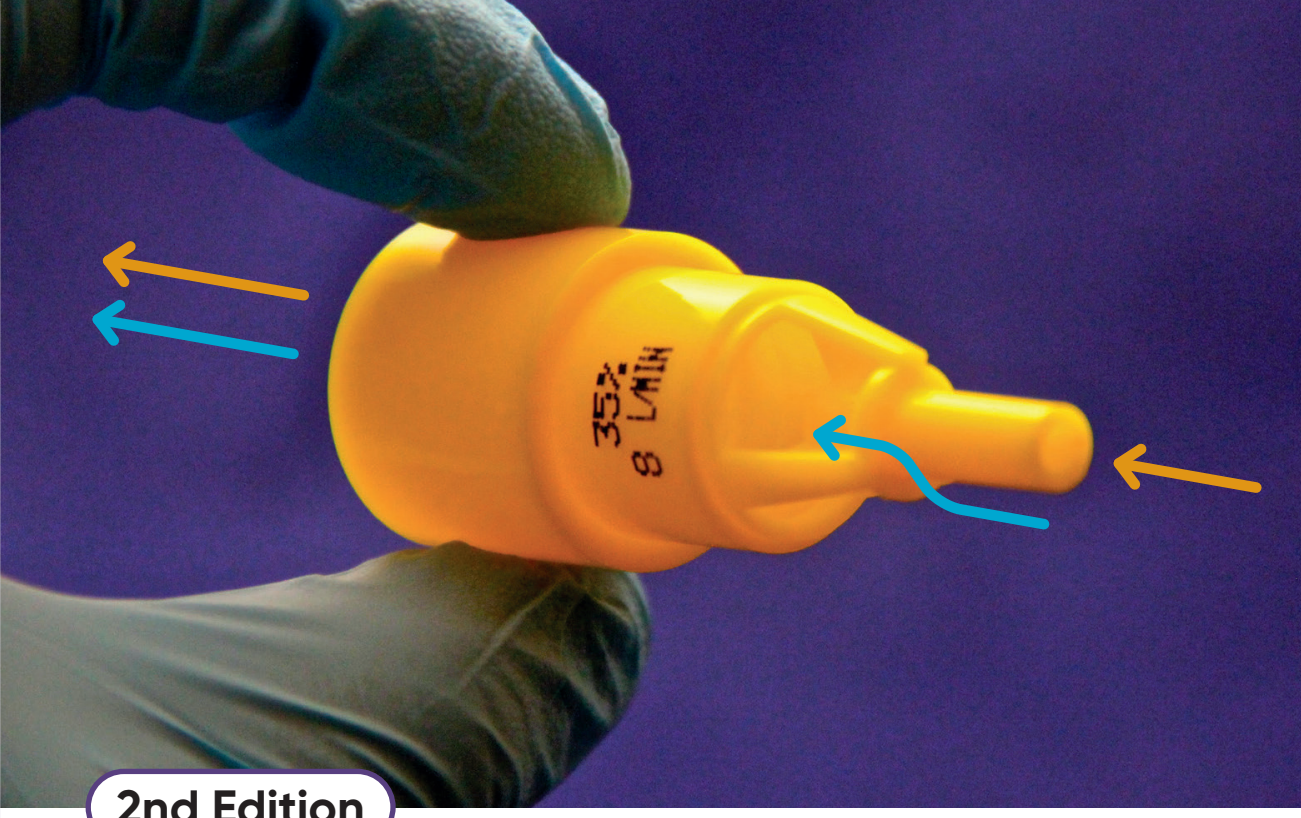

2nd Edition

Equipment in Anaesthesia and Critical Care

A complete guide for the FRCA

Angus Rivers & Daniel Aston

Equipment
in Anaesthesia and Critical Care

2nd Edition

Equipment in Anaesthesia and Critical Care

A complete guide for the FRCA

Angus Rivers
BSc, MBBS, FRCA
Consultant Anaesthetist, Bedfordshire Hospitals NHS Foundation Trust

Daniel Aston
BSc, MBBS, MRCP, FRCA, DPhil
Consultant in Cardiothoracic Anaesthesia and Critical Care, Royal Papworth Hospital NHS Foundation Trust, Cambridge

With contributions from

Asela Dharmadasa
MA, BM BCh, FRCA

Scion

Second edition published 2026
First edition published 2014

A CIP catalogue record for this book is available from the British Library.

ISBN 9781914961472

Scion Publishing Limited
Long Hanborough, Oxfordshire, UK
www.scionpublishing.com

Important Note from the Publisher
The information contained within this book was obtained by Scion Publishing Ltd from sources believed by us to be reliable. However, while every effort has been made to ensure its accuracy, no responsibility for loss or injury whatsoever occasioned to any person acting or refraining from action as a result of information contained herein can be accepted by the authors or publishers.

Readers are reminded that medicine is a constantly evolving science and while the authors and publishers have ensured that all dosages, applications and practices are based on current indications, there may be specific practices which differ between communities. You should always follow the guidelines laid down by the manufacturers of specific products and the relevant authorities in the country in which you are practising.

Although every effort has been made to ensure that all owners of copyright material have been acknowledged in this publication, we would be pleased to acknowledge in subsequent reprints or editions any omissions brought to our attention.

Registered names, trademarks, etc. used in this book, even when not marked as such, are not to be considered unprotected by law.

