Anesthetic Equipments

Breathing circuits and scavenging system

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Introduction

- Terminology concerning anesthetic breathing circuits is very varied with no universal agreement; multiple and inconsistent definitions in North American and British literatures.
- Traditionally, the systems of terminology consist of 'closed' and 'open' themes with variations, using 'Rebreathing' as distinguishing factor, but are of little value now.
  - It is very difficult to exactly determine the degree of 'Rebreathing' by the use of such terms as 'semi-closed', almost no rebreathing. Clearly this nomenclature or system m interpretation regarding actual inspired concentration or tension of any inhalational anesthetic.

- Currently, the terminology describes the breathing systems as 'Non-rebreathing' or 'Rebreathing'.
- For majority of procedures regardless of variations of teaching, practice, and geographical location, provision of two simple pieces of information can be quite adequate for description of a breathing circuit
  - First, the actual equipment used needs to be described (Bain etc.)
  - Second, the fresh gas flow should be stated.
  - Under certain and special circumstances, more detailed information may be provided, such as apparatus (mechanical) dead space volume, type of valves, type and location of the vaporizer (in or out of the breathing circuit etc.)
- Properties of the ideal breathing system
  - Simple and safe to use
  - Delivers the intended inspired gas mixture
  - Permits spontaneous, manual and controlled ventilation in all size groups
  - Efficient, requiring low fresh gas flow rate
  - Protects the patient from barotraumas
  - Sturdy, compact and lightweight in design
  - Permits easy removal of waste exhaled gases
  - Easy to maintain with minimal running cost
- Patient size and anesthetic breathing circuits
  - Two factors must be considered in proportion to the animal's size.
    - Apparatus (mechanical) dead space
    - Apparatus (mechanical) resistance

- Resistance is always high with turbulent flow, so narrow orifices, sharp bends, which produce this should be avoided in the apparatus.
- For the Laminar flow of a gas in a tube the Hagen Poiseille law (see equation below) states that the pressure drop is proportional to changes in the tube length, diameter (to the power of 4), viscosity, resistance and flow rate; thus narrow tubes cause the greatest resistance, but resistance is also increased by long tube lengths and at high flow rates.

$$\text{Resistance} = \frac{Flowrate \times Length \times Viscosity}{Radius^4}$$

- Modern volatile anesthetics are very potent and it is most important that the anesthetist does not come under their, acute or chronic, influence.
- The removal of waste anesthetic gases from the environment is now compulsory (Occupational Health and Safety Agency, OSHA, guideline), and installation of a scavenger with use of volatile anesthetics ensures compliance.
- Current legislation prescribes ‘maximal permissible’ concentrations of volatile anesthetic agents which are allowed to be present in the operating rooms.

Current terminology of the A

Old Terminologyof the Anesthetic breathing circuits

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F	Near to the patient	absent	Present	Present

- Advantages
  - Comparatively cheap , Mobile.
- Disadvantages
  - Absorption less efficient than in circle
  - Increasing dead-space as soda lime used up 'Layering', particularly when horizontal.
  - Hot dusty soda lime close to patient.
  - Weight of canister may kink endotracheal tube.

- *Circle*
  - Advantages
    - More efficient removal of carbon dioxide and use of soda lime.
  - Disadvantages:
    - Expensive to buy (now some cheap disposable circles available)
    - Can have high resistance due to length of tubing (but OK if tubes are wide)
    - Valves must be efficient, or rebreathing occurs

Circle rebreathing systems with vaporizer in circuit (VIC)

- Ohio No 8 machine, Goldman machine, Stevens machine and Kommesaroff machine.
- VIC systems are always "circle."
- In these, vaporization of the volatile agent depends on the flow through the vaporizer, which is 'pushed' through by the animal's own respiration. Thus, with every breath, more agent is vaporized.
- Advantages.
  - Very economical. O_2 requirement is that used by animal (5-10 mls/kg/min). Minimal volatile agent wasted and minimal pollution.
  - With all rebreathing circuits, retains heat and water.
- Disadvantages.
  - Cannot use N_2O in this circuit.
  - If oxygen flow is too high, difficult to get adequate concentrations of some volatile agents.
  - Cannot use safely for I.P.P.V. unless removing vaporizer.
  - Low efficiency and nonprecision
- These circuits are claimed by the manufacturers to be very safe because if animal becomes more deeply anesthetized, respiration is less, so uptake of volatile is reduced. However, this only happens at a depth of anesthesia at which (with isoflurane and sevoflurane) there is severe hypotension, and, as with any anesthetic system, it is, perfectly possible to accidentally kill patients when using these machines. The machines were originally designed to be used with ether or methoxyflurane, both of which are very much safer in this system.
- As these machines work on minimal intake of O_2 into the circuit, nitrogen will accumulate, reducing the concentration of O_2. Thus, before use the machine it is primed with 100% O_2; after about 5 minutes of anesthesia the bag is emptied, and re-primed with 100% O_2. Nitrous oxide must not be used.
- If these machines are used properly, with good monitoring, and if the animal is too deep the vaporizer setting is reduced, they can be excellent and economical for small animal anesthesia. However, if used as sometimes advertised; ie giving maximal

anesthetic agent and counting on respiratory depression to limit uptake, with the isoflurane and sevoflurane anesthesia, such depths of anesthesia will be excessive, and accompanied by severe hypotension, with subsequent morbidity.

