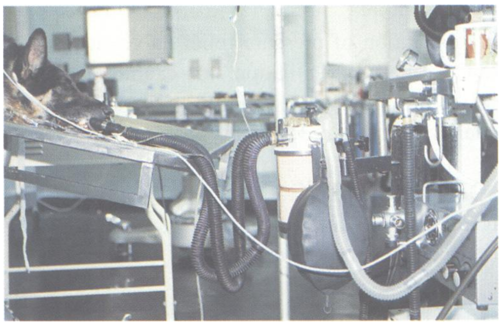


A range of breathing systems should be available to cover all potential clinical situations

The right anaesthetic breathing system for you?

EDDIE CLUTTON

THE types of anaesthetic machine available and factors influencing the selection of machine were discussed in an earlier article (*In Practice*, February 1995, pp 83-88). Here, attention is turned to anaesthetic breathing systems, or circuits, which connect the anaesthetic machine to the endotracheal tube connector or mask and convey oxygen and anaesthetic vapour to the patient. Improper system selection, misuse or circuit malfunction may jeopardise patients. Because each circuit has advantages (and disadvantages) in different circumstances, a range should be available to cover all potential clinical situations.

Eddie Clutton qualified from Liverpool University in 1981 and remained there for two years pursuing the diploma in veterinary anaesthesia. Between 1983 and 1989 he held the post of assistant professor of veterinary anesthesiology at the Virginia-Maryland College of Veterinary Medicine, in Blacksburg, Virginia, USA. He became lecturer in veterinary anaesthesiology at the Royal (Dick) School of Veterinary Studies in 1990 where he is currently director of anaesthesia.

FACTORS INFLUENCING BREATHING SYSTEM SELECTION

RESISTANCE

Anaesthetised animals hypoventilate if faced with an increased resistance to inspiratory and expiratory flow, although 'lightly' anaesthetised animals may overcome this at the cost of a greater breathing effort. Resistance stems from the circuit geometry (valves, absorbent, constrictions, hose tortuosity) and hose length. However, the most important contributor is hose radius; halving the radius increases resistance to gas flow 16-fold. Large animal circuits, especially, must incorporate wide-bore hoses.

Breathing system selection is normally based on bodyweight because larger (heavier) animals are able to overcome resistance (lightweight animals are also less able to cope with mechanical dead space). However, the limitations of this criterion must be appreciated – a fit dog weighing 5 kg may tolerate resistance that compromises an obese, older myasthenic animal weighing 20 kg.

CONTROLLED VERSUS SPONTANEOUS VENTILATION

Controlled or intermittent positive-pressure ventilation (IPPV) overcomes most of the problems of resistance to spontaneous breathing and reduces the work of breathing. It is mandatory during thoracotomy, when animals hypoventilate, or when neuromuscular blocking agents are used. The gas flow requirements of the Magill and Lack systems (see later) depend on the ventilatory mode and become uneconomically high during positive-pressure ventilation.

REBREATHING VERSUS NON-REBREATHING

Rebreathing is the re-inhalation of expired breath. Compared with fresh (inspired) gas from the machine, expired gas is warmer, more moist, higher in carbon dioxide but lower in oxygen and anaesthetic vapour. Total rebreathing results in undesirable carbon dioxide accumulation. Partial rebreathing, whereby breath from which carbon dioxide has been removed is re-aspirated, is advantageous (heat and water vapour are retained) and safe providing that oxygen and anaesthetic are replenished. Partial rebreathing is useful in animals at risk of hypothermia and those with certain types of tracheobronchial disease (dry, cold anaesthetic gases impair ciliary function and make airway secretions viscid). Circle and to-and-fro systems that allow partial rebreathing are described as rebreathing circuits.

■ FRESH GAS FLOW REQUIREMENTS. In rebreathing systems, gas flow from the machine replaces anaesthetic and oxygen uptaken by the patient (requirements are based on the animal's oxygen consumption). In non-rebreathing systems, fresh gas is needed to flush carbon dioxide from the system; flow requirements are based on multiples of the minute ventilatory volume (V_m). As these are considerably greater than the oxygen consumption (see table overleaf), non-rebreathing systems are uneconomical in large animals, during prolonged procedures or when carrier gas and vapour economy is important (eg, isoflurane anaesthesia).

