Review Article

The Closed Circuit And The Low Flow Systems

Address for correspondence:
Dr. S Parthasarathy, Department of Anaesthesiology and Critical Care, Mahatma Gandhi Medical College and Research Institute, Puducherry - 607 402, India.
E-mail: painfreepatha@gmail.com

S Parthasarathy
Department of Anaesthesiology and Critical Care, Mahatma Gandhi Medical College and Research Institute, Puducherry, India

ABSTRACT

A breathing system is defined as an assembly of components, which delivers gases from the anesthesia machine to the patients' airways. When the components are arranged as a circle, it is termed a circle system. The flow of exhaled gases is unidirectional in the system. The system contains a component (absorber), which absorbs exhaled carbon dioxide and it is not necessary to give high fresh gas flows as in Mapleson systems. When the adjustable pressure limiting (APL) valve is closed and all the exhaled gases without carbon dioxide are returned to the patient, the system becomes a totally closed one. Such a circle system can be used with flows as low as 250 to 500 mL and clinically can be termed as low-flow systems. The components of the circle system can be arranged in different ways with adherence to basic rules: (1) Unidirectional valve must be present between the reservoir bag and the patient on both inspiratory and expiratory sides; (2) fresh gas must not enter the system between the expiratory unidirectional valve and the patient; and (3) the APL valve must not be placed between the patient and the inspiratory unidirectional valve. The functional analysis is explained in detail. During the function, the arrangement of components is significant only at higher fresh gas flows. With the introduction of low resistance valves, improved soda lime canisters and low dead space connectors, the use of less complicated pediatric circle systems is gaining popularity to anesthetize children. There are bidirectional flow systems with carbon dioxide absorption. The Waters to and fro system, a classic example of bidirectional flow systems with a canister to absorb carbon dioxide, is valveless and portable. It was widely used in the past and now is only of historical importance.

Key words: Anesthesia, circle system, closed system, low flow

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INTRODUCTION AND DEFINITIONS

The administration of drugs through lungs as inhalational method forms an essential part of the armamentarium of anesthesiologists worldwide. The anesthesia machine supplies the needed drugs in precise quantities, which have to be safely given to the patient without any additions and omissions. Simple weightless tubing, which connects a few necessary components does this job to be given the name "circuit". The circuit in scientific terms is called a breathing system and it is defined as an assembly of components, which delivers gases from the anesthesia machine to the patients' airways.[1] In a circle system, gases flow in a circular pathway in one direction with inspiratory and expiratory tubings separate and hence the name. One of the essential components of this system is a technique to absorb the exhaled CO_2 chemically i.e., the absorbent inside a canister. The same system can be used for anesthesia without an absorbent so that the APL valve eliminates the CO_2 but with high fresh gas flows. If economy of gases is contemplated, the canister becomes essential. The term low flow comes where the economy of fresh gas flow (FGF) is given top priority. Even though there are many definitions, for most practical considerations, utilization of a fresh gas flow less than 2 L/min may be considered as low-flow anesthesia.[2] To come down on FGF, it is necessary to close the expiratory valve of the circle system completely and whatever the carbon dioxide exhaled has to be done away with chemical means only without exposing the system to atmosphere. The system becomes a closed one now.[3]

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Completely closed circuit anesthesia is based upon the reasoning that anesthesia can be safely maintained if the gases that are taken up by the body alone are replaced into the circuit taking care to remove the expired carbon dioxide with soda lime. The canister for adsorbing CO_2 can also be placed in systems with bidirectional gas flows. Ralph Waters used a to-and-fro system with bidirectional flows of gases but with practical difficulties in its use to be put to disuse in current anesthetic practice.

Circle systems

Let us discuss the anatomy of the circle system. This is classified as unidirectional flow system with carbon dioxide absorption. The essential components of the circle system are: (1) a soda lime canister, (2) two unidirectional valves, (3) fresh gas entry, (4) Y-piece to connect to the patient, (5) a reservoir bag (RB), (6) an APL (spill valve) and (7) a low-resistance interconnecting tubing. The tubing can either be as two separate ones or as a compact single tube enclosing both inspiratory and expiratory tubing inside. The commonest way in which the components are assembled is depicted below[4] [Figure 1].

We will try to detail the functional analysis and later discuss each of the components with precise points needed for clinical practice.