Cover design by Andrew Magee Design
Illustrations by Underlined, Marlow, Bucks
Typeset by Evolution Design & Digital Ltd (Kent)
Printed in the UK
Last digit is the print number: 10 9 8 7 6 5 4 3 2 1

Contents

Preface to the second edition

It is over a decade since the publication the first edition of *Equipment in Anaesthesia and Critical Care*, and we are grateful for all the comments, almost all positive, that we have received along the way. We were delighted when the first edition was highly commended at the BMA Book Awards and remain equally delighted when from time to time a trainee makes a passing comment that thanks to this book, they *finally* understand ventilators.

This second edition builds on the success of the first. It retains the same standardized format throughout; each major piece of equipment is given a single section that includes photographs and line diagrams that can be reproduced by FRCA candidates. Each section is subdivided into an *overview*, a list of *uses*, a description of *how it works*, an opinion on its relative *advantages* and *disadvantages*, and a list of *safety* considerations. Where relevant, we have included chapter introductions that provide a framework to help understand and classify the equipment featured within it. Starting out as a novice in anaesthesia can be overwhelming, so for the second edition chapter introductions we have included suggestions of which equipment to focus on as core knowledge for a novice, which is likely to feature at each stage of the FRCA. A point to note is that the comments on the relative advantages and disadvantages of pieces of equipment may differ from those expressed by the manufacturer, but are based on our interpretation of the best available evidence and on our opinion having used them.

So, what has changed in the world of anaesthetic equipment? Many things have not changed at all; chemistry and physics remain unaltered, and so the Severinghaus electrode and Venturi mask work just as they always have. The major changes have come in any device relying on electronics (videolaryngoscopes are now ubiquitous, and even their naming conventions have changed), where regulations have been updated (for instance in mandating NRFit needles) or evidence has evolved (as in recommendations for front of neck access). The exams themselves have changed significantly and will likely change again. This, combined with the fact that AI will now ask you questions on any topic in any style, has led us to remove the exam questions from this second edition.

Finally, we apologise to candidates, and especially to those who did not buy the first edition, that its release appears to have acted as inspiration for examiners to introduce questions on topics that we covered, but which had not yet made it into the FRCA exams. There are new topics in this new book, so perhaps history will repeat itself; fortunately, by buying (and reading!) our book you will be well prepared to face them.

Angus Rivers
Daniel Aston

Preface to the first edition

The Fellowship of the Royal College of Anaesthetists (FRCA) examination demands an in-depth knowledge of the mechanics, physics and clinical application of equipment used in anaesthesia and critical care.

Whilst working towards this exam ourselves, we struggled to find a textbook on equipment that distilled the required information into a clear and concise format that was easy to learn from. We have therefore spent considerable time researching equipment and liaising with manufacturers and trainees to produce a book specifically targeted at candidates sitting the primary and final FRCA exams. Our hope is that you will find it engaging, comprehensive and to the point.

For the sake of clarity, a standardized format is used throughout; each major piece of equipment is given a single section that includes photographs and simple line diagrams that can be reproduced in a viva or written exam. Each section is subdivided into an *overview*, a list of *uses* for the equipment, a description of *how it works*, an opinion on its relative *advantages* and *disadvantages*, and a list of *safety* considerations. Where relevant, we have also included chapter introductions that provide a framework to help understand and classify the equipment featured within it. A point to note is that the comments on the relative advantages and disadvantages of pieces of equipment may differ from those expressed by the manufacturer, but the views expressed are based on evidence, our experience or the opinions of other senior anaesthetists with whom we have worked.

Inevitably, many descriptions of equipment require an explanation of the physical variables used or measured. Where possible we have used the SI unit for these. However, in some areas of practice the unit in common use is not SI (e.g. the measurement of blood pressure) and in these cases we have used the more familiar term.

You will see that some words and phrases are written in purple. This highlighting indicates that a more detailed description of the subject can be found elsewhere in the book.

Thank you for using our book, we hope you find it useful and wish you the very best of luck with the exam.

Dan, Angus & Asela

August 2013

Acknowledgements

This book would not have been possible without the many people who helped us along the way.

Firstly, we must acknowledge that a large part of the first edition was the work of our friend and colleague, Asela Dharmadasa, and much of that has carried over into the second edition. At times recently, we have understood his wisdom in sitting this one out!

We are grateful to the significant number of individuals and companies, museums and other sources who have generously supplied us with or allowed us to take photographs of their equipment. They are credited within the text.

Once again, we are especially grateful to Jonathan Ray and Clare Boomer at Scion Publishing for all their expert help in putting the book together. We spent some time discussing possible front covers, with Jonathan recommending simply modernising the existing design for continuity. Shortly after, a trainee said to Angus 'ah, so you wrote the Venturi book…'. While we wouldn't quite put it like that ourselves, the Venturi is staying!

