ash fact sheet
action on smoking and health

Smoking, the heart and circulation

Introduction

Cardiovascular disease (CVD) incorporates the disorders of the heart and circulatory system. These include coronary heart disease (angina and heart attacks), cerebrovascular disease (embolism, aneurysms and stroke), rheumatic heart disease, congenital heart disease and peripheral arterial disease.[1,2] This factsheet examines the links between smoking and CVD, the mechanisms by which smoking causes CVD and how a person's risk may be reduced.

CVD is the leading cause of mortality across European countries, accounting for around 1.9 million deaths each year.[3] In the UK alone, 155,000 deaths were attributed to CVD in 2014 [4] which included 69,000 deaths from coronary heart disease (an average of nearly 200 people each day) and 39,000 from strokes.[4] Although these numbers are falling, CVD remains responsible for more than a quarter of all deaths in men and women.[5] The cost of premature death from CVDs, lost productivity, hospital treatment and prescriptions is estimated at £19 billion for the UK and €196 billion a year for the EU economy.[6]

The World Health Organization predicts a significant increase in prevalence over the next 10-20 years, with a rise from 17 million deaths worldwide attributable to CVD in 2008 to 23.4 million by 2030.[7] In 2012 CVD claimed 17.5 million deaths worldwide illustrating this upward trend.[8]
In the interim period, diagnosis of CVD has been found to result in poorer quality of life, life satisfaction and mental health [9]; with depression being two to three times more common among those with cardiovascular diseases.[10]

Behavioural risk factors are responsible for 80% of all diagnoses of coronary heart disease and cerebrovascular disease.[11] Although unhealthy diet, physical inactivity and harmful use of alcohol play a role; by far the leading behavioural risk factor of CVD is smoking. Smoking has been attributed to account for 14% of deaths from heart and circulatory disease[12]; with the risk being substantially reduced within two years of smoking cessation.[13] Compared with non-smokers, smokers have a 2 to 4 times increased risk of heart disease and of stroke.[14]

How smoking causes CVD

Inhaling tobacco smoke causes several immediate responses within the heart and its blood vessels. Within one minute of starting to smoke, the heart rate begins to rise. This is partially attributable to nicotine, the addictive substance in cigarettes. Nicotine stimulates the body to produce adrenaline, making the heart beat faster. Nicotine also increases blood pressure, which is a measure of the tension created upon the walls of the arteries by the blood.[15] The increase in heart rate and blood pressure means that smokers' hearts often have to work harder than non-smokers hearts, resulting in an increased risk of heart disease or stroke. Higher pressure can also cause damage to organs which filter blood, such as the kidneys.[16] However, clinical trials on the sole use of nicotine (i.e. in the form of Nicotine Replacement Therapy; NRT) in patients with underlying, stable coronary disease, suggest that use of therapeutic nicotine does not increase cardiovascular risk.[17]

Smoking tobacco also results in increased exposure to carbon monoxide (CO), a colourless, odourless gas which is produced from the incomplete burning of combustible products. CO is the fourth most common chemical of the 4,000 different constituents of tobacco smoke and can make up 3-5%of its volume.[18] When levels of CO in the blood increase the ability of the body to carry oxygen is significantly decreased. This is because carbon monoxide attaches itself to haemoglobin (the oxygen-carrying pigment in red blood cells) much more easily than oxygen does. This results in tissues being starved of oxygenated blood, which causes them to suffocate and die. Smokers are also likely to experience shortness of breath and increased heart rate as a result of carboxyhaemoglobin levels.

One major contribution to the increased risk of CVD among smokers is tobacco's effect on increasing overall blood cholesterol levels. This occurs as a result of the chemical acrolein, often used in pesticides, which affects the way the body processes cholesterol, allowing greater amounts to remain in the blood system.[19] This compound, among others, also decreases the ratio of high-density lipoprotein (the "good" cholesterol) to low-density lipoprotein (the "bad" cholesterol).[20, 21] Low density lipoproteins (LDLs) and other fatty substances over time stick to the blood vessel walls and cause narrowing, a process known as atherosclerosis. These substances are called atheroma. As the atherosclerosis progresses, blood flows less easily through rigid and narrowed arteries. If the atheroma ruptures and breaks off it is likely to lead to the formation of a thrombosis (clot). This sudden blockage of an artery may lead to a fatal heart attack, a stroke or gangrene of the leg. For further information see ASH's Research Report: Smoking and Peripheral Arterial Disease. The speed of this process is increased further by many of the toxins in tobacco which cause damage to the blood vessel walls, allowing plaques to form at a faster rate than in a non-smoker.[22]

The risk of thrombosis is also raised due to tobacco's effect on fibrinogen levels (a protein which causes blood to clot) and its effects on increased platelet aggregation which makes the blood more sticky.[23,24] Finally, it has been shown that smoking causes the body's blood vessels to constrict (vasoconstriction) by decreasing nitric oxide which dilates blood vessels and increasing endothelin-1 which causes constriction of blood vessels.[25] The net result is raised blood pressure and a transient reduction in blood supply.

Coronary Heart Disease (CHD)

The heart needs a steady supply of oxygen-rich blood to function effectively. Coronary heart disease (also known as coronary artery disease or ischemic heart disease) is a general term that describes conditions caused by an interrupted or diminished blood flow through the coronary arteries to the heart muscle.

