Anaesthesia for diagnosis and treatment of subglottic stenosis

ELSPETH FACER (London)

This can conveniently be divided into two parts. First, anaesthesia for diagnostic endoscopy and further assessment of subglottic stenosis and, second, anaesthesia for laryngeal reconstructive surgery.

Anaesthesia for endoscopy (laryngoscopy and bronchoscopy)

Progress in the skill and safety of anaesthesia, together with advances in endoscopic equipment has come a long way since one of the early pioneers in endoscopy, Holinger (1969) taught and I quote:

> "in newborn infants and most children, anaesthesia is unnecessary"

He was referring to bronchoscopy, but he did add that "secure restraint" of the patient was essential.

Fortunately infants and children can now safely be examined under general anaesthesia, however that for endoscopy, particularly in the presence of airway obstruction, remains one of the most demanding and potentially dangerous of all procedures.

Close co-operation and understanding between operator and anaesthetist are vital where sharing of the airway occurs, and I think many endoscopists would be prepared to acknowledge that the success and safety of the procedure lies in the hands of the anaesthetist.

Requirements for paediatric endoscopy

1. *Avoidance of hypoxia:* This is the single most important requirement. Not only should one be in a position to provide adequate oxygenation to the patient at all times, but the oxygen reserve should be as great as possible. This precludes the use of nitrous oxide, as 100 per cent oxygen should be used always, even in premature babies, where the risk of hypoxia far outweighs the risk of retrolental fibroplasia. Equally important is the *detection* of hypoxia, and until the advent of the pulse oximeter this was often delayed. All too frequently bradycardia was the first indication of hypoxia and it cannot be emphasized enough that during laryngoscopy or bronchoscopy *bradycardia must always be assumed to be due to hypoxia* until proved otherwise.

2. *Control of secretions:* This is a vital requirement for endoscopy for three reasons:

(a) Unless an anticholinergic agent has been used, the incidence of coughing, breathholding and laryngospasm on induction, emergence and during endoscopy will be greatly increased.

(b) If there are copious secretions, repeated suctioning will be required with an increased risk of hypoxia and prolongation of the procedure.

(c) Generous topical anaesthesia is essential for good operating conditions and if drying of secretions has not been achieved, the local anaesthetic will be diluted with little effect.

3. *Protection of the airway from acid stomach contents:* As everyone is aware, any patient undergoing general anaesthesia is at risk from regurgitation of acid stomach contents, and their subsequent aspiration into the lungs. This risk is much greater in the presence of upper airways obstruction where induction of anaesthesia may be prolonged and difficult, making gastric distension more likely. Silent aspiration post-operatively as a result of topical anaesthesia also makes strict pre-operative starvation mandatory.

4. *Avoidance of coughing, breathholding, laryngospasm, and bronchospasm:* It is impossible to assess any part of the airway accurately if coughing, and breathholding occur, and mistakes in diagnosis may be made unless the anaesthetist can produce adequate conditions for the operator. Good topical anaesthesia and adequate depth of anaesthesia are required, whatever technique is used, and, despite the newer inhalational agents, halothane remains the agent of choice as it is least irritant to the airway.

5. *Adequate ventilation:* Whether spontaneous, assisted or controlled ventilation is used, it must be adequate to prevent hypoxia, hypercarbia and ensuing acidosis.

In assessment of the larynx and subglottis much of the examination must be done without the safety of an endotracheal tube, therefore a technique relying on spontaneous respiration is essential. In adults and older children jet ventilation via an injector attached to the laryngoscope is an alternative, but the small size of even the *normal* infant airway precludes this technique.

Assisted or controlled ventilation may be required during bronchoscopy, but this can readily be achieved without relaxants in infants.

Consultant Anaesthetist, The Hospitals for Sick Children, London.

https://doi.org/10.1017/S0022215100600439 Published online by Cambridge University Press

Again, halothane is the inhalation agent of choice, as it produces less respiratory depression than either isoflurane or enflurane. Pre-operative sedation is obviously contraindicated.

6. *Rapid wakening:* This is important, not only for protection of the airway in the presence of upper airway obstruction, but for the assessment of cord and cricoarytenoid movement if dual pathology is suspected.

Pre-operative considerations

Patients presenting for diagnosis of subglottic stenosis will have a varying degree of upper airways obstruction from mild to critical. Some may be already intubated and others have undergone tracheostomy, in which case the anaesthetic problems will be considerably reduced.

