A Review of Smoking on Cardiovascular Disease: Impact on Human Health

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Received:- 8 March 2021/ Revised:- 16 March 2021/ Accepted: 21 March 2021/ Published: 31-03-2021

Abstract— *Cardiovascular diseases (CVD) are the leading cause of global morbidity and mortality. They also inflict huge direct and indirect financial costs on the worldwide society. With the ready availability of affordable therapeutics globally, and the relatively slow development of newer therapeutics, lifestyle behaviors are gaining importance, both as preventive and therapeutic interventions. Smoking tobacco is consistently and strongly related with a higher risk of CVD incidence, adverse progression, and increased mortality. Smoking is deleteriously associated with most cardiovascular diseases. Smokers die of more CVDs than from any other cause. Cessation of smoking is therefore paramount in improving worldwide CVD health. This paper reviews the negative effects of smoking on cardiovascular diseases.*

Keywords— Smoking, Cardiovascular Diseases, Lifestyles, Modifiable Risk Factors, Nicotine.

I. INTRODUCTION

Tobacco is consumed by over a billion people around the word[1]. Smoking is the most common mode of its use[2]. This is done using products like cigarettes, e-cigarettes and water pipes[3]. Smoking tobacco exposes individuals to tobacco related noxious gaseous and particulate matter in several ways[4-6]. Most commonly, smoke enters the smoker's mouth directly from the cigarette being smoked and this is known as the first-hand smoke or mainstream smoke[4]. Side-stream cigarette smoke emanates from the burning ends of a cigarette and along with the exhaled main-steam smoke, results in second-hand smoke that could be inhaled by others[5]. Third-hand smoke is the residue from tobacco products that cling to surfaces such as skin, hair, clothing, and furniture[6]. These pollutants resist removal with traditional cleaning methods and may persist on these surfaces for several months. Tobacco is also consumed by non-smoking methods[7]. The smokeless tobacco products include loosely chewed tobacco leaves, tobacco paste and several tobacco-based concoctions such as naswar, gutka, and snuff[8]. The ingredients in these products are mainly absorbed via the mucous membranes of the mouth and nose.

Tobacco is highly addictive, primarily due to its nicotine content[9,10]. All tobacco forms provide, besides nicotine, a plethora of harmful substances, many being extremely toxic and cancer provoking[11]. These include many harmful nitrosamines and polycyclic aromatic hydrocarbons[12,13]. Water pipe smoking results in large amounts of smoke being inhaled during a single smoking session and exposes the smoker to similar harmful substances as are present in cigarette smoke[14]. Inhaled e-cigarette vapor is usually lower in carcinogens and other toxins but is still harmful[15]. Smokeless tobacco also contains nicotine and more than 20 carcinogens, which enter the body via the oral and nasal mucous membranes[16].

Tobacco smoking adversely affects literally every organ in the human body[17]. Tobacco smoke has a several thousand compounds, including several toxic ones, such as benzene, formaldehyde, benzopyrene, carbon monoxide, acrolein, and metals[18]. The respiratory tract is the first to be hit with these, (before disseminating all over the body via the blood stream) causing inflammation, irritation, asphyxiation, carcinogenesis, and other deleterious effects[19]. Further dissemination, mainly via the blood stream, results in the development of many other serious disorders including several forms of cancer[20]. Smoking also affects pregnancy, causing a wide range of complications[21]. Infants exposed to cigarette smoke, either during the prenatal period or after birth have an increased risk of sudden death, orofacial clefts, periodontal disease, and dental caries[22]. Smoking accelerates aging, and smokers often develop wrinkles prematurely[23]. Cigarette smoking greatly reduces

the quality of life[24]. It is estimated that almost half of the smokers lose about 20 years of healthy life[25]. In 2017, 182 million disability-adjusted life-years (DALYs) were attributed globally to tobacco use[26]. Smokers over their lifetime demonstrate a higher mortality risk when compared to never smokers[27]. According to the Global Burden of Disease Study, in 2015, worldwide, one out of ten deaths was due to smoking[28]. Tobacco-related diseases are estimated to claim more lives than those due to AIDS, malaria and tuberculosis combined[29]. The estimated economic cost associated with smoking is 1.8% of global gross domestic product[30].

Smoking cessation before the age of 40 is associated with a reduction of more than 90% of the excess morbidity and mortality[31]. Cessation at the age of 30 eliminates nearly all the excess risk. Besides bestowing a healthier life, cessation also increases life expectancy[31]. Jha et al estimated that smokers who started smoking early in adult life, gain almost 10, 9, 6, and 4 years of increased life if they stop smoking at ages of 30, 40, 50, or 60 years of age, respectively, compared to those who continue to smoke[32].