The most common way that this flow of oxygen-rich blood becomes reduced is by atherosclerosis or the formation of a blood clot (thrombosis) in the arteries. When the blood supply to the heart is interrupted, it sometimes causes the chest pain known as angina. When the blood supply is cut off completely, a myocardial infarction or heart attack occurs, which may cause permanent damage to the heart muscle. If the pieces of the atheroma break away and cause a blood clot to form, this can result in a stroke if carried to the brain, or heart attack if within the heart.

For further information, please see the British Heart Foundation website.

Smoking: the principal risk factor for CHD

The 1990 US Surgeon General report firmly established that smoking is the "most important of the known modifiable risk factors for CHD".[26] This relationship has since been demonstrated across racial and ethnic groups and in women younger than 50 years of age, even though the

incidence of CHD in this population is low.[27,28] In the UK, the British Regional Heart Study cited smoking as one of the three principle non hereditary risk factors for coronary heart disease; the others being raised cholesterol and high blood pressure.[29] The National Institute for Health and Care Excellence (NICE) 2010 guidance on cardiovascular disease identifies smoking as a significant contributing factor and argues that any intervention to reduce risk should include referrals for smoking cessation.[30] Moreover, almost half of the decline in coronary heart disease mortality in England and Wales between 1981 and 2000 has been attributed to reductions in smoking prevalence.[31]

More recently, the European Prospective Investigation into Cancer and Nutrition (EPIC) examined risk factors for myocardial infarction and concluded that smoking is one of the leading causes,[32] while the CV-ASPIRE study, which recruited smokers across Europe in 2011, established that reductions in risk of CHD could be obtained by tackling the most important modifiable risk factor: smoking.[33] A 2015 Cochrane Review of the effects of laws prohibiting smoking in public places across 21 countries found that the introduction of the laws was associated with decreased incidence of acute myocardial infarction (AMI) and acute coronary syndrome (ACS). Of 43 studies included, 33 detected significant associations between the introduction of the smokefree measures and reductions in incidence of these disorders.[34]

Research into the link between smoking and CHD has found that:

- A cigarette smoker is at least twice as likely to have a heart attack as a non-smoker[35] with evidence emerging that the risk may be as much as five-fold higher in smokers younger than 50 years of age.[29,36,]
- For those who have a heart attack, risk of death is greater among current smokers. A study of 34,439 general practitioners between 1951 and 2001, found a 62% increased rate of death from heart attacks among smokers compared to lifelong non-smokers and a 32% increased risk compared to former smokers.[37] The more risk factors present (e.g., smoking, poor diet, high blood pressure and high cholesterol), the greater the chance of developing coronary vascular disease.[38] A collation of data from 18 studies established that having one risk factor at age 55 dramatically increased the lifetime risk of cardiovascular disease compared to having no risk factors, and having more risk factors during middle age increased risk even further.[39]
- Even light smokers are at increased risk of CHD. A large Danish study found that smoking the equivalent of 3-5 cigarettes per day significantly increased the risk of developing heart disease and all-cause mortality and that the relative risk was higher in women than in men.[40]
- Mortality from cardiovascular diseases is higher amongst smokers who started smoking at an earlier age, independent of the number of smoking years.[41] Regardless of gender, the risk of CHD is higher in smokers relative to ex-smokers and non-smokers. However, there is a slightly greater risk for female smokers relative to male smokers. Possible mechanisms include differences in biological make-up and smoking behaviour among men and women.[42]

Giving up smoking dramatically reduces the risk of a heart attack and is particularly important for those who have other risk factors such as high blood pressure, raised blood cholesterol levels, and are diabetic or overweight and physically inactive.

- Within a year of giving up, the risk of a heart attack halves compared to that of an active smoker and declines gradually thereafter.[29 43] After 15-20 years of abstinence, the risk of CHD is similar to that of people who have never smoked.[44 45]
- CHD patients who quit smoking reduce their CHD death risk. In 1994 there were 4,536 fewer deaths in Scotland from CHD than in 1975. This represented over 48,000 life years gained among those aged 45-84. Forty per cent of these were attributable to smoking cessation, compared to 25% attributable to medical and surgical treatments.[46]

Stroke

A stroke occurs when blood flow to the brain is interrupted causing brain cells to become damaged or die.[47] It can affect the way the body or mind functions. For example, it can result in paralysis, muscle weakness, trouble speaking and memory loss. It is also currently the second most common cause of death world-wide after heart disease. The World Health Organization has predicted that this will still be the case in 2030, with stroke expected to account for 12.1% of all deaths.[48]

Smokers are more likely to have a stroke than non-smokers and the risk increases with the number of cigarettes smoked.[49] [50] A number of studies have identified a relationship between smoking and stroke.

