Equipment in Anaesthesia and Critical Care
ALSO OF INTEREST
Equipment in Anaesthesia and Critical Care

A complete guide for the FRCA

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Preface

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.

A set of pertinent multiple choice, short answer and viva questions are provided to test your knowledge of each chapter.

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 blue. 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.
For taking the time to proof-read some of our work and for inspiring us with suggestions and constructive criticism, we would like to thank:

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We are also most grateful to the significant number of individuals, hospitals, 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.

For converting our hand drawn pictures into the high quality diagrams that appear in these pages, we owe our thanks to Elliot Banks.

Finally, there are three people who have been our principle source of inspiration and encouragement; our warmest and most heartfelt gratitude is reserved for Lindsay, Malin and Aneesha, to whom this book is dedicated.
## Abbreviations

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<th>Definition</th>
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<td>AC</td>
<td>alternating current</td>
</tr>
<tr>
<td>ACT</td>
<td>activated clotting time</td>
</tr>
<tr>
<td>AF</td>
<td>atrial fibrillation</td>
</tr>
<tr>
<td>APL</td>
<td>adjustable pressure limiting</td>
</tr>
<tr>
<td>APTT</td>
<td>activated partial thromboplastin time</td>
</tr>
<tr>
<td>AV</td>
<td>atrioventricular</td>
</tr>
<tr>
<td>BIPAP</td>
<td>bi-phasic positive airway pressure</td>
</tr>
<tr>
<td>BIS</td>
<td>bispectral index</td>
</tr>
<tr>
<td>COETT</td>
<td>cuffed oral endotracheal tube</td>
</tr>
<tr>
<td>CPAP</td>
<td>continuous positive airway pressure</td>
</tr>
<tr>
<td>CPB</td>
<td>cardiopulmonary bypass</td>
</tr>
<tr>
<td>CPU</td>
<td>central processing unit</td>
</tr>
<tr>
<td>CSA</td>
<td>compressed spectral array</td>
</tr>
<tr>
<td>CSE</td>
<td>combined spinal epidural</td>
</tr>
<tr>
<td>CSF</td>
<td>cerebrospinal fluid</td>
</tr>
<tr>
<td>CT</td>
<td>computed tomography</td>
</tr>
<tr>
<td>CVP</td>
<td>central venous pressure</td>
</tr>
<tr>
<td>CVVHD</td>
<td>continuous venovenous haemodialysis</td>
</tr>
<tr>
<td>CVVHDF</td>
<td>continuous venovenous haemofiltration</td>
</tr>
<tr>
<td>CVVHF</td>
<td>continuous venovenous haemofiltration</td>
</tr>
<tr>
<td>DC</td>
<td>direct current</td>
</tr>
<tr>
<td>DLT</td>
<td>double lumen tube</td>
</tr>
<tr>
<td>ECG</td>
<td>electrocardiograph</td>
</tr>
<tr>
<td>ECMO</td>
<td>extracorporeal membrane oxygenation</td>
</tr>
<tr>
<td>EEG</td>
<td>electroencephalograph</td>
</tr>
<tr>
<td>EMG</td>
<td>electromyography</td>
</tr>
<tr>
<td>ETT</td>
<td>endotracheal tube</td>
</tr>
<tr>
<td>EVD</td>
<td>external ventricular drain</td>
</tr>
<tr>
<td>EVLW</td>
<td>extravascular lung water</td>
</tr>
<tr>
<td>FFP</td>
<td>fresh frozen plasma</td>
</tr>
<tr>
<td>FGF</td>
<td>fresh gas flow</td>
</tr>
<tr>
<td>FiO₂</td>
<td>inspired fraction of oxygen</td>
</tr>
<tr>
<td>FRC</td>
<td>functional residual capacity</td>
</tr>
<tr>
<td>GEDV</td>
<td>global end diastolic volume</td>
</tr>
<tr>
<td>HFJV</td>
<td>high frequency jet ventilation</td>
</tr>
<tr>
<td>HFOV</td>
<td>high frequency oscillatory ventilation</td>
</tr>
<tr>
<td>HME</td>
<td>heat and moisture exchange</td>
</tr>
<tr>
<td>HMEF</td>
<td>heat and moisture exchange filter</td>
</tr>
<tr>
<td>IABP</td>
<td>intra-aortic balloon pump</td>
</tr>
<tr>
<td>ICD</td>
<td>implantable cardioverter defibrillator</td>
</tr>
</tbody>
</table>
Abbreviations

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
NIST non-interchangeable screw thread
NI nasojejunal
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
SIMV synchronized intermittent mandatory ventilation
SVP saturated vapour pressure
SVT supraventricular tachycardia
TCI target controlled infusion
TIVA total intravenous anaesthesia
TPN total parenteral nutrition
VAD ventricular assist device
VF ventricular fibrillation
VIC vaporizer-in-circuit
VIE vacuum insulated evaporator
VOC vaporizer-out-of-circuit
VT ventricular tachycardia
2.6 Laryngeal mask airways

Overview

The original laryngeal mask airway (LMA Classic, Teleflex Inc.) was introduced in 1988 by the British anaesthetist, Dr Archie Brain. It is a reusable device and may be steam autoclaved 40 times. The success of the LMA Classic led to the introduction of many other sealing supraglottic airways, including a number of single use designs. A selection of these is described here.