Functional analysis

Considering the patient to be on spontaneous ventilation, during inspiration the fresh gases along with the CO_2 free gas in the reservoir bag flow through the inspiratory limb and inspiratory unidirectional valve to the patient. No flow takes place in the expiratory limb as the expiratory unidirectional valve is closed by back pressure transmitted to the valve. During expiration, the inspiratory unidirectional valve closes and the expired gas flows through the expiratory unidirectional valve in the expiratory limb to the soda lime canister and to the reservoir bag. The CO_2 is absorbed in the canister. The FGF from the machine continues to fill the reservoir bag. When the reservoir is full, the APL valve opens and the excess gas is vented to atmosphere during expiration. By selecting a suitable position for the APL valve, the expired gas can be selectively vented when the FGF is more than the alveolar ventilation. The above description of flow is for a spontaneously breathing patient. To facilitate controlled ventilation, the APL valve has to be partly closed and the excess gas is vented during inspiration. The gas flow pattern otherwise is similar to that described above. The relative positions of the components of the circle system are of particular importance to the functioning of the system only when the FGF is high, the gas components of the system unmixed and CO_2 absorber not used. When the FGF is reduced below the alveolar ventilation, the CO_2 absorber is a must as the gas in the system become more uniformly mixed, and the relative position of the components become less important.[5] The basic difference between the circle system and the others is the presence of a unique component, which absorbs the exhaled CO_2 so that the system effectively functions at lower fresh gas flows. A simple description of each component follows:

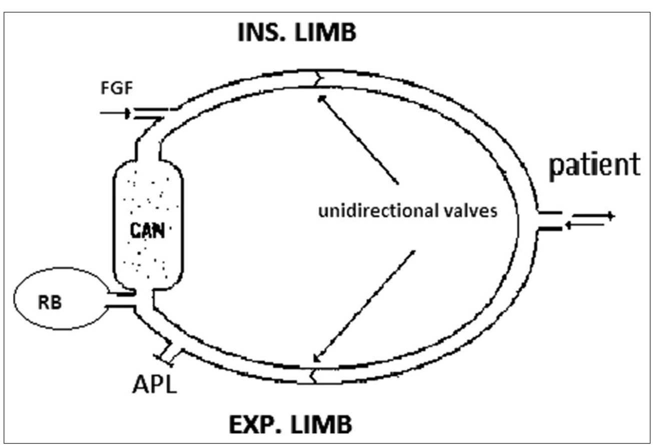

Figure 1: Arrangement of a circle system

Absorbers

An absorber is the whole system that contains one or two canisters in series. It is emphasized that the words canister and absorber are not synonymous. A single canister may also be used. Some newer machines use a single, small disposable canister that can be quickly changed during an anesthetic without interrupting breathing system continuity to ensure continued ventilation of the patient by the use of specific valves. Even though frequent changing of absorbent chemical is cumbersome, fresh smaller ones have better moisture content to be more effective for its purpose. As the internal volume of the breathing system is reduced, it allows changes in the FGF concentration to be reflected more quickly in the inspired concentration. A simple lever can tighten or loosen the canister for filling. Prepackaged absorbent containers to be placed inside the canisters as part of an absorber are available. These eliminate the need to pack absorbent chemical in the canister. It is essential to remember that the anesthesiologist will land up in obstruction of the system when the wrap is not removed in fresh ones. There are spaces at the top and bottom of the absorber for incoming gases to disperse before passing through the absorbent or for outgoing gases to collect before passing on through the circle. This promotes uniform distribution of gas flow in and out of the absorber. Also, this space allows dust and condensed water to accumulate. As the condensed water may be alkaline, it is ideal to avoid skin contact. Baffles, the annular rings, are used to increase the travel path for gases that pass along the sides of the canister and compensate for the reduced flow resistance along the walls of the canister. In a few machines, bypass valves are provided, so that the chemical absorbent is bypassed and the system will function as a circle system without absorber with high fresh gas flows.[6]

Absorbents

The absorption of carbon dioxide is an exothermic reaction, the end products being carbonate and water with a general principle of a base neutralizing an acid.[7]

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$$

$$H_2CO_3 + 2KOH \rightarrow K_2CO_3 + 2H_2O$$

$$Na_2CO_3\ (\text{or}\ K_2CO_3) + Ca(OH)_2 \rightarrow 2NaOH\ (\text{or}\ 2KOH) + CaCO_3$$

There are various chemical formulations, which can be classified into high alkali, low alkali, alkali free and others. The most common formulation is soda lime.