■ NITROUS OXIDE INCLUSION. The use of nitrous oxide in rebreathing systems is potentially hazardous, especially when using 'closed' systems. The uptake of oxygen and nitrous oxide from the system occurs at different rates

RESPIRATORY VARIABLES IN COMPANION ANIMALS					
		*Respiratory rate** *(breaths/minute)*	*V_t* *(ml/kg)*	*V_m* *(ml/kg/minute)*	*Oxygen consumption†* *(ml/kg/minute)*
Dogs	>30kg	15-20	12-15	150-250	5·8
	<30kg	20-30	16-20	200-300	6·2
Cats		20-30	7-9	180-380	7·3

*During surgery, factors such as pain, pyrexia and light versus deep anaesthesia will affect these
†Oxygen consumption depends on factors related to metabolic rate, ie, age, temperature, thyroid status, drugs, muscle tone, response to surgery
V_t Tidal ventilatory volume, V_m Minute ventilatory volume

and may leave hypoxic gas mixtures. This is identified by measuring inspired oxygen concentrations. Dohoo and others (1982) demonstrated that flows of 30 ml/kg/minute of oxygen and 60 ml/kg/minute of nitrous oxide are safe in rebreathing systems for dogs. These high flows limit partial rebreathing, increase pollution and wastage of volatile agents and so reduce efficiency.

MECHANICAL DEAD SPACE

Mechanical or apparatus dead space accommodates gas which is re-aspirated with every breath but which does not participate in gas exchange. Effectively an extension of the animal's anatomical dead space, the mechanical dead space is the volume between the animal's incisor arcade (rostral limit of anatomical dead space) and that part of the circuit where inspired and expired gas streams divide (see figure below). It reduces the portion of inspired gas reaching the alveoli and, in the absence of increased V_m, causes hypoventilation.

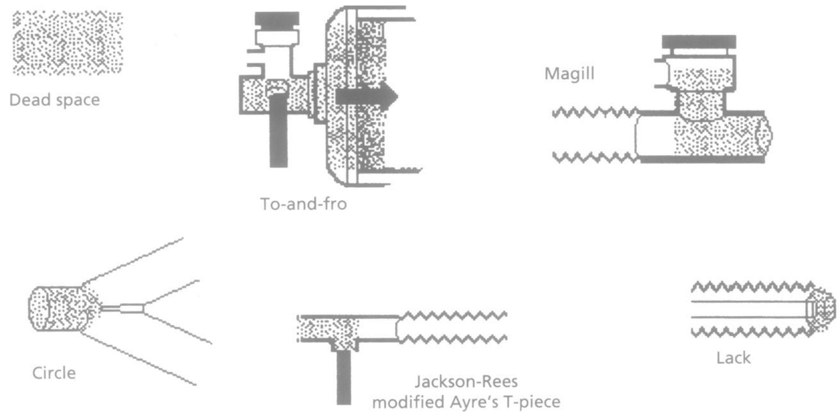
CIRCUIT 'DRAG'

Heavy hoses, valves and absorbent canisters create 'drag', increasing the risk of extubation or circuit disconnection if the animal moves or is moved. Lightweight plastic hoses without drag (or rigidity) are desirable in small subjects like birds. Valves and multiple hoses adjacent to patients contribute to drag; coaxial systems have neither and so are useful in very small animals.

EASE OF MAINTENANCE AND STERILISATION

The ease of sterilisation depends on the complexity of the system, circle systems being difficult to sterilise. Disposable, lightweight plastic versions of some systems (Intersurgical systems) are ideal for animals with infectious diseases. (For a discussion of sterilisation procedures see Dorsch and Dorsch 1984.)

Mechanical dead space is the volume between the animal's incisor arcade and that part of the circuit where inspired and expired gas streams divide



VALVE POSITION

Repeated operation of pressure relief valves located by the head (to control ventilation, for example) disrupts surgery and may compromise sterility. The development of coaxial systems has reduced this problem.

EASE OF SCAVENGING

A scavenging hose attached at pressure relief valves close to the patient contributes to drag.

REBREATHING SYSTEMS

In circle and to-and-fro systems, soda lime (absorbent) removes carbon dioxide from the expired gas. The advantages and disadvantages of rebreathing systems are compared in the top table on the right while some features of rebreathing system operation are explained below.

- CLOSED AND 'LOW FLOW'. Rebreathing systems are used in one of two ways. In some systems, the gas inflow precisely replaces the anaesthetic and oxygen uptaken by the patient (approximately 5 to 10 ml/kg/minute is required). Under these conditions the pressure relief valve is shut and the system is described as 'closed'. The oxygen consumption depends on factors related to the metabolic rate but typical values are given in the table above. In 'low flow' systems, the oxygen delivery exceeds basal requirements (>10 ml/kg/minute), with surplus gas leaking through the partly opened pressure relief valve; these are the easiest systems to operate and, therefore, the most common. The advantages of closed and low flow systems are compared in the table on the right.
- NITROUS OXIDE. Nitrous oxide cannot be safely used in rebreathing systems unless inspired oxygen or patient arterial oxygen tensions are monitored.
- DENITROGENATION. At the onset of anaesthesia, patients expire considerable volumes of nitrogen which may lower the circuit oxygen to hypoxic levels unless purged through the pressure relief valve (denitrogenation). Hypoxic gas mixtures are likely when nitrous oxide and/or closed systems are used. Denitrogenation is achieved using high flows for the first 10 to 15 minutes of anaesthesia. Alternatively, the reservoir bag should be 'dumped' every three minutes in the first 15 minutes and every 30 minutes thereafter.
- ANAESTHETIC CONCENTRATION. The rate of change of gas concentration in rebreathing systems is inversely proportional to the volume of the system and directly related to the gas inflow rate. Usually, circle systems have greater volumes than to-and-fro circuits so rapid increases in concentration (required, for example, when animals become 'light') rely on greater inflow rates and vaporiser settings. Flowmeter and vaporiser performance must meet this requirement.