II. DISCUSSION

The major CVDs are coronary heart disease (CHD) high blood pressure (HTN), stroke, heart failure (HF), cardiac arrhythmias, peripheral arterial disease (PAD), deep vein thrombosis (DVT) and vasculogenic erectile dysfunction (ED)[33]. These impart the greatest non-communicable diseases burden globally and this is expected to rise globally in the coming years[34]. They cause considerable disability and are responsible for an enormous number of deaths[35,36]. They are responsible for a huge financial burden worldwide[34].

Smoking exerts adverse effects on several CVDs, resulting in poor outcomes[37]. It is estimated that globally, smoking related CVD deaths exceed those from respiratory diseases or all forms of cancer combined[38]. A smoker has approximately 10 years shorter lifespan than a nonsmoker[39]. Smoking cessation is associated with a gradual reversion of the harmful cardiovascular effects[40]. It reduces mortality and increases longevity[41].

The relationship between smoking and CVD risk is non-linear[42]. It is estimated that 80% of the risk of smoking >20 cigarettes/day comes from smoking less than 3 cigarettes/day[43]. Even smoking 1 cigarette/day is associated with 30–50% of the risk of CHD and 34–65% of the risk of stroke that would occur with smoking 20 cigarettes/day[44]. Deleterious effects are also seen with low-tar cigarette, filtered cigarette, e-cigarette, cigar pipe, and water-pipe smoking[45]. Nonsmokers exposed to passive smoke also demonstrate a 25–30% increased CV risk[46].

Tobacco smoking plays a critical role in the maintenance and development, and progression of atherosclerosis via several mechanisms[47]. Tobacco smoking related chemicals increase low-density lipoprotein cholesterol levels, decrease high-density lipoprotein cholesterol level, increase inflammation, increase insulin resistance, increase catecholamines, increase the amount of fibrinogen, increase reactive oxygen species, and enhance platelet aggregation[47].

2.1 Smoking and HTN

According to the WHO, one in four men and one in five women have elevated BP globally and its prevalence is increasing steadily[48,49]. Elevated BP increases the risk for coronary heart disease, PAD, stroke, kidney failure, and heart failure[50]. It also increases CVD mortality[51]. It accounts for approximately 45% of all global CVD morbidity and mortality[52].

The adverse relationship between smoking and hypertension is well documented[53]. In the Physicians' Health Study, the risk of incident hypertension was increased by 15% in current smokers compared with never smokers[54]. In a recent study, a more than 5 pack-years smoking exposure increased the risk of BP by more than 30%[55]. Even passive smoking, after adjustments for several confounding factors, was found to be associated with a higher rate of hypertension in the exposed individuals, when compared to those not exposed to the secondhand cigarette smoke[56]. Besides smoking promoted atherosclerosis, the sympathetic nervous system and the baroreflex-system also play a deleterious role[57-59].

2.2 Smoking and CHD

CHD, or coronary artery disease/ischemic heart disease, is the most common CVD[60]. Its prevalence is increasing in the middle- and low-income countries[61]. It is primarily caused by atherosclerosis, which leads to a flow-limiting stenosis of large epicardial coronary arteries, initially resulting in angina[62]. A plaque rupture or erosion can provoke superimposed atherothrombosis and vessel occlusion, leading to a myocardial infarction, or even death[63]. It is responsible for an enormous amount of global disability[49]. This imparts a heavy disability-adjusted life year (DALY) burden and smoking remains the number one CHD killer in the world[49,65].

Smoking is strongly linked with CAD[65]. Smokers are two to four times more likely to develop CHD[66]. In women, smokers between the ages of 35–39, almost triple their risk of CHD if they smoke just 1-4 cigarettes a day[67]. The INTERHEART study found that smokers have a 1.95-fold increased risk of developing non-fatal myocardial infarction when compared to non-smokers[68]. Hackshaw et al. reported that while smoking one cigarette per day increased the excess CHD risk by 40-50%, smoking 5-20 cigarettes per day increased the excess risk to only 55-65% - indicating that the smoking-cad relationship is non-linear[69]. Passive smoking also increases the risk of ischemic heart disease[70]. Smoking increases mortality[71]. One study showed that men smoking 20 cigarettes per day were twice as likely to die from CHD, when compared with never smokers[71]. Smoking cessation can reduce CHD mortality risk by around 36%[72]. This is impressive, when compared to a 29% reduction with statins, a 23% reduction with either beta-blockers or angiotensin-converting enzyme inhibitors, and a 15% reduction with aspirin[72]. Smoking cessation is therefore strongly recommended for all coronary artery disease patients by most major cardiology associations[73]. The pathological basis of CHD is atherosclerosis, which is enhanced by smoking[74,75].