Soda lime consists of 4% NaOH, 1% KOH, 14-19% H_2O, and the remainder $Ca(OH)_2$. In addition, small amounts of silica or kieselguhr are added for hardening, and to reduce the formation of dust. Absorbents are supplied in pellets or granules. Small granules provide greater surface area but at the cost of increased resistance. The most frequently used size of soda lime granule is 4-8 mesh (i.e., 0.25-inch to 0.125-inch diameter). In theory, 100 g of CO_2 absorbent (soda lime) can absorb 26 L of CO_2. In practice, the amount of CO_2 actually absorbed is less because of the channeling of gas through the absorber.[8] Hence approximately, 450 g soda lime absorbs 47 L of CO_2 i.e., 4.5 h absorption at VCO_2@ 150 ml/min. FGF of 50% MV increases the duration to ~8 h. Indicators are added to the absorbent granules to show when they are becoming exhausted. The colour is not very reliable especially in single canister absorbers as hypercarbia tends to start earlier[6] [Table 1].

Table 1: Indicators with fresh and exhausted colours

Indicator	Fresh colour	Exhausted colour
Phenolphthalein	White	Pink
Ethyl violet	White	Purple
Clayton yellow	Red	Yellow
Ethyl orange	Orange	Yellow
Mimosa Z	Red	White

Baralyme was a very popular absorbent and used safely for many years. But desiccated Baralyme acting on sevoflurane can produce heat that could result in temperatures in excess of 400°C, fires, and explosions.[9] Monovalent bases (potassium hydroxide and sodium hydroxide) in absorbents cause the exothermic degradation of potent inhaled anesthetics to compound A and carbon monoxide. The formation of compound A is increased with prolonged anesthesia, low flows and higher concentration of sevoflurane. Now it has been established that formation of compound A with sevoflurane and soda lime is not that clinically significant.[10] Baralyme has no power of regeneration (i.e., minimal recovery of a power to absorb CO_2 after exhaustion) as soda lime. The newer absorbents may prove safer with inhalational agents but soda lime is still popular because it is an effective CO_2 remover. Historically speaking, an uncommon anesthetic, trichloroethylene, reacts with soda lime to produce toxic compounds. In the presence of alkali and heat, trichloroethylene degrades into dichloroacetylene, which can cause cranial nerve lesions and encephalitis. Another product, Phosgene, a potent pulmonary irritant, can cause adult respiratory distress syndrome, hence this agent is no longer used.[11] Calcium hydroxide lime is one of the newest clinically available carbon dioxide absorbents. It consists of calcium hydroxide and calcium chloride and contains two setting agents: Calcium sulfate and polyvinyl pyrrolidine. The latter two agents serve to enhance the hardness and porosity of the agent. In this context, it is mandatory to describe hardness.[12] It is measured by placing the granules in a steel pan with 15 steel balls of fixed diameter. The whole thing is shaken for 30 minutes followed by placing in a 40 mesh sieve and further shaken for three minutes. The amount retained should be at least 75% of the original and it is described as hardness number of 75. LoFloSorb®, Medisorb®, Intersorb Plus®, Sodasorb® are some of the newer absorbents which came to clinical use. They have the advantage of less CO and compound A production with minimal KOH content. Although they appear to be safer, compared to soda lime they are more expensive and absorb less CO_2.

With pros and cons of differing absorbents, soda lime remains popular among anesthesiologists.

The various absorbents with contents are tabled below[13,14] [Table 2].

Emergency care research institute recommendations for decreased carbon monoxide formation in absorbers[15]

1. Turn off all gas flow when the machine is not in use.
2. Change the absorbent regularly, on Monday morning for instance.
3. Change absorbent whenever the color change indicates exhaustion.
4. Change all absorbent, not just 1 canister in a 2-canister system.
5. Change absorbent when uncertain of the state of hydration, such as if the fresh gas flow has been left on for an extensive or indeterminate time period.
6. If compact canisters are used, consider changing them more frequently.

Unidirectional valves

The functional anatomy of a unidirectional valve Is discussed below.