CIRCLE SYSTEM

Circle systems have valves causing unidirectional gas movement through the circuit's components (see figure on the right). The positioning of the components influences efficiency, primarily when circle systems are used in a low flow manner.

Low resistance vaporisers (eg, Stephen's Universal) may be sited within the circuit (VIC) in the inspiratory limb. Alternatively, anaesthetic may be delivered by calibrated vaporisers 'out of circuit' (VOC).

ADVANTAGES AND DISADVANTAGES OF REBREATHING SYSTEMS	
Advantages	*Disadvantages*
Low gas flow requirements	High resistance to breathing
Low volatile agent consumption rate	Nitrous oxide cannot be safely used
'Closed' or 'low flow' options	Expensive
Expired moisture and heat conserved	Regular soda lime replacement required
Ventilation is altered (spontaneous to controlled) without changing system performance or efficiency	Denitrogenation required
Low explosion risk (when explosive gases are used)	Inspired gas content undetermined Slow to change level of anaesthesia
Less pollution	Cumbersome
	Cannot be used with trichloroethylene*

*No longer available as an anaesthetic. Sevoflurane, a volatile agent currently undergoing clinical evaluation, is unstable in and absorbed by soda lime

ADVANTAGES AND DISADVANTAGES OF CLOSED VERSUS 'LOW FLOW' SYSTEMS	
Advantages	*Disadvantages*
Optimum fresh gas economy	Constant attention to system required
Low pollution and explosion risk	Denitrogenation mandatory
Maximum preservation of heat and moisture	Nitrous oxide inclusion is imprudent unless oximetry is performed
	Slow response to changing inspired oxygen concentration
	Use possible only in subjects with oxygen consumption lying in the range of vaporiser function
	High output vaporisers required (VOC) and high output low resistance vaporisers (VIC)

VOC Vaporiser out of circuit, VIC Vaporiser in circuit

Fresh gas inflow

The fresh gas inflow pipe connects the circuit with the common gas outlet on the anaesthetic machine. Its location immediately upstream of the inspiratory valve and downstream from the canister allows the best control of the inspired gas composition.

Unidirectional valves

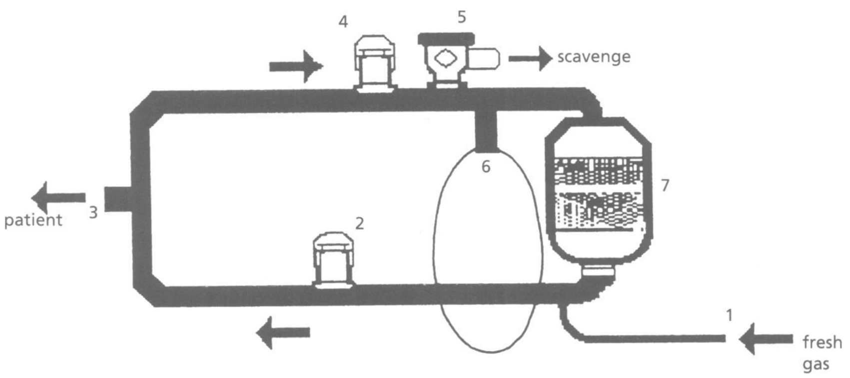
The inspiratory and expiratory unidirectional valves are light transparent discs resting on knife-edge annular valve seats, enclosed within a gas-tight transparent dome. Painted indicators on the disc accentuate disc movement. Units should be easily disassembled for cleaning and drying.

'Y' connector

The 'Y' connector connects the inspiratory and expiratory limbs with the endotracheal tube connectors or masks. In paediatric systems, it has a septum dividing the inspiratory and expiratory flows, reducing the apparatus dead space.

Pressure relief valve

Pressure relief valves are adjustable unidirectional valves venting at pressures from 1 to 50 mmHg. They are opened to release surplus gas from low flow systems and during denitrogenation, and closed when bag compression is imposed for lung inflation. In old systems this valve was sited at the 'Y' connector which made operation difficult. Relief valves should be shrouded (ie, fitted with connectors) for attachment to scavenge hoses.