2.3 Smoking and Stroke

Stroke is characterized by a sudden onset of a neurological deficit due to a vascular cause and typically occurs after the age of 50 years[76]. Vascular stroke may be ischemic or hemorrhagic or could result from a subarachnoid hemorrhage[76]. Ischemic stroke is the most common[77]. The Global Burden of Disease collaborators in a report published in 2018, estimated that the global lifetime risk of stroke from the age of 25 years was one in four and that the risk was twice as high for ischemic than hemorrhagic stroke[78]. Stroke is associated with considerable functional disability[79]. It is the second leading cause of death worldwide[49]. The total number of strokes, the related DALY burden, and deaths, are steadily increasing globally, with the bulk occurring in the medium- and low-income world[49].

Smoking is a major risk factor for stroke[80], irrespective of the age of the individual[81,82]. This increased risk appears to be dose-dependent[83], and the risk declines with smoking cessation[84]. As noted with CHD, the risk is high even with smoking only one cigarette a day[85]. Smoking one cigarette a day represents approximately 41% of the excess relative risk of getting a stroke when compared to the risk associated with smoking 20 cigarettes a day[85].

2.4 Smoking and Heart Failure

HF affects 2–4% of the global population, according to the World Health Organization[86]. It is characterized by several functions restricting symptoms, such as shortness of breath, fatigue, and swelling of the ankles[87]. These show frequent exacerbations and these result in repeated hospitalizations[87]. The prognosis is extremely poor, and the mortality rate is high, with almost 50% of HF patients dying within 5 years[88]. The main therapeutic goal in HF management is to reduce symptoms, decrease progression, diminish mortality, and improve the quality of life[89].

Smoking is associated with an increased risk of heart failure[90], and this is seen in both HFrEF (heart failure with reduced ejection fraction) and HFpEF (heart failure with preserved ejection fraction) after adjusting for other CVD risk factors[91]. The smoking-HF relationship is related to the amount and duration of smoking in HF patients[92]. Smokers not only demonstrate a reduced efficacy to treatment but are also more likely to experience undesirable long-term outcomes[93]. Unfortunately, about 16% of HF patients continue to smoke[94]. Exposure to second-hand smoke in HF patients is also detrimental and leads to a further reduction their quality of life[95]. Active smoking increases mortality in HF patients[96]. Even smoking in future donors results in a higher incidence of graft failure following heart transplantation and is associated with an increase in mortality[97]. Smoking cessation is the leading modifiable risk factor for HF[98]. The risk of HF declines steadily with increasing duration following smoking cessation[90].

The increased risk of HF and worse progression in existing HF in smokers are mediated via multifactorial pathways[99]. These included increased inflammation, oxidative stress, impaired endothelial function, increased systemic vascular resistance, atherosclerosis, and ischemic heart disease[100-103]. They also demonstrate sympathetic predominance, increased pulmonary vascular resistance, toxic effects of inhaled carbon monoxide and harmful structural changes in the ventricles[104-106].

2.5 Smoking and Arrhythmias

Atrial fibrillation (AF) is a common arrhythmic disorder[107]. Its prevalence is higher in the elderly[108] and in individuals with other cardiovascular risk factors[109]. It is a major risk factor for stroke, heart failure, and cognitive dysfunction, and the former two often being the first manifestations of AF[110]. Patients with established AF have a five-fold increase in their risk of stroke compared to those without this arrhythmia[111]. It also reduces the individual's quality of life and is associated with increased mortality[112,113]. According to Dai et al., AF contributed to about 290,000 deaths globally in 2017[114].

The link between smoking and increased risk of developing AF is well established[115,116]. A prospective, population-based study showed that the increased risk of developing atrial fibrillation was increased in both current and former cigarette smokers[117]. Similar conclusions have been reached in several other studies[118,119]. Chamberlain et al found that current smoking increased the incidence of AF more than two-fold[118]. Former smokers also demonstrate a higher risk, although this risk is lower than that seen in current smokers[119]. Secondhand smoke exposure during gestational development and childhood also increases the risk of AF in later in life[120]. Quitting smoking reduces the risk of AF[121].

