

Understanding Anesthetic Delivery Systems

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Knowing the functions of the anesthetic delivery system is extremely important in using them appropriately. When malfunctions occur, knowing the anesthetic delivery components will help in troubleshooting the system. The anesthetic delivery system consists of four parts: 1) Gas source, 2) Anesthetic machine, 3) Breathing system, and 4) Scavenging system. The functions of the anesthetic delivery system are to deliver oxygen and anesthetic gases, to remove CO₂ from the breathing system, to allow for ventilation (manual or mechanical) and to scavenge waste gases.

Compressed Gas Delivery

Most veterinary clinics utilize **compressed gas cylinders** for their source of oxygen and other medical gases. The pressure and volume of these cylinders varies for each type of gas being used. The two most common compressed gases are oxygen and N₂O. O₂ generators are available as well, but they are a little pricey and need a lot of maintenance. The two most common sizes of compressed gas cylinders are “H” and “E”. “E” tanks are usually attached to the anesthesia machine via a yoke. An “H” tank can be either on a central bank system with overhead drops or one tank attached to the anesthetic machine.

An “E” cylinder of oxygen contains about 700 liters and an “H” cylinder contains about 7000 liters. Both have a pressure of 2200 when they are full. The pressure of the oxygen cylinders is proportional to its volume, i.e. an “E” cylinder with a pressure of 1100 psi contains about 350 liters. The pressure in a full N₂O cylinder at room temperature is about 750 psi. A full “E” cylinder of N₂O contains about 1600 liters and a full “H” cylinder contains 16,000 liters.

The compressed gas cylinders are color coded, with oxygen being green and N₂O being blue. The “E” cylinders also utilize a pin index system so that only the correct gas may be connected to the appropriate yoke block. The hoses and flowmeters used with a specific gas are color coded as well. Also the connection fittings are different for each gas. This prevents the wrong gas from being attached to the wrong flowmeter, thus insuring that the correct gas at the correct flow is delivered to the patient. All tanks should be secured at all times for safety precautions. This can be achieved by securing the tanks in either a cart, chained to a wall, or for “E” tanks the use of the yoke block that is mounted on the anesthesia machine.

As the gas leaves the cylinders it passes through a **pressure gauge and regulator**. The **pressure gauge** is utilized to indicate the pressure on the cylinder side of the regulator. The **pressure regulator** is utilized to decrease and maintain the gases at a safe operating level, usually about 50 psi.

Anesthetic Machine

A **flowmeter** is used to deliver a specific flow rate. This flow rate is expressed in liters/ minute and is adjusted by the anesthetist. The flowmeter should be turned off when not in use to

prevent the sudden build up of pressure in the glass tube and indicator when the gas flow is turned on. Some other problems associated with the flowmeter are over tightening of the needle valve and sticking of the float or ball.

A **vaporizer** is where the anesthetic agent is added to the oxygen/medical gas, which mixes as it flows to the patient. This is done by adding a controlled amount of oxygen/medical gas mixture to the anesthetic liquid and changes it to a vapor, which then is delivered to the patient at a certain percentage. The percent of agent delivered is determined by the settings on the dial on the vaporizer that is set by the anesthetist. There are two types of vaporizers, precision and non-precision.

A *precision vaporizer* delivers an exact concentration of the anesthetic agent. These vaporizers are temperature, flow, and back flow compensated. The disadvantage of this type of vaporizer is that they are expensive and are calibrated for a specific anesthetic agent. Examples of precision vaporizers are the Tec, Ohio, and Vapor type vaporizers.

A *non-precision vaporizer* is used for agents with low vapor pressures. The concentration anesthetic agent is not exactly known. These vaporizers are not flow, temperature, and backpressure compensated. Examples of non-precision vaporizers are the Ohio NO 8 and Stephens vaporizers.

Other ways that vaporizer are classified is where they are located relative to the anesthetic circuit. The first is *Vaporizer out of Circle (VOC)*, which means that the vaporizer is not in the breathing circle. A precision vaporizer is a VOC. The other is a *Vaporizer in Circle (VIC)*, which means that the vaporizer is located in the breathing circuit. A non-precision is a VIC.