Circle anaesthetic breathing system components. (1) Fresh gas inflow valve, (2) Inspiratory unidirectional valve, (3) Patient 'Y' connector, (4) Expiratory unidirectional valve, (5) Pressure relief valve, (6) Reservoir bag, (7) Absorbent canister. Some circuits have manometers; these are useful, but not vital

Reservoir (rebreathing) bag

Normally sited between the expiratory valve and absorber, the reservoir bag allows positive-pressure ventilation and assists the monitoring of the respiratory rate and tidal volume (V_t). It should be three to six times the animal's V_t; over-sized bags increase circle volume, diminish perceptibility of respiration and are harder to compress manually, while inadequately sized bags collapse during large breaths and overdistend during expiration.

Bags of 25 to 35 litres capacity are needed for adult horses while 2, 4 and 6 litre bags are required for small animal use.

Absorbent canister

Siting the absorbent canister on the expiratory limb downstream from the pressure release valve allows carbon dioxide to be expelled before it reacts with and consumes the soda lime. In this position, dust aspiration is unlikely although heat conservation is poorer.

The filled canister contains approximately 50 per cent absorbent granules and 50 per cent air space. Efficient absorption requires an air space volume in excess of the V_t and so the minimum working soda lime volume required is 2 x V_t. Greater volumes than this are needed because absorbent is inactivated during use. Large canisters may confer resistance to breathing, but require less frequent changing. For optimum absorption efficiency the canister width-height ratio should be 1:1 or greater; gas flows more slowly through large diameter canisters and resistance caused by turbulent flow is reduced.

Two-compartment absorbent canister

Canisters for circle systems should have two compartments. When absorbent in one compartment becomes exhausted, it is discarded. After refilling, the canister is replaced in the reverse direction. Expired gas then passes through the remaining partially used absorbent, exhausting this completely before reaching the newly filled compartment. Circle system canisters may have a by-pass switch that excludes or incorporates absorbent from the circuit. This is used after controlled ventilation when low plasma carbon dioxide tensions may prevent the resumption of spontaneous breathing. Switching the absorbent 'off' allows circuit carbon dioxide levels to rise without curtailing oxygen and anaesthetic delivery; inadvertent operation of circle systems with absorbent switched off (excluded) results in fatal hypercapnia.

Absorbent canisters should be easy to open, fill, reseal and replace. They should also have a window so that absorbent colour and degree of filling can be checked.

Canisters for human use are suitable for calves, foals, sheep, most pigs, and dogs weighing over 15 kg. Mechanical dead space does not increase in the course of time but absorbent exhaustion occurs more acutely than with to-and-fro systems and replacement may become necessary at inconvenient times during surgery. Small animal systems require canisters of about 1·5 litres accepting 1·35 kg of absorbent. Large animal systems need 2 to 5 kg of soda lime, ie, 5·2 litre canisters.

Hoses

Corrugated hosing prevents kinking but generates turbulent gas flow and, therefore, resistance. Smooth-walled hose with external ribbing (as pictured above) is preferable. Hoses for human use (22 mm diameter) are suitable for companion and small food animals; adult large animals need 5 cm diameter tubing.

Advantages and disadvantages of circle systems

Advantages

Circle systems are very efficient and most suited to horses, adult food animals and dogs weighing over 15 kg. They are more convenient to use than to-and-fro systems. Circle systems are at their most efficient when used in a closed fashion (see table on previous page). The Komesaroff and Stephen's anaesthetic machines are designed for closed use and have been used in dogs as small as 5 kg (Waterman 1985) and 2 kg (Cust 1975). The 'level' of anaesthesia in animals connected to systems with VIC is to some extent self-regulating. As animals become 'lighter' their alveolar ventilation increases, which augments vaporiser output and so 'deepens' anaesthesia. Relatively inexpensive, lightweight plastic systems are now available (Arnolds). One range is disposable (Intersurgical).

Disadvantages

Circle systems are complex and cumbersome, difficult to sterilise and use in the field, although a field model is manufactured (supplied by International Marketing Supply). They are relatively expensive. Circuits described as paediatric, adult human (small animal) and large animal differ in hose length and radius, and volume of absorbent canisters. Despite availability, circle systems for small dogs and cats are less popular in the UK than elsewhere because resistance caused by absorbent and valves, and dead space in the 'Y' connector are alleged to be excessive (Hall and Clarke 1991). Circle systems designed for human use should not be used in dogs weighing less than 15 kg although they are useful and efficient in larger dogs. When circle systems are run with VIC, the risk of overdosage increases when ventilation is controlled. When controlled ventilation is required, animals must be closely monitored and the vaporiser output curtailed.

TO-AND-FRO (WATER'S) SYSTEM

In the to-and-fro system, gas oscillates over absorbent in the Water's canister. Canisters are designed for vertical use in large animal anaesthesia and horizontal use in companion animals (and people). Desirable features of to-and-fro circuits are outlined below.