Uses

LMAs are most commonly used for airway management in fasted patients who do not suffer from significant gastro-oesophageal reflux. They may also be used as an emergency airway where a practitioner skilled in intubation is not available (e.g. some paramedic crews), or as an emergency airway in 'can’t intubate, can’t ventilate’ situations.

Table 2.6.1: Sizing an LMA.

<table>
<thead>
<tr>
<th>LMA size</th>
<th>Patient weight (kg)</th>
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<tbody>
<tr>
<td>1</td>
<td>&lt;5</td>
</tr>
<tr>
<td>1½</td>
<td>5–10</td>
</tr>
<tr>
<td>2</td>
<td>10–20</td>
</tr>
<tr>
<td>2½</td>
<td>20–30</td>
</tr>
<tr>
<td>3</td>
<td>30–50</td>
</tr>
<tr>
<td>4</td>
<td>50–70</td>
</tr>
<tr>
<td>5</td>
<td>70–100</td>
</tr>
<tr>
<td>6</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

How it works

Insertion of an LMA requires the patient’s airway reflexes to be absent and is therefore only possible if they are anaesthetized or unconscious. LMAs are available in a broad range of sizes (Table 2.6.1). These sizes do not correspond to any particular dimension and are a guide only; in many instances it is possible to use a size higher or lower and achieve a similar, or superior, result.

Some sealing supraglottic airways have a design feature to prevent the epiglottis from obstructing the airway; in the LMA Classic, this is the two flexible ‘aperture bars’ (visible in Fig. 2.6.1). The utility of these features has been questioned.
Technique for inserting LMA

The technique for insertion as described by Dr Brain may be examined in the FRCA and is as follows.

- Prepare the LMA by fully deflating the cuff, apply water-soluble gel to the back of the cuff (not to the front as it may cause laryngospasm).
- Hold the LMA like a pen, with the index finger placed anteriorly at the junction of the cuff and tube (Fig. 2.6.2a).
- Push the mask backwards along the hard palate. As the mask moves downwards, the index finger maintains pressure backwards against the posterior pharyngeal wall to avoid collision with the epiglottis (Figs 2.6.2b & c).
- Insert the index finger fully into the mouth to complete insertion, stopping when resistance is felt (Fig. 2.6.2d).
- Inflate the cuff without holding the tube or connecting the breathing system. When correctly positioned, the LMA will be seen to rise slightly in the mouth.
- The manufacturers recommend using a bite block with the LMA Classic.

Other methods are routinely used in clinical practice.

Advantages

Advantages common to all sealing supraglottic airways

- Neuromuscular blocking drugs are not required.
- Insertion requires less skill than intubation.
- There is minimal haemodynamic response to insertion and removal (cf. endotracheal intubation).
- Emergence is smooth, which is particularly useful in head and neck surgery.

Specific advantages of the LMA Classic

- It has a proven track record during widespread use – there are over 2500 publications relating to the LMA Classic, far more than any other supraglottic airway.
- The LMA Classic (or alternatively the iLMA, see below) form part of the difficult airway algorithm.
- Aperture bars may prevent the epiglottis blocking the airway.

Disadvantages

Disadvantages common to all sealing supraglottic airways

- Achieving an adequate seal is not possible in a small proportion of patients.
- There is a risk of aspiration of gastric contents – it is not a ‘definitive airway’.
- They may cause laryngospasm.

Specific disadvantages of the LMA Classic

- It seals to a relatively low airway pressure of around 20 cmH₂O.
- It has no integrated bite block so it may be bitten flat during emergence.
- Its position is less stable in edentulous patients.
- The aperture bars may impede fibreoptic intubation through the LMA.
Safety

The LMA Classic is a reusable device, but sterilization may not inactivate prions. Concerns regarding the transmission of variant Creutzfeldt–Jakob disease, as well as economic considerations, have led to many hospitals phasing out reusable airway equipment in favour of single use devices.

Other notes

Propofol, introduced in 1986, inhibits airway reflexes to a much greater degree than thiopentone and is therefore ideal for anaesthetizing patients having an LMA inserted. Propofol and the LMA were therefore responsible for each other’s success.

Other sealing supraglottic airways

Single use LMAs

A number of companies manufacture single use LMAs using similar designs to the LMA Classic. They are factory sterilized using ethylene oxide, and discarded following use.

Whilst they share similar advantages and disadvantages to the reusable design, there are minor design differences (such as alternatives to aperture bars), and few comparative studies, so it should not necessarily be assumed that performance will be equal to the LMA Classic.
LMA Proseal (Teleflex Inc.)

This is a reusable LMA designed to overcome problems encountered with the LMA Classic. The inflatable cuff extends onto the reverse of the device in order to improve the seal, particularly around the oesophagus. Unlike the LMA Classic, there is a gastric drain tube that opens at the tip. This is designed to channel fluid away or permit the passage of an orogastric tube; it also reduces the likelihood of inflation of the stomach during prolonged ventilation. The LMA Proseal has an integrated bite block and a preformed metal introducer is available to aid insertion.

