British Journal of Anaesthesia 90 (3): 367–74 (2003)
DOI: 10.1093/bja/aeg053

BJA

Anaesthesia and tracheobronchial stenting for central airway obstruction in adults

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In the last decade, stents suitable for the management of tracheobronchial stenoses and obstruction have evolved from bulky prostheses requiring tracheal resection to small devices that are self-expanding and can be inserted using fibreoptic techniques. The experience base for this review is more than 100 patients between 1989 and 2001 who have been anaesthetized for stent insertion. Early cases required rigid bronchoscopy for the routine of insertion. Anaesthetic techniques have evolved from those that were designed and developed for laser surgery in the central airways. The advent of modern devices now extends the variety of anaesthetic management techniques that can be used. But the original one, based on the requirement for use of a rigid bronchoscope, is best for dealing with complications and extracting problem stents. The most frequent complication of the processes of stent insertion has been respiratory failure because of carbon dioxide retention, consequent on obstruction with secretions in the area of the carina. The nature of central airway problems suggests that anaesthesia induction, management and teaching should not be founded on the conventional model-base of upper airway obstruction.

Br J Anaesth 2003; **90**: 367–74

Keywords: complications, airway obstruction; equipment, stents

A common thoracic anaesthetic emergency to a tertiary referral centre is central airway obstruction. In the past, many sufferers would have been regarded either as inoperable or only manageable with surgery, with high morbidity and significant mortality.[13 40] Developments in other fields, particularly vascular and oesophageal, have been copied, paralleled and applied so that nowadays insertion of a tracheobronchial stent is often the first-line management. Stents are not licensed for non-malignant lesions, but are being used increasingly for physical and functional stenoses of a benign nature in the trachea and major bronchi.[18 30 32 38 39]

For anaesthetists, challenges relate to the management of sick patients with major comorbidities, coping with central airway obstruction distal to a site suitable for rescue with a surgical airway, and sharing an airway that is easily and critically compromised. Total airway obstruction is a possibility that has to be faced occasionally. It is particularly important to learn to detect the almost characteristic signs of developing or advancing central airway obstruction in the anaesthetized patient who has had a stent inserted.

The number of difficulties in management has been reduced because of developments in technology, chiefly in stent size reduction and simplification of application. The nature of competition for the airway has also changed. The instrumentation occupies less of the common and shared conduits. Anaesthesia has been rendered less hazardous and has been simplified by developments in pharmacology, notably in total i.v. anaesthetic agents and non-depolarizing neuromuscular blocking drugs.[8]

Using vascular stents extends the range of indications: placement in segmental bronchi and use in paediatric practice are possible.[4 12 16] However, procedures and processes are now within the ambit of practice of personnel, such as radiologists, not previously involved in the management of patients with acute airway problems. These personnel are inexperienced in the disciplines necessary to manage situations in which access has to be shared for vital functions to be maintained while therapy is undertaken.[3 9 10 31 37]

Stents

Early models were tubes of silicone based on a simplistic cylindrical concept of the trachea.[23] An early development was the T tube (Montgomery), the limb of which is a tracheostomy tube and which, like the bifurcated stents that followed, was unlikely to become dislodged or migrate, but can be awkward and cumbersome to place and replace.[11 14 16 17 36 46] Some later devices, based on a normal anatomical trachea, had stainless steel rings and a Silastic membranous portion. More recently, metal strut and