Fresh gas inflow

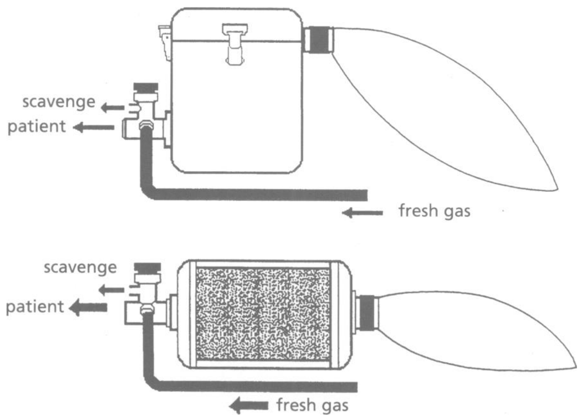
Situating the gas inflow next to the endotracheal tube connector reduces the mechanical dead space and allows optimal control of anaesthesia; dialled concentrations of anaesthetic are preferentially inspired.

Filter

A metal gauze screen sited at the patient end of the canister limits the inhalation of alkali dust produced by agitation or inferior-grade absorbent.

Scavenging shroud

Older to-and-fro systems may not have a scavenging



Vertical (top) and horizontal (bottom) to-and-fro system

Advantages and disadvantages of to-and-fro systems

Advantages

Simplicity, durability and portability make to-and-fro systems well suited to inhalation anaesthesia in the field. The circuit is useful with any anaesthetic machine capable of delivering gas vapour to anaesthetise large animals and ideal in animals with infectious airway disease as it is readily sterilised.

Disadvantages

Considerable circuit drag renders the system cumbersome (although a lightweight plastic system is now available [Arnolds]). Extubation is possible when inadequately anaesthetised animals move. The proximity of the pressure relief valve is awkward when IPPV is required during head, neck or dental surgery. The mechanical dead space increases with time and chemical bronchiolitis and hyperthermia are well known problems with both vertical and horizontal systems; channelling only occurs in the horizontal to-and-fro.

shroud fixed to the pressure relief value. This makes effective scavenging difficult.

Canister

The dimension requirements for the canister are the same as those for circle systems. Modern horizontal canisters are made from transparent perspex, allowing soda lime colour and filling adequacy to be checked. The latter is important as in improperly filled horizontal canisters, expirate 'channels' or takes the low resistance path over absorbent granules and so carbon dioxide is retained. Vertical canisters are made of alloy and incorporate a window for assessment of absorbent colour. Ideally, the window should extend the length of the canister although, in most commercially available patterns, it is situated in the 'lid'. Absorbent exhaustion becomes apparent only when the bulk of absorbent is useless. Therefore, such systems should have quick release toggles for rapid absorbent replacement. 'Channelling' does not occur in vertical to-and-fro canisters although they may contain baffles, which are annular rings directing gas flow towards the centre of the canister.

For adult horses, cattle and pigs, a vertical container with 5 kg absorbent may be required. For small pigs, sheep, goats, young calves and foals, canisters for humans containing 0·3 to 0·5 kg of absorbent are satisfactory. For dogs weighing over 10 kg it is said the human variety containing 0·5 kg of absorbent (650 ml volume) is satisfactory.

Bag mount

Vertical canisters require a caged bag mount to prevent the sides of the reservoir bag at the neck being sucked together during inspiration and inhibiting gas movement.

Rebreathing bag

The earlier discussion on rebreathing bags (page 231) applies equally to to-and-fro systems.

COMPARISON OF CIRCLE AND TO-AND-FRO SYSTEMS

	Advantages	*Disadvantages*
Circle	High gas efficiency	Expensive
	Mechanical dead space remains unchanged with use	Complex, cumbersome and difficult to sterilise
	Bronchiolitis unlikely	
	Low circuit inertia	
	Ventilation readily controlled	
To-and-fro	High gas efficiency	Valve position is inconvenient for positive-pressure ventilation
	Bi-directional gas flow improves carbon dioxide scrubbing efficiency	Mechanical dead space increases during surgery as absorbent is exhausted
	Greater heat conservation (hyperthermia is possible in high ambient temperatures)	'Channelling' gas over absorbent occurs in the poorly packed horizontal Water's canister
	Lower resistance to breathing than with circle systems (no valves and lower overall circuit length)	Aspiration of alkali dust from canister may cause chemical lung injury (bronchiolitis)
	Low circuit volume enabling denitrogenation and changes in gas concentration to be achieved rapidly	Considerable drag; the system has much inertia and is inconvenient during head surgery
	Simple, robust construction	
	Portable; easily moved from room to room and in field	
	Readily sterilised	
	Inexpensive	

NON-REBREATHING SYSTEMS

Non-rebreathing or semi-closed systems rely on high gas flow rates (based on multiples of the minute volume) to flush expired carbon dioxide from the circuit so that it cannot be rebreathed at the next breath.

MAGILL SYSTEM

The Magill system consists of a reservoir bag (volume 3 to 6 x V_t) and a corrugated hose that ends at an expiratory (Heidbrink) valve. The expiratory hose volume must exceed the V_t of the animal or else rebreathing occurs.

