Effects of Cigarettes Smoking on Common Carotid Arteries Resistance and Pulsatility Indices in Current Sudanese Smokers

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Abstract: The effects of smoking on human health are serious and in many cases, deadly. This study intended to evaluate the effect induced by the number of cigarettes smoked per day in the resistance index (RI) and pulsatility index (PI) of the common carotid arteries (CCAs), in Sudanese current smokers by using ultrasound. A prospective study was performed between May 2011 and May 2013 in a group consists of 900 (mean age of 28 ± 1.1 years) healthy adults who categorized after scanning to 26.7% smoked 1-4 Cigarettes/day, 16% smoked 5-9 Cigarettes/day, 53.3% smoked $\geq$ 10 Cigarettes/day and 4% were nonsmokers. CCAs ultrasound scanning protocol used should meet the standards established by the American Institute of Ultrasound in Medicine (AIUM) to measure RI and PI. Statistical Package for the Social Sciences (SPSS) was used to analyze the results. Significant, linear and positive correlation ($P<0.0001$) noted between the increases in consumption of cigarettes smoked per day and CCAs mean RI and PI, when compare to the nonsmokers participants. Increase the number of cigarettes smoked per day significantly altered the CCAs hemodynamics by increases the RI and PI values.

Keywords: Common carotid arteries (CCAs); pulsatility index (PI); resistance index (RI); ultrasound

1. Introduction

Tobacco smoking is a great health problem because it is a direct cause of high morbidity and mortality all over the world, which could be prevented. Five million persons die from smoking related disease every year in the world, particularly in developing countries as explained by Peto and Lopez (2001), and Mokdad et al. (2004).

The tobacco-related health problems cost the USA $ 167 billion per year (Marshall et al., 2006). People continue to smoke tobacco in spite of all the negative consequences because of nicotine dependence (Campo-Arias, 2006). 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 (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 (Müller et al., 2001).

The RI, a hemodynamic parameter that can be easily determined by Doppler sonography, reflects local wall extensibility and the related vascular resistance. There is a clear correlation between increasing RI values and arteriosclerosis risk factors and clinical out-come (Staub et al., 2006). PI is a reflection of the vascular resistance distal to the examined artery. Therefore, the pathologies of small intracranial perforating arteries may affect the PI of the proximal artery so, may be better than intima media thickness (IMT) for predicting cerebral infarction. Thus, it is conceivable that the PI and RI of the CCA may also be surrogate markers of

atherosclerosis in cerebral arteries and has been confirmed by Fukuhara and Hida (2006) and Lee et al. (2007).

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 (Barutcu et al., 2004). 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, Such results were extracted from two studies done by Vicenzini et al. (2007) and Jiang et al. (2000).

There is evidence that the compliance of both large and medium sized arteries decreases immediately after smoking a cigarette (Stefanadis et al., 1997). It has also been shown that smoking increases cerebral blood flow velocity and reduces vasomotor reactivity for 10 to 30 min as revealed by transcranial Doppler sonography (Silvestrini et al., 1996).

The aim of the present study was to determine the instantaneous effects of cigarettes smoking on CCAs hemodynamics such as waveform parameters (RI and PI) in current Sudanese smokers relative to nonsmoker participants.

2. Material and Methods

In this retrospective cohort study, one radiologist performed CCAs ultrasound and made a measure for the RI and PI of both Rt. and Lt. CCAs in a group of 900 participants between the ages of 18 and 50 years; mean age of 28±1.1 years. Although this research was carried out from 14 to 50 years old and a wide age group, but will match age among smokers with nonsmokers. Participants consisting of (12; 1.33%) nonsmokers females and (888; 98.67%) nonsmokers and current smokers males. Current smokers participants were categorized to 26.7% smoked 1-4 cigarettes per day, 16% smoked 5-9 cigarettes per day and 53.3% smoked $\geq$ 10 cigarettes per day.

Participants were scanned in the Ultrasound Department of the College of Medical Radiological Sciences in Sudan University of Science and Technology (SUST) between May 2011 and May 2013. Prior to samples scanning, a formal approval was obtained from Ethics and Scientific Committee of SUST, Khartoum- Sudan and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and all subsequent revisions. After the nature of the procedure was fully explained, informed consent was

obtained from both the consecutively enrolled participants and the ultrasound department. Data on the characteristics of participants, including number of cigarettes smoked per day, duration of smoking were collected using a standardized questionnaire. Smoking history was coded as non smokers, and current smokers (any amount of tobacco smoked per day).

