A Reminder to Anesthesiologists: Low-Flow Anesthesia

Anestezistlere Bir Hatırlatma: Düşük Akımlı Anestezi

Low-Flow Anesthesia

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Scientific letter

Although many modern anesthesia machines are suitable for using minimal/low-flow anesthetic techniques and closed-circuit drug delivery methods, high (4-6 L/min) gas flow anesthesia is generally preferred by the majority of the anesthesiologists in routine clinical practice [1]. The aim of this brief report is to indicate the benefits and potential risks of low-flow anesthetic techniques, and to attract the attention of anesthesiologists on this important issue which is not completely clear for most of those.

The classification of gas flow rates described by Baker [2] in 1994 has been well accepted by the anesthesia world (Table 1). According to this classification, gas flows less than 1 L/min are defined as low-flow anesthesia (LFA). The term of LFA is generally used to define the inhalation anesthesia techniques that have a re-breathing rate at least 50% and a semi-closed re-breathing system. Although these low-flow anesthetic techniques have been known for a long while, some reasons such as traditional anesthetic habits, little or no training in the use of these techniques during the residency, and concerns on providing a desirable anesthetic depth limited their widely use.

The practical aspects of LFA

Premedication, pre-oxygenation and induction of anesthesia are performed in accordance with the routine practice. After endotracheal intubation or insertion of a laryngeal mask, patient is connected to re-breathing system. LFA technique can be divided into three phases; initial high-flow, low-flow and recovery.

The initial phase lasts 10 to 20 minutes, and characterized a high fresh gas flow of about 4 L/min (for example 1.4 L/min O2 and 3.0 L/min N2O). During this period, sufficient denitrogenation is obtained, the desired anaesthetic gas composition is established within the breathing system, and an essential concentration of anesthetic agents is obtained in order to ensure adequate anesthetic depth. Denitrogenation is to provide the purification of nitrogen in the blood with ventilation of 100% O2 in a high flow. Nitrogen in the lungs is removed by denitrogenation, and thus takes its place to O2. As a result of this event, functional residual capacity and the oxygen reserves increase. Denitrogenation is completed in about 6-8 min with using a fresh gas

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Table 1. The classification gas flow rates [2].

Flow types	Definition
Metabolic flow	<250 mL·min-1
Minimal flow	250-500 mL·min-1
Low flow	500-1000 mL·min-1
Medium flow	1-2 L·min-1
High flow	2-4 L·min-1
Very high flow	>4 L·min-1

flow rate of 4-5 L/min. The vaporiser can be set as the following standard concentrations; halothane to 1.0 - 1.5 vol%, desflurane to 4.0 – 6.0 vol%, sevoflurane to 2.0 – 2.5 vol%, enflurane to 2.0 - 2.5 vol%, and isoflurane to 1.0 - 1.5 vol%. An expiratory concentration will be achieved corresponding to about 0.8 x MAC of the inhalation agent. Avoiding gas volume deficiency is another characteristic of this period.

In the low-flow phase, fresh gas flow is reduced at the desired level (≤1 L/min). Reducing the flow rate causes a significant increase in re-breathing rate. In order to keep the inspired oxygen concentration above 30% volume, the oxygen concentration should be increased to at least 40% when the flow is decreased. When deactivated vaporizer is used, the amount of anesthetic vapor given to the breathing system will be reduced in parallel to the reduction of flow rate. Therefore, monitoring of oxygen and anesthetic agent concentration is an important issue in LFA.

Wash-out of carbondioxide (CO2) is of great importance in low fresh gas flow anesthesia. Since re-breathing volume in LFA is larger than in high-flow anesthesia, CO2 concentration in the ventilation system significantly rises as a result of exhaustion of absorbent. Therefore, soda lime should be condumed until fully exhausted and should be replaced once a week. In anesthesia machines without CO2 monitoring equipment, double or large single canister should be used. Sodalime should be renewed with shorter intervals, or when the color change indicating the beginning of exhaustion appears.

If a little gas is put into the breathing system, little or none come out. This condition results in an accumulation of the gas which is not taken up by the patient or absorbed chemically. Such gases may be exhaled by the patient, be a contaminant of the medical gases or result from a reaction with the chemical agents used for CO2 absorption. Hence, the composition of the CO2 absorbent material has a critical role to prevent sevoflurane from producing compound A and to prevent desflurane from producing CO [3]. Normally, the CO volume is very small during the anesthesia, and usually has not any clinical importance [4]. It reaches to clinically significant values in cases of hemolysis, anemia, porphyria and heavy smoking. It is well known that CO has a high affinity to hemoglobin. Short-term and intermittent washing in high fresh gas flow is inadequate to clear CO accumulation because it is only effective in regions containing gas such as lungs and ventilation system. On the other hand, in LFA, CO concentration reaches a certain level to compensate for the partial pressure difference. Sufficient water content of the absorbent can prevent the formation of CO. In addition, the use of NaOH or KOH-free absorbent is an effective preventive factor to reduce the occuring of CO. It should be noted here that there is no increase in risk of accidental CO poisoning specific to LFA techniques, and continuously use of low fresh gas flow is a basic prevention for the formation of CO.

