The Effects of Cigarette Smoking on Anesthesia

Chandra Rodrigo, MBBS, FRCA, FFARCSI, FHKCA, FHKAM (Anaesthesiology)
Department of Anaesthesiology, University of Hong Kong, Hong Kong

Cigarette smoke contains over 4000 substances, some of which are harmful to the smoker. Some constituents cause cardiovascular problems, increasing the blood pressure, heart rate, and the systemic vascular resistance. Some cause respiratory problems, interfering with oxygen uptake, transport, and delivery. Further, some interfere with respiratory function both during and after anesthesia. Some also interfere with drug metabolism. Various effects on muscle relaxants have been reported. Risk of aspiration is similar to that of nonsmokers, but the incidence of postoperative nausea and vomiting appears to be less in smokers than in nonsmokers. Even passive smoking effects anesthesia. Best is to stop smoking for at least 8 weeks prior to surgery or, if not, at least for 24 hours before surgery. Anxiolytic premedication with smooth, deep anesthesia should prevent most problems. Monitoring may be difficult due to incorrect readings on pulse oximeters and higher arterial to end tidal carbon dioxide differences. In the recovery period, smokers will need oxygen therapy and more analgesics. It is time that anesthesiologists played a stronger role in advising smokers to stop smoking.

Key Words: Anesthesia; Cigarettes; Smoking.

Despite the warnings of health hazards of cigarette smoking, still one third of the population in industrial countries smoke.[1,2] Cigarette smoke contains over 4000 substances, some of which are pharmacologically active, some antigenic, some cytotoxic, some mutagenic, and some others carcinogenic.[3] It consists of a gaseous phase and a particulate phase. Eighty to 90% of cigarette smoke is gaseous, consisting of mainly nitrogen, oxygen, and carbon dioxide. The gaseous phase also contains carcinogens such as hydrocyanic acid and hydrazine, ciliotoxins, and irritants such as hydrocyanic acid, acetaldehyde, ammonia, acrolein, and formaldehyde, and an agent impairing oxygen transport, namely carbon monoxide. In the particulate phase, the main toxic ingredient is nicotine. It also contains carcinogens such as tar and polynuclear aromatic hydrocarbons and tumor accelerators such as indole and carbazole.

EFFECT ON THE CARDIOVASCULAR SYSTEM

Nicotine in smoke stimulates the adrenal medulla to secrete adrenaline, resets the carotid body and aortic receptors to maintain a higher blood pressure, and stimulates autonomic ganglia, increasing sympathetic tone. The result is an increase in systolic and diastolic blood pressure, an increase in heart rate, and an increase in peripheral vascular resistance. These increase the myocardial contractility, leading to an increase in oxygen consumption by the cardiac muscle. Increase in excitability leads to more frequent contractions and again an increase in oxygen consumption. Thus, the demand for oxygen is increased. An increase in coronary vascular resistance leads to a decrease in the coronary blood flow, resulting in a decrease in the supply of oxygen. These lead to a decrease in the myocardial oxygen supply : demand ratio.[4] Nicotine also increases intracellular calcium during ischemia. This may exacerbate myocardial cell damage.[5] In smokers, the plasma concentration of nicotine reaches 15–50 ng/mL. The half life of nicotine is 30–60 minutes.[6] Following the smoking of 1 cigarette, the pressor response lasts for about 30 minutes. Three to four hours of abstinence results in insignificant side effects due to nicotine and a significant improvement of the myocardial oxygen supply : demand ratio.

The other constituent of smoke that affects the cardiovascular system is carbon monoxide. Cigarette

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Address correspondence to Dr Chandra Rodrigo, Block 1, Flat A8, 23 Sha Wan Drive, Pokfulam, Hong Kong.