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 nonsmokers, non hypertensive, non diabetic and non affected with cardiopulmonary disorders so to avoid significant influence in the extra cranial blood velocities. Exclusion criteria were former smokers, thyroid or other known endocrine diseases, cardiovascular diseases (coronary heart disease, arrhythmia, heart failure), vascular brain diseases (stroke or a transient ischemic attack), peripheral obstructive artery disease (claudicatio intermittens, delayed or absent peripheral pulses), documented diabetes mellitus, a family or personal history of severe dyslipidemia (triglyceride or total cholesterol levels of >300 mg/dl), chronic liver disease, known kidney disease or any other chronic severe disease.

Ultrasound for CCAs was performed using a high-resolution General Electric (GE) medical system, logic 5 expert ultrasound machine (Sony Corporation, Japan) equipped with a linear probe of a frequency 7.5-10 MHz, model 2302650 with serial number of 1028924YM7, manufactured date of February 2010 and made by the Yokogawa medical system, Ltd. 7-127 Asahigaoka 4-chome Hino-shi Tokyo, Japan. Printing facility issued through the ultrasound digital graphic printer, 100 V; 1.5 A; and 50/ 60 Hz, with the serial number of 3-619-GBI-01 and made by Sony Corporation- Japan.

CCAs were scanned to determine the RI and PI in the 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. 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. An initial Doppler sweep of the CCA was performed to determine the values of RI and PI using the automatic calculation software. While the Doppler beam angle was maintained $\leq$ 60 degrees at all times, representative values of RI and PI were recorded. All

spectral Doppler measurements of RI and PI of CCAs in nonsmokers and current smokers were obtained with a small sample volume in the center stream of flow or within the area of greatest velocity shift.

For the statistical analysis, Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 15 was used. All results were shown as mean±SD in a form of comparison tables, graphs and correlations. The effects of cigarettes smoking upon Rt. and Lt. CCAs RI and PI were checked by paired t-test. *P*-value terms such as equal and less to be used for significance; *p*-value (*P*<0.0001) was considered to be significant.

3. Results

A population of 900 participants between the ages of 18 and 50 years; mean age of 28±1.1 years had their CCAs studied with duplex ultrasonography (DUS). Participants consisting of (12; 1.33%) nonsmokers females and (888; 98.67%) nonsmokers and current smokers males. Current smokers were categorized to 26.7% smoked 1-4 cigarettes per day, 16% smoked 5-9 cigarettes per day and 53.3% smoked ≥ 10 cigarettes per day.

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 cigarettes per day for the Lt. CCA (Table 1).

Table 1. Shows mean RI±SD in current smokers compare to RI±SD of nonsmokers for Lt. CCA

Left Common Carotid Artery (Lt. CCA)			
No. of cigarettes smoked per day	Current smokers RI mean values±SD	Non smokers RI mean values±SD	*P*-value
1-4 cigarettes/ day	0.74±0.01; (n=237)		*P*<0.0001*
5-9 cigarettes/ day	0.78±0.03; (n=142)	0.65±0.05; (n=36)	*P*<0.0001*
≥ 10 cigarettes/ day	0.81±0.02; (n=473)		*P*<0.0001*
*By conventional criteria, this different are considered to be extremely statistically significant.			

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 cigarettes/day (Table 2).

Such findings between increased cigarettes consumed per day and increased RI CCAs can be fitted in the following equations: [y=0.04x+0.8; (R^2=0.99), y=0.03x+0.7; (R^2=0.96) & *P*<0.0001], where y refers to RI and x refers to number of cigarettes smoked per day for the Lt. and Rt. CCAs respectively. These equations shown a positive and linear correlation (Figure 1 and Figure 2) between increase cigarettes consumed per day and RI of current smokers.

Table 2. Shows mean RI±SD in current smokers compare to RI±SD of nonsmokers for Rt. CCA.

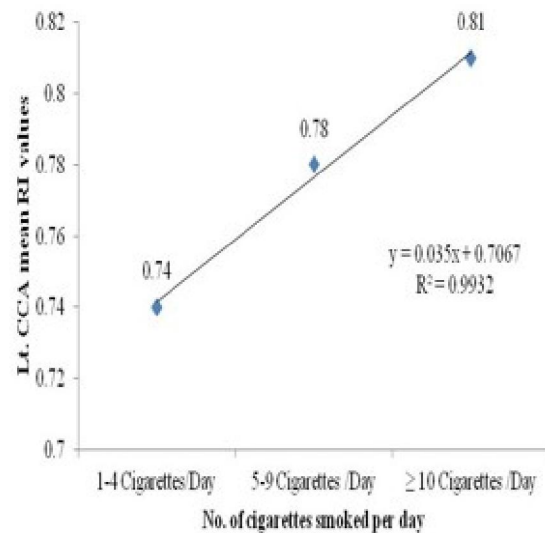| Right Common Carotid Artery (Rt. CCA)			
No. of cigarettes smoked per day	Current smokers RI mean values±SD	Non smokers RI Mean values±SD	*P*-value
1-4 cigarettes/ day	0.71±0.02; (n=237)		*P*<0.0001*
5-9 cigarettes/ day	0.75±0.02; (n=142)	0.63±0.04; (n=36)	*P*<0.0001*
≥ 10 cigarettes/ day	0.77±0.02; (n=473)		*P*<0.0001*
*By conventional criteria, this different are considered to be extremely statistically significant.			