Gas flow

Rebreathing is prevented when the gas flow equals or exceeds the patient's V_m (see table, page 230). When nitrous oxide is used, its flow rate is included within this value. For example, to supply 66 per cent nitrous oxide to a 15 kg dog (with a minute volume of 3 litres), flows of 1 litre/minute of oxygen and 2 litres/minute of nitrous oxide are required. Similarly, 1·5 litres/minute of oxygen and nitrous oxide would provide the same dog with a 50 per cent mixture.

LACK SYSTEM

The inconvenient valve location in Magill circuits is overcome in the coaxial (tube within a tube) version – the Lack system. In this, a reservoir bag connects to an outer inspiratory limb; this surrounds an inner expiratory tube that ends at the expiratory valve positioned at the machine connector.

Gas flow

Despite theoretical considerations, the behaviour of Lack and Magill systems is different and rebreathing occurs in people when gas flow equals V_m. In dogs, the Lack system is slightly more efficient than the Magill (Waterman 1986). Expiratory resistance is also lower and so the system may be used in smaller animals.

Advantages and disadvantages of the Magill system

Advantages

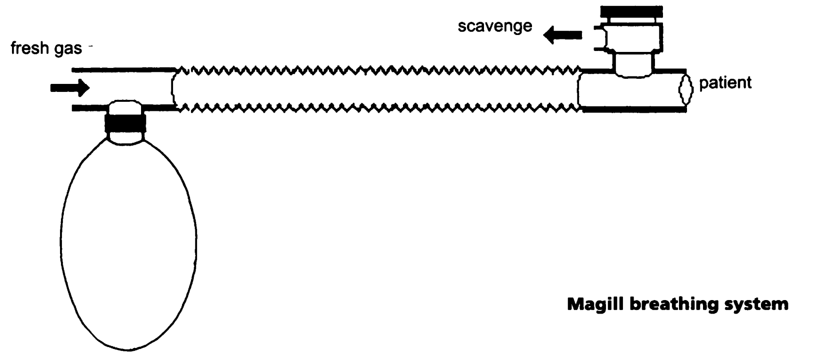
The Magill is an efficient general purpose circuit for most companion animal cases. It can be used in smaller pigs, sheep, goats and very young calves and foals up to about 60 kg bodyweight; gas flows required for these and larger animals may exceed flowmeter capability and, in any case, reduce economy. The circuit is readily maintained and sterilised.

Disadvantages

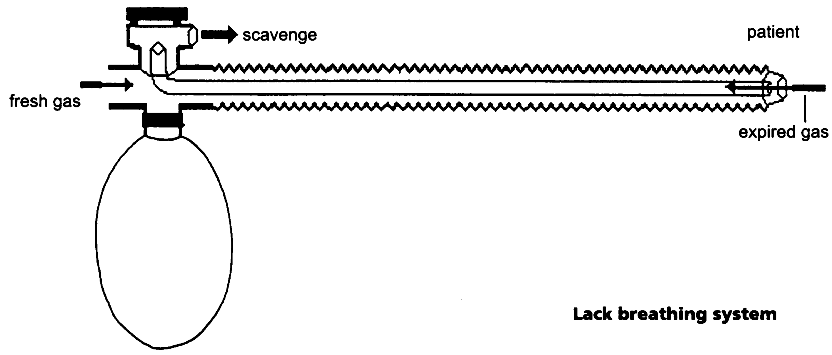
The Magill's mechanical dead space, inertia and considerable expiratory resistance preclude its usefulness in cats, and dogs weighing under 5 kg. The location of the Heidbrink valve is inconvenient for scavenging and operation, especially during surgery on the head. The system should not be used for prolonged positive-pressure ventilation because alveolar gas is rebreathed, causing hypercapnia. Higher gas flow rates and an altered ventilatory pattern permit IPPV without rebreathing, but this cannot be recommended when alternative systems are readily available.

ADVANTAGES AND DISADVANTAGES OF NON-REBREATHING SYSTEMS

Advantages	*Disadvantages*
Low resistance; ideal for small animals and birds	High gas flow requirements
Simple construction	High volatile agent consumption rate
Inexpensive to purchase	High running costs
Soda lime not required	Expired moisture and heat usually lost
Inspired gas content similar to that 'dialled' at anaesthetic machine	Ventilatory modes affect system performance
Denitrogenation not required	Different types of non-rebreathing circuits behave differently and have different flow requirements
Level of anaesthesia can be rapidly changed	Inefficient in larger animals
Can be used with trichloroethylene	