Many patients are small, poorly nourished, ex-premature babies, with poor temperature control and difficult venous access. In addition to subglottic narrowing they may have bronchopulmonary dysplasia, with lung fibrosis and scarring resulting in decreased compliance, ventilation/perfusion mismatch and often hyper-reactive airways. This makes the anaesthetists' job of fulfilling the requirements for endoscopy already outlined even more difficult.

No anaesthetist should embark on anaesthesia for the diagnosis of subglottic stenosis in a small baby unless both he and the operating theatre are properly prepared. There should always be skilled anaesthetic assistance and if possible a second anaesthetist.

There should be a wide range of tubes available, down to the smallest. In severe subglottic stenosis the subglottis may only admit an 8 FG Cole pattern neonatal tube. This has an external diameter of just over 2.5 mm. compared to the 3.4 mm. external diameter of a (nominal) 2.5 Portex endotracheal tube. It is also stiffer than other endotracheal tubes. Semi-rigid tube introducers should also be available. The anaesthetist must be familiar with the bronchoscopic equipment and its hazards and limitations. Emergency resuscitation drugs should be near at hand in the event of total obstruction and inability to secure an artificial airway, as should instruments and personnel for emergency tracheostomy.

General anaesthesia

Premedication: Anticholinergic premedication is essential for all endoscopic procedures in infants and children. Intramuscular atropine in a dose of 0.02 mg./kg. is used routinely. This not only dries secretions, but also stabilises a more rapid heart rate, which helps to maintain cardiac output in the presence of halothane. Sedation should be avoided. The importance of pre-operative starvation has already been emphasized.

Induction: In the presence of subglottic obstruction an inhalation induction is safest, using 100 per cent oxygen and an increasing concentration of halothane. Once consciousness is lost, the use of a tight-fitting face mask and semi-occlusion of the T-piece reservoir bag achieves a raised airway pressure which will improve gas exchange. Unlike the functional stridor of laryngomalacia which often improves or completely disappears, the fixed biphasic stridor of subglottic stenosis will only improve minimally.

It should be remembered that in the presence of significant obstruction, induction will be prolonged, taking many minutes to achieve sufficient depth of anaesthesia for intubation. Assisted ventilation will help by speeding-up induction.

Whilst anaesthesia deepens, monitoring is applied, intravenous access obtained, and a decision made whether to intubate using deep anaesthesia or a short-acting muscle relaxant. If there is any doubt at all about the ability to ventilate with a mask, muscle relaxants must not be used.

Intubation: A few advocate avoidance of intubation if subglottic stenosis is suspected, however, I think it would be very foolish to embark on endoscopy without prior knowledge that intubation is possible. Gentle oral intubation is performed with a well-lubricated endotracheal tube and will give a guide to subglottic size. The subglottis may only admit a very small tube, and if intubation is impossible the smallest available tube (i.e. the 8 FG rigid neonatal Cole pattern tube) should be impacted onto the stenosis while preparation is made for tracheostomy.

Topical anaesthesia

If a short-acting muscle relaxant is used the glottis is sprayed with lignocaine before intubation. In the presence of spontaneous respiration, however, the risk of laryngospasm is high, even in experienced hands, and it is safer to spray the glottis after intubation.

There is much discussion about the safe dose of lignocaine. Pelton *et al.*, (1970) reported safe levels with a dose of 3 mg./kg. The toxic level lies somewhere between 6 and 10 μg/ml. and a dose of 3 mg./kg. has been shown to give blood levels of about 3 μg/ml. It is known that general anaesthesia raises the toxicity threshold for local anaesthetics and with this in mind doses of up to 5 mg./kg. have been used in many large series without any complications.

Microlaryngoscopy

Unless the stenosis is critical the oral tube is replaced with a small-sized nasotracheal tube and anaesthesia continued with oxygen and halothane.

This allows the airway to be secure whilst the suspension laryngoscope and microscope are set up for preliminary assessment of the airway. The nasal tube is then withdrawn to the nasopharynx and anaesthesia maintained by insufflation of oxygen and halothane.

Bronchoscopy

When laryngoscopy is complete, bronchoscopy is performed with the Storz-Hopkins ventilating bronchoscope. This poses several problems for the anaesthetist, relating mainly to increased resistance to gas flow.

1. The bronchoscope has an anti-fog sheath; if this is used in sizes smaller than the 5 mm. (nominal size) there is an unacceptable increase in resistance. The sheath should be replaced by a spacing block which prevents the

FIGURE 1

STORZ-HOPKINS BRONCHOSCOPES

Gas flow resistance (cm H_2O L^{-1} Sec^{-1})

Bronchoscope size	Measured at 5 L flow		Measured at 10 L flow	
	Bronchoscope only	Bronchoscope and telescope	Bronchoscope only	Bronchoscope and telescope
2.5	42	1512	80	2700
3.0	21	40	30	65
3.5 (short)	12	16	15	26
3.5 (long)	12	34	19	39
4.0	8	20	15	25
5.0	6	12	12	18

Battersby & Ridley (unpublished data).

telescope from projecting from the end of the bronchoscope.