Abbreviations

AAGA	accidental awareness during general anaesthesia
AC	alternating current
ACh	acetylcholine
ACT	activated clotting time
AF	atrial fibrillation
APL	adjustable pressure limiting
APTT	activated partial thromboplastin time
AV	atrioventricular
BIPAP	bi-phasic positive airway pressure
BIS	bispectral index
BTS	British Thoracic Society
COETT	cuffed oral endotracheal tube
CPAP	continuous positive airway pressure
CPB	cardiopulmonary bypass
CPU	central processing unit
CSE	combined spinal epidural
CSF	cerebrospinal fluid
CT	computed tomography
CVP	central venous pressure
CVVHD	continuous venovenous haemodialysis
CVVHDF	continuous venovenous haemodiafiltration
CVVHF	continuous venovenous haemofiltration
DC	direct current
DLT	double lumen tube
DSA	density spectral array
ECG	electrocardiograph
ECMO	extracorporeal membrane oxygenation
EEG	electroencephalograph
EMG	electromyography
ETT	endotracheal tube
EVD	external ventricular drain
EVLW	extravascular lung water
FFP	fresh frozen plasma
FGF	fresh gas flow
FiO_2	inspired fraction of oxygen
FRC	functional residual capacity
GEDV	global end diastolic volume
GWP	global warming potential
HFJV	high frequency jet ventilation
HFNC	high flow nasal cannulae
HFNO	high flow nasal oxygenation
HFOV	high frequency oscillatory ventilation
HME	heat and moisture exchange
HMEF	heat and moisture exchange filter
IABP	intra-aortic balloon pump
ICD	implantable cardioverter defibrillator
ICP	intracranial pressure
ID	internal diameter
IPPV	intermittent positive pressure ventilation
ITTV	intrathoracic thermal volume
LMA	laryngeal mask airway
LOR	loss of resistance
MLT	microlaryngeal tube
MRI	magnetic resonance imaging
MV	minute ventilation
NG	nasogastric
NICE	National Institute for Health and Care Excellence
NIPPV	non-invasive positive pressure ventilation
NIRS	near-infrared spectroscopy
NIST	non-interchangeable screw thread
NJ	nasojejunal
NMJ	neuromuscular junction
OD	outer diameter
PAC	pulmonary artery catheter
PCA	patient-controlled analgesia
PCWP	pulmonary capillary wedge pressure
PDPH	post-dural puncture headache
PEEP	positive end expiratory pressure

PEG	percutaneous endoscopic gastrostomy
PICC	peripherally inserted central catheter
PIP	peak inspiratory pressure
PPV	positive pressure ventilation
PRVC	pressure-regulated volume control
PT	prothrombin time
PTV	pulmonary thermal volume
PVC	polyvinylchloride
RIL	rigid indirect laryngoscope
RMS	root mean square
RRT	renal replacement therapy
RUL	right upper lobe
SGA	supraglottic airway
SIMV	synchronized intermittent mandatory ventilation
SVP	saturated vapour pressure
SVT	supraventricular tachycardia
TCI	target controlled infusion
TIVA	total intravenous anaesthesia
TPN	total parenteral nutrition
TOF	train-of-four
VAD	ventricular assist device
VF	ventricular fibrillation
VIC	vaporizer-in-circuit
VIE	vacuum insulated evaporator
VL	videolaryngoscope
VOC	vaporizer-out-of-circuit
VT	ventricular tachycardia

Chapter 7
Filters and humidifiers

7.1 Introduction to filters and humidifiers

Maintaining humidification of the airways is essential to avoid fluid loss, cooling and infection. Passive and active techniques are used to achieve this, with the most common being the passive heat and moisture exchange filter found in every anaesthetic circuit. Novices can start here. Other filters are widespread in clinical use and are common primary FRCA questions.

7.2 Passive humidifiers

Fig. 7.2.1: A heat and moisture exchange filter (HMEF).

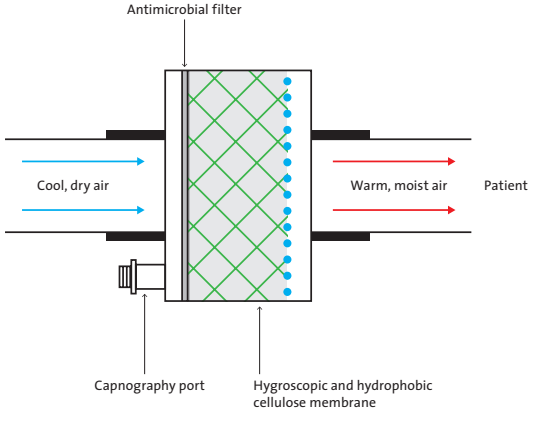

Fig. 7.2.2: Schematic of an HMEF.

Overview

Humidifiers add heat and moisture to cool dry inspired gases. Passive humidifiers do not require external energy to function. The heat and moisture exchanger (HME) is the commonest passive humidification device used in anaesthesia. It is used in patients whose nasal passages (the body's own HME) are bypassed by an airway device such as an endotracheal tube (ETT) or laryngeal mask. Mechanical ventilation with cool, dry gases is known to impair mucociliary clearance of sputum, contribute to airway plugging and atelectasis, as well as exacerbating intra-operative heat loss. HMEs are simple, efficient devices that provide a solution to these problems.

Uses

HMEs are incorporated into breathing systems in most ventilated patients. They are also attached to tracheostomy tubes in patients who no longer require a breathing system.

HMEs can also be combined with electrostatic microbial filters (HME filters, HMEF) so that they also protect the ventilated patient and equipment from particulate matter, including some bacteria.

How it works

An HME is a passive device that recovers and retains heat and moisture during expiration and then returns it to cool, dry gas that passes in the opposite direction on inspiration. An HME comprises a core of material within a plastic casing. The ability of an HME to recover and transfer heat and moisture depends largely on the characteristics of the material within its core. HMEs can be classified into three groups, each with their own particular performance characteristics, based on the nature and configuration of their core material:

- hydrophobic (water repelling) HMEs
- hygroscopic (water retaining) HMEs
- combined hygroscopic–hydrophobic HMEs.

