Inhalational Anesthesia Devices

Erich Siegel

Anesthesia devices are used in operating rooms in hospitals by medical staff to ensure that operative and diagnostic procedures can be performed on a patient without pain in an unconscious and relaxed state. This chapter provides an overview on the concept of these devices. It describes the intended medical use and based on this the necessary technical components. The principles of these main components are explained in detail: the mechanical or electronic dosing of the gases O₂ and N₂O or air, the dosing of anesthetic agent using the vaporizer principle, the ventilator with a re-breathing system, and the ventilation modes used in anesthesia. To ensure safe anesthesia, both the device and the patient have to be monitored. The measuring principles for the necessary device monitoring parameters are also discussed, such as the concentrations of oxygen, nitrous oxide, anesthetic agent, and carbon dioxide. In addition, the exhaled volume and the pressure in the breathing system are described.

30.1 Anesthesia Devices in General Anesthesia

Anesthesia devices are designed to assist trained medical anesthesia staff, so that operative and diagnostic procedures can be performed without pain, the consciousness of the patient can be suppressed, and the oxygen supply can be guaranteed.

To meet these aims, the following drugs are delivered by the device:

- Oxygen (approximately 30 vol. %) to ensure adequate oxygenation of the patient during the intervention
- Nitrous oxide (approximately 70 vol. %) or intravenous administration of an opioid, for example, remifentanil, to prevent the patient from feeling any pain
- An anesthetic agent (isoflurane, sevoflurane or desflurane) administered via the lung, or propofol administered intravenously, to suppress consciousness.

Anesthesia is called inhalation anesthesia if the analgesic (nitrous oxide) and the agent used to achieve unconsciousness (for example, isoflurane) are delivered to the body via the lung.

Anesthesia is called total intravenous anesthesia (TIVA) if the analgesic (for example, remifentanil) as well as the drug for unconsciousness (propofol) are administered intravenously.

Anesthesia is called balanced anesthesia if one drug is administered intravenously (for example, remifen-
Fig. 30.1 Example of an anesthesia device (Primus, Dräger, Lübeck)

tanil) and the other drug is delivered via the lung (for example, isoflurane).

Since patients are usually relaxed using muscle relaxants during surgery, their breathing musculature is paralyzed, which means that every anesthetic device must be equipped with a device for automatic, controlled ventilation. The possibility of manual ventilation is also important to allow the physician to intervene during induction and termination of anesthesia and also to provide assisted ventilation during these phases if required.

To ensure that anesthesia is safe and transparent, both the device and the patient are monitored. For this purpose, the parameters of the delivered anesthetic gas, i.e., the inspiratory oxygen concentration and the nitrous oxide and anesthetic agent concentrations, are measured. In addition, the exhaled CO₂ and the exhaled volume are determined and the pressure in the system is controlled. These device monitoring parameters are the parameters to be measured in accordance with current standards.

To test cardiovascular function, the electrocardiography (ECG) and noninvasive or invasive blood pressure are measured. Blood oxygenation is monitored by the oxygen saturation. In addition, the effect of anesthesia must be monitored, i.e., the level of patient unconsciousness, the degree of painlessness, and the level of relaxation.

Therefore, an anesthesia device (Fig. 30.1) consists of the following components, according to its intended medical purpose:

- Drug dosing unit
- Ventilator with breathing system
- Monitoring unit consisting of 3 subunits:
  - One which monitors drug dosing and the ventilator called device monitoring
  - One which monitors the patient called patient monitoring
  - One which monitors the depth of anesthesia called anesthesia effect monitoring.

30.2 Functional Principle, Medical Aspects

Figure 30.2 shows the three main components (drug dosing unit, ventilator, and device monitoring) of an inhalation anesthesia machine. During inspiration, the ventilator forces the gas from the breathing bellows through the CO₂ absorber and the inspiration valve into the patient’s lung. During this time, the drugs (oxygen and nitrous oxide at concentrations of approximately 30 vol. % O₂ and 70 vol. % N₂O as well as, e.g., 2 vol. % isoflurane) flow continuously from drug dosing to the reservoir bag, which also acts as the manual breathing bag at the same time. During expiration, the path to drug dosing is opened by the controlled valve. The gas from the reservoir bag flows together with the exhaled gas from the patient to the breathing bellows of the ventilator. All gas that exceeds the desired pressure at the end of expiration escapes through the anesthetic gas scavenging valve. During inspiration, the path to the reservoir bag is closed by the control valve, and the ventilator forces the gas back to the patient.

The amount of fresh gas flow is based on the following considerations.