The installation of the valve on the system may be either horizontal or vertical. A light, thin disc sits horizontally on an annular seat. The disc has a slightly larger diameter than the circular knife edge on which it sits. A cage with projections from the seat to prevent the disc from becoming dislodged laterally or vertically is present. The disc should be hydrophobic so that water condensate from the exhaled gas does not cause it to stick, which will increase resistance to opening. The top of the valve is covered by a clear plastic dome so that the movement of disc is visible. Gas enters at the bottom and flows through the centre of the valve, raising the disc from its seat. The gas then passes under the dome and on through the breathing system (open position). Reversing the gas flow will cause the disc to contact the seat, close it and prevents retrograde flow (closed position). It is light weight with a lift-clearance of half of valve seat diameter [Figure 2].

One or both unidirectional valves may become incompetent. Because an incompetent valve offers less resistance to flow, the flow of gas will be predominantly through the incompetent valve, resulting in rebreathing. The expiratory unidirectional valve is subjected to more moisture of expiratory gases and accompanying incompetence; it has also been reported with the inspiratory valve. Typical waveforms in capnograph identify specific problems of unidirectional valves. A unidirectional valve may also jam causing obstruction of gas flow.[16,17]

Table 2: Different absorbents and their properties

Absorbent	Hydroxide content	Compound A	Menthol
Baralyme	KOH 4.7% Ba $(OH)_2$ 7.4%	64.6	373
Soda lime	KOH 2.9% Ca $(OH)_2$ 80% approx NaOH 1.4%	56.4	606
Sofnolime	NaOH 2.6%	2.2	91
Amsorb® plus	Ca $(OH)_2$ $CaCl_2$	Negligible	-

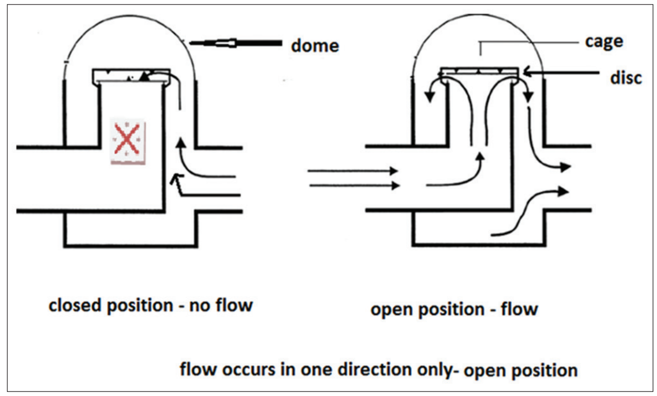

Figure 2: Function of unidirectional valves (inspiratory and expiratory)

The Y-piece

The Y-piece is a three-way tubular connector with two 22-mm male ports for connection to the breathing tubes and a 15-mm female patient connector for a tracheal tube or supraglottic airway device. The patient connection port usually has a coaxial 22-mm male fitting to allow direct connection between the Y-piece and a face mask. In simple terms, the Y-piece has an inner port for endotracheal tube with outer port for face mask attachment. In most disposable systems, the Y-piece and breathing tubes are permanently attached. A septum may be placed in the Y-piece to decrease the dead space. The apparatus dead space[3] regarding the circle system is up to the level of bidirectional flow of gases i.e., level of Y adapter [Figure 3].

The fresh gas inlet

The fresh gas inlet has an inside diameter of at least 4.0 mm and the fresh gas delivery tube has an inside diameter of at least 6.4 mm.[18] The fresh gas may enter the breathing system downstream of the inspiratory unidirectional valve.

Adjustable pressure-limiting valve

During spontaneous breathing, the valve is left fully open and gas flows through the valve during exhalation. When manually assisted or controlled ventilation is used, the APL valve should be closed enough that the desired inspiratory pressure can be achieved. When this pressure is reached, the valve opens and excess gas is vented to the scavenging system during inspiration. There is a case report where this valve got jammed in the closed position.[19] During mechanical ventilation the APL valve is isolated from the breathing system [Figure 4].