2. With the telescope in place, as the size of the bronchoscopes decrease, the resistance to airflow increases. When one reaches the smallest 2.5 mm. bronchoscope, the resistance is quite unacceptable (see Fig. 1). Attempts to achieve ventilation result in prolonged expiration, air trapping, the risk of pneumothorax and reduced venous return and cardiac output.

Adequate gas exchange can very simply be achieved by frequent removal of the telescope to allow unimpeded ventilation through the bronchoscope.

3. Occasionally, the presence of severe subglottic stenosis will preclude the use of any bronchoscope. In this situation the telescope alone is used and one is again dependent on insufflation of oxygen and halothane from the nasopharyngeal tube.

Although there should always be a background of spontaneous respiration, assisted ventilation and IPPV will often be required during bronchoscopy to achieve adequate gas exchange and avoid acidosis.

Monitoring

Constant close monitoring is essential and includes precordial stethoscope, ECG, automatic blood pressure monitor and, probably of greatest value, pulse oximetry.

Excessive monitoring may lead to a false sense of security and it must be remembered that no monitor can ever replace being in constant contact with the patient to assess colour and adequacy of both ventilation and circulation.

Pulse oximetry has transformed the early detection of hypoxia in these difficult cases. The pulse oximeter provides a non-invasive continuous measure of oxygen saturation. (Taylor and Whitwam, 1986). If we look at the normal oxygen dissociation curve (Fig. 2) we can see that on the steep part of the curve there is a large change in oxygen saturation for a small change in oxygen tension. Hypoxia is rarely detected clinically above a saturation of 89 per cent (point 2) and all too frequently much lower, therefore pulse oximetry, by detecting a drop in oxygen saturation before serious hypoxia occurs would seem to be a vital part of any endoscopy of the airway, particularly in the presence of subglottic stenosis. To give an effective warning of impending hypoxaemia the instrument must be set to alarm when the SaO_2 falls below 94 per cent (point 1).

An added advantage of these machines is their audible signal, which drops in pitch with falling saturation, thus alerting the operator to impending hypoxia. This seems to have a more immediate effect than repeated warnings from the anaesthetist!

Monitoring of the ECG is still essential for the detection of arrhythmias. Nodal rhythm, ventricular ectopic beats, bigeminy and bradycardia may all occur and are either due to inadequate ventilation with hypercarbia and hypoxia, or light anaesthesia.

Post-operative considerations

Subglottic stenosis may be worse following instrumentation, due to subglottic oedema. Any child having endoscopy for assessment of subglottic stenosis must be very closely observed post-operatively for signs of increasing stridor and critical narrowing of the airway.

Prophylactic dexamethasone is certainly helpful in the prevention of post-instrumentation oedema, but there is no evidence to support its use in chronic subglottic oedema. It is used in a dose of 0.25 mg./kg. I.V. initially, then three six-hourly doses of 0.1 mg./kg. I.V.

Nebulised racemic adrenaline has been widely used in North America to treat acute subglottic oedema, but it is not easily available in this country.

In addition to constant close observation, humidification with added oxygen, if necessary, should be administered.

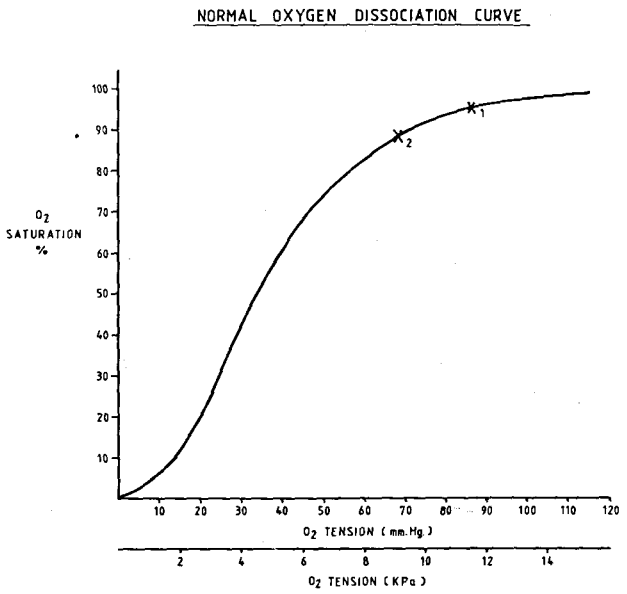

FIG. 2

https://doi.org/10.1017/S0022215100600439 Published online by Cambridge University Press

Children with subglottic stenosis often require repeated anaesthesia to assess the size of the subglottis and the need for reconstructive surgery. Many of these children will have tracheostomies, in which case moderate sedation can be administered safely, making repeated visits to the operating theatre less traumatic.