- It is estimated that 10% of deaths from stroke are due to active smoking and 3,500 deaths from passive smoking.[50] [51]
- In 2016, a major international study conducted across 32 different countries found a clear association between current cigarette smoking and experience of strokes. This was consistent across countries, genders and ages. Current cigarette smoking was particularly associated with incidence of ischaemic strokes.[52]
- A Finnish cohort study conducted by the University of Helsinki found that smoking increased risks of subarachnoid haemorrhage, often leading to strokes, in both men and women but this risk was considerably greater for female smokers. Hazard ratios between smoking and strokes differed by sex in all categories studied, with women consistently being at greater risk.[53]
- In 2013, a research team from the US who combined data from 81 studies confirmed that smoking was an independent risk factor for stroke in both men and women. However, in regional analysis there was evidence of a more harmful effect on women living in Western countries but no difference in Asian populations.[54]
- A prospective cohort study in China found a dose-response relationship between smoking and risk of stroke, with the risk increasing for both the amount of cigarettes smoked daily and duration of smoking.[55] This was replicated in another study which showed that the highest risk occurred in those smoking more than 15 cigarettes per day and having smoked for 25 years or more.[56]
- Continued smoking following a stroke is related to prognosis. In a large Canadian study, continued smoking had a negative effect on functional outcome at discharge, mortality at 1 year and length of stay in hospital.[57] A study from Australia similarly found an increased risk of death following stroke among smokers compared to past smokers and never smokers, with the risk maintained for the 10 years of the study.[58]
- The risk of stroke is particularly high among those who have other risk factors including hypertension or high serum cholesterol.[59]

Stopping smoking dramatically reduces the risk of a stroke occurring:

- Within two years of stopping smoking, a former smoker's risk of stroke is reduced to that of a non-smoker.[60]
- A 12 year study of female nurses found that the elevated risk of stroke in smokers disappeared within 5 years of quitting and that the decline in risk was independent of age, highlighting that it is never too late to quit.[61]
- Ex-smokers are less likely to die within a 10 year period from a stroke than current smokers.[47]
- The beneficial effects of smoking cessation among former smokers is similar for men and women.[54]

Aneurysm

An aneurysm is a bulge in a blood vessel that is caused by a weakness in the vessel wall. As the blood passes through the weakened part of the vessel, the blood pressure causes it to bulge outwards like a balloon. There is a danger that the aneurysm will cause the artery to burst (rupture) causing organ damage or internal bleeding, both of which can be fatal.[62]

Aneurysms occur most commonly in the aorta (the main artery in the heart that pumps blood out into the body) or in the brain (referred to as an intracranial aneurysm) but can occur in any artery in the body. An intracranial aneurysm which occurs near the surface of the brain may lead to blood seeping into the space between the skull and the brain. This is called a subarachnoid haemorrhage and is responsible for 5% of strokes in the UK.[63] Approximately 60% of people who experience a subarachnoid haemorrhage die within two weeks.[64] It has been estimated that ruptured abdominal aortic aneurysms cause 12,000 deaths per year; 8,000 of these occur below the kidneys.[65] An estimated 1 in 12,500 people in the UK will also experience rupture of an intracranial aneurysm[66] and 15% of these will die before reaching hospital.[67]

- Cigarette smoking is the most significant modifiable risk factor for cerebral aneurysm formation and rupture, with smokers being 3-4 times more likely to experience a rupture than non-smokers.[68,69] Up to 80% of patients who sustain an aneurysm have a history of smoking and 50-60% are current smokers.[70]
- Researchers examining the role of cigarette smoke in causing aneurysms concluded that: “Cigarette smoke appears to affect every step in the cascade of events leading to subarachnoid haemorrhage.”[71]
- Smoking is an important determinant of the risk of death due to aortic aneurysm.[72 73] A study of over 56,000 individuals in the Copenhagen General Population Study, which followed individuals for 7 years, established that tobacco smoking was the most important predictor of future aortic aneurysm outcomes in the general population. The attributable risk due to tobacco use was 47%.[74]
- Smokers are also much more likely to die from a ruptured aneurysm of the abdominal aorta than non-smokers.[75] A British study of over 5,000 men and women aged 65-79 years found that smoking was the most important avoidable risk factor for abdominal aortic aneurysm.[71]
- Smokers who also have certain chromosomal variations are at significantly increased risk of intracranial and abdominal aneurysm.[72,73]
- It has been estimated that 70% to 80% of people who have an aneurysm are current smokers or former smokers.[76] Other research suggests that there is a correlation between smoking and aneurysm recurrence.[80]
- There is evidence that smoking has a significant impact on peri-operative outcomes following endovascular aneurysm repair.[81]

Both the NHS and the UK Brain Aneurysm Foundation recommend that people who have an aneurysm stop smoking.[62 82] There is evidence that the risk of an aneurysm developing decreases after smoking cessation, although at a lower rate than risk for other types of CVD.[83]

Peripheral Arterial Disease

Peripheral Arterial Disease (also called Peripheral Vascular Disease) is a disease that affects the peripheral arteries. Most forms of PAD are caused by atherosclerosis. Over time, one or more of the principal arteries may become so narrow that they are unable to deliver oxygen-rich blood to the limbs. In severe cases, the blockage can cause gangrene requiring amputation.[84 85]

PAD is more often found in older people. The NHS estimates that PAD is found in 2.5% of people under 60, 8.3% of people aged 60–69 and 19% of people over 70.[86] However the British Medical Journal’s Clinical Evidence on PAD concludes that up to 20% of adults over 55

in the UK have a detectable form of PAD in the legs but that only a small proportion will have symptoms.[87] A further study estimated that one in five of the population aged 65 – 75 in the UK have some form of PAD but again not all will show symptoms of the disease.[88]

Smoking is the most important preventable risk factor for PAD.[89] Risks are cumulative, with smokers who also have high blood pressure or have high cholesterol being at the greatest risk. Some types of PAD are almost exclusively found in smokers, with the condition being a rare diagnosis in non-smokers.

