



## RESEARCH ARTICLE

**REVISED** Acute effects of cigarette smoke on Endothelial Nitric Oxide synthase, vascular cell adhesion molecule 1 and aortic intima media thickness [version 4; peer review: 2 approved]Meity Ardiana<sup>1</sup>, Anwar Santoso <sup>2</sup>, Hanesty Oky Hermawan<sup>3</sup>, Ricardo Adrian Nugraha <sup>1</sup>, Budi Susetyo Pikir <sup>1</sup>, I. Gde Rurus Suryawan<sup>1</sup><sup>1</sup>Department of Cardiology and Vascular Medicine, Faculty of Medicine Universitas Airlangga - Dr. Soetomo General Academic Hospital, Surabaya, East Java, 60272, Indonesia<sup>2</sup>Department of Cardiology and Vascular Medicine, Faculty of Medicine University of Indonesia - National Cardiovascular Centre Harapan Kita Hospital, Jakarta, DKI Jakarta, 11420, Indonesia<sup>3</sup>Department of Biomedicine, Faculty of Medicine, Universitas Brawijaya, Malang, East Java, 65145, Indonesia

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**Abstract**

**Background.** Cigarette smoking could induce endothelial dysfunction and the increase of circulating markers of inflammation by activation of monocytes. This can lead to increased intima media thickness (IMT) of entire blood vessels and result in acceleration of the atherosclerosis process. However, to our knowledge, little is known about the role of cigarette smoking in this atherosclerotic inflammatory process.

The aim of this study is to explore the link between cigarette smoking and its effect on endothelial nitric oxide synthase (e-NOS) and vascular cell adhesion molecule 1 (VCAM-1).

**Methods.** An experimental study with a post-test only controlled group design was used. We used 18 Wistar rats (*Rattus norvegicus*) randomly subdivided into two groups: group K (-) were not exposed to tobacco smoke, whereas group K (+) were exposed to smoke equivalent of more than 40 cigarettes for 28 days daily. After 28 days, samples were analyzed for e-NOS, VCAM-1 and aortic IMT.

**Results.** Our results indicate that tobacco smoke can enhance the expression of VCAM-1 on rat cardiac vascular endothelial cells,

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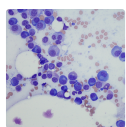
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resulting in a decreased expression of e-NOS level and increase of aortic IMT. Linear regression model found that eNOS level negatively correlated with aortic IMT ( $r^2 = 0.584$ ,  $\beta = -0.764$ ,  $p < 0.001$ ), whereas VCAM-1 expression did not correlate with aortic IMT ( $r^2 = 0.197$ ,  $p = 0.065$ ).

**Conclusion.** Low e-NOS level and high VCAM-1 level observed after cigarette smoke exposure which may increase aortic IMT.

### Keywords

aortic tissue, atherosclerosis, cigarette smoking, endothelial-NOS, intima media thickness, VCAM-1



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Few minor changes regarding the animal protocol. For anaesthesia, our standard operating procedures used the combination of isoflurane and ether to make sure that nitric oxide levels weren't altered significantly. For euthanasia, our standard operating procedures used intraperitoneal injection of sodium pentobarbital 200 mg/kg BW. Our procedures were approved by the animal research ethic committee in compliance with IACUC policy on the use of laboratory animal protocol. Study was carried out in strict accordance with internationally-accepted standards of the Guide for the Care and Use of Laboratory Animals of the National Institute of Health and in line with the 'Animal Research: Reporting in vivo Experiments' (ARRIVE) Guidelines.

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**Abbreviations**

ANOVA: analysis of variance  
 BH4: Tetrahydrobiopterin  
 ELISA: enzyme-linked immunosorbent assay  
 e-NOS: endothelial Nitric Oxide Synthase  
 H<sub>2</sub>O<sub>2</sub>: Hydrogen peroxide  
 IACUC: Institutional Animal Care and Use Committee  
 IHC: Immunohistochemistry  
 IMT: Intima-media thickness  
 IRS: Immunoreactivity Scoring System  
 LSAB: Labeled Streptavidin Avidin Biotin  
 NIH: National Institutes of Health  
 PCR: Polymerase Chain Reaction  
 SA-HRP: Streptavidin-Horse Radish Peroxidase  
 SD: standard deviation  
 SEM: standard error of the mean  
 SPSS: Statistical Package for the Social Sciences  
 TGF: Transforming Growth Factor  
 VCAM-1: Vascular Cell Adhesion Molecule-1

**Clinical significance**

Increasing evidence suggests that cigarette smoke exposure could induce VCAM-1 (enhance pro-atherogenic property), and a decrease of e-NOS level (anti-atherogenic depletion). Thus, cigarette smoke may represent a significant risk factor for atherosclerosis by increasing aortic IMT. This evidence is discussed herein.

**Introduction**

Cigarette smoking is the most important modifiable risk factor for developing atherosclerosis including cerebrovascular accident, peripheral arterial disease, and coronary heart disease.<sup>1</sup> In a meta-analysis from 55 eligible studies (43 cross-sectional, ten cohort and two case-control studies), the odds ratio (ORs) of peripheral arterial disease (PAD) associated with cigarette exposure was 2.71 (95% CI: 2.28-3.21;  $p < 0.001$ ).<sup>2</sup> In a meta-analysis from 75 cohorts (2.4 million participants) that adjusted for cardiovascular risk factors other than coronary heart disease, multiple-adjusted pooled ORs of smoking versus non-smoking was 1.25 (95% CI: 1.12-1.39,  $p < 0.0001$ ).<sup>3</sup>

Even though epidemiologic studies clearly stated the negative effect of cigarette smoke for cardiovascular diseases, the underlying mechanisms have yet to be confirmed. The pathogenesis and pathophysiologic mechanisms by which exposure to cigarette smoke could accelerate atherosclerosis cardiovascular disease are complex and challenging, due to more than 5,000 different mixtures of chemicals inside the cigarette smoke itself.<sup>4</sup> Several potential contributing factors to atherogenesis inside cigarette smoke are (1) polycyclic aromatic hydrocarbons, (2) oxidizing agents, (3) particulate matter, and (4) nicotine.<sup>5</sup>

One of the most important factor contributing for pro-atherogenic is nicotine, which has commonly been studied using cigarette smoke condensates.<sup>6</sup> In addition to its role as the habituating agent in tobacco, nicotine also accelerates atherosclerosis cardiovascular disease. There are several potential mechanisms of the pro-atherogenic effects of nicotine: (1) inducing endothelial dysfunction, (2) modifying lipid profile, (3) increasing inflammatory response, (4) inducing the release of catecholamines, which may increase heart rate and blood pressure, (5) increases platelet aggregability, (6) direct actions on the cellular elements participating in plaque formation, and (7) induces the proliferation and migration of

vascular smooth muscle cells into the intima, mediated in part by TGF $\beta$ .<sup>7</sup> These pathomechanisms of nicotine could lead to the increase of intima media thickness of the entire blood vessel, leading to the greater risk of developing atherosclerosis.<sup>8</sup>

To learn more about the pathomechanisms of the diseased endothelium, we need to study all the oxidizing, inflammatory, and thrombotic molecules which are not in an equilibrium state. In the model of atherosclerosis cardiovascular diseases, a pathological imbalance between prothrombotic and antithrombotic state, prooxidant and antioxidant state, and pro-inflammatory and anti-inflammatory state are observed.<sup>9</sup> Considerable evidence supports the importance of inflammation and hypercoagulability to promote atherogenic state.<sup>10</sup> There is abundant literature concerning the role of biomarkers of pathological imbalance in atherosclerosis.

Cell adhesion molecules are the essential pro-inflammatory and pro-atherogenic proteins that represent a hallmark of endothelial dysfunction and atherosclerosis. P-selectin, vascular cell adhesion molecule (VCAM)-1, intercellular adhesion molecule (ICAM)-1, and PECAM-1 were demonstrated to be involved in the formation of atherosclerosis plaque.<sup>11</sup> Beyond the other cell adhesion molecules, VCAM-1 plays as an important factor in neointima proliferation following nicotine-induced arterial injury, an area of research important for atherosclerosis cardiovascular diseases.<sup>12</sup> In the nicotine-induced arterial injury model, VCAM-1 expression is highly induced in the proliferation and migration of neointimal smooth muscle cells.<sup>13</sup>

Previous studies showed that upregulation of endothelial nitric oxide synthase (e-NOS) expression and activity has its important role in the protection of endothelium.<sup>14–16</sup> e-NOS could stimulate endothelium-dependent relaxation and protect against the development of VCAM-1-induced endothelial dysfunction.<sup>17</sup> However, to our knowledge, little is known about the role of cigarette smoke in this atherosclerotic inflammatory process. This study aims to explore the link between cigarette smoke on e-NOS and VCAM-1, which results in the development of aortic intima media thickness (IMT) of the experimental animals.