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smoke contains 400 parts per million. In the blood, carbon monoxide combines with hemoglobin to form carboxyhemoglobin (COHb). In smokers, the amount of COHb in the blood ranges from 5 to 15%. In nonsmokers, it is only about 0.3 to 1.6%. Even with environmental pollution, the COHb detected in nonsmokers does not exceed 1.9%.[7] The amount of COHb present in the blood of smokers depends on the type of cigarette smoked, the frequency, and the method of smoking. The concentration is said to be constant throughout the day. The affinity of carbon monoxide for hemoglobin (Hb) is 200 times that of oxygen.[8] Thus, the amount of Hb available for combining with oxygen is drastically reduced. It also shifts the oxyhemoglobin curve to the left due to (i) its high affinity for Hb, (ii) a change in shape of the oxyhemoglobin curve from a sigmoidal to a more hyperbolic curve by carboxyhemoglobin, and (iii) depletion of 2,3-diphosphoglycerate by carbon monoxide.[9] The left shift of the oxyhemoglobin curve makes it difficult for tissues to extract oxygen from the hemoglobin. The result is a decrease in the oxygen available to the tissues. Carbon monoxide also binds with cytochrome oxidase and myoglobin and inactivates mitochondrial enzymes in the cardiac muscle.[5] The result is a decrease in the intracellular oxygen transport and usage and a negative inotropic effect. These mechanisms lead to chronic tissue hypoxia. The body compensates with an increase in red blood cells. The result is an improvement of the oxygen availability at the expense of increased plasma viscosity.

Carbon monoxide also affects the cardiac rhythm. Patients with coronary artery disease having 6% of COHb in their blood have exhibited ventricular arrhythmias during anesthesia.[10] At a concentration of COHb of 4%, no arrhythmias have been detected.

The half life of carboxyhemoglobin depends chiefly on pulmonary ventilation.[11] At rest, the half life is about 4–6 hours. With strenuous exercise, due to rapid breathing, it is decreased to 1 hour. During sleep, when the breathing is slow, its half life is prolonged to about 10–12 hours. If one breathes 100% oxygen, its half life is reduced to 40–80 minutes, and with hyperbaric oxygen, it is even further reduced to 23 minutes. Recently, it has been found that its half life is longer in males than females.[12] Thus, on advising patients before anesthesia, these variations should be noted. During the day time, abstinence for 12 hours is sufficient to get rid of carbon monoxide. If an operation is scheduled for the next morning, the patient should not smoke the previous evening. Males should abstain for even a longer period.

EFFECT ON THE HEMOSTATIC SYSTEM

Smoking increases the production of Hb, red blood cells, white blood cells, and platelets and increases platelet reactivity.[5] There is also an increase in fibrinogen. These result in an increase in the hematocrit and the blood viscosity, leading to an increased thrombotic tendency. The result is an increased incidence of arterial thromboembolic disease in smokers. However, there is no increase in the incidence of deep vein thrombosis.[13] In fact, a decreased incidence in comparison with nonsmokers has been reported in some studies.[14–16]

Chronic hypoxia to the cardiac muscle and the increase in incidence of thromboembolic disease causes smokers to be at a 70% greater risk of coronary artery disease compared with nonsmokers, and the postoperative mortality in smokers is higher than in nonsmokers.[5] Of 38% of vascular patients with cardiovascular problems, 80% are smokers.[17]

EFFECT ON THE RESPIRATORY SYSTEM

As stated earlier, smoking affects oxygen transport and delivery.[9] Irritants in smoke increase mucus secretions. The mucus becomes hyperviscous, with altered elasticity. Cilia become inactive and are destroyed by ciliotoxins. The result is impaired tracheobronchial clearence.[13] Laryngeal and bronchial reactivity is increased. Cigarette smoke is known to disrupt the epithelial lining of the lung, causing an increase in pulmonary epithelial permeability. This loss of epithelial integrity allows irritants to penetrate the epithelium more easily and stimulate the subepithelial irritant receptors, resulting in increased reactivity. Smoking leads to small-airway narrowing, causing an increased closing volume. Pulmonary surfactant is also decreased. These lead to small-airway disease. An increase in pulmonary proteolytic enzymes or elastolytic enzymes causes loss of elastic lung recoil and emphysema. Lung infection is increased. Twenty-five percent of smokers suffer from chronic bronchitis,[18] occurring five times more often than in nonsmokers. The incidence of chronic obstructive airway disease is also higher than in nonsmokers. When pulmonary function tests are done, chronic smokers with chronic obstructive airway disease show an obstructive pattern. In asymptomatic smokers, the spirometric pulmonary function tests are normal. However, in asymptomatic smokers, closing volumes are significantly increased, exhibiting small-airway disease.[13]