Figure 1. Illustrates the changes in RI mean values versus No. of cigarettes smoked per day in current Sudanese smoker for the Lt. CCA

Considering the alteration of the PI due to number of cigarettes consumed per day in current smokers, also it was found that 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 cigarettes/day for the Lt. CCA (Table 3).
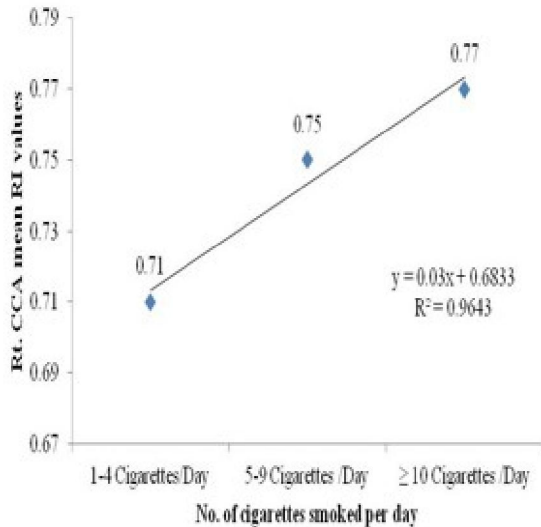

Figure 2. Illustrates the changes in RI mean values versus No. of cigarettes smoked per day in current Sudanese smoker for the Rt. CCA

Table 3. Shows mean PI±SD in current smokers compare to PI±SD of nonsmokers for Lt. CCA

Left Common Carotid Artery (Lt. CCA)			
No. of cigarettes smoked per day	Current smokers PI mean values±SD	Non smokers PI mean values±SD	*P*-value
1-4 cigarettes/ day	1.22±0.03; (n=237)		*P*<0.0001*
5-9 cigarettes/ day	1.30±0.07; (n=142)	1.11±0.11; (n=36)	*P*<0.0001*
≥ 10 cigarettes/ day	1.37±0.06; (n=473)		*P*<0.0001*
*By conventional criteria, this different are considered to be extremely statistically significant.			

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 cigarettes/day (Table 4).

Such results were described by a positive and linear correlation (Figure 3 and Figure 4)

between increased cigarettes consumed per day and PI. Also it could be fitted in the following equations: [y=0.08x+1.5; (R^2=0.99), y=0.04x+1.3; (R^2=0.99) & *P*<0.0001], where y refers to PI and x refers to number of cigarette smoked per day as founded between Lt. and Rt. CCAs respectively.

Table 4. Shows mean PI±SD in current smokers compare to PI±SD of nonsmokers for Rt. CCA

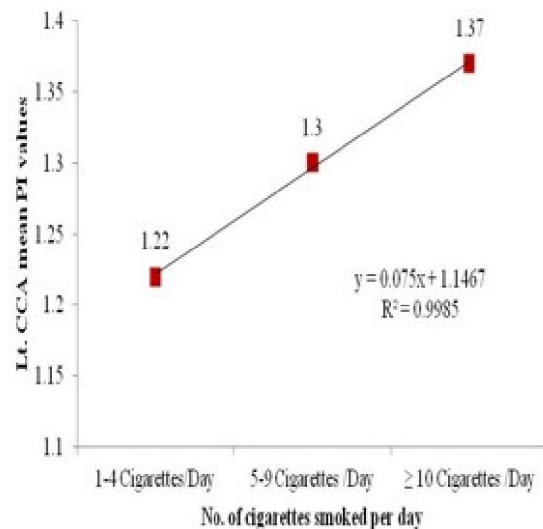| Right Common Carotid Artery (Rt. CCA)			
No. of cigarettes smoked per day	Current smokers PI mean values±SD	Non smokers PI mean values±SD	*P*-value
1-4 cigarettes/ Day	1.18±0.06; (n=237)		*P*<0.0001*
5-9 cigarettes/ Day	1.21±0.04; (n=142)	0.93±0.12; (n=36)	*P*<0.0001*
≥ 10 cigarettes/ Day	1.25±0.06; (n=473)		*P*<0.0001*
*By conventional criteria, this different are considered to be extremely statistically significant.			