Vaporizers should be serviced as recommended by the manufacture or any time you suspect it is not functioning properly. Also be careful not to overfill or fill with the incorrect agent.

The **common gas outlet** is where the oxygen/medical gas/anesthetic agent mixture exits the anesthesia machine to the breathing system, which can be either a rebreathing or non-rebreathing system.

The **oxygen flush valve** is used to bypass the vaporizer and delivers oxygen only to the common gas outlet then to the breathing circuit. The O₂ flush valve delivers a high flow of about 30 or more liters per minute depending on the machine. Do not use the oxygen flush valve to fill the breathing circuit with oxygen while connected to a patient. This may cause damage to patient's lungs due to the sudden increase in volume pressure. Turn up the flow on the flowmeter to fill the system when a patient is connected to the breathing circuit.

Breathing Systems

There are two types of **breathing systems**: *rebreathing (circle) and non-rebreathing systems*. Up to the common gas outlet the gas flow has been the same. The flow of gases and the components used for each system will differ beginning at the fresh gas inlet. The determination of which system to use is usually by patient size. Other considerations for determining which system to use are convenience, cost, and the control of the speed in the changing of anesthetic depth.

Rebreathing (Circle) System

The **rebreathing or circle system** allows for the rebreathing of the exhaled gases. The CO₂ is removed and the fresh gas mixture is continually added. Usually used for patients that weigh greater than 7kgs(15lbs). The components of a rebreathing system are fresh gas inlet, absorber circuit, manometer, rebreathing bag, hoses, Y piece, unidirectional valves (inspiration & expiration), pop off valve, and a scavenger system. These components of the rebreathing system increase the resistance to the movement of the gas mixture in the system comparatively to a non-rebreathing. Thus smaller patients may have more difficulty inhaling the gas mixture. The rebreathing systems are more economical because the gas flows are less. Changes in anesthetic depth are relatively slow due to the lower flow rate of the gas mixture.

Fresh gas inlet is where the gas mixture enters the breathing system. The inlet is usually located on the inspiratory side of a rebreathing circle system. This minimizes the dilution of the fresh gas with the expired gases, absorption of dust and the loss of fresh gas through the pop-off valve.

Unidirectional Valves prevent expired gases from being recirculated and **Breathing tubes and Y-piece** connect the patient to the absorber circuit. The Y-piece is connected to the endotracheal tube and the other ends of the hoses are connected at the expiratory and inspiratory valves. Upon inspiration, the *inspiratory valve* will open and allow the gas mixture to flow toward the patient. At expiration, the inspiratory valve will close and the *expiratory valve* will open to allow the expired gases to pass into the absorber circuit

Rebreathing Bag provides a tidal volume for the patient and compliance for the system. The rebreathing bag is used to store gases, observation of respirations, and to manually ventilate a patient.

Absorber canister is where CO₂ is removed from the expired gases. As the absorber is used the granules will change to a blue color as it becomes exhausted. The granules will return back to a normal color when not in use after sometime has passed. Fresh granules will be soft and easily crushed while exhausted granules will be hard and brittle.

Manometer measures the amount of pressure in the breathing circuit. The manometer is usually located on top of the absorber. Over pressurization of the system can cause damage to the lungs of the patient.

Pop off valve or APL valve is used to allow the excess/waste gases to be vented to a scavenging system and allows the anesthetist to increase the pressure in the breathing system when needed. The pop off valve is usually left open when the patient is spontaneously breathing and closed for manual or mechanical ventilation. The valve can be adjusted as needed to accommodate the appropriate pressure needed for that particular patient.

The fresh gas mixture enters the breathing system at the *fresh gas inlet*. Upon inspiration the gas mixture is delivered to the patient through the *inspiratory valve* into the *breathing tube* and *Y-piece* then to the patient via the endotracheal tube.. When the patient expires the expired gases enter the *Y-piece* and flow through the *breathing tube* to the *expiratory valve*. As the patient inhales the *reservoir bag* will deflate and at expiration the reservoir bag will inflate. The gas mixture may enter the *reservoir bag* before or after it has passed through the *absorber*

circuit. These components are arranged to allow movement of the gas mixture in one direction. The expired gas mixture will always pass through the absorber circuit before inhalation by the patient.