Despite the recent controversies about repeated halothane anaesthesia, and the undoubted rare occurrence of halothane hepatitis in children, it remains the agent of choice for paediatric endoscopy as the risk of morbidity from the use of other agents far outweighs the risk of halothane hepatitis. (Noble and Battersby 1987).

Anaesthesia for laryngeal reconstructive surgery

This poses few problems for the anaesthetist compared to anaesthesia for laryngoscopy and bronchoscopy, however there are still possible pitfalls.

As for any elective surgery, the child should be in an optimum condition prior to surgery with no evidence of intercurrent infection.

The patient will already have a low tracheostomy but the chest must be as clear of secretions as can be achieved immediately prior to operation.

The main problem for the anaesthetist is maintenance of an unobstructed, stable airway throughout the operation. The operation site is just above the tracheostome, therefore access to this once surgery has commenced is difficult. Bulky connectors will impinge on the operating site and are liable to disconnection.

We have found that the use of a cuffed latex armoured tube inserted into the tracheostome and taken through 180° to connect with the anaesthetic circuit over the chest, provides the most satisfactory airway. There are, however, problems attached to their use.

It is important to make sure that the entire cuff is within the airway or it is likely to extrude during the operation. With a low tracheostomy the distance between it and the carina is short, making accurate placement of the tube essential. Its tip must be clear of the carina to allow ventilation of both lungs, which can more readily be achieved by abolishing the bevel at the end of the tube.

The walls of these cuffed armoured tubes are very thick and occasionally it is impossible to pass even the smallest size. A shortened preformed plastic tube (e.g. Mallinckrodt, Rae tube) is an alternative, but does not have the advantages of a cuffed tube. The use of a cuffed tube prevents anaesthetic gases leaking into the operation site, and more important, blood trickling down into the trachea.

Anaesthesia consists of any technique using muscle paralysis and IPPV, having first induced anaesthesia via the tracheostome and sprayed the glottis with lignocaine. Further clearance of secretions should always be attempted using saline and suction prior to changing to the armoured tube.

The tube is inserted (using a semi-rigid tube introducer if necessary) and securely strapped in place after positioning the child as for surgery with a sand bag under the shoulders and the neck extended. A suitable connector (e.g. Cardiff or Cobbs) should be used to allow easy access for further suction, should it become necessary. A nasogastric tube is inserted, as swallowing and drinking may be delayed post-operatively.

Extensive monitoring is essential and includes a precordial stethoscope, airway pressure gauge and disconnection alarm. ECG, automatic blood pressure monitor and pulse oximetry should also be routine.

Access to the patient once surgery has commenced is very limited, making close continuous monitoring of ventilation paramount.

Intravenous fluids are administered as necessary and continued post-operatively, as the use of a silastic splint, if too long, may give rise to aspiration.

If a rib graft is taken a post-operative chest X-ray is essential to exclude pneumothorax.

All patients are nursed in humidified air, with added oxygen if necessary, and chest physiotherapy should not be forgotten, as there is often a temporary increase in secretions post-operatively.

In conclusion, I should like to emphasize that nowhere in the practice of anaesthesia is the potential for hypoxia so great as in diagnostic laryngoscopy and bronchoscopy, particulary in an infant with significant upper airways obstruction. General anaesthesia is hazardous and should, if possible, be undertaken by trained paediatric anaesthetists. Being suitably prepared with a wide range of endotracheal tubes and thoroughly familiar with endoscopes likely to be used, are essential for safe anaesthesia.

Anaesthesia for laryngeal reconstructive surgery, on the other hand, is less hazardous. However, meticulous attention must be paid to placement of the tracheal tube and subsequent ventilation.

References

Holinger, P. (1969) Endoscopy. In Mustard, W. T., Ravitch, M. M., Snyder, W. H. *et al.*, (Eds) *Paediatric Surgery.* Year Book Medical Publishers. Chicago.

Noble, D. W. and Battersby, E. F. (1987) Halothane hepatitis in children. *British Medical Journal;* **295:** 117.

Pelton, D. A., Daly, M., Cooper, P. D. and Conn, A. W. (1970) Plasma lidocaine concentration following topical aerosol application to the trachea and bronchi. *Canadian Anaesthetic Society.* **17:** 250–255.