Figure 3 Illustrates the changes in PI mean values versus No. of cigarettes smoked per day in current Sudanese smoker for the Lt. CCA

Significant correlations (*P*<0.0001) from the above results were noted between increased tobacco consumption per day and RI and PI values in current Sudanese smokers in compare to nonsmokers participants, which reflects the effective role of ultrasound in the evaluation and attention even to the minor changes that develop in CCAs.
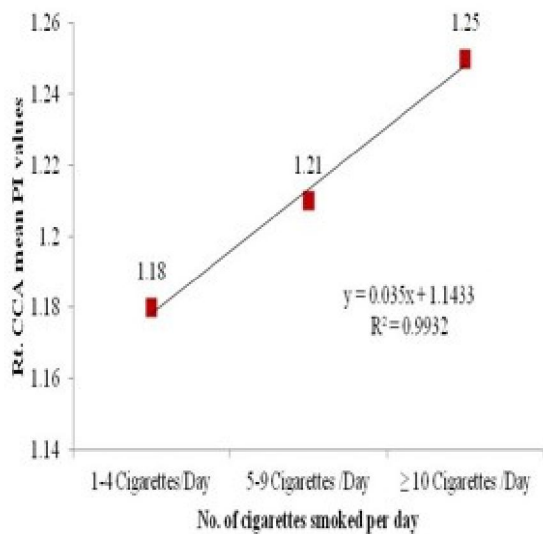
Figure 4 Illustrates the changes in PI mean values versus No. of cigarettes smoked per day in current Sudanese smoker for the Rt. CCA

4. Discussions

The findings of the present study demonstrate that increases the number of cigarettes smoked per day in current Sudanese smokers significantly increases the RI and PI which in turn reflects an increase in blood flow volume inside the CCAs (Tables 1-4).

The development of Duplex ultrasound techniques over the past two decades has led to the current routine application of extracranial and transcranial blood flow velocity measurements for the detection of stenosis, vessel occlusions, or hyperemic status. Commonly used parameters for characterizing the Doppler wave form are the RI and PI. The RI is used to characterize the arterial waveform and both in vitro and in vivo studies which have shown that the RI is related to vascular resistance (Halpern et al., 1998). The PI, which is closely related to the RI, has also been shown in vitro to be related to vascular resistance as approved by Halpern et al., (1998) and Bude and Rubin (1999). We therefore used both indexes as well as flow volumes to investigate the effects of smoking a cigarette on carotid artery hemodynamics.

We found that cigarette smoking significantly altered the CCAs hemodynamics and the mechanism is probably complex. Previous cerebral blood flow study of the acute effects of smoking on cerebral vasculature has shown an increase in cerebral blood flow velocity and PI (Boyajian and Otis, 2000). Other cerebral blood flow study have reported that there was an increased

stiffness index in the carotid artery of middle aged and elderly smokers compared with nonsmokers (Liang et al., 2001). This significant alteration of CCAs hemodynamic caused by cigarette smoking can alter cerebral flow velocity and vasomotor reactivity such findings were approved by Barutcu et al. (2004) where cigarette smoking significantly altered the CCA hemodynamic in nonsmokers, probably as a consequence of enhanced adrenergic activity.

Cigarette smoking is associated with consistent and widespread changes in small arteries and arterioles that rarely occur in nonsmokers and are independent of the atherosclerotic process. It is also consider as a risk factor for the acceleration of atherosclerotic cardiovascular disease and is strongly associated with coronary, cerebral and peripheral vascular disease, such risk factor was determined by Fujiwara (2003) and Itani et al. (2004). Considering the mean RI and PI in current Sudanese smokers were 0.78 ± 0.04 and 1.26 ± 0.22, stiffer arteries have also been shown to be associated with reduced blood flow velocity in diastole, which is reflected by an alteration of RI and PI as emphasized by Sidhartha et al. (2001), Vicenzini et al. (2007) and Jiang et al. (2000).

One of the limitations of this study is that the information obtained cannot be applied to the whole of society, but it sheds light on a specific age group. Also this study adds available evidence about the effect of smoking on human health as studied by using ultrasound. The effects of cigarette smoking according to results of this study are destructive, widespread on human health and considered serious in many cases. These findings could effect on patient care and health policy, possible mechanisms. While future research directions related to this study include the morphological changes that could be caused due to cigarette consumption among current and former smokers in addition to change that occurs in blood flow velocity in such cases.

In conclusion, Increase the number of cigarettes smoked per day significantly altered the CCAs hemodynamics by increases the RI and PI values, probably as a consequence of enhanced adrenergic activity. However, whether these alterations are associated with the adverse cerebrovascular events attributed to the smoking warrants further study.

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