## Methods

### Ethics approval

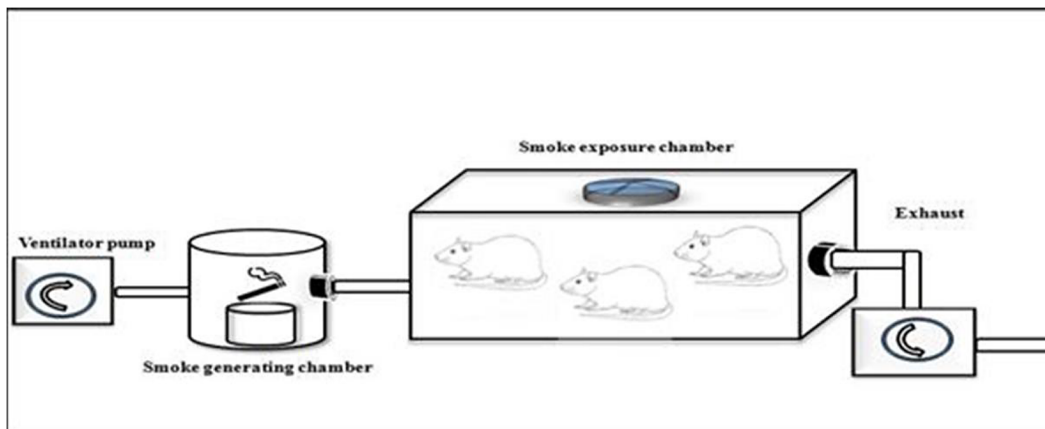
This article was reported in line with the ARRIVE guidelines. Animal experimental study were conducted under the approval of the Institutional Animal Care and Use Committee of Universitas Airlangga (UNAIR), Surabaya, Indonesia (animal approval no: 2.KE.184.10.2019) under the name of Meity Ardiana as the Principal Investigator. All efforts were made to ameliorate any suffering of animals through using anaesthetic to euthanize the rats at the end of the experimental procedure.

### Animals

The present study used 18 male Wistar rats (*Rattus norvegicus*), eight weeks of age (average body weight 150–200 grams). The rats were adapted to their environment for seven days before the experiment start. They were nurtured at the Animal House at Faculty of Veterinary Medicine, Universitas Airlangga in polycarbonate cage, which measured 480 mm  $\times$  265 mm  $\times$  210 mm. Each cage had wood shavings on the floor, and contained three or four animals, which were marked for each subgroup. The rats were housed in microisolator cages and maintained in a constant room temperature ranging from 22°C to 25°C, with a 12-h light/12-h dark cycle, under artificially controlled ventilation, with a relative humidity ranging from 50% to 60%. The rats were fed a standard balanced rodent diet and water was provided *ad libitum*. The rats were chosen for each group by simple random sampling. For anaesthesia, our standard operating procedures used the combination of isoflurane and ether to make sure that nitric oxide levels weren't altered significantly. For euthanasia, our standard operating procedures used intraperitoneal injection of sodium pentobarbital 200 mg/kg BW. Our procedures were approved by the animal research ethic committee in compliance with IACUC policy on the use of laboratory animal protocol. Study was carried out in strict accordance with internationally-accepted standards of the Guide for the Care and Use of Laboratory Animals of the National Institute of Health and in line with the 'Animal Research: Reporting in vivo Experiments' (ARRIVE) Guidelines. After that rats were euthanized, we collected the aortic tissue to obtain aortic intimal media tissue including isolation of rat aortic artery, removal of the fat tissue and branches, separation of longitudinal cutting edge, and peeling off the adventitia.

### Experimental design and groups

The present study design was a randomized post-test only controlled group design using quantitative method. We extracted 18 male Wistar rats, randomized and then allocated them into two groups. Group 1 were not exposed to tobacco smoke, whilst group 2 were given 40 or more cigarette smokes daily for 28 days as seen in [Figure 1](#). Each cigarette smoke dose contains 39 mg of tar and 2.3 mg of nicotine. The enrolled animals were analysed for vascular cell adhesion molecule 1 (VCAM-1), endothelial nitric oxide synthase (e-NOS), and aortic intima media thickness (IMT) after 28 days of consecutive experiments.



**Figure 1. Illustration of how to exposed rats in the K(+) group to the cigarette smokes.** Exposure to tobacco smokes were done using side stream technique from peristaltic pump, smoke producer chamber, and inhalation chamber, connected by modified silicon tube.

#### Aortic Intima Media Thickness (IMT)

Thoracic aortas were prepared as distal aortic arch by cutting from the left ventricle of each rat. The post mortem samples of descending thoracic aortas obtained by dissection were fixed in 10% formaldehyde, embedded in paraffin, and sectioned at a thickness of 6  $\mu\text{m}$ . The mounted tissues were stained using hematoxylin and eosin. Aortic intima media thickness was measured via Leica DMD 108 (Leica Microsystems GmbH, Wetzlar, Germany). Each sample was measured as “micrometer ( $\mu\text{m}$ )” from six different locations of the vessel wall. Arithmetic averages of these six measurements are presented in the results section.

#### Vascular cell adhesion molecule 1 (VCAM-1)

We used streptavidin-biotin method which uses a biotin conjugated secondary antibody to link the primary antibody to a streptavidin-peroxidase complex for Immunohistochemistry (IHC) staining. The labeled streptavidin-biotin (LSAB) method were utilized to measure expression of VCAM-1 in the aortic tissue of the rats. Firstly, the aortic tissue were prepared and preserved through deparaffinize models following fixation. Secondly, the aortic tissue was rehydrated by immersing the slides through the xylene (three washes, five minutes each), 100% ethanol (two washes, 10 minutes each), 95% ethanol (two washes, 10 minutes each), 70% ethanol (two washes, 10 minutes each), 50% ethanol (two washes, 10 minutes each), and deionized water (two washes, five minutes each). Thirdly, the aortic tissue was washed using Phosphat Buffer Sollution and then dipped into 3% of  $\text{H}_2\text{O}_2$  solution withing 20 minutes. Fourthly, we added 1% of Bovine Serum Albumin to the Phosphat Buffer Sollution and then incubated them within 30 minutes in the room temperature. Fifthly, primary antibody anti-VCAM-1 (Santacruz biotech SC-13160) was added and incubated within 30 minutes, then washed again using Phosphat Buffer Sollution. Secondary antibody (Anti-Rat IgG Biotin Labelled) was added and incubated within 30 minutes in the room temperature, then washed using Phosphat Buffer Sollution. Sixthly, SA-HRP (Streptavidin-Hoseradish Peroxidase) complex was added and incubated within 10 minutes in the room temperature and then washed using Phosphat Buffer Sollution. Seventhly, Chromogen DAB (3,3-diaminobenzidine tetrahydrochloride) was added and incubated within 10 minutes in the room temperature, and then washed using Phosphat Buffer Sollution and sterile water. Finally, counterstain Hematoxylin-Eosin was added into the object glasses and expressions of VCAM-1 were measured and analyzed by a biological microscope (400 $\times$  magnification) from tunica intima and tunica media of the aortic tissue. Semiquantitative measurements of VCAM-1 were done by immunoreactivity scoring system (Table 1).

#### Endothelial Nitric Oxide Synthase (e-NOS)

All samples were assessed by direct-sandwich enzyme-linked immunosorbent assay (ELISA) under the manufacture's system (R&D System Europe Ltd, Abingdon, UK) according to the National Institute for Biological Standards and

**Table 1. Immunoreactivity Scoring System (IRS).**

Score for percentage of cells staining	Score for intensity of staining
0 = no stained cells	0 = no reaction
1 = <10% cells are stained	1 = mild intensity of staining
2 = 10-50% cells are stained	2 = moderate intensity of staining
3 = 51-80% cells are stained	3 = heavy intensity of staining
4 = >80% cells are stained	

Controls (Blanche Lane, South Mimms, Potters Bars, Hertfordshire, UK) protocol. We used eNOS kit from the elabscience (catalogue number: E-EL-R0367). Briefly, samples from the aortic tissue were collected and stored at  $-70^{\circ}\text{C}$  ( $-94^{\circ}\text{F}$ ) at the Institute of Tropical Diseases Universitas Airlangga (UNAIR). Samples were homogenized into solution. Then,  $100\ \mu\text{L}$  of the solution was mixed with the well-coated primary antibody for e-NOS. Overnight incubation was done in a temperature of  $4^{\circ}\text{C}$  with a shaking machine for minimum 24 hours. Wash Buffer (20x) were diluted to 1x working solution with D.I. water prior to ELISA wash procedures. After that,  $50\ \mu\text{L}$  of the stop solution was added into each sample. A minimum value of  $0.01\ \text{pg/mL}$  were assigned for below the limit of detection.