Respiratory gas monitor sensor or connector, pressure gauge, airway pressure monitor sensor, respirometer, positive end-expiratory pressure valve filters and heated humidifiers are useful additions to the components to perform their respective functions. These components can be connected by either rubber (in olden days) or plastic corrugated hoses to complete the circle system. The hoses have to have the following specifications. ISO 5356-1 specifies 22 mm/15 mm conical tapered fittings, leak <50 mL/min, kink resistant so that resistance does not increase by more than 50% when pulled into contact with half a 2.5 cm diameter cylinder. 1 m of 22 mm hose has an internal volume of about 450 mL. Compliance typically 0.7 mL/cm H_2O/m (i.e., 2 × 3 m hoses at 10 cmH_2O = 40 mL). It means that a high compliant tube can hold more air for the similar pressure change and reduces actual delivered tidal volume compared to bag movement, and during spontaneous breathing allows a little gas flow from both inspiratory and expiratory hoses. Resistance typically is less than 0.5 cmH_2O at 30 L/min in adult hoses. The tubes can also be arranged coaxially with its inherent advantages and problems[6] [Figure 5].

The above description is about the commonest type in which components are arranged. There are certain advantages and disadvantages with differing position of its parts. They are detailed below.

Arrangement of Individual Components

Fresh gas inlet

If the system has to deliver a set concentration in the shortest possible time to the alveoli, the FGF should be delivered as near the patient's airway as possible. Fresh gas inlet is usually placed between absorber and the

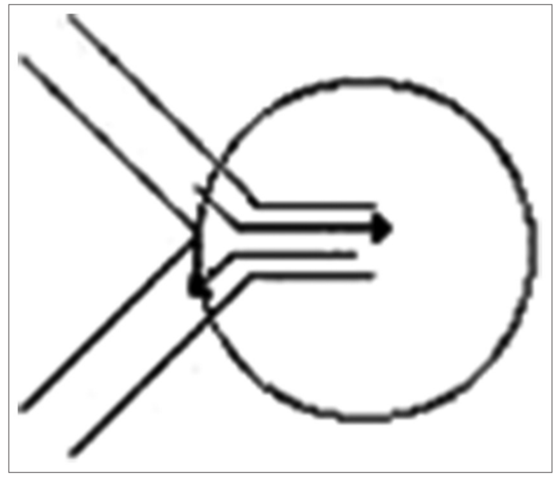

Figure 3: Y-piece and the apparatus dead space

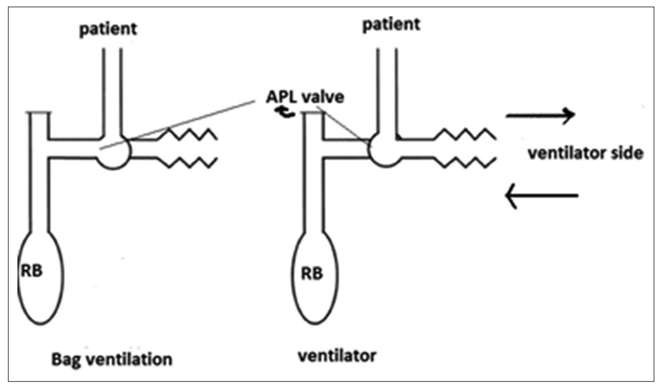

Figure 4: Bag/ventilator switch, which isolates APL valve during mechanical ventilation