Following smoking cessation, ciliary activity starts to recover within 4–6 days.[1] The sputum volume takes 2–6 weeks to return to normal. There is some improvement in tracheobronchial clearance after 3 months. It takes 5–10 days for laryngeal and bronchial reactivity to settle. There is improvement in small-airway narrowing after 4 weeks, and marked improvement is seen af-

ter 6 months. One must be careful in stopping smoking in asthmatics as the asthma may worsen.[13]

THE EFFECT ON PERIOPERATIVE EVENTS

Schwilk et al,[18] in a large survey, compared specific respiratory events such as reintubation, laryngospasm, bronchospasm, aspiration, hypoventilation, hypoxemia, and others during anesthesia in smokers and nonsmokers. The incidence was found to be 5.5% in smokers, compared with 3.3% in nonsmokers. They calculated the relative risk of these events occurring during anesthesia and found that the risk in all smokers was 1.8 times than in nonsmokers. In young smokers, it was 2.3 times, and in obese smokers, it was 6.3 times the normal. Thus, obese smokers are at a high risk of having respiratory problems during anesthesia. It was found that smokers have a significantly high risk of having bronchospasms during anesthesia. The risk was higher in female smokers, and the risk was 25.7 times normal in young smokers with chronic bronchitis.

The currently available pulse oximeters measure light absorbance at only 2 wavelengths and cannot distinguish between more than 2 species of hemoglobin.[19] Therefore, they cannot distinguish oxyhemoglobin (HbO_2) from carboxyhemoglobin. As a result, the oxygen saturation exhibited by pulse oximeters in chronic smokers will be a gross overestimation of the oxygen saturation. It combines the saturation of HbO_2 and COHb as the result. If 10% of COHb is present in the blood and the oximeter reads 100%, the actual reading is less than 90%. To get a correct reading, the oxygen saturation should be measured using a CO oximeter.

Fletcher[20] found that the difference between the partial pressure of arterial carbon dioxide and end tidal carbon dioxide ($PaCO_2 - EtCO_2$) in nonsmokers was 0.3 kPa while in smokers it was 0.9 kPa. They also found that this difference increased with age in smokers but not in nonsmokers. It increased by 0.2 kPa per decade. Thus, a 60-year-old smoker will need 25% more minute ventilation than a nonsmoker to maintain a given partial pressure of arterial carbon dioxide.

THE EFFECT ON RESPIRATORY FUNCTION DURING SPINAL ANESTHESIA

In moderate or heavy smokers, the forced expiratory volume-/second (FEV-1) is reduced following spinal anesthesia above T10.[21] Also, the forced midexpiratory flow and the forced expiratory flow are markedly reduced. Thus, for prevention of accumulation of secretions in small airways, it is advised that patients be instructed to frequently take deep breaths and cough during the period of the block.

THE EFFECT ON POSTOPERATIVE MORBIDITY

Postoperatively, hypoxia occurs following both general anesthesia and spinal anesthesia. However, it is greater following general anesthesia.[22] Hypoxia occurs more frequently in chronic smokers due to the increased closing volumes, giving rise to higher alveolar arterial oxygen differences, and increased carbon monoxide, decreasing the oxygen availability to tissues.[13] Postoperative pulmonary complications were reported by Morton in 1944[23] to be six times higher in smokers compared with nonsmokers. Wellman and Smith[24] reported that it was two times higher in smokers following abdominal and thoracic surgery. Bluman et al[25] found it to be four times that of nonsmokers.