The simplest and earliest HMEs were hydrophobic. These models have an aluminium core, which provides a surface that rapidly cools warm, humid expired gases. The cooling causes water vapour to condense and collect between the aluminium inserts. During inspiration cool, dry inspired gas passes through this insert in the opposite direction and absorbs heat and moisture from it. This returns the aluminium to its cooled

state and the cycle repeats itself during the next expiration. Hydrophobic devices are the simplest and cheapest, but least efficient, HME devices, producing a modest moisture output of 10–14 mg $H_2O.l^{-1}$ at tidal volumes of 500–1000 ml. In addition, they can suffer from problems caused by the pooling of condensed water.

The efficiency of HMEs was increased by the development of a hygroscopic core. A material with a low thermal conductivity such as paper or foam is impregnated with hygroscopic salts such as calcium or lithium chloride. Instead of moisture being stored as condensed water droplets, the moisture is preserved by a chemical reaction with the salts. These HMEs are more efficient and can produce higher absolute humidities of 22–34 mg $H_2O.l^{-1}$ at tidal volumes of 500–1000 ml.

Newer devices combine hygroscopic, hydrophobic and electrostatic filters in varying configurations to produce even more efficient devices.

Advantages

- Cheap and simple.
- Do not require a power source.
- Produce 60–80% humidification of inspired gases.
- Reduce heat and moisture loss from the conducting airways and therefore improve mucociliary function and sputum clearance.
- When combined with a filter, can be very efficient at removing bacteria and viruses. Some studies show a reduction in rates of ventilator-associated pneumonia in critical care.

Disadvantages

- Increase the dead-space of the breathing system. Smaller HMEs are therefore used for children.
- Increase the resistance of the breathing system.
- A progressive increase in resistance through the HME is seen after several hours of use due to an increase in the material density of the HME.
- Add bulk to the patient end of the breathing system.
- HMEs can become occluded with secretions, blood or water.
- The efficiency falls as tidal volumes and inspiratory flow rates increase.
- It can take 10–20 minutes for HMEs to equilibrate and reach maximal efficacy.

7.3 Active humidification

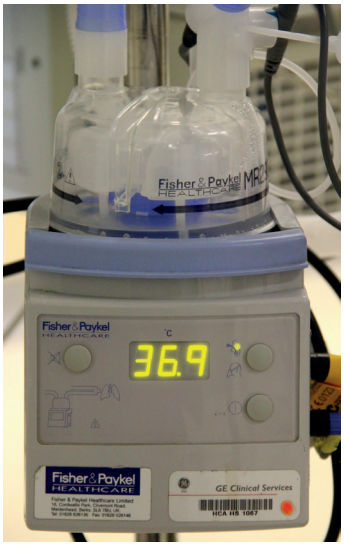

Fig. 7.3.1: A surface water bath humidification device used in ITU.

Overview

Active gas humidifiers humidify (and often warm) cool, dry inspired gases using an energy-dependent process. This is in contrast to passive humidification where no external energy source is required. Active gas humidification is used to prevent the effects of breathing cool, dry gases for long periods. These effects are known to include atelectasis, exacerbation of intra-operative heat losses, and impaired mucociliary function. Active humidification is generally more effective (in terms of the relative humidity achieved) than passive humidifiers like HMEs.

Uses

Used in patients who are mechanically ventilated or require oxygen therapy for significant periods, or have respiratory problems and are at risk of airway plugging (e.g. asthmatics).

How it works

Gases that are fully saturated with water at body temperature (37°C) have an absolute humidity of 44 $g.m^{-3}$. An approximate comparison of the absolute humidity achieved by various devices is shown in *Table 7.3.1*. Note that values quoted by the manufacturer are usually measured under optimal conditions, and the actual humidity achieved may be less in clinical practice. If the absolute humidity achieved in the lungs is greater than 44 $g.m^{-3}$, water may precipitate within the alveoli.

Table 7.3.1: Absolute achievable humidities for active and passive humidifiers.

Humidifier	Achievable absolute humidity ($g.m^{-3}$)
Cold water bubble active humidifier	10
Heat and moisture exchanger (NB. a passive humidifier)	25–30
Warm water bubble active humidifier or warm water surface humidifier	40
Gas-driven nebulized active humidifier (with anvil or rotating disc)	50–60
Ultrasonic nebulized active humidifier	80–90

Surface water bath humidifiers

Inspiratory gas is passed over the surface of a heated water bath. As it does so, it picks up water vapour from above the surface of the water and carries it to the patient. The water bath is usually heated to 40–45°C, but may be increased to 60°C to reduce bacterial growth.

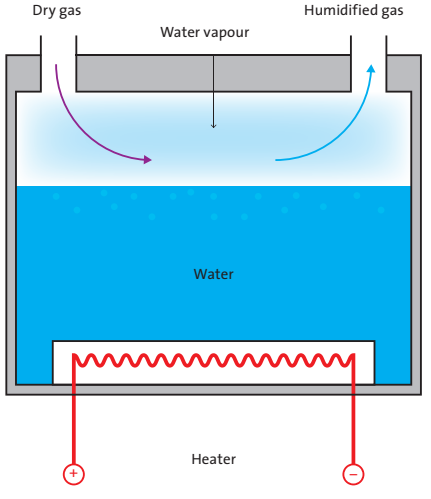

Fig. 7.3.2: Schematic of a surface water bath humidifier.

