Original Article

Effect of Acute Smoking on Diastolic Function

ME Ghaidari[1], MA Akbarzadeh[1], Sh Yazdani[1], M Asadpour Piranfar[1], A Aslani[2]

[1]Cardiology department, Taleghani hospital, Shaheed Beheshti Medical University, [2]Department of Pacemaker and Electrophysiology, Rajaei Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, Iran

Background: Smoking is a known risk factor of atherosclerosis, endothelial dysfunction, athermanous plaque rupture, unstable coronary syndrome and sudden cardiac death.
Methods: The present study comprised 40 randomly selected healthy male hospital staff without a history of hypertension or cardiac or pulmonary disease. Participants were divided into two groups. The first group included 20 professional smokers (at least 5 pack/year till the time of study) and the second group consisted of 20 non-professional smokers defined as 0.5 pack/ year or less till the time of study. Participants were instructed not to smoke for 6 hours before the study. Patients underwent echocardiography before smoking. The participants were then asked to smoke a whole cigarette. After smoking, echocardiography was repeated within 7 to 15 minutes. Echocardiographic indices of diastolic function (E wave, A wave, Ea, E/A ratio and deceleration time) were measured before and after smoking.
Results: There was no statistically significant difference in the baseline measures in both groups before smoking and also there was no significant difference between measures in the two groups after smoking. The analysis of the pooled data from two groups showed that, smoking resulted in significant increase of heart rate ($P<0.001$). A wave, E wave, Ea, E/A ratio and deceleration time changed significantly after smoking ($P<0.001$, $P=0.027$, $P=0.011$, $P<0.001$ and $P<0.001$ respectively).
Conclusion: Smoking of only a cigarette in both professional and nonprofessional smokers, resulted in the same significant diastolic dysfunction.

Key Words: Smoking, Diastolic Function, Echocardiography

Introduction

In cardiovascular system, smoking is a known risk factor of atherosclerosis, endothelial dysfunction, atheromatous plaque rupture, unstable coronary syndrome and sudden cardiac death (SCD).[1-3] Chronic smokers usually have higher pulse rate and blood pressure at rest compared with nonsmokers.[4] Acute smoking has also been found to cause a transient increase in pulse rate and blood pressure. Acute smoking is associated with a constriction of epicardial coronary arteries, an increase in coronary resistance, a reduction in the coronary flow reserve, and is associated with coronary spasms in patients with coronary artery disease.[5,6] Smoking can cause detectable silent regional myocardial ischemia.[7] After smoking, elevation in the systemic blood pressure occurs as a result of an increase in peripheral resistance. Also an increase in heart rate is a result of direct chronotropic effects and adrenal catecholamine secretion.[8,9] Recent studies investigated the effect of smoking on diastolic dysfunction. Echocardiographic evidence of diastolic dysfunction has been demonstrated during acute cigarette smoking in patients with coronary artery disease. Similar studies in healthy patients have shown conflicting results. Diastolic function is impaired during acute exposure to cigarette smoke but unchanged after exposure to nicotine gum. It is therefore unlikely that nicotine alone is responsible for cigarette-induced acute diastolic dysfunction.[10] Conventional Doppler echocardiography detected a significant change in diastolic function immediately after smoking in healthy participants. The results might be interpreted as a disturbed relaxation of the LV myocardium after smoking.[11]

Correspondence:
M.A. Akbarzadeh
Cardiology Department, Taleghani Hospital, Tehran, Iran
Postal Code: 1985717413
E-mail: akbarzadehali@yahoo.com