For example, in countries where 30% of the population smoke, around 50% of all PAD diagnoses are attributable to tobacco use.[90] The risks have been estimated to be 10-16 times higher for smokers than those who have never smoked [91] and the diagnosis of PAD on average is made a decade earlier in smokers than non-smokers.[92] The risk of PAD increases proportionally with the number of cigarettes smoked. Heavy smokers are three times more likely to develop intermittent claudication – a severe pain in the legs that is brought on by exercise and relieved by rest.[84] Smokers who continue to smoke after surgery for PAD are more likely to develop gangrene in a leg, leading to amputation, and in some cases early death.[93]

While there are pharmacological therapies and surgical options available for the treatment of PAD, stopping smoking is also an important means of stabilising or improving PAD.[94 95] In a small study, the risk of PAD was found to drop dramatically following smoking cessation. Ex-smokers who had not smoked for 5 years or more had a near normal risk, while those who had not smoked for less than 5 years had a significantly lower risk than continuing smokers.[96] This finding was supported by researchers in Glasgow who combined data from 55 studies on peripheral arterial disease and smoking. They concluded that the risk of PAD was lower among ex-smokers although it still appeared to be significantly increased compared with never smokers.[97]

Smoking results in the development of PAD in a number of ways:

- Chemicals in tobacco smoke damage endothelial cells which line the walls of blood vessels. This increases permeability to fats and other blood components.
- Smoking also stimulates the formation of atheroma. This has the effect of narrowing the arteries, reducing the amount of blood which can flow through them. This can reduce blood and oxygen supply to tissues.[19]
- Nicotine and carbon monoxide constrict the blood vessels. This problem is exacerbated by reduced oxygen supply to the tissues because the carbon monoxide in tobacco smoke attaches to haemoglobin (found in red blood cells) leading to elevated levels of carboxyhaemoglobin. The lack of oxygenated blood is a cause of ischaemia (i.e. a restriction of blood supply to tissues) which can cause ulceration and gangrene.[25]
- Smoking also encourages thrombosis (blood clots) by increasing platelet stickiness.[98]

Thromboangiitis Obliterans (Buerger's Disease)

Buerger's Disease is a rare form of PAD that most commonly affects the small and medium-sized arteries, veins, and nerves of the arms and legs. It is characterised by the swelling of blood vessels, which prevents blood flow and causes clots to form. This can lead to pain, tissue damage and even gangrene. In some cases, amputation may be required.

There is an extremely strong association between the heavy use of tobacco and Buerger's disease,[99] with just 5% of patients being non-smokers. There is also some evidence to suggest that users of smokeless tobacco are at risk.[100 101] Mechanisms by which this occurs include tobacco's effect on the triggering of an immune response in susceptible persons or unmasking a clotting defect; either of which incites an inflammatory reaction of the vessel wall.[102] The

disease typically occurs in young male smokers aged 20 to 40. The only proven treatment to prevent progression of the disease and avoid amputation is the complete cessation of smoking or other use of tobacco.[103] In fact, smoking cessation leads to dramatic improvements of the symptoms almost immediately. In one study, 19% of patients diagnosed with Buerger's disease who continued to smoke required amputation, while none of those who stopped underwent amputation.[104]

Passive smoking

In line with active smoking, it is generally accepted that passive smoking, which is breathing in someone else's smoke, leads to increased prevalence of various types of CVD. Passive smoking is also referred to as secondhand smoke or environmental tobacco smoke. Despite the well-known risks of smoke exposure and smoking bans, millions of children worldwide are still exposed to environmental tobacco smoke in their homes.[105] Such passive smoking has been implicated in deteriorating cardiovascular status in children in terms of high-density lipoprotein levels and deteriorated vascular function.[106]

- The 2004 report of the Government appointed Scientific Committee on Tobacco and Health (SCOTH) found that exposure to second-hand smoke is a cause of heart disease. The Committee estimated that there is an increased relative risk of about 25%.[107]
- The Institute of Medicine in the United States also confirms that exposure to secondhand smoke is a cause of heart disease in non-smokers.[108]
- After the introduction of smokefree legislation in England in 2007, emergency hospital admissions for myocardial infarction (heart attack) fell by 2.4% (equivalent to 1200 fewer admissions.)[109]
- Hospital admissions for acute coronary syndrome in Scotland fell by 14% among smokers, 19% amongst former smokers, and 21% amongst persons who had never smoked after the introduction of smokefree legislation in 2006.[110]
- A Cochrane review on the impact of the introduction of smokefree legislation found that legislation does lead to improved public health outcomes through reductions in exposure to secondhand smoke. There is consistent evidence of a positive impact on cardiovascular health with the clearest evidence for this observed in reduced admissions for acute coronary syndrome.[111]
- Exposure to secondhand smoke can increase the risk of CHD by 50% to 60%.[112]
- The effects of passive smoke exposure on the heart can be rapid.[113] For example, a Japanese study has shown that just 30 minutes of exposure to environmental tobacco smoke by healthy non-smokers can have a measurable impact on coronary blood flow.[114] There is now also evidence that passive smoking is associated with increased risk of stroke in men and women.[115]
- Passive smoking appears to compromise health not only when individuals are exposed frequently for prolonged periods of time, but also after single brief exposure.[116] There is a dose response relationship, with greater exposure associated with greater risk.[117]

Smoking reduction

In June 2013 NICE released guidance on tobacco harm reduction.[118] One method of harm reduction which NICE advocates is smoking reduction i.e. reducing the number of cigarettes smoked per day. This is on the basis of evidence that smoking reduction among smokers who are unable or unwilling to stop smoking could increase their motivation to quit; particularly if they do so with pharmacological help such as nicotine replacement therapy (NRT). In other words, those who are unmotivated to stop smoking are more likely to quit if they cut down with NRT than if they continue smoking at their original level, or cut down without NRT. However, NICE also acknowledges that there is little evidence that smoking reduction has any immediate impact on morbidity or mortality. This is because smokers tend to compensate for their reduced

nicotine intake by smoking each cigarette harder.