Advantages

- In contrast to aerosolized water droplets, water vapour does not usually carry microbes. Therefore, in comparison with nebulizers and bubble humidifiers there is, theoretically, a reduced risk of infection.
- The humidifier does not significantly increase resistance to gas flow.
- Usually located some distance from the patient. This reduces the risk of liquid water entering the inspiratory limb of the breathing system.

Disadvantages

- Condensation can build up in the inspiratory limb of breathing system.
- Thermostat failure could lead to airway scalding.
- Bacterial and fungal colonization of the water reservoir can occur.

Bubble humidifiers

Fresh gas is directed through a reservoir of sterile water via a fine capillary network or nozzle with multiple apertures. As the gas bubbles through and out of the reservoir, it becomes saturated with water vapour and transports it to the patient. The absolute humidity achieved by the bubble humidifier can be increased by heating the water. A typical reservoir has a volume of 300 ml.

Advantages

- Compact.
- Cheaper than other active humidifiers.
- Produces a higher absolute humidity than passive humidifiers.

Disadvantages

- Risk of bacterial growth and colonization in the water bath.
- Water aerosols can lead to transmission of infection into the patient's respiratory tract.
- Increases resistance to flow in the inspiratory limb of the breathing circuit because the fresh gas flow is bubbled through water.
- As water vapour cools, it may condense and build up within the oxygen tubing (rain-out).
- Mineral build-up along capillary network can cause occlusions to oxygen inlet.
- There is a risk of overheating and airway burns if the thermostat fails. If the water is not heated, a bubble humidifier's efficiency may be less than that of a HME.

Safety

Some bubble humidifiers incorporate a high-pressure alarm that triggers at 4–6 p.s.i. with an automatic pressure relief valve. Newer designs also include baffle systems to prevent liquid water entering the oxygen tubing.

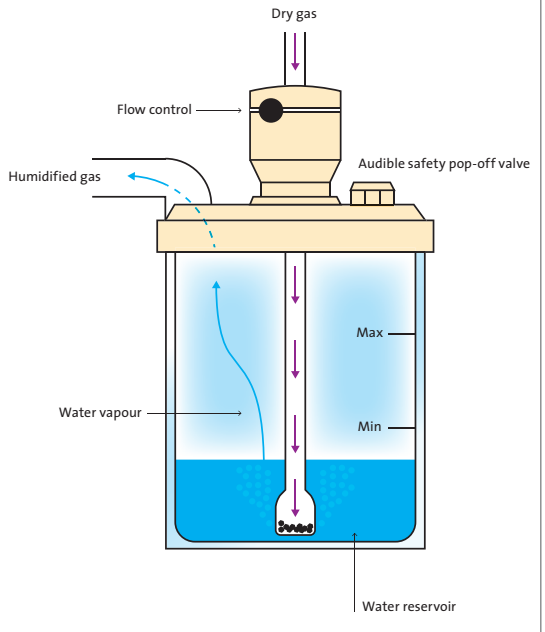

Fig. 7.3.3: Schematic of a bubble humidifier.

Nebulized humidifiers

A gas-driven nebulizer passes a high velocity stream of gas across the end of a tube that is positioned in a reservoir of water. The fast moving gas generates a negative pressure around the nozzle and draws water into the tube as a result of the Venturi effect (see *Section 1.15*: Venturi masks). The impact of the high velocity gas causes the water to break up into tiny droplets, which are carried by the gas flow to the patient. Droplets of water may be broken up further by colliding with an anvil.

Spinning disc nebulizers comprise a porous spinning disc partially immersed in a water bath. As the disc spins, it draws water up from the bath and releases it as small droplets through small holes into the path of the fresh gas flow. The absolute humidity generated may be augmented by heating the water reservoir.

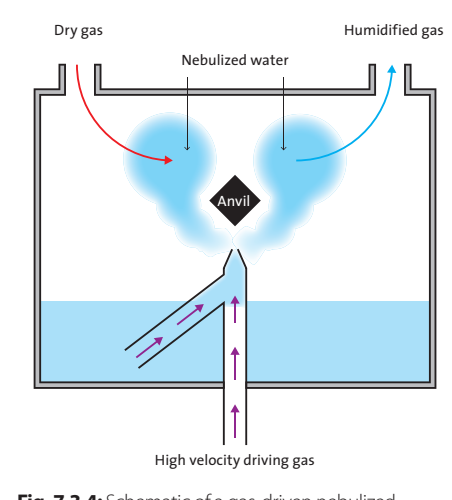

Fig. 7.3.4: Schematic of a gas-driven nebulized humidifier.

Ultrasonic nebulizers apply a 2–3 MHz vibration to a plate that is positioned in a water reservoir. The vibrational force is transmitted to the water surface and can produce water droplets as small as 1 µm in size. These water droplets are entrained into fresh gas that flows through the nebulizer chamber. Over-humidification of gases with an ultrasonic humidifier is a risk and may result in pulmonary oedema.

Advantages

- Produce higher absolute humidities compared to passive HMEs.
- There is no added dead space.
- Less likely to occlude.
- Decreased resistance to breathing when compared to HMEs.

Specific disadvantages

- Risk of over-humidifying patient leading to pulmonary oedema or altered fluid balance through absorption.
- Provide a route for bacterial and viral infection.
- Expensive.
- Require an electrical power supply.
- Bulky and noisy when compared to other humidifiers.
- Require a sterile water supply.