**Statistical analysis**

All measurements were performed and replicated at least three times. Results were presented as (1) means  $\pm$  standard deviations (SD) for normally distributed data; (2) medians with lower and upper value for abnormally distributed data. The assumption of the normality for the complete data was assessed by Shapiro-Wilk test. Test of homogeneity of variances was assessed by Levene Statistics. Statistical significance were examined by Independent T-test, Mann-Whitney U test, and logistic regression using SPSS version 17.0 for Microsoft (IBM corp, Chicago, USA).

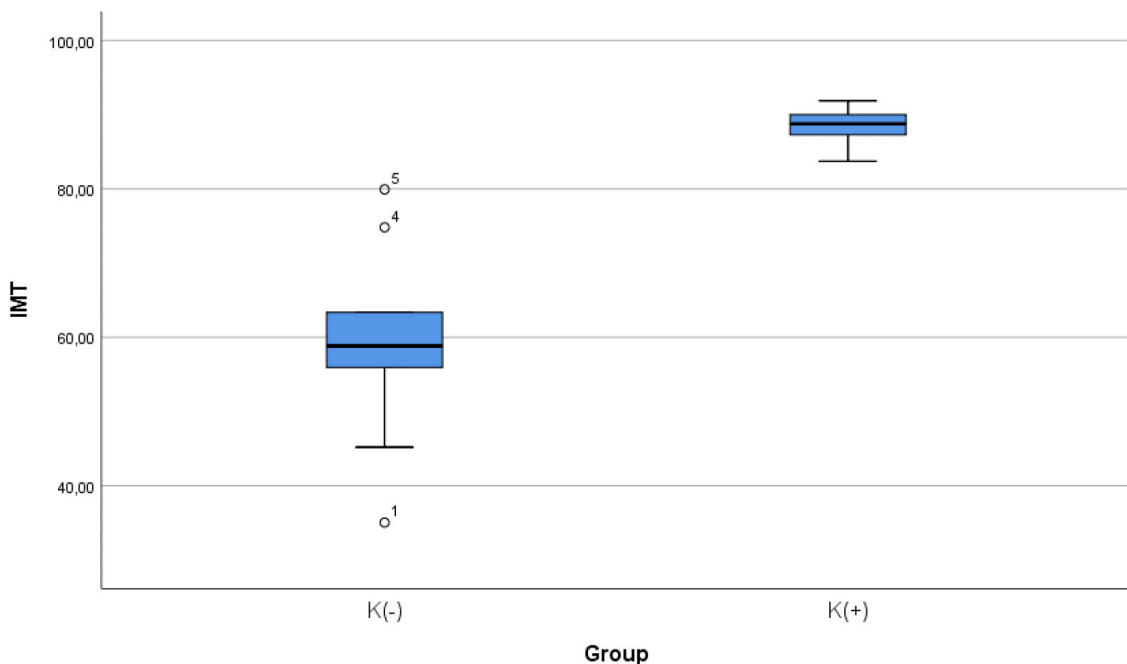
**Results**

**Comparison of IMT level between smoke and non-smoke groups**

After 28 days following experiments, there was a significance difference in IMT level between both groups ( $p < 0.001$ ). The mean of the aortic IMT in all animals were  $73.68 \pm 17.86\ \mu\text{m}$ . The mean of the aortic IMT in the cigarette smoke group was  $88.39 \pm 2.51\ \mu\text{m}$ . Thean of the aortic IMT in the control group was  $58.98 \pm 13.61\ \mu\text{m}$ . Table 2 presents the impact of the exposure of smoke from 40 cigarettes daily on the aortic IMT profile of the experimental animals. The comparative analysis of IMT parameters demonstrated that there were statistically significant differences between the groups ( $p < 0.001$ ; Mann-Whitney’s test) (Figure 2).

**Table 2. Statistic table IMT between K(+) group which is exposed to the daily 40 cigarrete smokes and K(-) group as the control group.**

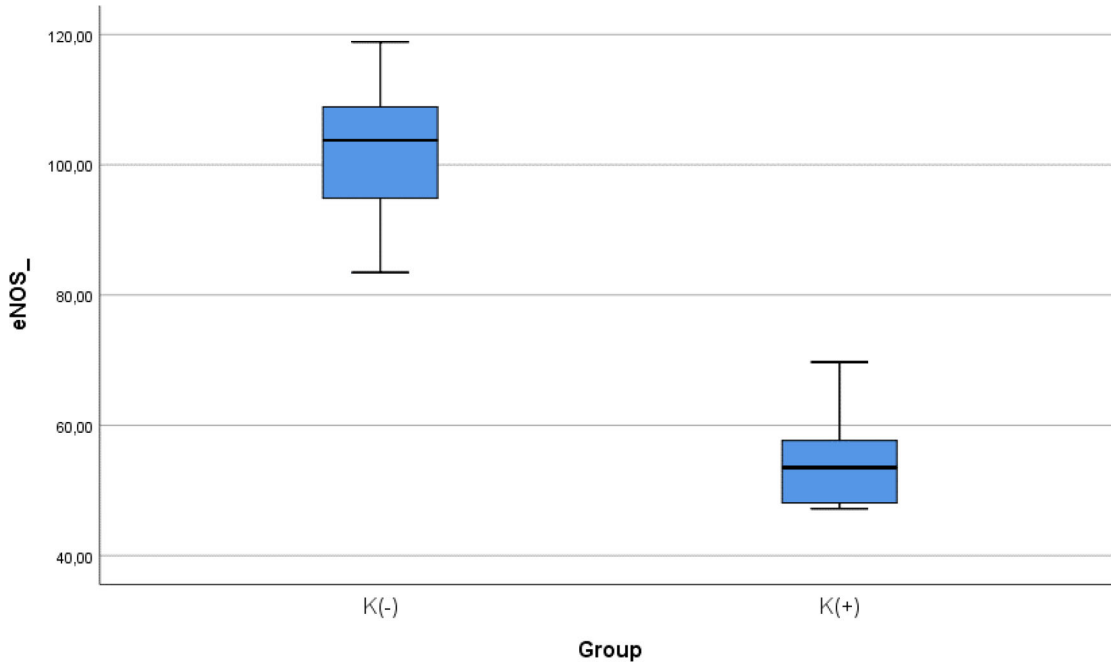
Group statistics						Sig (Mann-Whitney)
	Group	N	Mean	Std. Deviation	Std. Error Mean	
IMT	K(-)	9	58.9800	13.61075	4.53692	<0.001
	K(+)	9	88.3911	2.51766	0.83922	



**Figure 2. Median with lower and upper value of IMT between K(+) group which is exposed to the daily 40 cigarrete smokes and K(-) group as the control group.**

**Table 3.** Statistic table e-NOS between K(+) group which is exposed to the cigarette smokes and K(-) group as the control group.

Group statistics						
	Group	N	Mean	Std. Deviation	Std. Error Mean	Sig (Mann-Whitney)
eNOS_	K(-)	9	101.2233	11.80266	3.93422	<0.001
	K(+)	9	54.8267	8.30862	2.76954	



**Figure 3.** Median with lower and upper value of e-NOS between K(+) group which is exposed to the cigarette smokes and K(-) group as the control group.