Magill breathing system



Lack breathing system

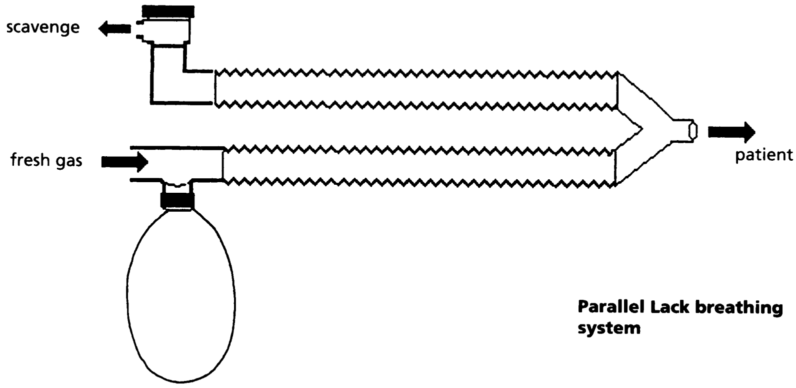
Advantages and disadvantages of the Lack system

Advantages

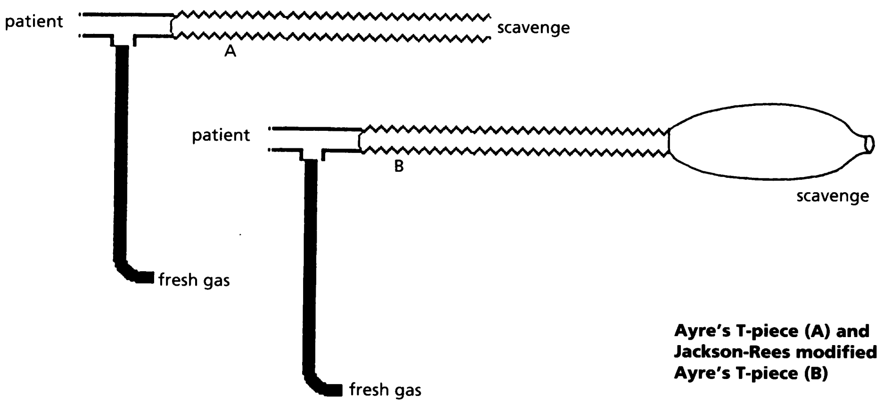
The Lack circuit is lightweight and exerts less drag than Magill systems. The valve location facilitates operation and scavenging. The system is 1·5 m long, allowing the anaesthetic machine to be positioned away from the site of surgery. Lack systems can be used in place of the Magill circuit.

Disadvantages

Older versions of the Lack had high expiratory (inner limb) resistance and inner hose disconnection, causing considerable rebreathing, was reported. The system is stiffer and inconvenient to use in very small animals. Ventilation should not be controlled with the Lack circuit.



Parallel Lack breathing system



Ayre's T-piece (A) and Jackson-Rees modified Ayre's T-piece (B)

PARALLEL LACK SYSTEM

The problems of coaxial geometry (disconnection, fracture or kinking of the inner limb) are avoided when the inspiratory and expiratory limbs are juxtapositioned, as in the parallel Lack system. The system behaves like a Magill attachment, although additional 'bulk' created by two hoses may increase drag, so conferring little advantage in very small animal anaesthesia.

AYRE'S T-PIECE

Four T-piece configurations are possible, based on the volume of the expiratory limb. In the most effective type, the expiratory limb volume exceeds the patient's V_t; there is no reservoir bag or expiratory valves.

Gas flow

Gas flows for T-piece systems must exceed 2 x V_m otherwise expired gas is rebreathed. Rapid respiratory rates with short expiratory pauses may require even higher (3 x V_m) flows.

Advantages and disadvantages of the Ayre's T-piece

Advantages

Minimal apparatus dead space and resistance make the T-piece ideal for cats, small dogs (under 5 kg), neonates and birds. It is simple, inexpensive and easy to sterilise. Modest drag occurs because two hoses are present. The system is scavenged with appropriate connectors.

Disadvantages

Ventilation is controlled by occluding the distal end of the expiratory limb but the gas flow must be increased otherwise the duration of inspiration is prolonged, limiting adequate ventilation.

Advantages and disadvantages of the Ayre's T-piece with Jackson-Rees' modification

Advantages

The bag facilitates IPPV and bag movement acts as a useful respiratory monitor. Ventilation is controlled by occluding the bag's end, allowing distention, then squeezing the contents into the patient. The end is then released. The system has the advantge of a T-piece so is used in similar circumstances. Imposing positive-pressure ventilation does not require increased flow rates.

Disadvantages

Scavenging the system may be complicated. Connectors tend to twist and cause rapid over-distention of the bag.