EFFECTS OF SMOKING CESSATION PRIOR TO SURGERY ON POSTOPERATIVE MORBIDITY

Warner et al[26] reported pulmonary complications such as purulent sputum, atelectasis, and pleural effusion in those that had stopped smoking for 8 weeks or more prior to surgery to be only 14.5%, compared with 57.9% in those who stopped smoking less than 8 weeks before surgery, a four times higher incidence in those who stopped less than 8 weeks from surgery. Mitchell et al[27] reported the incidence of postoperative purulent sputum to be 25% more for those that stopped smoking 8 weeks before surgery and 50% more in those who stopped smoking less than 8 weeks before surgery than in nonsmokers. Warner et al[26] found that, if patients stopped smoking for 6 months or more prior to surgery, the incidence was the same as that in nonsmokers. Bluman et al[25] found that risks were seven times higher in those that reduced smoking near surgery than for those who smoked continuously up to the time of surgery. These results indicate that stopping smoking less than 8 weeks before surgery is not beneficial with regard to postoperative morbidity.

EFFECT ON POSTOPERATIVE NAUSEA AND VOMITING

The incidence of postoperative nausea and vomiting is less in smokers compared with both nonsmoking males

and in females.[28–30] It is suggested that this may be due to an antiemetic in the constituents of smoke.[30]

EFFECT ON THE GASTROINTESTINAL SYSTEM

Cigarette smoking does not increase the gastric volume or alter the pH of the gastric secretions.[31] Smoking does make the gastroesophageal sphincter incompetent, which allows reflux, with accompanying risks of pulmonary aspiration. The incompetence in the gastroesophageal sphincter begins within 4 minutes of beginning to smoke and returns to normal within 8 minutes after the end of smoking.[32] Usually patients are unable to smoke up to 8 minutes prior to surgery. Thus, in contrast to previous beliefs, there is no increased risk of acid pulmonary aspiration in smokers.

EFFECT ON THE IMMUNE SYSTEM

Smoking impairs the immune response.[13] The result is an increased risk of infections and neoplasia. Anesthesia further impairs the immune response, leading to a compounded detrimental effect on the immune system.

EFFECT ON THE RENAL SYSTEM

Cigarette smoking results in an increased secretion of antidiuretic hormone (ADH), leading to dilutional hyponatremia.[33]

EFFECT ON DRUG METABOLISM

Cigarette smoking induces liver microsomal enzymes, increasing the metabolism of some drugs.[34] In chronic smokers, larger doses of benzodiazepines appear to be necessary to produce the same drowsiness as in nonsmokers despite the pharmacokinetics of the drugs not exhibiting a significant difference in smokers and nonsmokers. It is probably due to the decreased response of end organs rather than being due to increased metabolism. There is no effect on thiopentone,[35] lignocaine,[34] or corticosteroids.[34]

EFFECT ON PAIN AND ANALGESIC DRUGS

Chronic smokers exhibit a decreased tolerance to pain.[34] Thus, independent of the action on the analgesic drugs, they require more analgesics for pain. Fentanyl[36] and pentazocine[34] are metabolized quicker in smokers. Morphine[34] and meperidine[34] have been metabolized quicker in rats in the presence of nicotine. However, in humans, mean total meperidine clearance has been shown not to differ significantly between smokers and nonsmokers. There is no effect on codeine or paracetamol.[34] Phenylbutazone[34] metabolism is increased.

EFFECTS ON NEUROMUSCULAR BLOCKERS

Nicotine in small doses (<100 ng/mL) stimulates the acetylcholine receptors, requiring larger doses of muscle relaxants to block the receptors.[23] In large doses (>10 μg/mL), it blocks the receptors. In smokers, the concentration of nicotine does not go beyond 75 ng/mL. Thus, in smokers, the action of nicotine is stimulation of the receptors. The reports on the effect of smoking on individual neuromuscular blocking drugs vary.