**Comparison of e-NOS level between smoke and non-smoke groups**

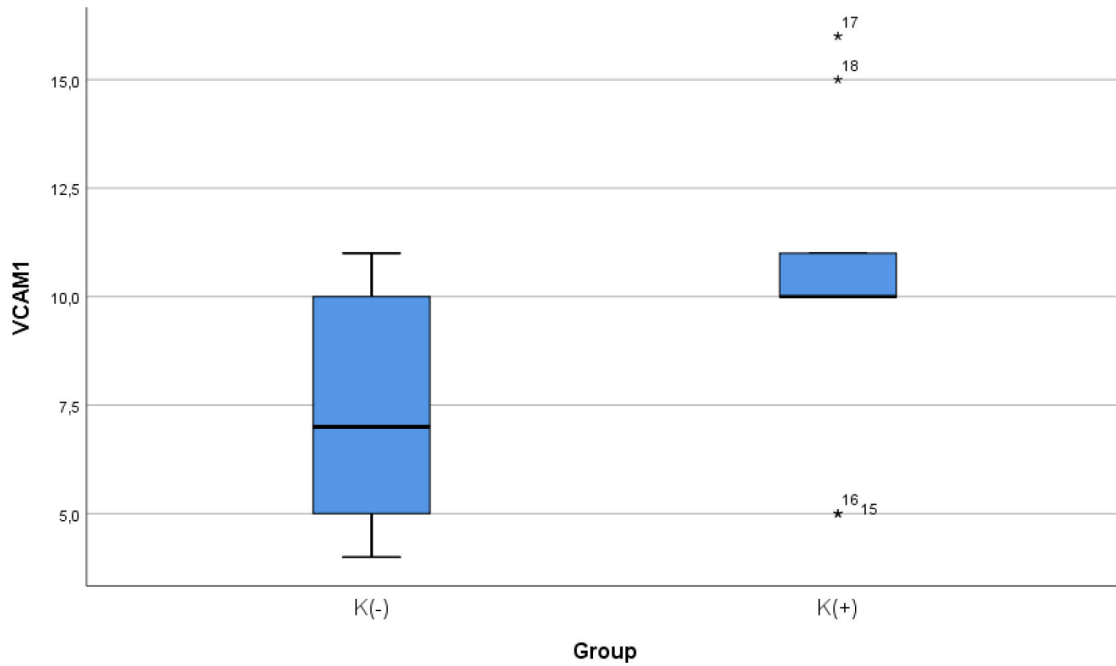
After 28 days following experiments, there was a significance difference of e-NOS level between both groups ( $p < 0.001$ ). The mean of the e-NOS in all subjects was  $78.02 \pm 25.84$  pg/ml. The mean of the e-NOS level in the cigarette smoke group was  $101.22 \pm 11.8$  pg/ml. The mean of the e-NOS level in the control group was  $54.83 \pm 8.3$  pg/ml. **Table 3** presents the impact of the exposure of daily smoke from the equivalent of 40 cigarettes on the e-NOS profile of the experimental animals. The comparative analysis of e-NOS parameters demonstrated that there were statistically significant differences between the groups ( $p < 0.001$ ; Mann-Whitney’s test) (**Figure 3**).

**Comparison of VCAM-1 expression between smoke and non-smoke**

After 28 days following experiments, the mean of the VCAM-1 expression in all animals was  $9.00 \pm 3.51$ . The mean of the VCAM-1 level in the cigarette smoke group was  $10.33 \pm 2.9$ . The mean of the VCAM-1 level in the control group was  $7.67 \pm 3.7$ . **Table 4** presents the impact of the exposure of daily 40 or more cigarette smokes on the VCAM-1

**Table 4.** Statistic table of VCAM-1 between K(+) group which is exposed to the cigarette smokes and K(-) group as the control group.

Group statistics						
	Group	N	Mean	Std. Deviation	Std. Error Mean	Sig (Independent T)
VCAM1	K(-)	9	7.67	2.915	0.972	0.112
	K(+)	9	10.33	3.742	1.247	

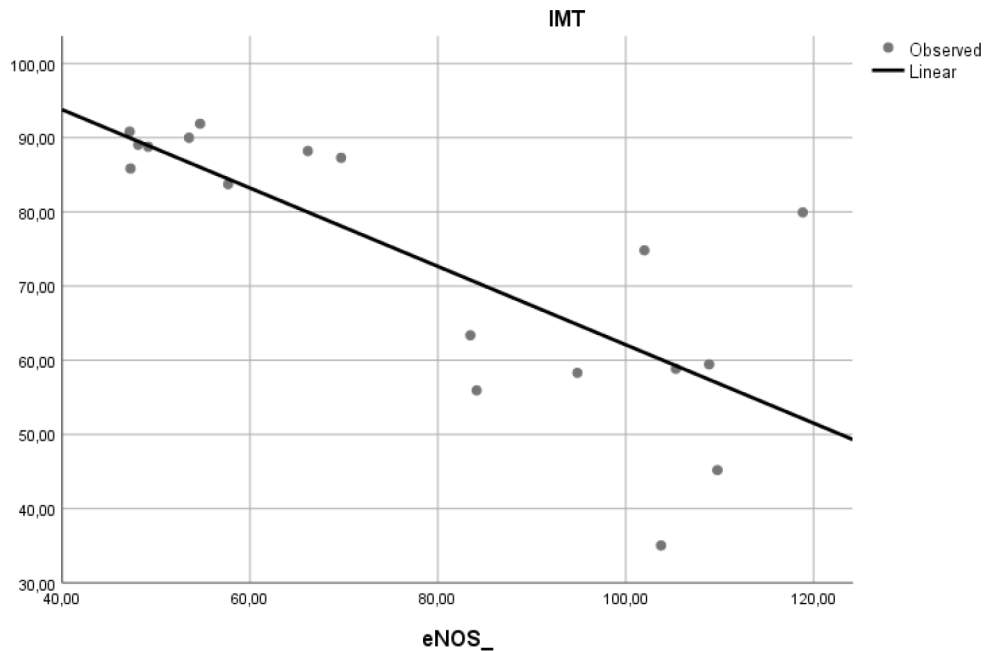


**Figure 4.** Median with lower and upper value of VCAM-1 between K(+) group which is exposed to the cigarette smokes and K(-) group as the control group.

expression of the experimental animals. The comparative analysis of VCAM-1 expression demonstrated that there were no statistically significant differences between the groups ( $p = 0.112$ ; independent t test) (Figure 4).

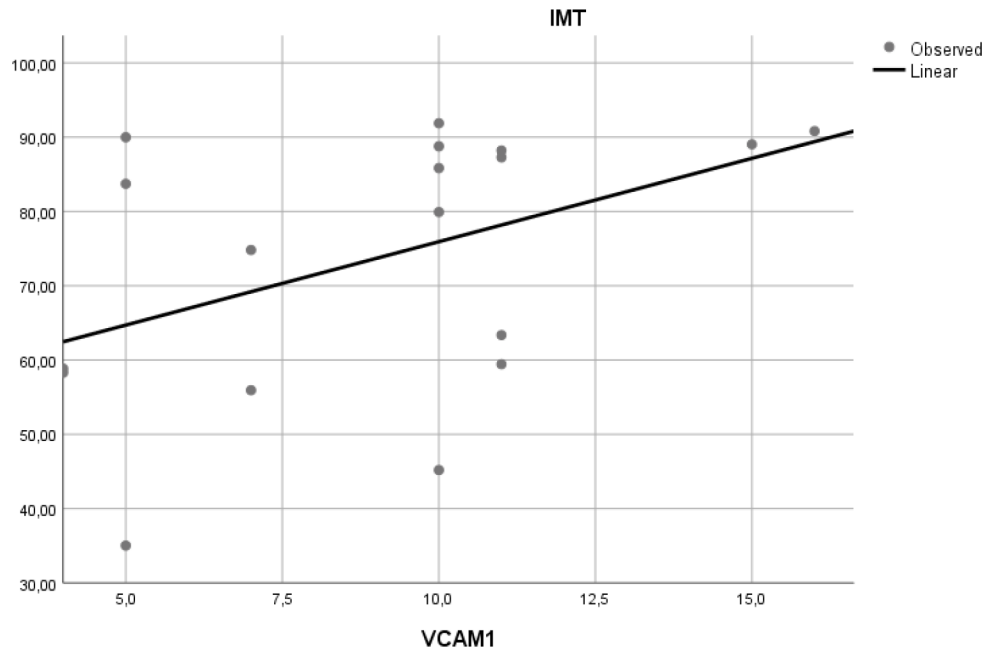
**Correlation of e-NOS level and aortic IMT**

To determine if the level of e-NOS is correlated with atherosclerosis, we measured e-NOS as a parameter of endothelial cell function in aortic tissue of Wistar rats. Linear regression model found that e-NOS was negatively correlated with aortic IMT in our experimental study ( $r^2 = 0.584$ ,  $\beta = -0.764$ ,  $p < 0.001$ ) (Figure 5).



**Figure 5.** Relation between e-NOS level and aortic IMT in experimental rats. A negative linear relationship was found between e-NOS level and aortic IMT.





**Figure 6. Relation between aortic VCAM-1 expression and aortic IMT in experimental rats.** A positive but non-significant linear relationship was found between aortic VCAM-1 expression and aortic IMT.

#### Correlation of VCAM-1 expression and aortic IMT

To determine if expression of VCAM-1 precedes atherosclerosis, we measured expression of this adhesion molecule in aortic tissue of Wistar rats. Linear regression model found that VCAM-1 expression did not correlate with aortic IMT ( $r^2 = 0.197$ ,  $p = 0.065$ ) (Figure 6).