Non-Rebreathing System

In a **Non-Rebreathing system** little to no exhaled gases are recirculated. The gases are evacuated by the scavenge system. Usually used for patient less than 7kgs(15 lbs). A non-rebreathing system offers little resistance to the patient when breathing, a significant advantage to smaller patients. A non-rebreathing system has less drag on the ET tube than does a rebreathing system. Due to the higher flow rates needed for a non-rebreathing the cost does increase as compared to a rebreathing system. The components of a non-rebreathing system differ from a rebreathing system as that there are no unidirectional valves, manometer, or absorber circuit. The use of a reservoir bag allows for bagging when needed and a buffer between the scavenging system.

Scavenging System

The **scavenging system** removes the waste anesthetic gases from the anesthetic breathing system and reduces the contamination of the workplace. There are two types of scavenging systems. The *passive system* uses the positive pressure of the anesthetic machine to push the gas into the system. The other is an *active system*, which uses suction created by a vacuum pump or fan to draw the gas into the system. Both systems are effective when correctly assembled, operated, and maintained properly. However, the active system appears to be the most efficient in removing waste gases.

All of the components of the anesthetic delivery system, especially the anesthetic machine and breathing system, should be tested prior to use to ensure that they are functioning properly. This will help prevent anesthetic complications associated with the anesthetic machine and breathing systems during the procedure. Preventative maintenance and cleaning of the anesthetic delivery system is extremely important to its longevity and proper function. Knowing the functions and being able to follow the flow of gases through the anesthesia delivery system will aid when troubleshooting problems.

Testing Procedures

1. All components of the anesthesia delivery system need to be visually inspected daily.
 - a. Check all fittings and connections for proper fit.
 - b. Check unidirectional valves; ensure that the discs are present and properly placed.
 - c. Check all hoses, tubing, and rebreathing for any deterioration.
 - d. Check vaporizer level.
2. Gas Source
 - a. Open valve on tank(s) to verify that the tank has 500 psi or more in it. If less than 500 then tank(s) needs to be changed to ensure proper line pressure is maintained in the system.
 - b. Check for any high-pressure leaks and correct if any are present.
3. Anesthesia machine and Circle Breathing System

- a. Turn flowmeter(s) to verify that float does not stick in any position in the tube, and then turn off.
 - b. Connect tubes to the inhalation and exhalation valves.
 - c. Attach breathing bag.
 - d. Close Pop-off valve.
 - e. Occlude the end of the circuit with your thumb.
 - f. Pressurize system to 30 cm H₂O by depressing the flush valve.
 - g. Observe that the manometer holds pressure for 10 seconds. It should not drop more than 5 increments in 10 seconds (*If a leak is present, turn on the flowmeter to compensate for the leak, a leak of greater than 200ml must be corrected before use. However, All leaks should be corrected before use. Use soapy water to locate leak(s), then correct.*)
 - h. Relieve pressure by opening the pop-off, the pressure on the manometer should go to 0-2 cm H₂O (*This will insure that the pop-off is functioning correctly*) If pressure is maintained then disconnect scavenging hose from the pop-off valve. If pressure is relieved then inspect scavenging system.
4. Non-Rebreathing system
- a. Ensure connection of fresh gas from the anesthesia machine to non-rebreathing circuit.
 - b. Occlude the patient port.
 - c. Close the relief valve.
 - d. Fill the reservoir bag until it is distended. Should remain full and the pressure should not decrease.
 - e. The inner tube can be tested, by occluding it at the patient end with the O₂ flowing at 1-2 L/min. The float in the flowmeter should fall.
5. Scavenging System
- a. Ensure that the scavenging system is connected to pop-off valve.
 - b. If a canister is being used, ensure that the canister output is not occluded. This will cause a build up of pressure in the system.
 - c. If an active system is being used make sure that it is working appropriately and no occlusions are present.

An anesthesia delivery system that has been appropriately tested will allow for the correct flow of the anesthetic gas mixtures through the system. Thus allowing the removal of CO₂ from the exhaled gases before the patient inhales. Also the proper removal of waste gases will ensure a safe work environment for the hospital staff.