Patients and Methods

Study Population

The study included 40 randomly selected healthy male hospital staff without a history of hypertension or cardiac or pulmonary disease. The inclusion criteria were age < 40 years and normal BP (BP<140/90).The exclusion criteria which represented potential causes of diastolic dysfunction, were infiltrative diseases, history or evidence of coronary artery disease and echocardiographic evidence of LV hypertrophy, systolic dysfunction, wall motion abnormalities or pericardial disease or poor echocardiographic view. Cases with potential causes of pseudonormalization were therefore excluded from the study. Also we Excluded patients with restrictive patterns (a considerably taller E wave with a reduced A wave and low Ea velocity), with moderate or severe degrees of valvular regurgitation or stenosis on TTE, as well as those with chronic morbidities, including diabetes mellitus, bronchial asthma, chronic hepatitis or renal failure and cases on chronic medication or evidencing any form of dependency. All participants underwent measurement of blood pressure, electrocardiography and routine cardiovascular examination by the same cardiologist at the beginning of the research. The participants were not on any cardiovascular drugs and had normal blood pressure, electrocardiography and normal cardiovascular and pulmonary examination. All findings were normal in resting echocardiography. Participants categorized into two groups. The first group included 20 habitual smokers defined as having at least 5 pack/year till the time of study, and the second group consisted of 20 non-habitual smokers defined as having 0.5 pack year or less till the time of study.

Study protocol

All participants were instructed not to smoke for 6 hours before the study. Consumption of tea, caffeinated beverages and strenuous physical activity were prohibited 3 hours before the study. A baseline echocardiographic investigation was performed on all participants. They were then asked to smoke a whole cigarette containing 1.1 mg nicotine. Echocardiography was carried within 7 to 15 minutes after smoking. Recording of the underlying echocardiographic parameters were repeated in the same order as before the smoking. The protocol was approved by the Bioethical Committee of Shaheed Beheshti University of Medical Sciences.

Echocardiography

A ViVid 3 system equipped with tissue Doppler imaging (DTI) technology was used. Transducer frequency was 2.5 MHz. LV diastolic function was assessed using transmitral flow parameters. In the 4 chamber view, mitral inflow velocity was assessed by positioning the pulse Doppler at the tip of mitral valve. Peak early diastolic flow (E wave), peak late diastolic flow (A wave), deceleration time of E wave (DT) and E/A ratio were measured. In the apical 4-chamber view, the DTI cursor was placed near the septal and lateral borders of the mitral annulus, while the mitral annulus moved along the sample volume line, and early diastolic velocity was measured (Ea). Normal values for persons < 40 years old and based on previously reported data were as follows: E/A > 1 and DT < 180 ms. Impaired relaxation was defined by the diminution of E/A and prolongation of DT. Recordings and calculation of the different cardiac chambers were performed according to the current recommendations of Echocardiography.[12]

Statistical Analysis

Results are expressed as the mean±SD. Data analysis were performed using SPSS statistical

Table 1: ECG and echocardiographic findings obtained separately before and after smoking in habitual and non-habitual smokers

	Non-habitual smokers		Habitual smokers	
	Before smoking	After smoking	Before smoking	After smoking
Heart rate (bpm)	68 ± 5	77 ± 6	67 ± 5	77 ± 6
A(m/s)	0.60 ± 0.14	0.82 ± 0.25	0.61 ± 0.14	0.87 ± 0.25
E(m/s)	0.88 ± 0.19	0.89 ± 0.20	0.86 ± 0.12	0.90 ± 0.15
E/A	1.48 ± 0.22	1.14 ± 0.29	1.47 ± 0.37	1.11 ± 0.34
DT(ms)	190 ± 35	211 ± 31	185 ± 33	208 ± 38
Ea(cm/s)	12.15 ± 0.93	11.80 ± 0.95	11.05 ± 1.05	11.80 ± 1.0

Values are mean±SD; E = early diastolic transmitral velocity; A = late diastolic transmitral velocity; DT = deceleration time of the early diastolic transmitral velocity; Ea = early diastolic mitral annulus velocity

Table 2. ECG and echocardiographic findings obtained before and after smoking

	Before smoking	After smoking	P value
Heart rate (bpm)	68±5	77±6	<0.001
A(m/s)	0.61±0.14	0.84±0.25	<0.001
E(m/s)	0.87±0.16	0.89±0.17	0.027
E/A	1.47±0.3	1.13±0.31	<0.001
DT(ms)	187±34	209±34	<0.001
Ea(cm/s)	12.10±0.98	11.80±0.97	<0.001

Values are mean±SD; E = early diastolic transmitral velocity; A = late diastolic transmitral velocity; DT = deceleration time of the early diastolic transmitral velocity; Ea = early diastolic mitral annular velocity

software (version 17.0). Comparisons of the results were made using the paired t test, Mann-Whitney, and Wilcoxon signed ranks tests. Pearson correlation coefficients were calculated to determine the strength of linear relationships between variables. A p value < 0.05 was considered statistically significant for all tests.