#### Discussion

##### Oxidative stress-mediated cigarette smokes precedes atherosclerosis

Smoking cigarettes is one of the well-established modifiable risk factors for developing atherosclerosis, which mechanisms remain closely linked to the increased oxidative stress. The total amount of cigarettes smoked per day plays an essential role in increasing the level of oxidative stress and depletion of the antioxidant system. Cigarette smoke contains high concentrations of reactive oxygen species and tiny particles that are easily inhaled in the human body.<sup>18</sup> It is believed that smoking causes increased oxidative stress because of several mechanisms, including direct damage by radical species and the inflammatory response caused by cigarette smoking. The production of oxidative stress and reactive oxygen species due to the cigarette smoke is expected to increase VCAM-1 expression and decrease of e-NOS level. According to the previous research by Yang *et al* (2014), an increase of VCAM-1 expression in rat arteries after being exposed to cigarette smoke had been observed for seven days.<sup>19</sup> Translational research completed by Teasdale *et al* (2014) and Pott *et al* (2017) also supported the findings that increased oxidative stress, reactive oxygen species, and VCAM-1 expression in endothelial cell cultures followed exposure to cigarette smoke.<sup>20</sup> Previously, researchers had been studying the influence of smoking on the levels of several biomarkers of oxidative stress, antioxidant status and redox status, including plasma hydroperoxides, e-NOS and VCAM-1. Using different assays to our study, they confirmed that smokers have elevated concentrations of VCAM-1 and compromised e-NOS status.<sup>21</sup>

##### Cigarette smoke extract induces expression of cell adhesion molecules

VCAM-1 is expressed in vascular endothelial cells, and expression of VCAM-1 may promote the adhesion of leukocytes to the endothelial cells. VCAM-1 accelerates the migration of adherent leukocytes along the endothelial surface, and promotes the proliferation of vascular smooth muscle cells; thus, VCAM-1 may play an essential role as a pro-atherogenic molecules.<sup>22</sup> Exposure to cigarette smoke in this study can increase VCAM-1 expression in the aorta although the increase is not statistically significant between the two groups. An insignificant increase in VCAM-1 expression was also found in the previous human research held by Noguchi (1999). In his previous research, soluble VCAM-1 levels were increased in smokers' serum but not significantly when compared to non-smokers' serum.<sup>23</sup>

Increase of VCAM-1 expression is a multifactorial process, smoking could not increase VCAM-1 independently without other risk factors such as dyslipidemia. Mu *et al* (2015) had proven this hypothesis by examining VCAM-1 expression

in aortic tissue of dyslipidemia patients. As a result, VCAM-1 expression was positively correlated with triglyceride, total cholesterol and LDL levels while VCAM-1 and HDL had a negative correlation<sup>24</sup> because the expression of VCAM-1 in endothelial cells requires a trigger that is high lipid levels, especially LDL. An increase in oxidized LDL in the endothelium will be phagocytosed by macrophages. Recruitment of these macrophages requires the role of VCAM-1.<sup>25</sup> In our study, other factors contributing to the development of atherosclerosis such as dyslipidemia weren't included. Our study did not use experimental animals with high-fat diets and serial lipid profile measurement. Therefore, results of our study didn't show any statistical significance of VCAM-1 expression between K (-) and K (+) groups.

### Cigarette smoke extract counteracts atheroprotective effects of endothelial nitric oxide synthase

Decreased bioavailability of NO is a central mechanism in the pathophysiology of endothelial dysfunction. Endothelial nitric oxide synthetase (e-NOS) is an enzyme that responsible to produce NO in endothelial cells, so the level of eNOS can represent the availability of NO in endothelial cells.<sup>26</sup> Endothelial-cell dysfunction itself could be tested by acetylcholine response function and adenosine coronary flow reserve tests.<sup>27</sup> Celermajer *et al* (1992) published a study showing that smoking reduces flow-mediated dilatation (FMD) in systemic arteries in healthy young adults.<sup>28</sup>

Our study showed that exposure to cigarette smoke can reduce levels of eNOS in the aorta. Our results are consistent with the findings of He *et al* (2017), which shows a significant decrease of eNOS level in endothelial cell cultures exposed to cigarette smoke. He *et al* (2017) showed that exposure to cigarette smoke in endothelial cell culture can reduce the expression of eNOS genes and proteins, resulting endothelial-cell dysfunction.<sup>29</sup> On the other hand, Su *et al* (1998) had already proven that administration of cigarette smoke extract can reduce the expression of genes and proteins eNOS. The effect of eNOS reduction depends on the duration of exposure to the cells. The longer the duration of cigarette smoke exposure, the more eNOS levels will be decreased.<sup>30</sup> In addition to decreasing eNOS at the gene level, Pini *et al* (2016) showed that exposure to secondhand smoke had also been shown to reduce eNOS at protein levels. eNOS levels decreased in the aorta of guinea pigs after exposure to cigarettes for eight weeks.<sup>31</sup>

It has been demonstrated that smoking cigarettes triggers demethylation, leading to a consecutive reactivation of epigenetically silenced genes *in vitro* and *in vivo* of eNOS and NO production.<sup>32</sup> Peroxynitrites, a very reactive oxygene species and pro-oxidant properties from cigarette extract, is believed to promote demethylation and inactivation of e-NOS.<sup>33</sup> In addition, peroxynitrite and other free radicals can deactivate BH4 which is an important cofactor in eNOS production. This was explained by the research of Abdelghany *et al* (2018) which showed that exposure to cigarette smoke has been shown to reduce the BH4 cofactor and correlated with the amount of superoxide and NO production in endothelial cell cultures.<sup>34</sup> A decrease of e-NOS and NO level will increase vascular tone, increase expression of adhesion molecules, and trigger coagulation cascade and inflammation.<sup>35</sup> In the final pathway, smoking cigarettes leads to increase of aortic intima-medial thickness as an earlier sign of atherosclerosis

Based on this literature and our own data, we suggest that the exposure to cigarette smoke for 28 days daily might be an independent risk factor for atherogenic process through several mechanisms. Aortic IMT in this study increased in group K (+) as was also found in studies conducted by Ali *et al* (2012).<sup>36</sup> Increased aortic and entire blood vessels' IMT are due to the pathological conditions such as apoptosis and excessive proliferation as a compensation mechanism.<sup>37</sup> In the previous study, the increase of IMT as a complication of endothelial dysfunction leads to the atherosclerosis process.<sup>38</sup> Cigarette smoke exposure underlies the endothelial dysfunction by the reduction of e-NOS level and increase of VCAM-1 expression.<sup>39</sup>

Exposure to cigarette smoke also affects the histological structure of the aorta. In this study, we found not only an increase of IMT, but also structural changes marked by disorganization and vacuolization of smooth muscle cells in the tunica media of the aortic tissue. On the contrary, no changes were observed at the tunica intima level. Exposure to cigarette smoke for 28 days in the study of Ali *et al* (2012) also found the same results: no changes in the tunica intima were observed from the experimental rat.<sup>36</sup> Another experimental study from Jaldin *et al* (2013) found that exposure to cigarette smoke for eight weeks only resulted in a disorganization in the vascular smooth muscle cells in the tunica media.<sup>40</sup> Vacuolization is one of the complications from cytotoxic processes in the cells and an earlier marker of preclinical atherosclerosis. Chemical components from cigarette smoke can cause oxidative stress which is characterized by permanent vacuolization in cells. In the microscopic phenotyping, vacuolization makes the vascular smooth muscle cells have different shapes and sizes, thus resulting in the cells becoming disorganized and leading to atherosclerosis.<sup>41</sup>

### Limitations

Every study has its limitations which emerge during the realization of the study, creating challenges and, thus, should be highlighted. Firstly, only 3 parameters are being studied which may limit the wide pathophysiology of how nicotine could make acute toxicity in animal model. Secondly, results from animal models often do not translate into

replications in human models. Level of e-NOS and VCAM-1 expression in Wistar rats are typically transient, whereas in human they can persist for many years. Another crucial difference is IMT, which is usually much lower in the Wistar rats than in humans. These factors may have an impact on the interpretation of our results. Thus, the findings should be interpreted within the context of this study and its limitations. The strengths of the study were its high statistical power and the homogeneity of each group to enable comparisons between groups and periods.