Porous surface contact humidifiers

A porous polyethylene fibre block is positioned on top of a heated water bath and fresh gas flows over and through it. Water is drawn up by capillary action along the fibres, creating a three-fold increase in the surface area for humidification, when compared to traditional chamber-type humidification systems.

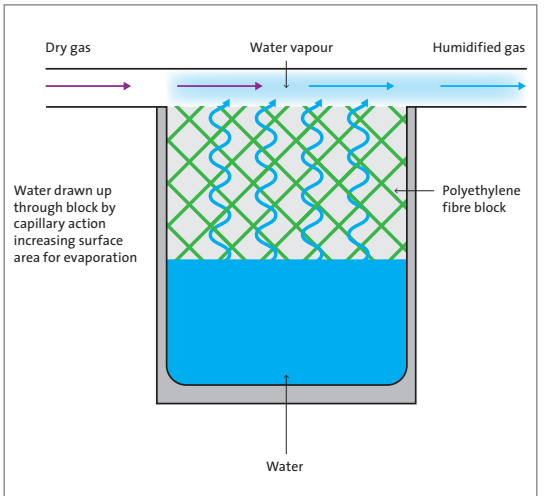

Fig. 7.3.5: Schematic of a porous contact humidifier.

Advantages

- 0.1 µm pore size can theoretically filter bacteria.
- Efficient humidification is possible because of the increased water/gas contact surface area.

Disadvantages

- Calcification of the porous surface over time reduces efficiency.

7.4 Filters

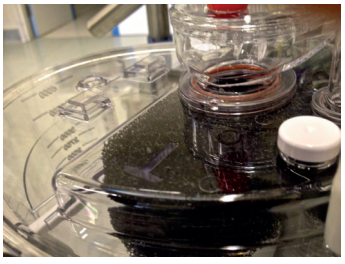

Fig. 7.4.1: A Medtronic cardiotomy blood reservoir filter that forms part of a cardiopulmonary bypass circuit.

Overview

Filtration is the process by which particles are removed from streams of fluid or gas by a semi-permeable membrane. Various types of filter play an important role in anaesthesia and critical care. These may be classified into screen and depth filters. In screen filters, all the pores rest in the same plane. Depth filters possess multiple layers of pores that force the fluid through a tortuous path that increases the likelihood of particle impaction. This classification is controversial, not least because screen filters exhibit depth when observed microscopically.

Uses

Examples of commonly encountered filters include breathing system filters, epidural filters, IV infusion filters, blood filters, platelet filters, filter needles and haemofilters.

How it works

The principle mechanisms of filtration are:

- direct interception
- diffusional interception
- inertial impaction
- electrostatic deposition.

The degree to which each of these mechanisms plays a role in a given filter depends on the physical properties of the particles being filtered, whether they are suspended in a liquid or a gas, and the properties of the filter itself.

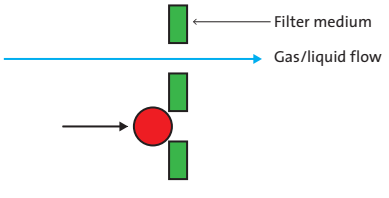

Fig. 7.4.2: Direct interception.

Direct interception

Particles that are larger than the pore size of the filter will be trapped (or intercepted) by it.

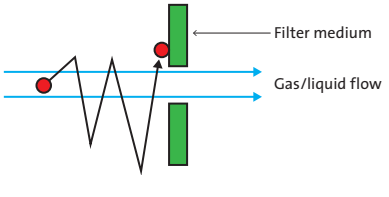

Fig. 7.4.3: Diffusional interception.

Diffusional interception

One might expect that particles that are smaller than the pores in a filter would pass freely. However, separation of these small particles can still occur because their random (Brownian) movement within the gas or liquid make them 'appear' larger than they are. These random movements (caused by multiple collisions with other molecules) mean that these particles deviate away from the line of fluid flow and are therefore more likely to impact filter fibres.

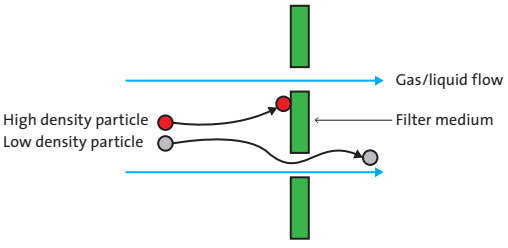

Fig. 7.4.4: Inertial impaction.

Inertial impaction

Inertial impaction affects particles that are denser than the fluid in which they are travelling. Less dense particles can change direction quickly to follow the fluid flow around the solid fibres of the filter medium. However, higher density molecules are unable to change direction as readily because of their inertia (the tendency of a body to resist changes in its speed or direction, which is dependent on its mass). These particles therefore tend to continue in a linear trajectory and impact the filter.

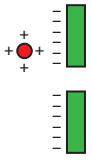

Fig. 7.4.5: Electrostatic deposition.

Electrostatic deposition

This is the process by which weakly charged particles are attracted towards opposite weak charges on the filter material. These weak electrostatic forces are also known as van der Waals forces.

Filter efficacy

Both inertial and diffusional impaction work best when filtering solid particles from a gas rather than a liquid. This is in part because the difference in density between a solid particle and a gas is far greater than between a solid particle and a liquid.