On the basis of these findings, smokers who wish to reduce their risk of CVD should be informed: 1) that the only reliable way of doing so is stopping smoking completely and 2) that smoking reduction alone is unlikely to significantly reduce their risk. However, if they are unable to stop smoking they may wish to attempt smoking reduction with the help of NRT, but that their ultimate goal should be to quit smoking in the near future when they feel they are able to do so.

E-cigarettes

In recent years there has been a significant growth in the number of smokers using e-cigarettes (electronic nicotine delivery devices) as an aid to cutting down or stopping smoking.[119] Whilst the evidence to date shows that e-cigarettes are considerably safer than tobacco products and can help people to stop smoking,[120] the long term health impacts of inhaling nicotine vapour are not yet known, particularly with reference to the impact of vaping on the heart and circulatory system. A study funded by the British Heart Foundation at Dundee University will compare the effects of e-cigarettes and tobacco cigarettes on smokers' heart health.[121]

References

1 World Health Organization website. Media Centre. Factsheet: Cardiovascular Diseases. June 2016 [Accessed 08 August 2016]

2 British Heart Foundation website. Cardiovascular Disease. [Accessed 08 August 2016]

3 European Heart Network and European Society of Cardiology. 2012 European Cardiovascular Disease Statistics. September 2012. [Accessed 08 August 2016]

4 Cardiovascular Disease Statistics 2015. British Heart Foundation. [Accessed 08 August 2016]

5 Heart Statistics. British Heart Foundation. [Accessed 08 August 2016]

6 Nichols M, Townsend N, Luengo-Fernandez R, et al. European Cardiovascular Disease Statistics 2012. European Heart Network, Brussels, European Society of Cardiology, Sophia Antipolis.

7 World Health Statistics 2008. World Health Organization 2008

8 World Health Statistics 2016 World Health Organization 2016

9 Miguel-Díez J, Carrasco-Garrido P, Rejas-Gutierrez J. et al. The influence of heart disease on characteristics, quality of life, use of health resources, and costs of COPD in primary care settings. BMC Cardiovascular Disorders 2010; 10:8.

10 Arthritis Research UK, British Heart Foundation, Diabetes UK, National Rheumatoid Arthritis Society, We are Macmillan Support. Twice as likely: putting long term conditions and depression on the agenda. April 2012. [Accessed 10 August 2016]

11 Global status report on non-communicable diseases 2010. Geneva, World Health Organization, 2011

12 Health and Social Care Information Centre (HSCIC), Lifestyles Statistics. Statistics on Smoking: England, 2012.

13 Salonen JT. Stopping smoking and long-term mortality after acute myocardial infarction. Br Heart J. 1980; 43: 463-469.

14 US Department of Health and Human Services. The Health Consequences of Smoking: A Report of the Surgeon General. Atlanta: U.S. Department of Health and Human Services, Office on Smoking and Health, 2004

15 Primatesta, P, et al., Association between smoking and blood pressure. Hypertension 2001; 37:187-193.

16 Righetti, M & Sessa, A. Cigarette smoking and kidney involvement. Journal of Nephrology 2001; 14(1):3-6.

17 Nicotine vs tobacco smoke. www.treatobacco.net [Accessed 2 Sept. 2016]

18 Hoffman, D. and I. Hoffman. The changing cigarette: Chemical studies and bioassays. In: Risks Associated with Smoking Cigarettes with Low Machine-Measured Yields of Tar and Nicotine (Smoking and Tobacco Control Monograph No. 13). 2001, NCI: Bethseda. p. 159-191.

19 Tamamizu-Kato, S. et al. Modification by acrolein, a component of tobacco smoke and age-related oxidative stress, mediates functional impairment of human Apolipoprotein E. Biochemistry 2007; 46(28): 8392-8400.

20 Gossett et al. Smoking intensity and lipoprotein abnormalities in active smokers. Journal of Clinical Lipidology 2009; 3(6): 372-378

21 Campbell, SC, Moffatt, RJ, Stamford, BA. Smoking and smoking cessation—the relationship between cardiovascular disease and lipoprotein metabolism: a review. Atherosclerosis 2008; 201: 225–235

22 Mitchell B, et al. Tobacco use and cessation: The adverse health effects of tobacco and tobacco-related products. Primary Care: Clinics in Office Practice 1999; 26(3):463-98.

23 Kannel WB, Wolf PA, Castelli WP, D'Agostino RB. Fibrinogen and risk of cardiovascular disease. The Framingham Study. JAMA 1987; 258:1183–6

24 Hunter KA et al. Effects of smoking and abstention from smoking in fibrinogen synthesis in humans. Clinical Science 2001; 100(4): 459-65.