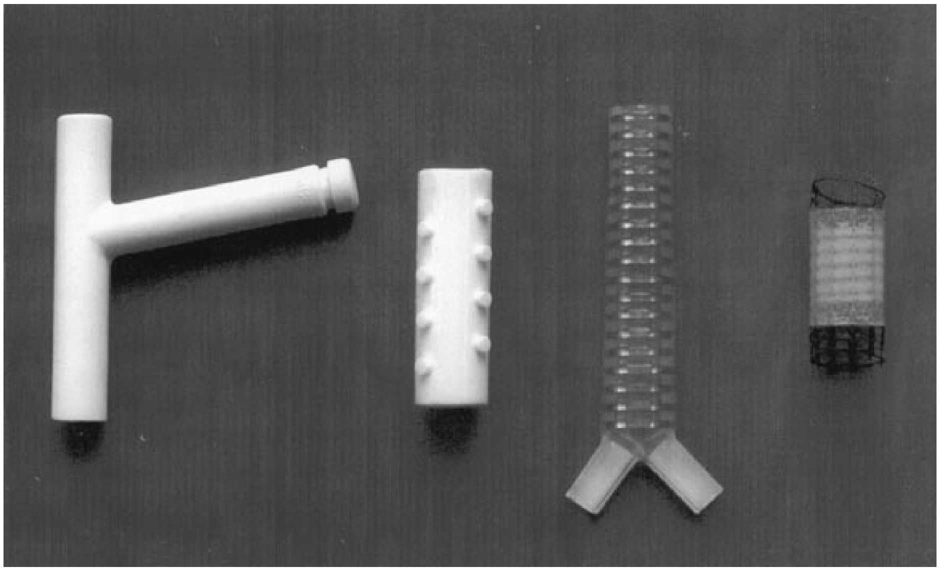

Fig 1 Stents through the decade. Left to right: Montgomery, Dumon, Dynamic Stent (Rusch) and covered Wallstent (Microvasive).

self- and balloon-expanding devices, which are more stable and better anchored, have become available (Fig. 1).

In principle, the Cook Z stent (Gianturco venal caval design) is the simplest of the modern self-expanding models. Made of stainless steel with struts, in position it looks on x-ray like a paper-clip. The latest are metal mesh devices, either steel or nitinol (titanium plus nickel, with 'memory' properties), some covered with a polyurethane membrane (Fig. 2).[22]

There are advantages and disadvantages for the different materials and constructions. Sputum retention is a problem in those with a solid, imperforate Silastic or polyurethane wall.[10] Strutted metal and uncovered meshes have the long-term advantage that epithelial tissue will fill the interstices over a period of months, and some ciliary activity and sputum clearing ability returns. Equally, these devices can be placed across bronchi without causing obstruction to air flow. But tumours grow through the interstices and can re-obstruct. In the event of becoming constricted, newer devices are malleable enough to be re-expanded by balloon dilatation.[22 25 41]

Stents are best regarded as permanent. Earlier versions were relatively easy to remove, but the modern ones tend to become embedded on expanding and invisible to the naked eye, with the potential to become difficult and traumatic to remove. Those with a nylon braid on either end are more visible, flexible and malleable, so that removal is possible, and they should be considered for use in predictably temporary situations, such as weaning off ventilators.[7 32] There is a risk of these disintegrating (Fig. 3).

Ignition of silicone stents by lasers is possible. The risk is reduced with ambient oxygen concentrations <40%. However, it is advised that if this is not possible the pulse generation and power output of the laser should be reduced, or the stent removed before lasering.[33]

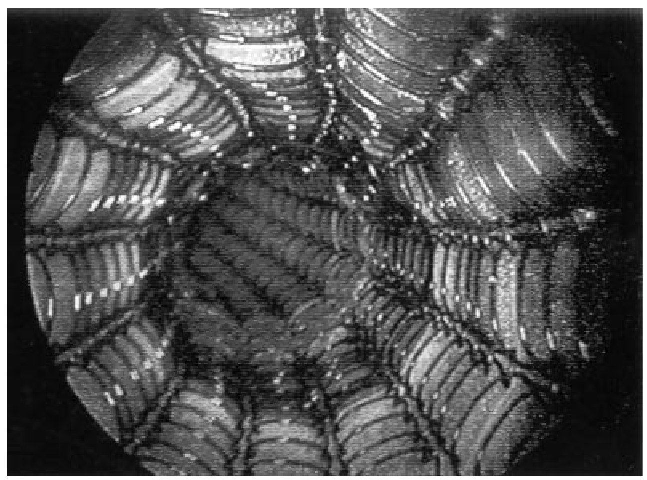

Fig 2 Clinical record of covered Wallstent *in situ* in the lower trachea for management of a bronchopleural fistula.

The mechanics of inserting stents

Tracheal surgery, including resection, was required for the early prostheses.[11 14 16 17 28 31 36] The next development was devices that could be inserted through a rigid bronchoscope. Anaesthetic techniques were those used for prolonged rigid bronchoscopy under general anaesthesia. Complex manipulations of applicators, bougies and guide wires were required within the confines of a rigid bronchoscope. Inevitably, there were significant periods of competition for the airway between operator and anaesthetist, notably on positioning of stents.[11 39] There were periods when the stents and instrumentation, some of it sharp-pointed and rigid, were not visible to the operator, with the potential for the airway to become traumatized or totally obstructed.

