI, which is a measure of the variability of blood velocity in a vessel, equal to the difference between the peak systolic and minimum,

diastolic velocities divided by the mean velocity during the cardiac cycle (Bames and Nobel, 2009), considering the normal range for RI is 0.4 up to 0.7 and for PI is 0.8 up to 1.2 (Margaret et al., 2005).

This study was designed with an aim to determine the changes occur in RI and PI of common carotid arteries, in related to number of cigarettes smoked per day in current Sudanese smokers. Furthermore, to determine which CCA is more affected in this state relative to non-smokers subjects.

2. Material and Methods

In this retrospective study, a group of 900 individuals between the ages of 18 and 50 years with mean age of 28±11 years, consisting of 12 (1.33%) non-smokers females and 888 (98.67%) non smokers and current smokers' males scanned by using an scanning protocol in accordance with 2011 the American Institute of Ultrasound in Medicine (AIUM), practice guidelines for extracranial cerebrovascular (Julia et al., 2012).

In order to avoid interobserver variance, all measurements were done by the same radiologist using general electric (GE) medical system, logic-five expert ultrasound machine. Informed consent was obtained from both the consecutively enrolled healthy outpatient and the ultrasound department after the nature of the procedure was fully explained. Inclusion criteria for this study include current Sudanese smokers who smoke tobacco through cigarettes regularly for a period not less than ten years beside healthy Sudanese non smokers, non hypertensive, non diabetic and none affected with cardiopulmonary disorders so to avoid significant influence in the extracranial blood velocities.

Common carotid arteries sonography brightness mode (B-mode) and spectral Doppler analysis, were performed using General Electric (GE) medical system, logic 5 expert ultrasound machine (Sony Corporation, Japan). The applied ultrasound transducer was a linear probe of a frequency 6.0 MHz, made by the Yokogawa medical system, Ltd. 7-127 Asahigaoka 4-chome Hino-shi Tokyo, Japan. Model 2302650 with serial number of 1028924YM7 and manufactured date of April 2005. Printing facility issued through ultrasound digital graphic printer, 100 V; 1.5 A; and 50/60 Hz. Made by Sony Corporation-Japan, with serial number of 3-619-GBI-01.

Samples were scanned by the radiologist in the Ultrasound Department of Sudan University of Science and Technology (SUST) - College of Medical Radiologic Sciences (CMRS) in the period of April 2009 up to April 2012. Scanning done to visualize the common carotid arteries while patients were in supine position with knee support, and the examiner seated towards the patient's head. The neck scanning was enhanced by tilting and rotating the head away from the side being examined, with possible adjustment for the position of the head and neck during the examination to facilitate visualization of the common carotid arteries. Several transducer positions were used in this research to examine the common carotid arteries in the long-axis (longitudinal) planes.

The short-axis (transverse) view of the carotid artery was obtained from an anterior and lateral or posterolateral approach, depending on which best shows the vessels. Color Doppler (CD) mode applied to detect the blood flow and followed by pulse wave Doppler (PW) mode for the spectral display analysis to determine the values of RI and PI using automatic calculation software. The obtained numerical values for RI and PI in current smokers were taken from the middle part of each artery because the flow pattern seems to be steady and uniform, which will actually help in avoiding any overestimated values. In addition using a Doppler angle of 60 degrees or less could help in making a Doppler signal waveform stronger and clearer.

Data statistical analysis issued through Microsoft Excel Software program and Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 15 for windows. Obtained results were summarized as (mean±SD) in a form of comparison tables, graphs and correlation. The difference in values, between right and left common carotid arteries RI and PI in current Sudanese smokers were checked by t-test. P-value terms such as equal and less to be used for significance and (P-value $\geq$ 0.0001) considered to be significant.

3. Results

The number of cigarettes smoked per day increases the RI from (0.74±0.01) among those who smoked 1-4 cigarettes/day to (0.78±0.03) among those who smoked 5-9 cigarettes/day up to (0.81±0.02) among those who smoked 10 and more cigarettes/day for the Lt. CCA (Table 1). Moreover, the RI for the Rt. CCA increases from (0.71±0.02) among those who smoked 1-4 cigarettes/day to (0.75±0.02) among those who smoked 5-9 cigarettes/day up to (0.77±0.02) among those who smoked 10 and more cigarettes/day (Table 1).