Components of the circle system

CO_2 absorbent (Sodalime, baralyme)

- These are used to absorb the CO_2 in rebreathing circuits.
- Sodalime consists of 90% calcium hydroxide, 5% sodium hydroxide, plus 5% silicate and water to prevent powdering.
- Indicators are added to show when it is fully used (but do not trust them; they can get leached out by water vapor, and most change color a little too late, and also reverts to its original color when not in use).
- The absorption of CO_2 by these is exothermic (ie, the soda lime gets hot) - you can use this action to test your soda lime - if in doubt blow on some and see if its gets hot.
- The reaction of CO_2

  CO

One-way (unidirectional) valves

- They direct gas flow away from the patient on expiration and toward the patient on inspiration
- Prevents the rebreathing of exhaled gases before they pass through the absorbent canister
- Gases enter a unidirectional valve from below, raise the disc, and pass under the dome to the reservoir bag, the absorbent canister or the inspiratory breathing tube
- Valve incompetence contributes to accumulation of CO_2 within the breathing circuits

Fresh gas inlet

- The location at which gas from the common gas outlet of the anesthesia machine or from the outlet of the vaporizer enter the circle system
- Placed on the absorbent canister near the inspiratory one way valve or on the inspiratory one way valve
- Entry of fresh gases on the inspiratory side of the circle
  - minimizes dilution of the gases with exhaled gases and VOC
  - prevents absorbent dust inhalation
  - reduces loss of fresh gases through the pop-off valve

Adjustable pressure limiting valve (Pop-off valve)

- A valve which allows exhaled waste gases and fresh gas flows to leave the breathing system when the pressure within the breathing system exceeds the valve's opening pressure.
- Also called as; Pop-off valve, Exhaust valve, Scavenger valve, Relief valve, Expiratory valve, Over-spill valve etc.
- It is a one way, adjustable, spring-loaded valve.
- The spring adjusts the pressure required to open the valve.
- The patient may be exposed to excessive positive pressure if the valve is closed for prolonged period (always pay great attention to the valve closure). Some designs have a safety mechanism, allowing the relief valve open when a pressure within the breathing circuit reaches about 60 cmH_2O.

e Tc 0 Tw 5.34 0 15.94

Pressure manometer

- A pressure gauge that is attached within the breathing circuits
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- It accommodates fresh gas flow during expiration acting as a reservoir available for use of the following inspiration.
- It acts as a monitor of the patient's ventilatory pattern, but is inaccurate for assessing the tidal volume.
- It can be used to assist or control the ventilation.
- Because of its compliance the rebreathing bag can accommodate rises in pressure in the breathing system better than other parts. When grossly over-inflated the reservoir bag can limit the pressure in the breathing system to about 40 cm H_2O. This is due to the 'law of Laplace' dictating that the pressure (P) will fall as the bag's radius (r) increases; $Pressure = \frac{tension}{radius}$
- A small bag may not be large enough to provide a sufficient reservoir for a large tidal volume.
- Too large a bag makes it difficult to act as a respiratory monitor.

Scavenging

- For halogenated hydrocarbon anesthetic agents (isoflurane, halothane, sevofurane and desflurane), 2 ppm is the allowed concentration, and 25 ppm for nitrous oxide. When the halogenated hydrocarbon anesthetic agent is used with nitrous oxide the maximum permissible concentration is reduced to 0.5 ppm.
- All 'anesthetic facilities' (including recovery rooms) must be tested for levels of escaped gases. Testing is done on an occasional basis (at the moment most vets intend to test once a year), the anesthetist wearing a 'badge' for a prescribed time which is then sent away for analysis.
- There are many scavenging devices suitable for veterinary purposes but care must be taken to ensure that their use does not have an adverse effect on the patient.
- The following reference "Commentary and recommendations on control of waste anesthetic gases in the workplace (JAVMA, 209(1), pp75-77)" describes more in detail the precautions and measures necessary to minimize the waste gas exposure.

Methods of scavenging

Passive scavenging.

- Tubes from the expiratory valve of the patient circuit lead to outside.
- Advantage
  - Cheap to install.
- Disadvantage.
  - Ineffective.
  - High expiratory resistance.
  - Can obstruct expiration.
  - Not acceptable now.

Passive with adsorption

- The tube from the expiratory valve now goes to a canister of activated carbon.
- Advantage.