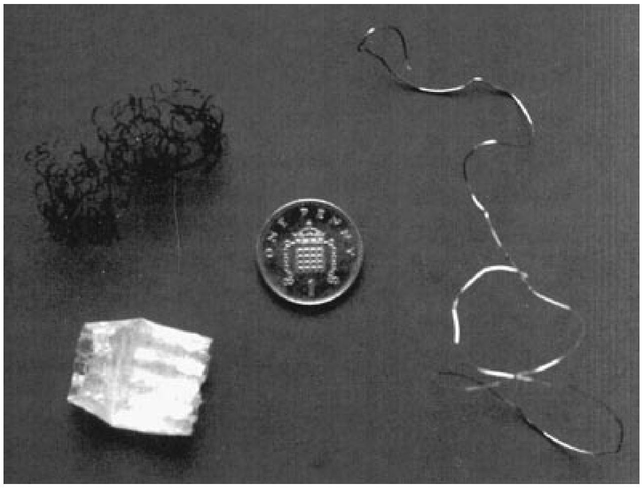

Fig 3 Inner space debris. A disintegrated covered stent (left) and a disrupted Gianturco stent (right) removed from the same patient.

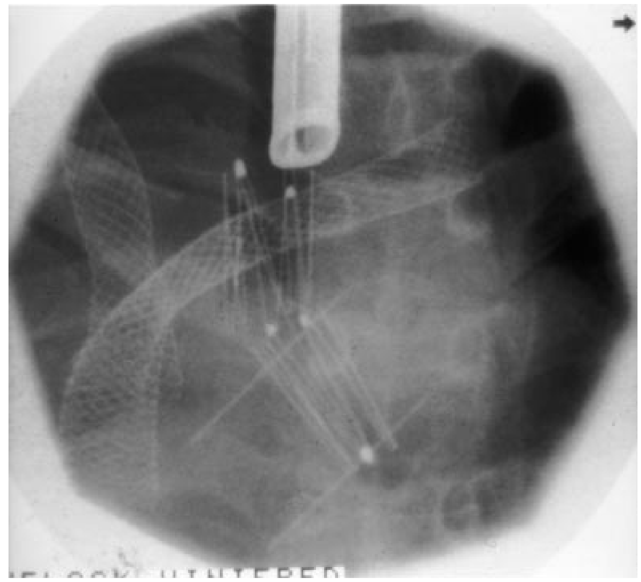

Fig 4 X-ray taken while inserting a tracheal stent into a patient with malignant carcinoid. A superior vena cava stent is in position in the background. Below the rigid bronchoscope tip is a deployed Gianturco stent in the trachea and one in the left main bronchus, the siting of which is between two needle markers on the skin.

During such heady days, it was possible to experience a desperate scramble to abstract a kinked prosthesis that was preventing a patient from being ventilated or oxygenated.

Correctly siting an intraluminal stent was often difficult and attempts to do so were the usual reason for blind spots in the insertion process. The position for the stent was judged by placing the tip of a rigid bronchoscope first at one end and then at the other end of the stenosis, and using fluoroscopy to guide the placement of skin markers. The advent of metal components and radio-opaque markers has reduced the requirement for such manoeuvres. Much more can be done, including some adjustment if necessary, under direct vision with small-bore fibreoptic bronchoscopes, either rigid or flexible, inserted through the rigid conduit formed by a metal bronchoscope (Fig. 4).

The recent development of devices that expand after endoscopic placement, has allowed much more room for manoeuvre and adjustment within the airway conduit.[27 34 46] Any risk of contemporaneous ventilation problems developing is reduced. Older devices, and the techniques necessary for insertion, have almost been rendered obsolete. The need for radiological facilities on site at the time of operation is getting less.

Indications

Indications for the use of stents are becoming legion but the bulk in the adult population are for palliation in various guises. Currently, stents are only licensed for malignant conditions, in part because the incidence of stent erosion or malfunction is probably a function of time. Unfortunately, for many of the more benign conditions alternative therapeutic options have been exhausted, sufficiently so for unlicensed stent use to be regarded as justifiable on clinical grounds (Table 1). All types of stent are limited functionally for use in abnormalities of the trachea and main bronchi, and will collapse if the circumferential pressure continues to build up with an expanding pathology.