Teiria et al[37] found the 95% effective dose (ED95) for vecuronium to be higher in smokers. Smokers also needed more frequent doses to maintain neuromuscular block, indicating an increased requirement at the receptor site. The reason is possibly because the smokers stopped smoking about 6 hours before the surgery. Thus, small doses of nicotine may have stimulated the receptors, requiring a higher dose to block the receptors. More frequent doses needed for maintenance may have been due to increased metabolism.

The reports on rocuronium differ in their findings. Latorre et al[38] found that, in the case of rocuronium, there was no difference in onset of block or recovery times with the same dose used in smokers and nonsmokers. They attribute this to a longer period (12 hours) of refraining from smoking than in the previous study and to a possible different elimination pathway of rocuronium. However, Rautoma and Svartling[39] have found the ED95 of rocuronium to be the same as in nonsmokers, as reported in the previous study,[38] but the maintenance dose to be higher, indicating a higher metabolism of the drug in smokers.

Puura et al[40] found even different results with atracurium. Smoking had no effect on neuromuscular blockade. However, in smokers who abstained from smoking for greater than 10 hours, recovery was prolonged and the maintenance doses required were smaller. When nicotine patches were used with these patients, the prolonged recovery was abolished and the maintenance doses required were the same as in nonsmokers. The probable explanation for this response is as follows: In humans, up and down regulation of nicotinic acetylcholine receptors continuously modify the transmission at the neuromuscular junction. Continuous agonistic stimulation of a receptor leads to down regulation of the

receptor and the number of receptors decrease due to internalization. The chronic presence of nicotine may also down regulate the production of acetylcholine. Thus, chronic smokers require the same dose of atracurium as nonsmokers. However, in those who abstain from smoking for more than 10 hours, the effect of nicotine is negligible—they have fewer receptors and the acetylcholine production is also less. Thus, the maintenance dose of atracurium needed is also less. Nicotine patch introduces nicotine, which stimulates the receptors and leads to the requirement of increased maintenance doses.

PSYCHOLOGICAL ASPECTS OF SMOKING

Smoking is an addictive process.[5] The sensation of drawing smoke into the mouth and the effect of nicotine provides smokers with satisfaction. Acute withdrawal may result in increased anxiety, sleep disturbances, and irritability.

EFFECTS OF PASSIVE SMOKING ON ANESTHESIA

In a study by Dennis et al,[41] adverse effects such as coughing, breath holding, and laryngospasm during induction were significantly higher in smokers and passive smokers than in young smokers. There was no difference in the incidence between smokers and passive smokers. During adverse effects, the decrease in the oxygen saturation was greater in smokers and passive smokers. In this study, COHb was a better predictor of adverse effects than the status of smoking.

In children with a history of passive smoking, desaturation was significantly higher in the postoperative period when compared with that of nonexposed children.[42] The desaturation was related to the cumulative number of cigarettes smoked to which the child was exposed. It had no relationship to the COHb. Thus, the desaturation is probably more due to respiratory infection due to increased risk of exposure to microdroplets from respiratory disease of smokers who cough while smoking than due to exposure to the smoke itself.

MANAGEMENT OF ANESTHESIA IN SMOKERS

Management of anesthesia in smokers includes the following:

Stopping Smoking

- Ideally, stop smoking for at least 8 weeks prior to surgery.
- Stop for 24 hours before surgery to negate effects of nicotine and COHb.
- If an operation is scheduled for the next morning, stop smoking the previous evening.

Preparation

- Treat lung infections such as chronic bronchitis.
- Prescribe bronchodilators, breathing exercises, and chest physiotherapy in symptomatic smokers.
- Do blood gases to get baseline PaO_2 and $PaCO_2$ if a long operation is planned.

Choice of Technique

- Avoid general anesthesia. Local or regional anesthesia is better.