## Conclusion

The present study indicates that smoking cigarettes adversely affects endothelial function and increases the risk of atherosclerosis. Smoking cigarettes as a risk factor for atherosclerosis is closely linked to the increased inflammatory process on the vascular endothelium. Low e-NOS level and high VCAM-1 level observed following smoke exposure may increase aortic IMT. Furthermore, smoking has also been found to influence the aortic IMT. Aortic IMT itself reflects the level of established CVD risk factors in apparently healthy men and women, adding to the evidence that cigarette smoking contributes to CVD through its inflammatory effects on the vascular endothelium.

## Ethical approval

Animal experimental study were conducted under the approval of the Institutional Animal Care and Use Committee of Universitas Airlangga (UNAIR), Surabaya, Indonesia (animal approval no: 2.KE.184.10.2019) under the name of Meity Ardiana as the Principal Investigator. Study was carried out in strict accordance to internationally-accepted standards of the Guide for the Care and Use of Laboratory Animals of the National Institute of Health.

## Data availability

### Underlying data

Figshare. Raw Data - Acute effects of cigarette smoke: <https://doi.org/10.6084/m9.figshare.14252639.v1>.<sup>42</sup>

BioRxiv: Acute Effects of Cigarette on Endothelial Nitric Oxide Synthase, Vascular Cell Adhesion Molecule 1 and Aortic Intima Media Thickness “Cigarette smoke–induced pro-atherogenic changes”: <https://doi.org/10.1101/2021.01.17.426972>.<sup>43</sup>

Universitas Airlangga Repository: <http://repository.unair.ac.id/id/eprint/102952> (DOI 10.1101/2021.01.17.426972)

This project contains the following extended data: acute effect of jinten hitam (*Nigella sativa*) as protective factor from cigarette smoke on aortic intima media thickness of rat.<sup>44</sup>

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/) (CC-BY 4.0).

## Acknowledgments

The authors would like to acknowledge Dr. Hari Basuki Notobroto from Public Health Department Universitas Airlangga whose statistical expertise was invaluable during the analysis. The authors, hereby, acknowledge the above authorities and all staff, fellows, residents and laboratory assistants from Department of Cardiology and Vascular Medicine, Faculty of Medicine Universitas Airlangga, who are willing to help in the technical aspect.

## References

- Zhu J, Nelson K, Toth J, *et al.*: **Nicotine dependence as an independent risk factor for atherosclerosis in the National Lung Screening Trial.** *BMC Public Health.* 2019; **19**(1): 1–6. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- Lu L, Mackay DF, Pell JP: **Meta-analysis of the association between cigarette smoking and peripheral arterial disease.** *Heart.* 2014; **100**(5): 414–423. [PubMed Abstract](#) | [Publisher Full Text](#)
- Huxley RR, Woodward M: **Cigarette smoking as a risk factor for coronary heart disease in women compared with men: A systematic review and meta-analysis of prospective cohort studies.** *Lancet.* 2011; **378**(9799): 1297–1305. [PubMed Abstract](#) | [Publisher Full Text](#)
- Münzel T, Hahad O, Kuntic M, *et al.*: **Effects of tobacco cigarettes, e-cigarettes, and waterpipe smoking on endothelial function and clinical outcomes.** *Eur. Heart J.* 2020 Nov 1; **41**(41): 4057–4070. [PubMed Abstract](#) | [Publisher Full Text](#)
- Wang T, Jiang CQ, Xu L, *et al.*: **The mediating role of inflammation in the association between cigarette smoking and intima-media thickness: The Guangzhou biobank cohort study.** *Med (United States).* 2020; **99**(8). [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
- DiGiacomo SI, Jazayeri MA, Barua RS, *et al.*: **Environmental Tobacco Smoke and Cardiovascular Disease.** *Int J Environ Res Public Health.* 2018 Dec 31; **16**(1): 96. [PubMed Abstract](#) | [Publisher Full Text](#)
- Centner AM, Bhide PG, Salazar G: **Nicotine in Senescence and Atherosclerosis.** *Cells.* 2020 Apr 22; **9**(4): 1035. [PubMed Abstract](#) | [Publisher Full Text](#)
- Klein LW: **Pathophysiologic Mechanisms of Tobacco Smoke Producing Atherosclerosis.** *Curr Cardiol Rev.* 2022 Apr; **11**.
- Geovanini GR, Libby P: **Atherosclerosis and inflammation: overview and updates.** *Clin Sci (Lond).* 2018 Jun 21; **132**(12):