Anaesthesia

In the 10 yr up to the end of 2001, there were 115 patient episodes recorded locally for stent insertion (Table 2). Patients were most commonly graded ASA III or IV because of comorbidity, often related to central airway obstruction, that included pulmonary sepsis, obstructive airway disease, advanced neoplastic disease, superior vena cava obstruction and significant myocardial disease.

Patient selection

Embarking on the management of severe central airway obstruction has been testing in regard to wisdom to treat, and hence, anaesthetize. It is a field of high stakes; the balance between benefit and risk is a knife-edge. Some situations are now known to be forlorn and dangerously meddlesome. A lung that has been collapsed for more than 2 or 3 weeks is not recoverable; there is a significant danger that the patient will be further insulted by infected secretions, released by attempting to relieve obstructed bronchi, and the resulting condition has been fatal in allied situations.[8]

It has proved of value to view the dilemmas these cases present from the perspective of the potential of the immediate consequences of treatment to alter ASA status, positively or negatively. For instance, if upstaging of ASA grading is considered achievable, say from ASA grade IV to

Table 1 Reported indications for stents. *Local experience. Modified from Allen JN. Tracheobronchial stents, http:/home.columbus.rr.com/allen/tracheobronchial_stents.htm

Cancer: small cell*, non-small cell*, metastatic*, lymphoma
Tracheobronchial malacia*
Inflammatory stenoses: post-tuberculous, Wegener's granulomatosis*, amyloidosis
Strictures: postintubation*, post-traumatic*
Post anastomotic: tracheobronchial resection*; heart, lung transplantation*
Extrinsic compression: neoplastic*, vascular* oesophageal stenting*, kyphoscoliosis, iatrogenic obstruction*
Tracheo-oesophageal and bronchopleural fistulae*

Table 2 Number of patients per annum. Many had two or more stents inserted on separate occasions and several had multiple operations. Data from Cardiothoracic Centre, Freeman Hospital, Newcastle

Stent type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Montgomery	1	1	2									
Gianturco			3	3	7	3	5	3	15	6	7	14
Mesh/covered									2	1	16	23
Other	1					2						
Total	2	1	5	3	7	5	5	3	17	7	23	37

III as a consequence of early recovery of functioning lung or an immediate increase in size of the airway, then the risks, including anaesthesia, are worth taking. The corollary is that, if this degree of confidence in improvement is not felt, there should be serious consideration about whether to proceed.

Preoperative investigation

Preoperative investigations beyond chest x-rays and tomography were usually unhelpful: the information gleaned was academic as it related to the degree of obstruction and the functional disability and rarely gave useful insight into the nature of the obstruction and its pathophysiology. Modern radiological techniques, however, can give very good representations of the pathological anatomy.[4 5 45] But the mechanics of obtaining them, for instance by lying patients flat for a prolonged period, may increase the risk and, in our experience, is often an unjustified ordeal for the very sick.

First aid

The majority of our patients are only slightly distressed at rest on presentation and few have significant stridor, but all benefit from being in a sitting-up position and receiving supplementary inspired and humidified oxygen. These simple manoeuvres reduce the likelihood of precipitating severe coughing episodes, which in turn can lead to sudden and significant airway obstruction, particularly if other comorbidities, such as superior vena cava obstruction, are present. A few benefit from helium and oxygen (Heliox) before induction.[20] Steroids continue to be advocated empirically, but we rarely administer them.[40]

Intubation

Most of our patients embody a category of airway problems for which there is no fail-safe procedure: the pathology is sufficiently central that transtracheal ventilation, tracheostomy or a similar surgical airway would not relieve the obstruction. Coughing is likely to set off a chain of events that can reduce the airway to a critical size and even total obstruction. For these two reasons, anaesthetic management plans for the airway are, in practice, not modelled on those traditionally advocated for upper airway obstruction.

The 'can't intubate—can't ventilate' scenario has occurred only once in this cohort of patients and in the significant body of those with similar conditions requiring anaesthetic intervention.[8] On that solitary occasion, both a significant upper airway problem and subglottic stenosis were present in the same patient. 'Can intubate (with a bronchoscope)—with potential for can't ventilate' has been, virtually invariably, the worst-case scenario faced. Therefore, it has been concluded that local anaesthesia approaches for securing airways and gaseous inductions are usually contraindicated as, with either, the risk of precipitating a life-threatening coughing fit is very high. This advice could be qualified in the light of the introduction of sevoflurane into clinical practice.[42 44] It is now possible to induce anaesthesia without sufficient irritation of the airways to provoke coughing but, in this patient population, the margin for error is small and there are no suitable surgical airways to deal with a consequent total airway obstruction.