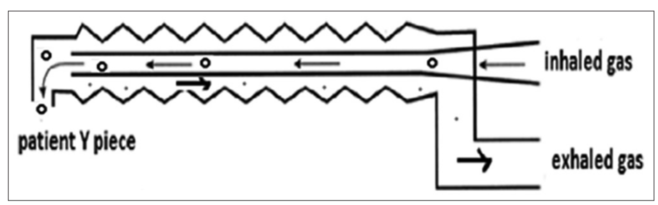

Figure 5: Coaxial arrangement of inspiratory and expiratory limbs

inspiratory unidirectional valve.[6] In this position (FGF 1), during exhalation and the expiratory pause, fresh gas can also flow retrograde into the absorber and then, depending on the fresh gas flow, in the circuit from the expiratory unidirectional valve and the absorber. This flow can cause absorbent desiccation at the absorber outlet. However, this position is close to the patient and advantageous in many aspects. Placing the fresh gas inlet just upstream of the absorber (position 2) will improve humidification at the cost of more venting, more absorbent desiccation and dust blow during oxygen flush usage. In position 3, changes in the fresh gas composition will be reflected more rapidly in the inspired gases without retrograde flow of FGF through the absorbent. During exhalation, fresh gases join exhaled gases and escape through the APL valve without reaching the patient resulting in poor economy of FGF and absorbent, because fresh gas will be lost during exhalation. It will also dilute the concentration of carbon dioxide in the gas vented through the APL valve with erring values in capnography. Placing the fresh gas inlet upstream of the expiratory unidirectional valve (position 4) has all of the disadvantages of position 5. In addition, during inspiration, the fresh gas flow will force exhaled gases that contain carbon dioxide back toward the patient. Placing the fresh gas inlet upstream of the bag and the APL valve (position 5) has all of the disadvantages of position 2 and will result in more venting of fresh gas and dilution of exhaled gas before it is vented. Hence it is common to have FGF entry in position 1 [Figure 6].

Reservoir bag

The characters of a reservoir bag are as follows:

- Permits manual ventilation, manual assessment of compliance.
- Volume buffer.
- Indicator of adequacy of fresh gas, over leak.
- Sizes from 500 mL-3 L.
- Small bags on 15 mm circle circuits provide excellent feel of the lung when hand-ventilating neonates.
- Can hold 10 × nominal volume before bursting.
- Pressure rises to peak of about 50-70 cmH_2O but falls late with massive distension.

It is most commonly placed between the expiratory unidirectional valve and the absorber (position 1). A disadvantage of placing the bag upstream of the absorber is that a sudden increase in pressure from squeezing the bag may force dust from the absorber into the inspiratory limb.[6] If the bag is placed between the patient and either of the unidirectional valves (position 2 or 3), it will form a reservoir for exhaled gases that will then be re-breathed. Considering position 4, exhaled gases would pass through the absorber to the bag during exhalation. Squeezing the bag during inhalation would cause the gases to pass retrograde through the absorber, to be vented through the APL valve. Keeping it just downstream of the FGF (position 5) allows better results in controlled ventilation [Figure 7].

Two locations have been used for the unidirectional valves: In the Y-piece and attached to the absorber. Valved Y-pieces are no longer available commercially. Valves in this position are bulky, and serious accidents have occurred when a valved Y-piece[20] was placed in a circle system that already contained absorber-mounted valves.

Adjustable pressure-limiting valve

Placing the valve at position 2 will cause a decrease in inspired heat and humidity. During spontaneous ventilation, absorbent use is inefficient if the APL valve is downstream of the absorber (positions 3 and 4) because vented gas will have passed through the absorber. If the APL valve is placed at position 3, fresh gas will be vented. If the APL valve is in position 4, exhaled gases will move retrograde in the inspiratory tubing during exhalation, causing an increase in apparatus dead space. The placement of APL valve in position 1 is near ideal for all its purpose with fewer side effects[6] [Figure 8].