- 1243–1252.  
[PubMed Abstract](#) | [Publisher Full Text](#)
10. Ambrose JA, Bhullar AS: **Inflammation and Thrombosis in Coronary Atherosclerosis: Pathophysiologic Mechanisms and Clinical Correlations.** *Eur Med J.* 2019;(March): 71–78.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  11. Malekmohammad K, Sewell RDE, Rafeian-Kopaei M: **Antioxidants and Atherosclerosis: Mechanistic Aspects.** *Biomolecules* 2019 Jul 25; **9**(8): 301.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  12. Dos Santos JC, Cruz MS, Bortolin RH, et al.: **Relationship between circulating VCAM-1, ICAM-1, E-selectin and MMP9 and the extent of coronary lesions.** *Clinics.* 2018; **73**(4): 1–5.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  13. Wang T, Tian J, Jin Y: **VCAM1 expression in the myocardium is associated with the risk of heart failure and immune cell infiltration in myocardium.** *Sci Rep.* 2021 Sep 30; **11**(1): 19488.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  14. Hong FF, Liang XY, Liu W, et al.: **Roles of eNOS in atherosclerosis treatment.** *Inflamm Res.* 2019 Jun; **68**(6): 429–441.  
[Publisher Full Text](#)
  15. Suvorova T, Nagy N, Pick S, et al.: **Impact of eNOS-Dependent Oxidative Stress on Endothelial Function and Neointima Formation.** *Antioxid Redox Signal.* 2015 Sep 20; **23**(9): 711–723.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  16. Yu J, Wu X, Ni J, et al.: **Relationship between common eNOS gene polymorphisms and predisposition to coronary artery disease: Evidence from a meta-analysis of 155 published association studies.** *Genomics* 2020 May; **112**(3): 2452–2458.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  17. Leloup AJA, Van Hove CE, De Moudt S, et al.: **Ex vivo aortic stiffness in mice with different eNOS activity.** *Am J Physiol Heart Circ Physiol.* 2020 May 1; **318**(5): H1233–H1244.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  18. Kamecva G, Arsova-Sarafinovska Z, Ruskovska T, et al.: **Cigarette smoking and oxidative stress in patients with coronary artery disease.** *Maced J Med Sci.* 2016; **4**(4): 636–640.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  19. Yang GH, Li YC, Wang ZQ, et al.: **Protective effect of melatonin on cigarette smoke-induced restenosis in rat carotid arteries after balloon injury.** *J Pineal Res.* 2014; **57**(4): 451–458.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  20. Teasdale JE, Hazell G, Newby AC, et al.: **Paradoxical effects of cigarette smoke extract and high laminar flow on tumour necrosis factor- $\alpha$  induced VCAM-1 up-regulation – Implications for endothelial dysfunction.** *Atherosclerosis.* 2014; **237**(2): e13–e14.  
[Publisher Full Text](#)
  21. Konstantinidou F, Budani MC, Sarra A, et al.: **Impact of Cigarette Smoking on the Expression of Oxidative Stress-Related Genes in Cumulus Cells Retrieved from Healthy Women Undergoing IVF.** *Int J Mol Sci.* 2021 Dec 5; **22**(23): 13147.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  22. Lembas A, Zawartko K, Sapula M, et al.: **VCAM-1 as a Biomarker of Endothelial Function among HIV-Infected Patients Receiving and Not Receiving Antiretroviral Therapy.** *Viruses* 2022 Mar 11; **14**(3): 578.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  23. Belcastro E, Rehman AU, Remila L, et al.: **Fluorescent nanocarriers targeting VCAM-1 for early detection of senescent endothelial cells.** *Nanomedicine* 2021 Jun; **34**: 102379.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  24. Mu W, Chen M, Gong Z, et al.: **Expression of vascular cell adhesion molecule-1 in the aortic tissues of atherosclerotic patients and the associated clinical implications.** *Exp Ther Med.* 2015; **10**(2): 423–428.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  25. Toma L, Sanda GM, Deleanu M, et al.: **Glycated LDL increase VCAM-1 expression and secretion in endothelial cells and promote monocyte adhesion through mechanisms involving endoplasmic reticulum stress.** *Mol Cell Biochem.* 2016; **417**(1–2): 169–179.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  26. Messner B, Bernhard D: **Smoking and cardiovascular disease: Mechanisms of endothelial dysfunction and early atherogenesis.** *Arterioscler Thromb Vasc Biol.* 2014; **34**(3): 509–515.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  27. Bruno RM, Gori T, Ghiadoni L: **Endothelial function testing and cardiovascular disease: Focus on peripheral arterial tonometry.** *Vasc Health Risk Manag.* 2014; **10**: 577–584.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  28. Bruno RM, Reesink KD, Ghiadoni L: **Advances in the non-invasive assessment of vascular dysfunction in metabolic syndrome and diabetes: Focus on endothelium, carotid mechanics and renal vessels.** *Nutr Metab Cardiovasc Dis.* 2017 Feb; **27**(2): 121–128.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  29. He Z, Chen Y, Hou C, et al.: **Cigarette smoke extract changes expression of endothelial nitric oxide synthase (eNOS) and p16 (INK4a) and is related to endothelial progenitor cell dysfunction.** *Med Sci Monit.* 2017; **23**: 3224–3231.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  30. Do VQ, Park KH, Seo YS, et al.: **Inhalation exposure to cigarette smoke induces endothelial nitric oxide synthase uncoupling and enhances vascular collagen deposition in streptozotocin-induced diabetic rats.** *Food Chem Toxicol.* 2020 Feb; **136**: 110988.  
[Publisher Full Text](#)
  31. Pini A, Boccalini G, Baccari MC, et al.: **Protection from cigarette smoke-induced vascular injury by recombinant human relaxin-2 (serelaxin).** *J Cell Mol Med.* 2016; **20**(5): 891–902.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  32. Plimack ER, Kantarjian HM, Issa JP: **Decitabine and its role in the treatment of hematopoietic malignancies.** *Leuk Lymphoma.* 2007; **48**(8): 1472–1481.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  33. Incalza MA, D’Oria R, Natalicchio A, et al.: **Oxidative stress and reactive oxygen species in endothelial dysfunction associated with cardiovascular and metabolic diseases.** *Vascul Pharmacol.* 2018; **100**: 1–19.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  34. Abdelghany TM, Ismail RS, Mansoor FA, et al.: **Cigarette smoke constituents cause endothelial nitric oxide synthase dysfunction and uncoupling due to depletion of tetrahydrobiopterin with degradation of GTP cyclohydrolase.** *Nitric Oxide - Biol Chem.* 2018; **76**: 113–121.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  35. Kaur R, Kaur M, Singh J: **Endothelial dysfunction and platelet hyperactivity in type 2 diabetes mellitus: Molecular insights and therapeutic strategies.** *Cardiovasc Diabetol.* 2018; **17**(1): 1–17.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  36. Ali SS, Ayuob NN, Al Ansary AK, et al.: **Antioxidants protect against increased risk of atherosclerosis induced by exposure to cigarette smoke: Histological and biochemical study.** *Saudi J Biol Sci.* 2012; **19**(3): 291–301.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  37. Skilton MR, Celermajer DS, Cosmi E, et al.: **Natural History of Atherosclerosis and Abdominal Aortic Intima-Media Thickness: Rationale, Evidence, and Best Practice for Detection of Atherosclerosis in the Young.** *J Clin Med.* 2019; **8**(8): 1201.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  38. Poredoš P: **Endothelial dysfunction in the pathogenesis of atherosclerosis.** *Clin Appl Thromb.* 2001; **7**(4): 276–280.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  39. Zhou J, Li YS, Nguyen P, et al.: **Regulation of vascular smooth muscle cell turnover by endothelial cell-secreted microRNA-126 role of shear stress.** *Circ Res.* 2013; **113**(1): 40–51.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  40. Jaldin RG, Castardelli É, Perobelli JE, et al.: **Morphologic and biomechanical changes of thoracic and abdominal aorta in a rat model of cigarette smoke exposure.** *Ann Vasc Surg.* 2013; **27**(6): 791–800.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  41. Harrington J, Peña AS, Gent R, et al.: **Aortic Intima Media Thickness is an Early Marker of Atherosclerosis in Children with Type 1 Diabetes Mellitus.** *J Pediatr.* 2010; **156**(2): 237–241.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  42. Ardiana M, Santoso A, Hermawan HO, et al.: **Raw Data - Acute effects of cigarette smoke.** *figshare. Dataset.* 2021.  
[Publisher Full Text](#)
  43. Ardiana M, Santoso A, Hermawan HO, et al.: **Acute Effects of Cigarette on Endothelial Nitric Oxide Synthase, Vascular Cell Adhesion Molecule 1 and Aortic Intima Media Thickness “Cigarette smoke-induced pro-atherogenic changes”.** *BioRxiv.* 2020.  
[Publisher Full Text](#)
  44. Ardiana M: **Pengaruh Dan Mekanisme Pemberian Ekstrak Etanol Jintan Hitam Dalam Menghambat Terjadinya Disfungsi Endotel Pada Tikus Yang Terpapar Asap Rokok. Disertasi thesis.** *UNIVERSITAS AIRLANGGA Repository.*  
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## Version 4

Reviewer Report 30 November 2023

<https://doi.org/10.5256/f1000research.157098.r213800>

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**Leila Mohammadi** 

Division of Cardiology, University of California San Francisco, San Francisco, California, USA

The current revised format looks good.

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Cardiovascular disease, endothelial function, nitric oxide, cell culture, biomarkers of endothelial function, women cardiovascular health, tobacco cannabis, e-cigarettes use and cardiac health,

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

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## Version 3

Reviewer Report 05 October 2023

<https://doi.org/10.5256/f1000research.151452.r182590>

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**Leila Mohammadi** 

Division of Cardiology, University of California San Francisco, San Francisco, California, USA

I have thoroughly reviewed the manuscript by Ardiana et al. on the acute effects of cigarette smoke on endothelial NOS, vascular adhesion molecule 1, and aortic intima media thickness.

While the manuscript is well written and the data are presented meticulously, I have some concerns about the study's design and novelty, which I believe need to be addressed for further clarity and scientific rigor. My specific concerns are as follows:

1. **Insufficient Explanation of Exposure Design:** The authors have not adequately explained the exposure session and puff volume, which are essential to ensure the relevance of the study to real-life smoking scenarios. I recommend adding these details to the experimental design and group section to provide a comprehensive understanding of the exposure conditions.
2. **High Number of Cigarettes Used:** It appears that the study involved the use of 40 or more cigarettes, indicating 2 or more packs a day. This exposure level seems to be an extreme amount of smoke inhalation, which may not accurately reflect real-life daily use. I urge the authors to clarify why such a substantial amount of exposure was chosen for this study, and if it aligns with the objectives and relevance to human smoking patterns.
3. **Correlations and sVCAM1 Levels:** While I appreciate the inclusion of correlations between different variables, it is essential to acknowledge that the impact of acute cigarette smoke on sVCAM1 levels has already been investigated in previous studies. The authors should provide a concise rationale for re-examining this aspect and highlight any novel findings or unique perspectives offered in their study.
4. **Clarification on Terminology:** The term "cigarette smoke extract" is used multiple times throughout the manuscript, but it is unclear whether the authors are referring to the actual extract or the smoke itself. I kindly request the authors to clarify this terminology to avoid confusion and ensure accuracy in the interpretation of their findings.

I believe addressing these concerns will significantly enhance the clarity and scientific value of the study. Please feel free to reach out if you require any further information or have any questions regarding my feedback.

## References

1. Blann AD, Seigneur M, Steiner M, Miller JP, et al.: Circulating ICAM-1 and VCAM-1 in peripheral artery disease and hypercholesterolaemia: relationship to the location of atherosclerotic disease, smoking, and in the prediction of adverse events. *Thromb Haemost.* 1998; **79** (6): 1080-5 [PubMed Abstract](#)
2. Gellner CA, Reynaga DD, Leslie FM: Cigarette Smoke Extract: A Preclinical Model of Tobacco Dependence. *Curr Protoc Neurosci.* 2016; **77**: 9.54.1-9.54.10 [PubMed Abstract](#) | [Publisher Full Text](#)
3. Farra YM, Matz J, Ramkhalawon B, Oakes JM, et al.: Structural and functional remodeling of the female Apoe<sup>-/-</sup> mouse aorta due to chronic cigarette smoke exposure. *Am J Physiol Heart Circ Physiol.* 2021; **320** (6): H2270-H2282 [PubMed Abstract](#) | [Publisher Full Text](#)
4. Osterud B, Elvevoll EO, Brox J, Anderssen T, et al.: Haemostatic parameters related to lipids and adhesion molecules. *Blood Coagul Fibrinolysis.* 1999; **10** (8): 465-70 [PubMed Abstract](#) | [Publisher Full Text](#)
5. Scott DA, Palmer RM: The influence of tobacco smoking on adhesion molecule profiles. *Tob Induc Dis.* 2002; **1** (1): 7-25 [PubMed Abstract](#) | [Publisher Full Text](#)

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**

I cannot comment. A qualified statistician is required.