Even ventricular tachyarrhythmia's are increased in smokers with ischemic left ventricular dysfunction[122]. Ventricular arrhythmias are a major cause of sudden cardiac death[123]. Cigarette smoking is pro-arrhythmic due to the combined effects of nicotine, carbon monoxide, and pro-cyclic aromatic hydrocarbons[124,125].

2.6 Smoking and Valvular Diseases

Severe calcification of the aortic valve invariably results in impaired left ventricular outflow[126]. The prevalence of moderate to severe aortic valve stenosis (AS) increases with age[126]. Shortness of breath eventually develops in these patients and symptomology gradually progresses to angina, heart failure, and syncope[127]. Once symptoms develop, mortality is extremely high, and more than half of AS patients die within 2 to 3 years[128]. Treatment of severe aortic stenosis includes aortic valve replacement, either via a surgical or percutaneous approach[129]. Globally, the prevalence of aortic valve calcification has steadily increased over the last 3 decades[49].

Several observational studies have established that smoking increases the risk of aortic valve stenosis[130-133.] Thanassoulis et al reported that greater cigarette use was associated with elevated odds for aortic valve calcification (AVC), even after adjusting for other cardiovascular factors[131]. In the MESA study, the risk for incident AVC was more than doubled in active smokers relative to never smokers, independent of other clinical factors[132]. The Cardiovascular Health Study reported 35% increased odds for aortic stenosis in smokers[133]. This increased risk of aortic valve stenosis associated with smoking has also been noted in several prospective cohort studies[134]. Stenotic aortic valve disease is pathologically like atherosclerosis, with lipoprotein deposition, chronic inflammation, and active leaflet calcification[135].

2.7 Smoking and Aortic Aneurysm

An aortic aneurysm, either thoracic or abdominal, is defined as a permanent localized dilatation of the vessel at least 150% compared to a relative normal adjacent diameter or with a maximal transverse diameter that exceeds 30 mm[136,137]. It is estimated that abdominal aortic aneurysms, have a prevalence of 1.4% in those studied aged 50 to 84[138]. They are potentially life-threatening, as rupture carries an extremely high mortality rate of 80–85%[139].

There is a strong association between smoking and the risk of developing abdominal aortic aneurysms, both in current and ex-smokers[140,141]. It is estimated that smokers are almost 4 times more likely to die from aortic aneurysm than nonsmoking men and women[142]. Thoracic aortic aneurysms are uncommon but smoking also appears to increase the risk of their occurrence[143]. Although decline in smoking has reduced their prevalence in some areas, abdominal aortic aneurysms continue to increase morbidity and mortality, in most parts of the world[49]. Isolated aortic aneurysms develop from complex mechanisms, including apoptosis of vascular smooth muscle cells, oxidative stress, and inflammation[144].

2.8 Smoking and Peripheral Artery Disease

PAD is an atherosclerotic disease involving the pelvic and leg arteries[145]. It is characterized by intermittent claudication[146]. As the disease progresses, pain occurs at rest and the critical limb ischemia ultimately leads to tissue necrosis and amputation[147]. PAD is a cardiovascular disease equivalent and is associated with a high rate of non-fatal and fatal cardiovascular events[148]. PAD is diagnosed by measuring the ankle brachial index (ABI), and an ABI < 0.90 is extremely sensitive, and specific for a diagnosis of PAD[149,150]. It affects more than 200 million people worldwide[151]. Its global prevalence and its associated mortality is rising[49].

Smoking is causally associated with PAD[152]. It is estimated that almost 80% if individuals with PAD smoke or have smoked in the past[153]. Not only is the risk of PAD in smokers increased several-fold, but continuation of smoking also worsens prognosis in these individuals[154,155]. Smoking is also associated with restenosis after endovascular revascularization, graft failure and amputation in PAD patients[156]. Individuals smoking more than 1 pack per day have significantly greater adverse limb complications at one year, compared to those who smoked less[157]. Continued smoking also increases the risk of myocardial infarctions and premature death in patients with PAD[158]. Cessation of smoking helps reduce symptoms of

claudication in these patients but also helps reduce cardiovascular morbidity and mortality[159,160]. PAD is an atherosclerotic disease and smoking promotes the pathogenesis of atherosclerosis, the primary pathology in these patients[161].