AYRE'S T-PIECE WITH JACKSON-REES' MODIFICATION

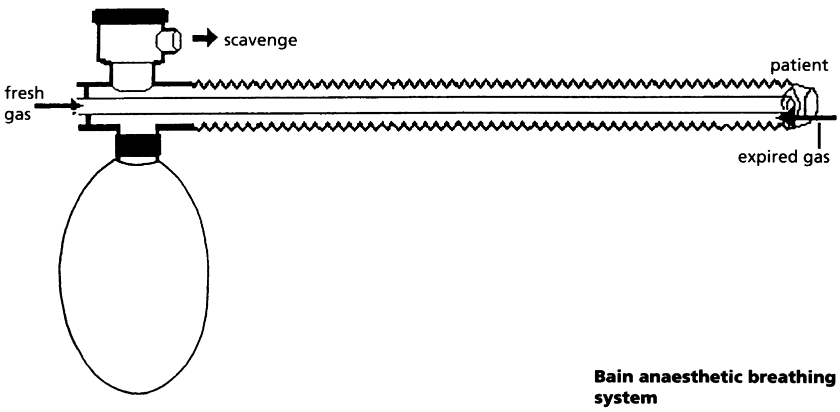
This circuit is an Ayre's T-piece with an open-ended reservoir bag on the expiratory limb.

Gas flow

Flows of 2·5 to 3 x V_m are needed to prevent rebreathing.

BAIN SYSTEM

The Bain system is a 'coaxial' T-piece with an inner inspiratory limb surrounded by an outer expiratory hose. The expiratory limb ends either in (i) an open-ended tube, (ii) a reservoir bag and expiratory valve or (iii) an open-ended bag.



Bain anaesthetic breathing system

Gas flow

The circuit probably requires marginally higher flows than corresponding T-piece systems although reports on its performance vary. Flows of 1·5 x V_m should be used.

DISPOSABLE BREATHING SYSTEMS

A complete range of breathing systems is available for single use in human patients. Constructed entirely of plastic, these are lighter and less expensive (though less

Advantages and disadvantages of the Bain system

Advantages

Bain systems without valves (Mapleson E or F) are recommended for cats and very small dogs because of lower expiratory resistance. Ventilation is controlled by occluding the expiratory limb in 'E' systems. In 'D' systems the expiratory valve is closed then the bag squeezed. In Mapleson 'F' versions the reservoir bag is used like that in a Jackson-Rees' modification. The circuit is useful for IPPV in small dogs and cats, especially when patient access is limited. The length of the system (1·8 m) allows the anaesthetic machine to be positioned away from the site of surgery, improving access. Spontaneous ventilation is satisfactory in dogs over 10 kg. The system has low drag and mechanical dead space, is easily maintained and sterilised. It is claimed that warm expirate raises the temperature of the gas flowing in the inner limb, so conserving the patient's temperature.

Disadvantages

Expiratory resistance with high flows reduces the system's usefulness in spontaneously breathing cats and small dogs weighing less than 10 kg. Rebreathing problems caused by inner limb disconnection prompted development of a parallel Bain system. However, inspiratory limb integrity is easily tested by occluding its end with a 5 ml syringe plunger; when gas is flowing the flowmeter indicator falls and/or the machine's over-pressure valve is heard.

robust) than traditional circuits made of carbonised rubber and stainless steel. They can be safely reused in animals but must be discarded when leaks develop (usually around the neck of the reservoir or rebreathing bag), or after use on animals with infective respiratory or systemic disease. Disposable circle and to-and-fro systems cannot be used once the soda lime is expended.

Manufacturers and suppliers of anaesthetic breathing systems

ARNOLDS VETERINARY PRODUCTS, Cartmel Drive, Harlescott, Shrewsbury, Shropshire SY1 37B

COX SURGICAL, 1 Greencroft Industrial Park, Stanley, County Durham

INTERNATIONAL MARKETING SUPPLY, Dane Mill, Broadhurst Lane, Congleton, Cheshire CW12 1LA

INTERSURGICAL, Crane House, Molly Millars Lane, Wokingham, Berkshire RG11 2RZ

VETERINARY INSTRUMENTATION, (Stephen's Anaesthetic Machine), 62 Cemetery Road, Sheffield S11 8FP

References

CUST, R. E. (1975) A new method of closed circuit anaesthesia utilising halothane and methoxyflurane. *Australian Veterinary Journal* **51**, 32-36

DOHOO, S. E., McDONELL, W. N. & DOHOO, T. R. (1982) A comparison of fresh gas flows during anaesthesia with nitrous oxide in the dog. *Journal of the American Animal Hospital Association* **18**, 900-904

DORSCH, J. A. & DORSCH, S. E. (1984) Understanding Anaesthesia Equipment. Baltimore, Williams & Wilkins. pp 415-422

HALL, L. W. & CLARKE, K. W. (1991) Veterinary Anaesthesia, 9th edn. London, Baillière Tindall. p 165

WATERMAN, A. E. (1985) Clinical Experiences with the Komesaroff Anaesthetic Machine. *Journal of the Association of Veterinary Anaesthetists* **13**, 42-49

WATERMAN, A. E. (1986) Clinical evaluation of the Lack coaxial breathing circuit in small animal anaesthesia. *Journal of Small Animal Practice* **27**, 591-598