The efficacy of a filter can be measured by its removal rating. Many manufacturers quote a 'nominal filter rating', which gives a percentage rating for the efficacy of a filter for particles of a given size. It is calculated by introducing a contaminant of known size upstream of the filter and then microscopically analysing the downstream filtrate; a nominal rating of 99% at 0.2 µm means that 99% of contaminants equal to or greater than 0.2 µm have been successfully removed by the filter. This rating can be misleading because under certain circumstances, larger particles can pass through the filter, e.g. due to high upstream pressures.

Advantages

- Reduce contamination, particularly of a patient's body by solid contaminants.
- Reduce risk of bacterial transmission.

Disadvantages

- Increase resistance to the flow of fluids.
- Add bulk and weight to equipment.
- Limited lifespan due to clogging.
- Efficacy falls under extremes of pressure and temperature, which can alter the physical characteristics of the filter material.
- Filter media may trigger inflammatory reactions such as the activation of complement or leukocytes.
- Filters are not effective at protecting against most viruses.

Specific types of filter

Heat and moisture exchange filters and haemofilters are covered in separate dedicated sections within the book (*Sections 7.2* and *9.10*, respectively).

Epidural filters

Epidural filters are used to prevent the injection of contaminants that have the potential to induce CNS infection or inflammation. They are low volume hydrophilic filters, used for two-way in-line filtration of aqueous solutions. The average volume of an epidural filter is 0.45 ml. One end attaches to an epidural catheter and the other has a non-Luer connector (see *Section 8.8*) that attaches to syringes or epidural giving sets. Most epidural filters have a strong acrylic casing that has a flat profile to improve patient comfort and is transparent to aid the identification of blood during aspiration.

Fig. 7.4.6: An epidural filter.

Most epidural filters quote filtration efficacy for a particle size of 0.2 µm over a filter surface area of 4 cm^2. This should be effective in removing the majority of bacteria. Modern epidural filters have been engineered to minimize drug binding, withstand pressures of up to 7 bar, retain bacteria and endotoxin effectively for up to 96 hours and eliminate injected air bubbles.

The filter adds significant resistance to injection. Whilst all epidural filters vary in their resistance, a typical water flow through a 0.2 µm filter is 15 $ml.min^{-1}$ when a pressure of 80 cmH_2O is applied.

Specific advantages

- Effective filter of particulate matter and bacteria down to 0.2 µm.
- Able to maintain efficacy up to burst pressures of 7 bar.
- Transparent so that blood in the filter can be identified quickly.
- Allows two-way filtration.
- Non-Luer connections prevent inadvertent injection of IV drugs.

Specific disadvantages

- Has a residual volume of approximately 0.45 ml.
- Adds bulk to the end of an epidural catheter.
- Effective for approximately 96 hours.

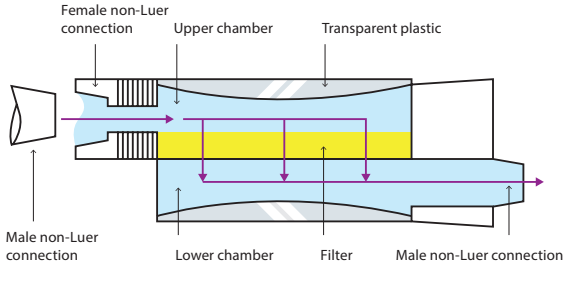

Fig. 7.4.7: Schematic of an epidural filter.

Blood (giving set) filters

With the exception of human albumin, immunoglobulin and stem cells which require a 15 µm filter (found on standard intravenous giving sets), all blood products must be given through a blood giving set with a 170–200 µm filter to filter particulate matter and thrombi from donor blood products during infusion.

A standard blood giving set has a compressible double-chambered reservoir with an in-line mesh filter (170–200 µm pore size). This removes large clots and aggregates and is used for transfusions of fresh frozen plasma (FFP), cryoprecipitate, platelets and leucocyte-depleted red cells. The tubing is usually 150 cm long, with a Luer lock fitting at its distal end.

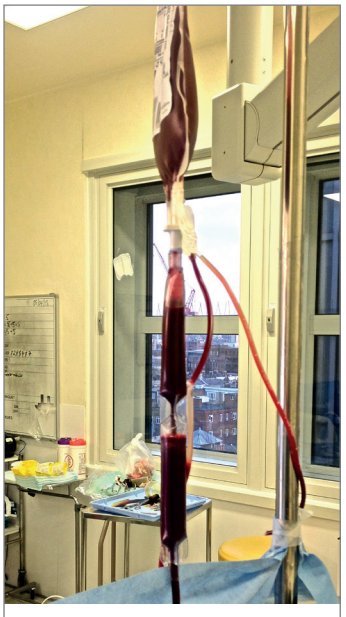

Fig. 7.4.8: Blood giving set.

Blood and platelets in the UK are now leucodepleted pre-storage in an effort to reduce the transmission of vCJD and transfusion reactions. A specific bedside leucodepletion filter to remove white cells (20–50 µm pore size) is therefore no longer required. Platelets must, however, still be administered through a giving set with a 170–200 µm filter. This can either be through a standard blood giving set or a specific platelet giving set with a 200 µm filter (e.g. the Baxter platelet administration set). The only real advantage of a specific platelet giving set is that it has a lower prime / deadspace volume, which reduces platelet wastage. If a standard blood giving set is used to administer platelets, it is important that a fresh giving set is used, because platelets may be wasted by getting caught up in red blood cell fragments within the filter.