25 Kioski W, Linder L, Stoschitzky K et al. Diminished vascular response to inhibition of endothelium-derived nitric oxide and enhanced vasoconstriction to exogenously administered endothelin-1 in clinically healthy smokers. Circulation 1994; 90: 27–34

26 US Department of Health and Human Services. The Health Benefits of Smoking Cessation. Surgeon

General's Report on Smoking and Health. Atlanta: US Department of Health and Human Services, 1990.
27 US Department of Health and Human Services. Tobacco Use Among US Racial/Ethnic Minority Groups—African Americans, American Indians and Alaska Natives, Asian Americans and Pacific Islanders, and Hispanics. A Report of the Surgeon General. Atlanta: U.S. Department of Health and Human Services,1998.
28 Croft P, Hannaford PC. Risk factors for acute myocardial infarction in women: evidence from the Royal College of General Practitioners' oral contraception study [letter] British Medical Journal 1989; 298 (6667):165–8
29 Cardio and Vascular Coalition. Modelling the UK burden of Cardiovascular Disease to 2020. British Heart Foundation, 2008.
30 NICE. Cardiovascular disease prevention. NICE public health guidance 25. June 2010. [Accessed 02 Sept 2016]
31 Unal, B et al. Explaining the decline in coronary heart disease mortality in England and Wales between 1981 and 2000. Circulation 2004; 109: 1101-1107
32 Heidemann C, Hoffmann K, Klipstein-Grobusch K, et al Potentially modifiable classic risk factors and their impact on incident myocardial infarction: results from the EPIC-Potsdam study. Eur J Cardiovasc Prev Rehabil. 2007; 14(1): 65-71.
33 Mallaina P, Lionis C, Rol H, et al. Smoking cessation and the risk of cardiovascular disease outcomes predicted from established risk scores: results of the Cardiovascular Risk Assessment among Smokers in Primary Care in Europe (CV-ASPIRE) study. BMC Public Health 2013; 13; 362.
34 Fraser K et al. Legislative smoking bans for reducing harms from secondhand smoke exposure, smoking prevalence and tobacco consumption. Cochrane Database of Systematic Reviews, 4February 2016.
35 British Heart Foundation website. Smoking [Accessed 02 Sept 2016]
36 Mahonen, M et al. Current smoking and the risk of non-fatal myocardial infarction in the WHO MONICA Project populations. Tobacco Control 2004; 13: 244-250
37 Doll, R., Peto, R., Boreham, J., Sutherland, I. Mortality in relation to smoking: 50 years' observations on male British doctors. BMJ, 2004; 328
38 American Heart Association. Coronary Artery Disease - Coronary Heart Disease. 2013. [Accessed 02 Sept 2016]
39 Berry, J. D et al. Lifetime Risks of Cardiovascular Disease 2012; 366(4): 321-9.
40 Prescott, E et al. Importance of light smoking and inhalation habits on risk of myocardial infarction and all cause mortality. A 22 year follow up of 12,149 men and women in The Copenhagen City Heart Study. Journal of Epidemiology and Community Health 2002; 56: 702-706
41 Honjo K, Iso H, Tsugane S The effects of smoking and smoking cessation on mortality from cardiovascular disease amongst Japanese: pooled analysis of three large-scale cohort studies in Japan. Tobacco Control 2010; 19: 50-57
42 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; 1297-305.
43 The health benefits of smoking cessation: A report of the Surgeon general. US DHHS, 1990.
44 Tang JL., Cook DG, Shaper AG. Giving up smoking: how rapidly does the excess risk of ischaemic heart disease disappear? Journal of Smoking-Related Disease 1992, 3, 203–215.
45 Shields M, Wilkons K. Smoking, smoking cessation and heart disease risk: A 16-year follow-up study. Health Reports 2013; 24: 12-22.
46 Critchley JA, Capewell S, Unal B. Life-years gained from Coronary Heart Disease mortality reduction in Scotland: prevention or treatment? Journal of Clinical Epidemiology 2003; 56: 583-590.
47 The Stroke Association website. What is a stroke? Accessed 07 Sept 2016.
48 WHO. World Health Statistics 2008. World Health Organization 2008.
49 Aldoori M, Rahman SH. Editorial: Smoking and stroke: a causative role. BMJ 1998; 317: 962
50 The Stroke Association. Smoking and the Risk of Stroke. April 2012.
51 Health Committee second report 2000: The Tobacco Industry and the health risks of smoking. The Stationery Office Ltd. P3
52 Global and regional effects of potentially modifiable risk factors associated with acute stroke in 32 countries (INTERSTROKE): a case-control study O'Donnell, M. J et al. The Lancet 2016; 388: (10046) 731-840
53 Lindbohm J et al. Sex, smoking, and risk for subarachnoid haemorrhage. Stroke 2016; 47: 1975-1981