2.9 Smoking and Erectile Dysfunction

ED is defined as a consistent or recurrent inability to attain or maintain a rigid penile erection suitable for satisfactory sexual intercourse[162]. It is a common male disorder and is expected to affect more than 320 million men worldwide by 2025[163,164]. Causes may be endocrine or non-endocrine, and non-endocrine vasculogenic etiology is present in about 80% of cases[165]. It is associated with many comorbidities and risk factors including increasing age, obesity (BMI>30 kg/m2), excessive alcohol intake, diabetes mellitus, other cardiovascular diseases, depression, and several other psychological disorders[166]. It is usually a part of a more widespread atherosclerotic vascular disease and is known to be a strong predictor of other cardiovascular disorders, especially coronary artery disease[167]. Its presence significantly reduces the quality of life in men and their partners[168].

Several epidemiological and prospective studies have shown that smoking increases ED[169,170]. This adverse relationship has been noted in both former as well as current smokers[171]. He et al studied the association between smoking and ED among 7684 men without vascular disease[172]. The odds ratio of erectile dysfunction was 1.41 for cigarette smokers compared with never smokers[172].Comparable data was obtained in men aged 40–70 years followed for up to 10 years, with the likelihood of developing ED being double in smokers[173]. In a cross-sectional study of Chinese men in Hong Kong, smoking of ≥20 cigarettes daily was associated with a 50% increase of having ED[174].Smoking also increases the risk of ED in patients with other CVD risk factors[175-177]. The relationship between smoking and ED appears to be dose dependent[172]. In one study, penile rigidity during nocturnal erection inversely correlated with the number of cigarettes smoked per day[174]. Smoking in ED is a modifiable risk factor and smoking cessation improves ED[178,179]. This benefit has been noted in middle aged adults regardless of pack-year smoked[180].

Penile erection is largely caused by the presence of sufficient blood flow into the erectile tissue, simultaneous arterial endothelium-dependent dilatation, and sinusoidal endothelium-dependent corporal smooth muscle relaxation[181,182]. This dilatation is impaired resulting in reduced blood blow to the penis in smokers, due to impaired nitric oxide (NO) synthesis and degradation[183]. NO is the main neurotransmitter mediating vascular actions in the penile vasculature. Further, smoking results in the development of atherosclerosis in the internal pudendal and common penile arteries[184]. Smoking may also cause ultrastructural damage to the corporal tissue[185].

2.10 Smoking and Venous Disease

DVT of the lower extremities is a common venous disorder and is associated with significant morbidity and a high rate of recurrence[186,187]. These patients are at an extremely high risk of developing pulmonary embolism (PE)[188]. PE is third most common cause of cardiovascular death in hospitalized patients in the West after stroke and heart attack[189]. Acute PE is a significant cause of mortality worldwide, accounting for over 100,000 deaths in 2018 alone[190]. Early diagnosis and intervention are paramount as 70% of deaths occur within the first hour of its occurrence[191].

The increased risk for developing venous thrombo-embolism (VTE) with smoking has been determined by systemic meta-analytic studies[192,193]. Kaptoge and group analyzed data from more than 1.1 million participants in 76 cohorts, and found that, smoking was associated with higher risk of VTE[194]. El-Nasser recently re-confirmed this adverse link[195]. Excess risk for VTE in smokers is also related to hospitalization[196]. This risk is more during the first 12 weeks in smokers if there was surgery involved[197]. Smoking induces endothelial dysfunction, along with oxidative stress and thrombo-inflammation and these contribute to the venous complications[198,199].

2.11 Smoking and other CVD risk factors

Smoking also aggravates many other CVD risk factors, such as diabetes mellitus[200], dyslipidemia[201], insulin resistance[202], metabolic syndrome[203], systemic inflammation[204], and renal failure[205].

III. CONCLUSION

The relationship between tobacco intake and the increased risk of CVDs is well established. The major mode of tobacco use is by smoking cigarettes. This is the number one preventable cause of CVDs. Further, quitting smoking after a major cardiovascular event is also the most effective secondary prevention measure[206]. The risks of CVDs drop dramatically following smoking cessation, irrespective of the age at cessation. Smoking cigarettes is also the number one preventable

cause of CVD mortality[207]. These risks are also increased with smokeless tobacco. Cessation of cigarette smoking dramatically reduces the risk of premature death from all smoking-related diseases[208]. The health risks associated with smoking show a dose-response relationship and there is no lower limit for deleterious effects[209]. No exposure to tobacco is safe for the cardiovascular system.

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