**Uses**
- Obese patients, laparoscopic surgery, positive pressure ventilation (i.e. in those likely to have high airway pressures).

**Advantages**
- Seals to around 30 cmH₂O.
- Gastric drain tube.
- Integrated bite block.
- May seal where other LMAs have failed.

**Disadvantages**
- Bulky.
- A different technique is required for insertion (rarely practiced).

LMA Supreme (Teleflex Inc.)

The LMA Supreme was recently designed by Archie Brain and attempts to overcome some of the shortcomings of his LMA Classic. It is a single use device similar, but not identical, to the LMA Proseal. Unlike the LMA Proseal, it is pre-curved to facilitate insertion and has its gastric tube integrated with the airway tube. The cuff does not extend onto the reverse of the device, but is designed to provide an improved oesophageal seal. The LMA Supreme tends to seal to a slightly lower airway pressure than the LMA Proseal, at approximately 25 cmH₂O.
Section 2.6 Laryngeal mask airways

i-gel (Intersurgical Ltd)

The i-gel has a non-inflatable cuff made of an anatomically shaped elastomer gel which further moulds to the airway shape when it warms to body temperature. It seals to around 25 cmH₂O. A thin coating of lubricant should be applied to all sides of the device before insertion.

**Advantages**
- Integrated gastric drain tube.
- Integrated bite block.
- Simple insertion without inserting hand into patient’s mouth.
- No cuff to inflate.
- Improved stability in edentulous patients.

**Disadvantages**
- Bulky – oral surgery is impossible.
- Lower pharyngeal and oesophageal seal pressures compared with the LMA Proseal.

*Fig. 2.6.6:* The i-gel has an elastomer gel seal instead of an inflatable cuff.
Chapter 2 Airway equipment

Flexible LMAs

The LMA Flexible (Teleflex Inc.) and similar designs differ from the single use LMAs due to the wire-reinforced airway tube, which facilitates positioning away from the surgical field whilst maintaining a good seal.

**Uses**
- Dental, ophthalmic and head and neck surgery.

**Advantages**
- Less likely to become dislodged during surgery to the head and neck than a non-flexible device.
- Compared with an endotracheal tube, the large cuff may reduce tracheal soiling in tonsillectomy and dental surgery.

**Disadvantages**
- Insertion may prove more difficult than the non-flexible designs.
- The coil reinforcement remains deformed once bitten, and may therefore cause airway obstruction if the patient bites down.
- It carries a higher risk of becoming dislodged during surgery than a reinforced endotracheal tube.

Intubating LMA (Teleflex Inc.)

The intubating LMA is designed to facilitate endotracheal intubation. It is rigid and anatomically curved, with a lumen wide enough to accept a reinforced size 8.0 endotracheal tube, and short enough to ensure passage of the endotracheal tube cuff beyond the vocal cords.

**Uses**
- Achieving and maintaining control of the airway in anticipated or unexpected difficult airways.

**Advantages**
- Can be used blindly or to facilitate fibreoptic intubation.
- Allows ventilation between intubation attempts.
- All sizes (3, 4 and 5) will accept an 8.0 mm endotracheal tube (whereas a size 4 LMA Classic will accept a 6.5 mm tube).
CobraPLA (perilaryngeal airway, Pulmodyne Ltd.)

The CobraPLA was designed as an alternative to a laryngeal mask. The ‘cobra head’ abuts the laryngeal inlet holding the epiglottis out of the airway, but the device seals using a cuff in the hypopharynx.

**Uses**
- Controlled or spontaneous ventilation.

**Advantages**
- Insertion time and success are similar to the LMA Classic.
- Airway pressures of up to 30 cmH₂O are possible.

**Disadvantages**
- There may be an increased risk of pulmonary aspiration; one prospective study was halted after two cases.

- Reusable and single use designs available.

**Disadvantages**
- Blind intubation can lead to pharyngeal trauma and the deterioration of an already difficult airway.

Fig. 2.6.9: The CobraPLA (Pulmodyne Ltd.).

Fig. 2.6.10: The CobraPLA creates a seal in the hypopharynx rather than at the laryngeal inlet. Images courtesy of Pulmodyne Ltd.
Oesophageal/tracheal tubes

These are often called Combitubes after the Covidien/Nellcor version. The device has two cuffs and is designed for blind insertion. It usually enters the oesophagus where the distal cuff is inflated. The proximal cuff then acts as a pharyngeal seal, and ventilation takes place through the side holes between the cuffs. If the device enters the trachea, the other lumen is used as a normal tracheal tube.

**Uses**
- Resuscitation, usually in pre-hospital settings.

**Advantages**
- Blind insertion.
- Ventilation theoretically possible wherever the tube is placed.
- Protection from aspiration.

**Disadvantages**
- Identifying which lumen to ventilate is critical.
- It is unsuitable in patients with oesophageal pathology.
- Tracheal succioning is not possible.
- It has been largely superseded by LMAs.