Results

The mean ages of habitual and non-habitual smokers were 31.6±4.8 and 31.0±5.6 respectively. Mean baseline and intervention measures (heart rate, A wave, E wave, Ea, E/A ratio, DT) in the aforementioned smokers are summarized in Table 1. There were no statistically significant differences in the baseline values between either group and also between those after smoking.

Pooled Data Analysis

As previously mentioned, there was no significant difference between the indices of the two groups; consequently we pooled the data from both habitual and non-habitual smokers to evaluate the effect of smoking on our variables. Mean heart rate before and after smoking were 68 and 77 respectively. Difference between heart rate before and after smoking was 9 which is statistically significant. (P<0.001) Mean A wave before and after smoking were 0.61 and 0.84 respectively. Difference between A wave before and after smoking was 0.24 which was statistically significant (P<0.001). Respective mean E wave before and after smoking were 0.87 and 0.89. Difference between E wave before and after smoking was 0.03 which was statistically significant (P=0.027). Mean E/A ratio before and after smoking were 1.47 and 1.13. Difference between E/A ratio before and after smoking was -0.35 which is statistically significant (P<0.001). Mean DT before and after smoking were 187 and 209. A significant difference of 22 was found between DT ratio before and after smoking (P<0.001, Table 2) Mean Ea wave before and after smoking were 12.10 and 11.80 respectively. Difference between Ea wave before and after smoking was 0.30 which was statistically significant. (P<0.011) (table 2) Difference of HR before and after smoking was not significant in linear correlation with E, A waves, DT and E/A ratio difference. (R=-0.02, R=0.1, R=-0.17, R=-0.04 respectively; All P values > 0.2), (Fig. 1)

Discussion

Smoking results in inhalation of nicotine, tar products, nitric oxide derived free radicals, carbon monoxide, and numerous other chemicals.[13,14] Cigarette smoking is one of the major risk factors for cardiovascular disease. Abnormalities of LV diastolic function were detected in smokers with coronary artery disease.[15,16] In our research, there was a significant increase in A and E wave amplitude and DT after smoking. E/A ratio and Ea significantly decreased after smoking. These findings in accordance with previous researches show that smoking acutely impairs the diastolic function of the heart.[10,11] As mentioned, in habitual and non-habitual smokers there was no significant difference between variables before smoking. After smoking again there was no significant difference between variables in the two groups. Smoking had significant effect on all variables. The acute effects of smoking on healthy participants significantly changed LV diastolic function assessed by conventional transmitral flow velocities and mitral annular velocities evaluated by DTI. The changes in transmitral flow velocities remained unaltered in the following 30 minutes. The changes in LV diastolic function were similar in both smokers and non-smokers. The mechanism of smoking-related changes in diastolic function is probably complex and cannot be explained only by the increase in heart rate or changes in loading conditions.[11] Similar to previous research, we found that the extent of HR increase after smoking had no significant correlation with changes in echocardiographic parameters which confirmed the independence of diastolic dysfunction and HR. In accordance with previous researches, smoking acutely increased the heart rate, E and A wave amplitude, and DT. It decreased E/A ratio and Ea. In summary, smoking impaired the diastolic function of the heart. After smoking of only a cigarette, we found significant impairment in diastolic function. Apart from cumulative effect of smoking on cardiovascular system, it should be considered that