Taylor, M. B. and Whitwam, J. G. (1986) The current status of pulse oximetry. Clinical value of continuous non invasive saturation monitoring. *Anaesthesia.* **41:** 943–949.

Elspeth Facer discussion

Question

How is anaesthesia maintained during endoscopy?

Facer

The nasal endotracheal tube is withdrawn into the nasopharnx and the oxygen/halothane mixture insufflates freely down into the trachea. The baby breathes spontaneously otherwise you cannot maintain a stable situation.

Astly

To keep the baby asleep you need to feed him halothane which we do down the side of the tube. You cannot laryngoscope with the tube in the way.

Graham
We occasionally give a little extra by popping the tube straight down the laryngoscope if they look as though they are becoming light and that can be held by hand long enough to give an extra boost.

Facer
Does that not affect your view of the larynx?

Graham
No. The tube is removed by the surgeon after a brief period of IPPV.

Facer
One should be able to maintain a stable state without doing that.

Graham
The difficulty is with a rather narrow trachea, through which the child simply cannot get enough anaesthetic.

Facer
Yes. Much of the problem is getting them to an adequate depth before you reach that stage.

Evans
I am surprised you need to keep putting the tube down if the child is, as Dr Facer says, anaesthetised adequately first. You almost implied that you do not endotracheally intubate the child before you get set up.

Astley
Yes we do normally intubate them.

Evans
So the child is intubated and being anaesthetised while all the apparatus is set up, and when the endotracheal tube is removed you have 10-15 minutes for endoscopy in most instances.

Cinnamond
Why is it necessary to intubate them at all. We only take them down with face mask to a suitable depth.

Facer
In many cases I would be very unhappy to embark on such a procedure without the knowledge that you had the right size tube available to intubate them.

Cinnamond
It is always easier to put in a rigid bronchoscope than a soft endotracheal tube.

Facer
With the time it takes to set up for micro-laryngoscopy it is much safer for the baby and one is in a much more controlled situation with a tube in place.

Bull
The problem is really under what circumstances micro-laryngoscopy is required. For routine laryngoscopy, say, children with laryngomalacia, my practice is not to use the microscope. We do not then intubate but get them deep on a face mask which the anaesthetist holds on in theatre until everything is ready.

Facer
I accept if you are not doing micro-laryngoscopy the situation is very different.

Bull
Micro-laryngoscopy is not a routine procedure in looking at subglottic stenosis. I regard micro-laryngoscopy not necessarily as a diagnostic procedure, so much as needed for therapeutic procedures.

Bailey
I disagree. I feel that to look at the larynx under the microscope gives very much better appreciation of the problem, so I use it routinely.

Evans
Can we establish who uses micro-laryngoscopy routinely?

Cinnamond
No.

Bull
No.

Graham
Yes.

Bull
From an anaesthetic point of view, it is much more controllable if you do not, because you have less equipment in the way.

Facer
Yes. It is certainly much simpler and quicker.

Cinnamond
Another possibility is high pressure/high frequency ventilation through a transcutaneous needle, which we have tried but does not work.

Facer
It is a perfectly acceptable technique but very dangerous in a small baby with subglottic obstruction, because to use the technique requires free flow of air and no resistance to it coming out. With an obstruction there is the risk of pneumothorax and it really is not a technique that is applicable to this situation.

Graham
Most of us have probably had the experience of only being able to get in a nasogastric feeding tube.

Facer
The problem is that the nasogastric tube is very soft and often difficult to get through a subglottic stenosis, which is why in that situation, I always use the rigid neonatal tube.

Cinnamond
But why not use the bronchoscope?

Facer
With a stenosis of perhaps only two millimetres you are not going to get a bronchoscope in.

Cinnamond
You would get a 2.5 millimetre bronchoscope in.

Evans
We infrequently have to endoscope children with a subglottic stenosis that is really a pinhole and there is no possibility of even getting the telescope of the bronchoscope in, let alone the bronchoscope, so the impaction/intubation method works well in that situation.

Cinnamond
In those circumstances you can often achieve adequate ventilation by face mask alone.

Bull
It is possible to do tracheostomies on a face mask but it is very difficult.

Cinnamond
You mentioned that the stridor of laryngomalacia lessens under anaesthesia but in my experience it worsens as anaesthesia deepens, presumably related to loss of rigidity in the surrounding muscles and so on.

Facer
This is certainly not my experience. In nearly all these children we find that with positive pressure in the system the stridor virtually disappears.

Evans
It is almost diagnostic.

https://doi.org/10.1017/S0022215100600439 Published online by Cambridge University Press