Such results can be fitted in the following equations that show linear and positive correlation (Figure 1 and Figure 2) between the number of cigarettes consumed per day and RI, where [$Y=0.02x+0.72$; ($R^2=0.99$), $Y=0.02x+0.70$; ($R^2=0.96$)], where y refers to RI and x refers to number of cigarette smoked per day on the left and right common carotid arteries respectively.

Table 1. Changes in RI values, in the left and right common carotid arteries, as the number of cigarettes smoked per day increases in current Sudanese smokers

Number of cigarettes smoked per day	Left common carotid artery (Lt. CCA)	Right common carotid artery (Rt. CCA)	P-value
	Mean RI value	Mean RI value	
1-4 Cig/Day (N = 240)	0.74±0.01	0.71±0.02	* < 0.0001
5-9 Cig/Day (N = 144)	0.78±0.03	0.75±0.02	* < 0.0001
10 and more Cig/Day (N = 480)	0.81±0.02	0.77±0.02	* < 0.0001
* P-value and statistical significance: The two-tailed P-value is less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant.			

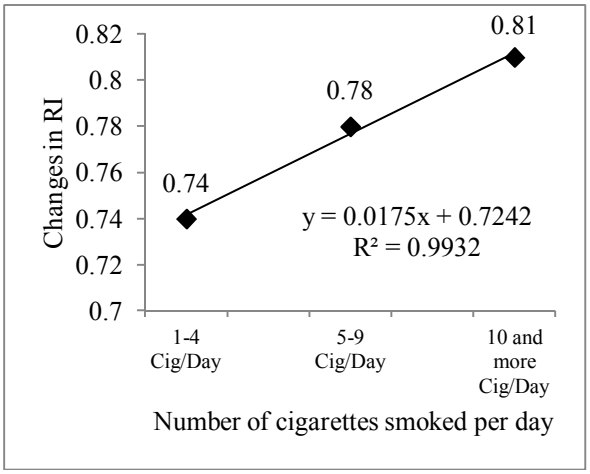

Figure 1. Changes in RI values versus number of cigarettes smoked per day in current Sudanese smoker for the left common carotid artery

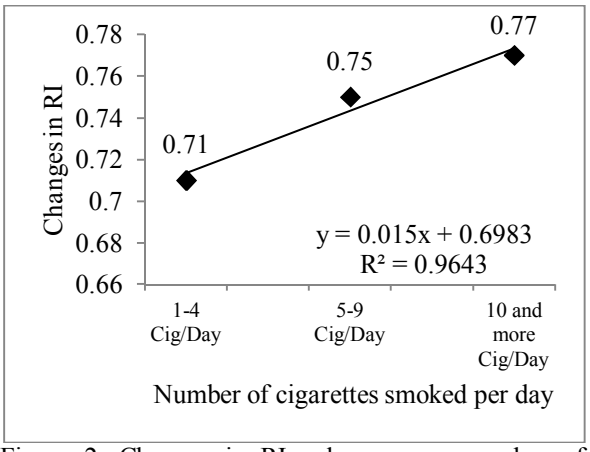

Figure 2. Changes in RI values versus number of cigarettes smoked per day in current Sudanese smoker for the right common carotid artery

Also the number of cigarettes smoked per day increases the PI from (1.22±0.03) among those who smoked 1-4 cigarettes/day to (1.30±0.07) among those who smoked 5-9 cigarettes/day up to (1.37±0.06) among those who smoked 10 and more cigarettes/day for the Lt. CCA (Table 2). In addition, the PI for the Rt. CCA increases from (1.18±0.06) among those who smoked 1-4 cigarettes/day to (1.21±0.04) among those who smoked 5-9 cigarettes/day up to (1.25±0.06) among those who smoked 10 and more cigarettes/day (Table 2).

Such results can be described by linear positive correlation also (Figure 3 and Figure 4) between the number of cigarettes smoked per day and PI, fitted in the following equations: [$Y=0.04x+1.20$; ($R^2=0.99$), $Y=0.02x+1.20$; ($R^2=0.99$)], where y refers to PI and x refers to number of cigarette smoked per day, found between left and right common carotid arteries respectively.