Even though there are various positions of the

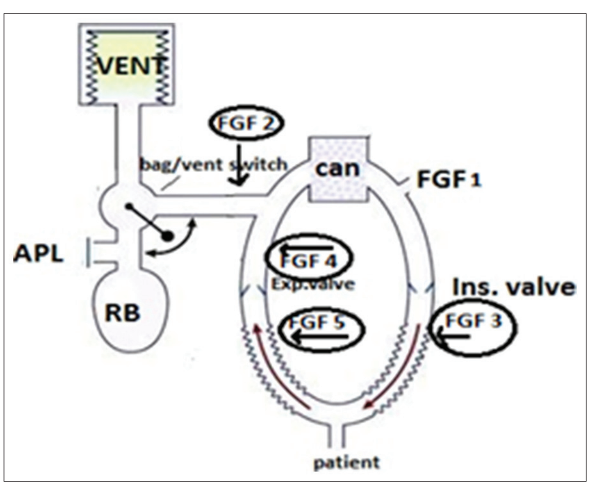

Figure 6: Different positions of fresh gas flow

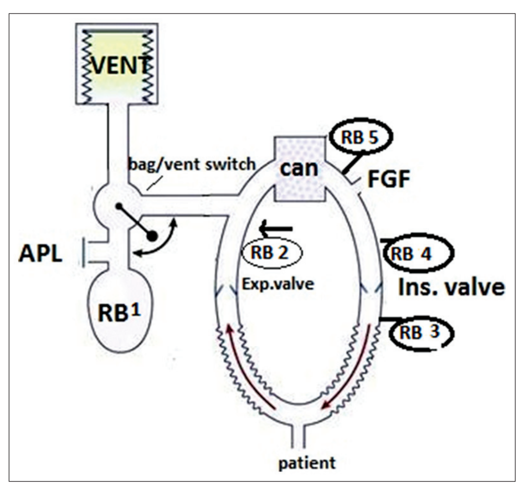

Figure 7: Different positions of reservoir bag

described components, Eger proposed 3 basic rules for minimizing CO_2 rebreathing in a circle system: (1) a unidirectional valve must be present between the reservoir bag and the patient on both inspiratory and expiratory sides; (2) fresh gas must not enter the system between the expiratory unidirectional valve and the patient; and (3) the spill (APL) valve must not be placed between the patient and the inspiratory unidirectional valve.[21]

Unidirectional gas flow occurs only in that part of the circle between the unidirectional valves and the patient. In the part of the circuit between the fresh gas inlet and the APL valve, gas flow is bidirectional.[8] This so-called bidirectional flow is only for the fresh gas flows and not for the exhaled gases. This concept is given so that the reader clearly understands a unidirectional flow system. Incompetence of either unidirectional valve permits bidirectional gas flow in the corrugated patient circuit tubing, leading to re-breathing of previously exhaled CO_2.

The flow and the leak tests for circle system

The flow test[5] checks the integrity of the unidirectional valves, and it detects obstruction in the circle system. It can be performed by removing the Y-piece from the circle system and breathing through the two corrugated hoses individually. The valves should be present, and they should move appropriately. The operator should be able to inhale but not exhale through the inspiratory limb and able to exhale but not inhale through the expiratory limb. The flow test can also be performed by using the ventilator and a breathing bag attached to the "Y"-piece.

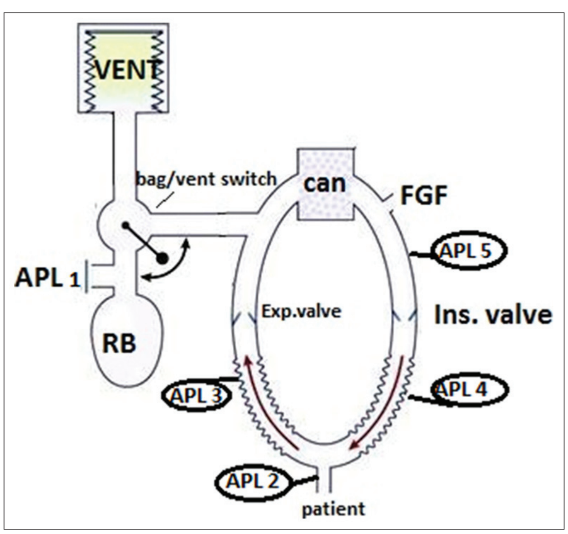

Figure 8: Different positions of APL valve

The leak test is performed by closing the APL valve, occluding the Y-piece, and pressurizing the circuit to 30 cmH_2O with the oxygen flush valve. The value on the pressure gauge will not decline if the circle system is leak free, but this does not ensure valve integrity. The value on the gauge will read 30 cmH_2O even if the unidirectional valves are stuck shut or the valves are incompetent.

Totally closed system

The systems with CO_2 absorption can be used in a completely closed mode. After a period of approximately 10-20 min breathing with high inflow of fresh gas for denitrogenation, the expiratory valve is closed. The FGF is then adjusted to meet only the patients' basal oxygen requirements together with anesthetic. A number of advantages have been demonstrated for totally closed systems.[22-24]

A) Economy: The FGF could be reduced to as low as 250-500 mL of oxygen alone. The consumption of Halothane/Isoflurane has been found to be around 3.5 mL/h.
B) Humidification: In the completely closed system, once the equilibrium has been established, the inspired gas will be fully saturated with water vapor.
C) Reduction of heat loss: The CO_2 absorption is an exothermic reaction and the system may actively help in maintaining body temperature.
D) Reduction in atmospheric pollution: Once the expiratory valve has been closed, no anesthetic escapes, except for the small percutaneous loss from the patient.
E) Control of anesthesia: It is possible to compute the time course of uptake of anesthetic in a patient of known size and add the appropriate quantity of the anesthetic to the circuit at a rate decreasing in a manner calculated to maintain a constant alveolar concentration. In practice, an alveolar concentration of about 1.3 × minimum alveolar concentration (MAC) is found to be suitable.