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Cardiovascular disease, endothelial function, nitric oxide, cell culture, biomarkers of endothelial function, women cardiovascular health, tobacco cannabis, e-cigarettes use and cardiac health,

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.**

Author Response 05 Oct 2023

**Ricardo Adrian Nugraha**

Thank you for reviewing our manuscript and give constructive feedback to improve our manuscript better for the reader. There are several points from the reviewer which we would like to address:

**1. Insufficient Explanation of Exposure Design:** The authors have not adequately explained the exposure session and puff volume, which are essential to ensure the relevance of the study to real-life smoking scenarios. I recommend adding these details to the experimental design and group section to provide a comprehensive understanding of the exposure conditions.

Author Response: As it might be difficult to measure real-time cigarette smoke and nicotine concentrations at this moment, thus the level of cigarette smoke was titrated to the amount of total suspended particulate matter that was measured using a real-time monitoring probe (Casella Microdust Pro; Casella USA, Nashua, NH, USA). We want to study the relationship between acute inhalation of suspended particulate level and tobacco smoke concentration in the exposure room. We developed experimental models use of 40-puff smoking session conducted during the 12-h tobacco smoke exposure sessions each day for 28 days. Puff volume may be up to 100-140 mL. These experimental models were made

using a research cigarette of conventional construction, made only from Virginia tobacco, which contains 39 mg of tar and 2.3 mg of nicotine. During the experiment, air was continuously drawn in parallel, through three resin-filled glass filters (XAD-4) set up in parallel at approximately 2 L per min.

**2. High Number of Cigarettes Used:** It appears that the study involved the use of 40 or more cigarettes, indicating 2 or more packs a day. This exposure level seems to be an extreme amount of smoke inhalation, which may not accurately reflect real-life daily use. I urge the authors to clarify why such a substantial amount of exposure was chosen for this study, and if it aligns with the objectives and relevance to human smoking patterns.

Author Response: Smoking behaviour is various among socioeconomic, education, occupation and geographic patterns. Indeed, the subsequent deposition of smoke constituents in the respiratory tract of smokers is an equally complex process both in terms of quantification of dose and time. In fact, assuming that the consumed portion of each cigarette contains 0.7 g of combustible material, 39 mg of tar, 2.3 mg of nicotine and that the smoker inhales two-thirds of the CO<sub>2</sub> produced by the cigarette, smoking two packs a day would produce an error of about 0.6 mol of CO<sub>2</sub> per day or 2-4% of true CO<sub>2</sub> production. Thus, only a heavy smoking is expected to result in an acute toxicity within 28 days, whilst 20 cigarettes, indicating 1 packs a day might develop subacute toxicity within 1-2 years.

**3. Correlations and sVCAM1 Levels:** While I appreciate the inclusion of correlations between different variables, it is essential to acknowledge that the impact of acute cigarette smoke on sVCAM1 levels has already been investigated in previous studies. The authors should provide a concise rationale for re-examining this aspect and highlight any novel findings or unique perspectives offered in their study.

Author Response: Yes, previous studies from Blann AD, et al (1998), Scott DA and Palmer RM (2002) had been studying the relationship of soluble intercellular adhesion molecule-1 (sICAM-1) and vascular cell adhesion molecule-1 (sVCAM-1) with smoking. The reason why we re-examine the role of cell adhesion molecules is because sVCAM-1 is the essential pro-inflammatory and pro-atherogenic proteins that represent a hallmark of endothelial dysfunction and atherosclerosis. We want to study the putative mechanism of subclinical atherosclerosis by short duration of tobacco smoke. Our results showed that acute exposure of tobacco smoke can enhance the upregulation of sVCAM-1 and the involvement of important known intermediaries which leading to subclinical atherosclerosis.

**4. Clarification on Terminology:** The term "cigarette smoke extract" is used multiple times throughout the manuscript, but it is unclear whether the authors are referring to the actual extract or the smoke itself. I kindly request the authors to clarify this terminology to avoid confusion and ensure accuracy in the interpretation of their findings.

Author Response: I apologize for that error. After careful discussion with all of the authors, it is not cigarette smoke extract but the smoke itself. We will revise it.

Once again, thank you very much for the suggestion and feedbacks.



**Competing Interests:** No competing interests were disclosed.

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**Version 2**

Reviewer Report 18 October 2022

<https://doi.org/10.5256/f1000research.137198.r150339>

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**Amilia Aminuddin**

Department of Physiology, Faculty of Medicine, Universiti Kebangsaan Malaysia Medical Centre, Kuala Lumpur, Malaysia

The authors have made appropriate changes and there are no other queries from me.

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**

Yes

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Cardiovascular

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

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**Version 1**

Reviewer Report 05 August 2022

<https://doi.org/10.5256/f1000research.31386.r145923>

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**Amilia Aminuddin**

Department of Physiology, Faculty of Medicine, Universiti Kebangsaan Malaysia Medical Centre, Kuala Lumpur, Malaysia

This study determines the effects of 1-month exposure to tar and nicotine on eNOS, VCAM-1, and aortic stiffness in a rats model.

- The authors should highlight the novelty of this study since there are a lot of studies that have been conducted in this area and for these parameters. The parameters also were limited (three parameters only). If the authors can add more parameters then it will be good.
- Out of 44 references, only 12 references are the latest (within 5 years).
- In the results section, the authors should show which statistical analysis has been conducted, rather than presenting both. For example, Table 2 presented both the t-test and Mann-Whitney, and actually one should be chosen based on the normality of the parameters. The mean value and SD in the table also should use a dot, instead of a comma.
- There were abbreviations used without the full names given, such as TGF and BH4.
- Please identify rats as animals and not subjects.
- The manuscript should be proofread as there were grammatical/spelling errors.
- A sample size of nine per group is more than enough and not the limitation of the study.

**Is the work clearly and accurately presented and does it cite the current literature?**

Partly

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**

Partly

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Cardiovascular

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.**

Author Response 07 Aug 2022

**Ricardo Adrian Nugraha**

This study determines the effects of 1-month exposure to tar and nicotine on eNOS, VCAM-1, and aortic stiffness in a rats model.

- The authors should highlight the novelty of this study since there are a lot of studies that have been conducted in this area and for these parameters. The parameters also were limited (three parameters only). If the authors can add more parameters then it will be good.

**Author Response:** The novelty of this study is the strong correlation between those three parameters in the setting of acute cigarette smoke exposure, which may change the paradigm about only chronic or sub-chronic cigarette smoke exposure can induce the atherogenic process. Increasing evidence suggests that cigarette smoke exposure, even in the short-term period could induce VCAM-1 (enhance pro-atherogenic properties), and a decrease in e-NOS level (anti-atherogenic depletion). Thus, acute cigarette smoke may represent a significant risk factor for atherosclerosis by increasing aortic IMT. This evidence is discussed herein.

- Out of 44 references, only 12 references are the latest (within 5 years).

**Author Response:** Thank you for your suggestion. We try to replace the reference with the latest one. However, several data and information are only available in the old references

- In the results section, the authors should show which statistical analysis has been conducted, rather than presenting both. For example, Table 2 presented both the t-test and Mann-Whitney, and actually one should be chosen based on the normality of the parameters. The mean value and SD in the table also should use a dot, instead of a comma.

**Author Response:** Table 2 (IMT) and Table 3 (e-NOS) used Mann-Whitney u test. On the contrary, Table 4 (VCAM-1) used an independent t-test. This is based on the normality test by the Shapiro-Wilk test. Thank you for your constructive feedback to shape our manuscript

better.

- There were abbreviations used without the full names given, such as TGF and BH4.

**Author Response:** Thank you for your suggestion, we have added TGF (transforming growth factor) and BH4 (Tetrahydrobiopterin) in the abbreviation lists

- Please identify rats as animals and not subjects.

**Author Response:** Thank you for your suggestion, we have replaced “subjects” with “animals”

- The manuscript should be proofread as there were grammatical/spelling errors.

**Author Response:** Thank you for your constructive feedback. We try to fix the grammatical/spelling errors in the second version of the manuscript.

- A sample size of nine per group is more than enough and not the limitation of the study.

**Author Response:** Thank you for your suggestion, we have removed the sample size in the limitation of this study

**Competing Interests:** Authors declare no competing interest

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