There has been some interest in pieces of debris that develop in blood products during storage which are too small to be filtered by standard blood giving set filters (microaggregates). These can in theory act as micro-emboli which mediate both mechanical obstruction of capillary beds and adverse immune reactions. However, the evidence is limited for the use of specific microaggregate filters and their small pore size (20–40 µm) may impair flow rates. Microaggregate filter pore sizes are also similar to those of leucocyte depletion filters, so the filter may trap a proportion of the platelets. For these reasons, microaggregate filters are not frequently used.

Table 7.4.1: The administration of blood products.

Component	Filter pore size required (µm)	Speed of transfusion
Packed red cells (leucodepleted)	170–200	Complete within 4 h of issue
Platelets (leucodepleted)	170–200	Should be administered within 30 min of issue
Fresh frozen plasma	170–200	Usually administered over 30 min
Cryoprecipitate	170–200	Usually administered over 30 min
Human albumin solution (HAS)	15 – vented filter set (standard IV admin. set)	Usually administered over 30 min

Advantages

- Reduces the infusion of blood clots and aggregates.

Disadvantages

- Requires changing when flow rate is compromised or at least 12 hourly.
- Increased resistance to flow leads to increased transfusion times.

Standard IV giving sets and burette filters

Standard IV fluid infusion sets and burettes are used for the administration of all IV fluids except blood products, although it should be noted that specialist burettes incorporating a blood filter are available for paediatric transfusion.

A standard infusion set or burette usually incorporates a 15 µm filter. Standard IV infusion sets have a drip factor of 20 drops/ml (i.e. for every 20 drops that enter the drip chamber, 1 ml of fluid is infused under standardized conditions).

Fig. 7.4.9: A standard IV fluid giving set.

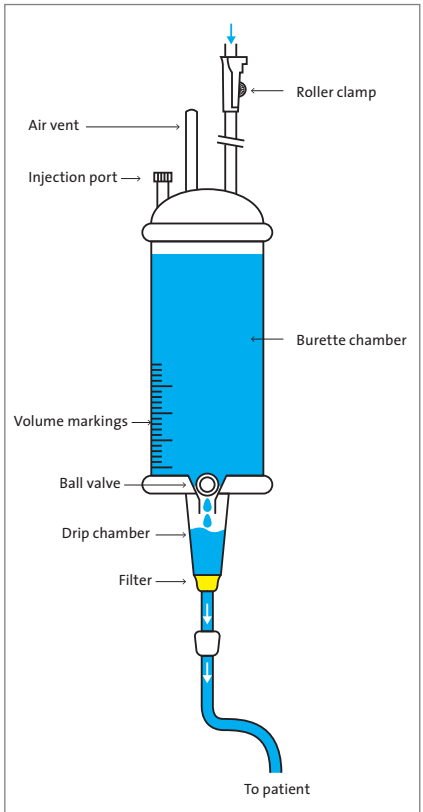

Fig. 7.4.10: Schematic of a standard paediatric burette.

Burette sets are used, particularly in paediatrics, for more accurate and controlled delivery of IV fluids and drugs. The dependent end of the burette's chamber empties into a drip chamber through a 'microdropper' that delivers 60 drops/ml of fluid. Most burettes also incorporate a floating ball valve that prevents entrainment of air from the empty burette chamber into the drip chamber.

Advantages

- Simple.
- Accurate.
- Kink resistant tubing.
- Can be used with infusion pumps.

Disadvantages

- Need to be changed at least every 72 hours.
- Unsuitable for the transfusion of blood products.
- Rapid infusion is not possible due to high resistance to flow.

Filter needles

Filter needles are used to prevent the inadvertent injection of particulate contaminants into the body. These can include small shards of glass from vials, plastic, rubber and undissolved or precipitated drugs. Studies have shown that particles as small as 6 µm can cause occlusion of the micro-circulation and phlebitis. Injected glass particles have also been reported to induce fibrotic reactions in the lungs, liver and gastrointestinal system. Current guidelines recommend that filter needles used for drawing up drugs have a maximum pore size of 5 µm, which can effectively filter particles from 10 to 1000 µm in diameter. Smaller pore filters (e.g. 0.22 µm) are also effective at removing bacterial contaminants.

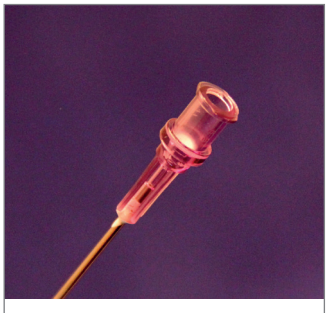

Fig. 7.4.11: A filter needle.

Advantages

- Prevent drawing up and injection of particulate matter from glass vials.
- Smaller (0.22 µm) filters are also effective at filtering bacteria.

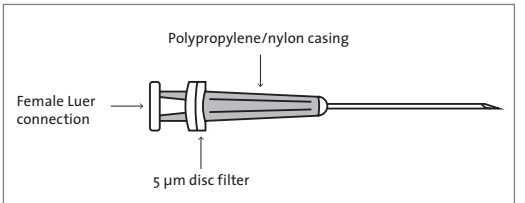

Fig. 7.4.12: Schematic of a filter needle.

Disadvantages

- Need to change to a standard needle before patient is injected.
- Increase resistance when drawing up drugs.
- Single use only.
- Not all drawing up needles incorporate a filter. The difference is not always clear.

Index