Some of volatile anesthetics cause the formation of volatile haloalkanes, as a result of chemical interaction with CO2 absorbents. The 2-Bromo-2-chloro-1,1-difluoroethyl and Compound A-E are the break-down products of halotane and sevoflurane, respectively. Prolonged sevoflurane anaesthesia with low fresh gas flows, in particular Compound A, was considered to be resulted in renal toxicity; however, this was not shown to be associated with any clinical manifestations in human. Compound A is reached clinically significant concentration, with use of Barolime and absorbents contining KOH. Therefore, both the composition and hydration of the CO2 absorbent material are of importance in low and minimal fresh gas flows in terms of minimal production of compound A and CO [5].

In the recovery phase, 10-20 min before surgery ended, vaporizor is closed and reduced fresh gas flow is maintained. Spontaneous breathing of the patient is provided with manual breathing or SIMV. Approximately 5-10 min before extubation, high fresh gas flow, usually 100% O2, is necessary, to facilitate the washout of the inhalation agents from the patient and to remove the agent to the scavenging system. Subsequently, the general postoperative care protocol is applied.

LFA in children

Children have different anatomical and physiological features compared with adult population. For this reason, there are several concerns regarding the use of low-flow anesthetic techniques in pediatric population; gas leakage within the breathing system especially during the use of uncuffed endotracheal tube, increase in dead space due to the connection hoses, and etc. However, there is no certain contraindication in using of LFA in children, and many studies showed that these potential problems can be prevented with proper technique and adequate monitoring [6,7]. Desflurane may cause respiratory symptoms such as increased secretion, cough, and laryngospasm during the induction of anesthesia. Unlike adults, these respiratory side effects may result in hypoxemia in children, and thus desflurane is not recommended for use in pediatric patients. On the other hand, sevoflurane does not cause a respiratuar irritation, and can be safely used in induction of anesthesia of adults and children. It should be specified here that both low dose desflurane and sevoflurane anesthesia do not adversely affect haemodynamic parameters, hepatic and renal function in children [8].

Advantages of LFA

There are several benefits of LFA, including decrease in use of inhalational anaesthetic agents, improvement of body temperature and humidity homeostasis, reduce in environmental pollution, and significant economical advantages [9]. Many studies showed that low-flow techniques provide improvements in the heat and moisture conditions of the anesthetic gases, which let to better impacts on respiratory functions and mucociliary clearance [10]. Heating of the gases also play a significant role in the prevention of postoperative hypothermia. Reducing gas flow was shown to be clearly associated with lower drug-related costs since it led to decrease in using volati-

le agents and anesthetic gases [11]. Another beneficial effect of LFA is avoiding the potential negative health effects by reducing the workplace pollution. Finally, the necessity of close monitoring of patients in LFA enables to be quickly aware of the complications, and thus improve patient safety. Conventional anesthetic agents can be safely used in low-flow anesthetic techniques, with continuous monitoring of the inspired oxygen fraction, end-tidal anesthetic concentration, and the CO2 concentration. In the literature, there are many studies which show the safety and advantages of LFA by using various inhalational anaesthetic agents [10-12].

Disadvantages of LFA

Low-flow anesthetic techniques also have several disadvantages such as increased hypoxia risk during anesthesia, potential for gas volume deficiency, hypercapnia, and accumulation of endogenous released gases due to the low rate of wash-out. A significant difference between Inspired O2 concentration and the fresh gas O2 concentration may occur during LFA, and therefore inspired partial oxygen concentration may decrease as long as the fresh gas flow rate decreases and the amount of re-inhaled gas mixture increases. For this reason, O2 concentration in fresh gas should be increased to reach safe levels. In addition, LFA should not be applied without continuous inspired O2 monitoring. Gas volume deficiency may develop when the gas volume supplied to the system cannot meet the the total gas uptake and gas leaks. Hypercapnia is the other potential risk of LFA, and requires continuous CO2 monitoring during anesthesia. Accumulation of toxic gases such as argon, methane (due to halothane), hydrogen, nitrogen (due to inadequate denitrogenation), haloalkanes, acetone, ethanol, and carbon monoxide (especially in heavy smokers) carries a potential risk during LFA. Among those, acetone, ethanol, and carbon monoxide have high solubility, and cannot be removed by intermittent high fresh gas flow. Acetone is formed by the oxidative metabolism of free fatty acids. Its high serum levels are seen in cases of prolonged starvation and decompensated diabetes mellitus. Ethanol accumulates in the closed system similar to acetone. The removal of ethanol by exhalation cannot be possible in alcoholics underwent an emergent operation. Hence, reducing the gas flow under 1 L/min are not recommended in cases of poorly controlled diabetes, prolonged starvation, chronic alcohol use, heavy smoking, and acute alcohol intoxication. Additionally, septicemia, severe bronchial asthma, and malignant hyperthermia are the other reported contraindications to using low-flow techniques [9]. Accumulation of other exogenous gases such as argon, methane and hydrogen has not a clinical significance. Toxic concentrations of these gases are hardly possible even in long-term closed system anesthesia.

In conclusion, concerns due to insufficient knowledge and traditional habits limit the widespread use of LFA techniques. However, with using modern anesthesia machines and new-generation anesthetic agents, LFA has become a safe anesthetic technique with obvious economic and environmental benefits. I suggest that all anesthesiologists should focus on this important but neglected issue, and should use these techniques more frequently than in their current practices.

Competing interests

The authors declare that they have no competing interests.

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