54 Sanne et al. Smoking as a risk factor for stroke in women compared with men: A systematic review and meta-analysis of 81 Cohorts, including 3 980 359 Individuals and 42 401 strokes. Stroke 2013; DOI: 10.1161/STROKEAHA.113.002342
55 Kelly TN, Gu D, Jing C, Jian-feng H et al. Cigarette smoking and risk of stroke in the Chinese adult population. Stroke 2008; 39: 1688
56 Tse LA, Fang XH, Wang WZ, et al. Incidence of ischaemic and haemorrhagic stroke and the association with smoking and smoking cessation: a 10-year multicentre prospective study in China. Public Health 2012; 126: 960-6.
57 Edjoc RK, Reid RD, Sharma M, Fang J. Registry of the Canadian Stroke Network. The prognostic effect of cigarette smoking on stroke severity, disability, length of stay in hospital, and mortality in a cohort with cerebrovascular disease. J Stroke Cerebovasc Disease 2013; doi:10.1016/j.jstrokecerebrovasdis.2013.05.001
58 Kim J, Gall SL, Dewey HM, et al. Baseline smoking status and the long-term risk of death or nonfatal vascular event in people with stroke: a 10-year survival analysis. Stroke 2012; 43: 3173-8.
59 Nakamura K, Nakagawa H, Sakurai M, et al. EPOCH-JAPAN Research Group. Influence of smoking combined with another risk factor on the risk of mortality from coronary heart disease and stroke: pooled analysis of 10 Japanese cohort studies. Carebrovasc Dis; 2012: 480-491.
60 Aldoori M, Rahman SH. (Editorial) Smoking and stroke: a causative role. BMJ 1998; 317: 962
61 Kawachi,I et al. Smoking cessation and decreased risk of stroke in women. JAMA 1993; 269: 232-236
62 NHS Choices. Brain aneurysm. [Accessed 08 Sept 2016]
63 The Stroke Association. Bleeding in the brain - haemorrhagic stroke. [Accessed 08 Sept 2016]
64 NHS Choices. Brain aneurysm. [Accessed 08 Sept 2016]
65 Abdominal aortic aneurysm - endovascular stent-grafts NICE Technology Appraisal Guidance (February 2009) [Accessed 08 Sept 2016]
66 NHS Choices. Brain aneurysm [Accessed 08 Sept 2016]
67 van Gijn J, Kerr RS, Rinkel GJ. Subarachnoid haemorrhage. The Lancet 2007; 369 (9558): 306–18
68 Chalouhi, N., et al. The case for family screening for intracranial aneurysms. Neurosurgical Focus 2011; 31(6): Article ID E8,
69 Woo D, et al. Smoking and family history and risk of aneurysmal subarachnoid haemorrhage. Neurology 2009; 72: 69–7
70 Chalouhi N et al. Cigarette smoke and inflammation: role in cerebral aneurysm formation and rupture. Mediators of Inflammation 2012; Article ID 271582
71 Chalouhi N, et al. Cigarette smoke and inflammation: role in cerebral aneurysm formation and rupture. Mediators of Inflammation. 2012; Article ID 271582.
72 Alcorn HG, Wolfson SK, Sutton-Tyrell K, et al. Risk factors for abdominal aortic aneurisms in older adults enrolled in the cardiovascular health study. Arteriosclerosis, Thrombosis and Vascular Biology 1996;16: 963
73 Lee AJ, Fowkes FGR, Carson MN, et al. Smoking, atherosclerosis and risk of abdominal aortic aneurysm. Eur Heart J 1997; 18 (4):671 – 676
74 Sode BF, Nordestgaard BG, Grønbæk M, Dahl M. Tobacco smoking and aortic aneurysm: Two population-based studies. Int J Cardiol 2012; 167 (5): 2271–2277
75 The health consequences of smoking - cardiovascular disease: a report of the Surgeon General. US DHHS 1983
76 Vardulaki KA et al. Quantifying the risks of hypertension, age, sex and smoking in patients with abdominal aortic aneurysm. Br J Surgery 2000; 87: 195-200
77 Deka R, Koller DL, Lai D, et al. The relationship between smoking and replicated sequence variants on chromosomes 8 and 9 with familiar intracranial aneurysm. Stroke 2010; 41: 1132 – 1137.
78 Strauss E, Waliszewski K, Oszkinis G, Staniszewski R. Gene-environment interaction for the HIF1-A 1772C>T polymorphisms and cigarette smoking increase susceptibility to abdominal aortic aneurysm. Przegl Lej 2012; 68: 744-9.
79 American Heart Association. Press release of the American Stroke Association meeting report: Smoking significantly increases risk of aneurysm in people with certain genes. 26 February 2010.
80 Ortiz R, Stefanski M, Rosenwasser R, Veznedraoglu E. Cigarette smoking as a risk factor for recurrence of aneurysms treated by endosaccular occlusion. Journal of Neurosurgery 2008; 108: 4