The technique has several potential disadvantages.

i) A greater knowledge of uptake and distribution is required to master closed circuit anesthesia.
ii) Inability to alter any concentration quickly.
iii) Real danger of hypercapnia may result from: A) an inactive absorber, B) incompetent unidirectional valves and C) incorrect use of absorber bypass and hence monitors to identify such defects should be readily available.

iv) A monitor to measure inspired oxygen fraction is mandatory.

Low-flow anesthesia

The possibility of a totally closed mode with circle systems with closed APL valves prompt us to peep into a new arena named low-flow anesthesia. As low-flow anesthesia is a separate topic, the definitions are mentioned here for the sake of completion.

Low-flow anesthesia has various definitions. Any technique that utilizes a fresh gas flow (FGF) that is less than the alveolar ventilation can be classified as 'low-flow anesthesia'. Baum *et al*.[22] defined it as a technique wherein at least 50% of the expired gases had been returned to the lungs after carbon dioxide absorption. This would be satisfied when the FGF was less than about two liters per minute.

Baker,[25] in his editorial had classified the FGF used in anesthetic practice into the following categories:
Metabolic flow : about 250 mL/min
Minimal flow : 250-500 mL/min
Low flow : 500-1000 mL/min
Medium flow : 1-2 L/min

For most practical considerations, utilization of a fresh gas flow less than 2 L/min may be considered as low-flow anesthesia.[26,27]

To and fro systems

These systems are classified as bidirectional flow systems with carbon dioxide absorption.[28] The Waters to and fro system, a classic example of such systems, is valveless and conveniently portable. It has been widely used in the past and now is only of historical importance. The canister is placed between the mask (ET tube) and the reservoir bag. Fresh gases are introduced near the face mask, so that any alteration is immediately transferred to the patient. The close proximity of canister towards patient ensures minimal temperature and humidity loss at the cost of its awkward and heavy presence. There are reports of use of low flow with this system.[29] A standard canister is cylindrical and measures 8 × 13 cm. When filled with soda lime, the air capacity lies between 375 and 425 mL, which may sometimes be less than the normal tidal volume. For the initial 90 min, the canister may perform carbon dioxide elimination satisfactorily but becomes inefficient later on to add to dead space. It was useful to conduct infected cases so that it can be disposed but later put to total disuse[30,31] [Figure 9].

Figure 9: To and fro breathing system

Circle system in pediatric use

The circle system differs from others by the presence of unidirectional valves and canister which add resistance. When contemplating its use in children, this fact comes to play. The dead space extends from the partition of Y piece to the patient airway. For spontaneous use in pediatric patients, a divided airway adaptor was used where a 8.5 mm concentric tube was added to the inspiratory limb (Columbia paediatric circle). This allows for ideal area of inspiratory and expiratory pathways with a resistance of 1 cmH_2O/15 L/min and a dead space of 0.5 mL. The Revell Circulator was introduced to minimize mechanical dead space and decrease the valve resistance. The device moves gas around the circle by a pneumatic driven fan placed in the circle. The circulator may provide a method to obtain identical anesthetic gas concentration throughout the circle during priming.[32] With the introduction of low resistance valves, improved soda lime canisters and low dead space connectors, the use of less complicated pediatric circle systems like Ohio and Bloomquist are becoming popular.[33] The modern pediatric circle absorber system is a safe and efficient method for delivery of anesthetic gases to the infant. With regard to cost, it offers some advantages over the Jackson-Rees system[34] due to lower volumes of agent vaporized per unit time. Heat and fluid conservation are also promoted by the low flows,[35,36] and with more efficient scavenging equipment available for the circle system, there is less contamination of the operating room environment.

SUMMARY

It is necessary to know the various breathing systems with a special mention about circle systems. Understanding the different components, their functional analyses are needed for the safe conduct of anesthesia. Totally closed anesthesia with distinct advantages is to be promoted with more vigor in all established institutions for the sake of better economy, humidification with a reduction of cost and atmospheric pollution. With the development of low-resistance equipment, it is safe to practice low flows in pediatric anesthesia.

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