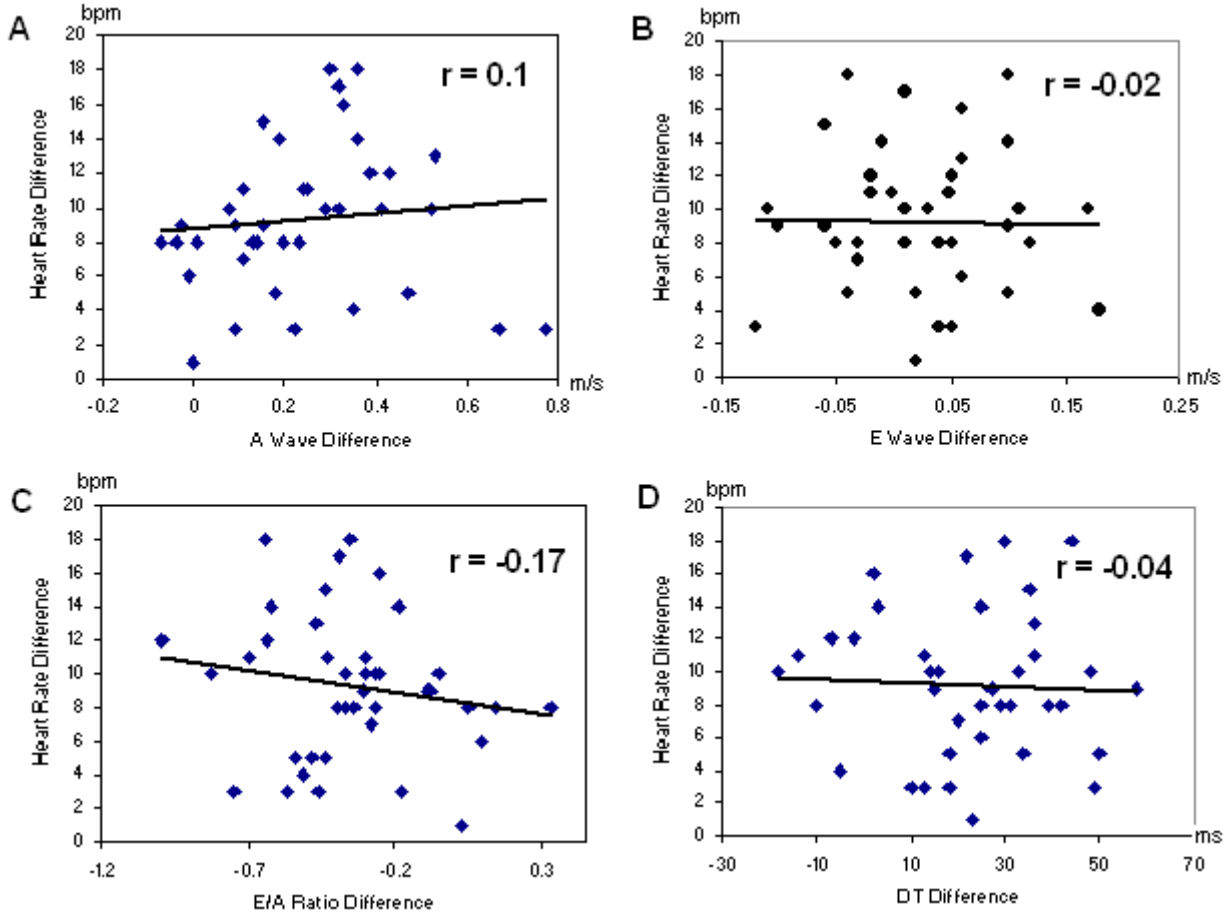

Figure 1. Scatter plots of correlation between difference of heart rates before and after smoking and (A) difference of A wave, (B) difference of E wave, (C) difference of E/A ratio, and (D) difference of deceleration times before and after smoking. DT=deceleration time

a single cigarette induces the potential of sudden cardiac death. Participants in our research were all smokers. Interesting finding was worsening of diastolic function in both groups. In other words there was no cardiac adaptation to cigarette smoking even in habitual smokers. Patients, who routinely smoked, after exposure to a single cigarette, again had worsening of diastolic function; consequently there was no cardiac tolerance to smoking.

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