81 Koole D, Moll FL, Buth J, et al. (EUROSTAR collaborators.) The influence of smoking on endovascular abdominal aortic aneurysm repair. J Vsc Surg 2012; 55: 1581-6.
82 The Brain Aneurysm Foundation website. Treatment Options. [Accessed 08 Sept. 2016]
83 Wilmink TB, Quick CR, Day NE. The association between cigarette smoking and abdominal aortic aneurysms. J Vasc Surg 1999; 30 (6): 1099–105
84 British Heart Foundation. Peripheral arterial disease. London, British Heart Foundation, 2004
85 Scottish Intercollegiate Guidelines Network. Diagnosis and Management of Peripheral Arterial Disease: a National Clinical Guideline. NHS Scotland 2006.
86 NHS Choices website. Conditions: Peripheral Arterial Disease (PAD). [Accessed 08 Sept 2016]
87 Cassar K. Clinical Evidence: Peripheral Arterial Disease. British Medical Journal 2010.
88 Burns P, Gough S, Bradbury AW. Management of peripheral arterial disease in primary care. British Medical Journal 2003; 326: 584
89 Scottish Intercollegiate Guidelines Network. Diagnosis and Management of Peripheral Arterial Disease: a National Clinical Guideline. NHS Scotland 2006. (see 79)
90 Willigendael EM, Teijink JA, Bartelink ML, et al. Influence of smoking on incidence and prevalence of peripheral arterial disease. J Vasc Surg 2004;40:1158–65.
91 Cole, CW et al Cigarette smoking and peripheral arterial occlusive disease. Surgery 1993; 114: 753-757
92 Management of peripheral arterial disease (PAD). TransAtlantic Inter-Society Consensus (TASC). J Vasc Surg 2000;31(suppl):S1-28
93 Myers, K A et al. Br J Surg 1978; Faulkner, K W et al. Med J Austr 1983; 1: 217-219
94 Mayo Clinic. Peripheral Artery Disease. [Accessed 08 Sept 2016]
95 Wiseman S, Kenchington G, Dain R, et al. Influence of smoking and plasma factors on patency of femoropopliteal vein grafts. BMJ 1989; 299: 643-6.
96 Weiss NS. Cigarette smoking and arteriosclerosis obliterans: an epidemiologic approach. Am J Epidemiol 1972; 95: 17-25.
97 Lu, L, Mackay, DF, Pell JP. Meta-analysis of the association between cigarette smoking and peripheral arterial disease. Heart 2014; 100(5): 414-23.
98 Krupski WC. The peripheral vascular consequences of smoking. Ann.Vasc.Surg. 1991; 5: 291-304.
99 Olin,J .Thromboangiitis obliterans (Buerger's disease) Review article. N Eng J Med. 2000; 343: 864-869
100 O'Dell JR, Linder J, Markin RS, Moore GF. Thromboangiitis obliterans (Buerger's disease) and smokeless tobacco. Arthritis Rheum. 1987;30:1054-6.
101 Lawrence PF, Lund OI Jimenez JC Muttalib R. Substitution of smokeless tobacco for cigarettes in Buerger's disease does not prevent limb loss. J Vasc Surgery 2008; 48 (1): 210-212.
102 Tanaka K. Pathology and pathogenesis of Buerger's disease. Int J Cardiol 1998; 66: 237-42
103 Mills JL. Buerger's disease in the 21st century: diagnosis, clinical features, and therapy. Seminars in Vascular Surgery 2003; 16 (3): 179-189.
104 Ohta T, Ishioashi H, Hosaka M, Sugimoto I. Clinical and social consequences of Buerger disease. J Vasc Surg. 2004; 39: 176–180.
105 Rushton L. Health impact of environmental tobacco smoke in the home. Reviews on Environmental Health 2004; 19: 291–309.
106 Metsios GS, Flouris AD, Angioi M, Koutedakis Y. Passive smoking and the development of cardiovascular disease in children: a systematic review. Cardiol Res Pract 2011; 587650: doi: 10.4061/2011/587650
107 Secondhand smoke: Review of evidence since 1998. Scientific Committee on Tobacco and Health (SCOTH). Department of Health, 2004.
108 Board on Population Health and Public Health. Secondhand smoke exposure and cardiovascular effects: making sense of the evidence. Institute of Medicine of the National Academies. 2010.
109 Sims M, Maxwell R, Bauld L Gillmore A. Short term impact of smoke-free legislation in England: retrospective analysis of hospital admissions for myocardial infarction. BMJ 2010; 340:c2161
110 Pell JP, Haw S, Cobbe S, et al. Smoke-free legislation and hospitalizations for acute coronary syndrome. N Engl J Med 2008; 359:482-91.
111 Frazer K. et al. Does legislation to ban smoking reduce exposure to secondhand smoke and smoking behaviour? Cochrane Review, February 2016.
112 Whincup, P et al. Passive smoking and risk of coronary heart disease and stroke: prospective study with

cotinine measurement. BMJ 2004; 329: 200-205
113 Raupach T et al. Secondhand smoke as an acute threat for the cardiovascular system: a change in paradigm. Eur Heart J 2006; 27: 386-392
114 Otsuka, R et al. Acute effects of passive smoking on the coronary circulation in healthy young adults. JAMA 2001; 286: 436-441
115 Bonita R et al. Passive smoking as well as active smoking increases the risk of acute stroke. Tobacco Control 1999; 8: 156-160
116 Flouris AD, Metsios GS, Carrillo AE, et al. Acute and short-term effects of secondhand smoke on lung function and cytokine production. Am J Respir Crit Care Med 2009; 179: 1029-33.
117 Jordan RE, Cheng KK, Miller MR, Adab P. Passive smoking and chronic obstructive pulmonary disease: cross-sectional analysis of data from the Health Survey for England. BMJ Open 2011; 1; e000153
118 NICE. Smoking: harm-reduction. Public health guideline [PH45]. June 2013. [Accessed 02 August 2016]
119 ASH Fact sheet: Use of e-cigarettes among adults in Great Britain. ASH, May 2016
120 McNeill A et al. E-cigarettes: an evidence update. Public Health England. August 2015.
121 Isles R. Smokers asked to help measure effects of electronic and tobacco cigarettes. University News, 26 Aug. 2016 University of Dundee.