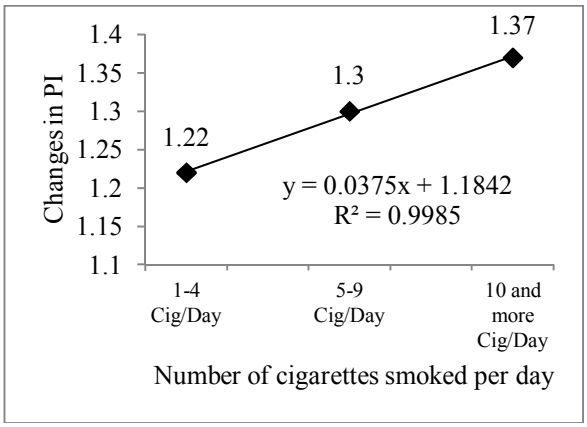

Figure 3. Changes in PI values versus number of cigarettes smoked per day in current Sudanese smoker for the left common carotid artery

Table 2. Changes in PI values, in the left and right common carotid arteries, as the number of cigarettes smoked per day increases in current Sudanese smokers

Number of cigarettes smoked per day	Left common carotid artery (Lt. CCA)	Right common carotid artery (Lt. CCA)	P-value
	Mean PI value	Mean PI value	
1-4 Cig/Day (N = 240)	1.22±0.03	1.18±0.06	* < 0.0001
5-9 Cig/Day (N = 144)	1.30±0.07	1.21±0.04	* < 0.0001
10 and more Cig/Day (N = 480)	1.37±0.06	1.25±0.06	* < 0.0001
* P-value and statistical significance: The two-tailed P-value is less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant.			

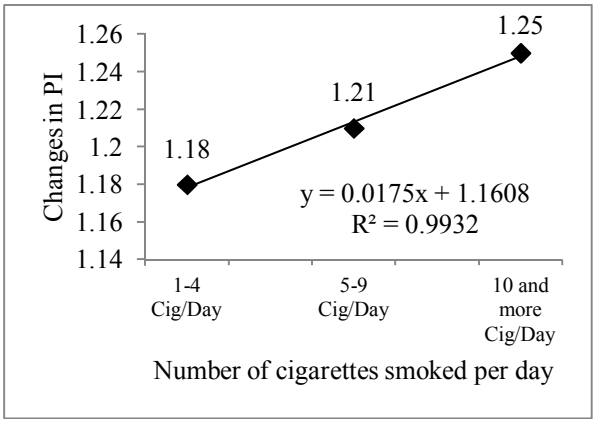

Figure 4. Changes in PI values versus number of cigarettes smoked per day in current Sudanese smoker for the left common carotid artery

4. Discussions

The data reveal that the number of cigarettes smoked per day significantly increase the RI and PI value (Table 1 & Table 2) above the normal range when compared to Sudanese non smokers group, and this finding was supported by Margaret et al., 2005 in which they stated that: "considering the normal range for RI is 0.4 up to 0.7 and for PI is 0.8 up to 1.2". Increases of the RI values above the normal range stated by Margaret et al., 2005 will lead to stiffness of intima media layer such obtained relationship and effect has been mentioned by Edoardo et al., 2007, Jiang et al., 2000 and Jiang et al., 1998 where they stated that: "stiffer arteries have also been shown to be associated with reduced blood flow velocity in diastole, which is reflected by an increase in the RI.

Also Sidhartha et al., 2011 reported that the mean PI and RI in smokers were (1.82±0.22) and (0.77±0.04) were significantly higher than the controls, and this increase in the PI has been suggested to reflect distal vascular resistance due to smoking. This significant alteration of CCA hemodynamic caused by cigarettes smoking can alter cerebral flow velocity and vasomotor reactivity such as finding was approved by Barutcu et al., 2004 in which they stated that "Cigarette smoking significantly altered the CCA hemodynamic in nonsmokers, probably as a consequence of enhanced adrenergic activity."

Duplex scanning in presumably normal persons of different ages was studied by Zbomikova and Lassvik, 1986 in which they stated that: "Systolic and late diastolic velocities were significantly (P-value < 0.05 and 0.001 respectively) faster in the left CCA at low position than in the right, and, conversely, in the right ICA (P-value < 0.05) than in the left. At CCA high position faster diastolic velocities were noted than at CCA low, on both sides." Such results confirmed findings obtained in this study about the significant different in RI and PI between right and left common carotid arteries in non smokers and in current smokers respectively.

In conclusion, the number of cigarettes smoked per day in current Sudanese smokers significantly increases the RI and PI values above their normal ranges, in a positive and proportional linear manner. RI for the Lt. CCA was found to be greater than the right one with a value of (0.03), while the increment of PI for the Lt CCA is usually greater than the right one with a value of (0.08).

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