Premedication

- Use a parasymptholytic agent like glycopyrrolate to dry secretions.
- Use an anxiolytic agent such as midazolam to negate the psychological effects of stopping smoking before the surgery.
- Instill nebulized 4% lignocaine inward on call to the operating theater to prevent respiratory problems during anesthesia.[43]

General Anesthesia

Induction

- Do preoxygenation to decrease carbon monoxide.
- When using intravenous induction, any intravenous induction agent is satisfactory. Use intravenous lignocaine to prevent laryngospasm during intubation.
- When using induction with volatile agents, sevoflurane or halothane is preferred.
- Avoid manipulation under light anesthesia, which may result in coughing, breath holding, laryngospasm, or bronchospasm.

Intubation

- Prior to intubation, if nebulized lignocaine not given, spray with lignocaine to anesthetize the larynx and suppress laryngeal hyperreactivity.

Maintenance

- Avoid light anesthesia, which may result in bronchospasm.

- Avoid desflurane, which is a respiratory irritant. It stimulates the respiratory irritant receptors in chronic smokers and thereby the sympathoadrenal system, resulting in higher blood pressure and tachycardia.[44]
- Increase minute volume over that used for nonsmokers to maintain the same $PaCO_2$.

Monitoring

- When using current pulse oximeters, remember a gross overestimation of oxygenated hemoglobin saturation (SaO_2) occurs.
- Use a CO oximeter to measure oxygen saturation.
- Monitor the electrocardiogram, especially in those having coronary heart disease since ventricular arrthythmias may occur during anesthesia.
- Use a peripheral nerve stimulator to monitor the neuromuscular block since there are various reports on the requirement of muscle relaxants.
- In long operations, carry out intermittent blood gas analysis to check the $PaCO_2$ since $PaCO_2$ – Et CO_2 is higher than in nonsmoking patients.

Recovery

- Do not extubate under light anesthesia because it may result in cough, breath holding, laryngospasm, or bronchospasm.

Postoperative Period

- Give oxygen in the recovery room, while being transported, and for some time in the ward.
- Postoperatively, administer more analgesics, which are needed due to (i) anxiety from stopping smoking, (ii) decreased pain threshold, and (iii) increased metabolism of the drug.
- Give breathing exercises and chest physiotherapy to symptomatic smokers.

ANESTHESIOLOGISTS' ROLE IN ADVISING SMOKERS

In recent years, medical officers have been more involved in advising smokers to give up smoking. Preoperatively, Shah et al[45] gave written advice to patients to stop smoking for 5 days before their operations. Though the majority did not comply with the 5-day advice, the majority had reduced or stopped smoking before the procedure. Verbal advice to stop smoking is regularly given to smokers by anesthesiologists prior to an operation. Many patients follow the anesthesiologists' advice.

Intraoperatively during anesthesia, tape-recorded messages advising patients to stop smoking have been tried by anesthesiologists, with some success. In one study,[46] some patients reduced their cigarette intake and some stopped smoking. In another study,[47] there was no difference. In the latter study, 8% had stopped smoking after 6 months. The majority of those that stopped were the ones who had had major surgery and those that smoked less than 10 cigarettes a day.

Egan and Wong[1] have suggested that anesthesiologists should advise smokers to stop smoking during the postoperative ward rounds. This should be done especially in those patients who had smoking-related problems during anesthesia. Egan and Wong found patients to be especially compliant in those circumstances.

CONCLUSION

In conclusion, patients must stop smoking prior to surgery. The best result occurs when the patient stops 8 weeks or more before surgery. Doing so will significantly reduce perioperative-specific respiratory events and postoperative morbidity, and it will eliminate carbon monoxide and nicotine, improve the clearance of tracheobronchial secretions, decrease small-airway narrowing, and improve immune functioning. If the patient does not stop smoking 8 weeks before surgery, the patient should at least stop smoking 12 hours before surgery or, if the surgery is the next morning, the previous evening. This will eliminate problems in tissue oxygen uptake due to carbon monoxide and reduce the cardiac and hemodynamic effects of nicotine. Last, it is time that anesthesiologists played a stronger role in advising patients to stop smoking.

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