Specimen philosophy and technique

Much experience of handling these cases has been learnt from using lasers in the airway.[8] Standard local policy is

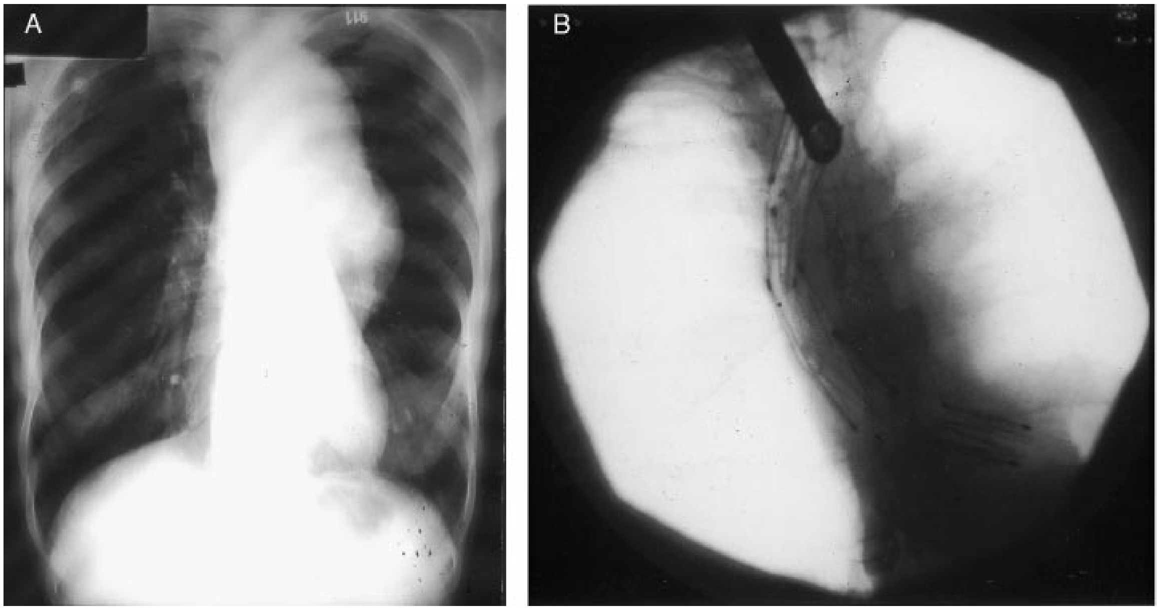

Fig 5 Plain chest x-ray (A) and operative post-stent tomogram (B) of a 77-yr-old patient with severe tracheal obstruction resulting from an inoperable, near-rupture arch of aorta aneurysm. (B) Trachea and left main bronchus distal to the tip of the rigid bronchoscope, rendered patent by five Gianturco stents.

that insertion of a rigid bronchoscope is the first line of management. This secures and maintains the airway while intelligence as to how to proceed is garnered at leisure from a well-protected, securely ventilated and oxygenated patient. The technique caters for the sicker cases as the single most stimulating effect—that of inserting rigid instrumentation and any subsequent pressor response—is ablated by using the modern agents in the way detailed. In principle, the technique has altered little over many years, except for the use of more specific pharmacological agents as and when they became available. Thus, propofol replaced etomidate; remifentanil infusions replaced alfentanil, which in turn had replaced fentanyl and phenoperidine; and mivacurium has ended the need for succinylcholine by bolus and infusion.[8] Target-controlled total i.v. anaesthesia (TIVA) is recommended for those unfamiliar with the field, but current local procedures, based on simple infusion devices, empiricism, simple non-invasive monitoring, and experience, have proved more than adequate to safely manage cases of the kind illustrated in Figure 5.

Initially, a small dose of glycopyrrollate (0.2–0.3 mg) is administered. This is to counter the vagotonic effect of remifentanil and the vasovagal effect of rigid bronchoscopy, and does not make the bronchial secretions too viscid. After midazolam 2–4 mg, a remifentanil infusion (5 mg in 50 ml normal saline) is started at 20 ml h^{-1} and reduced to a maintenance rate of 5–10 ml h^{-1}. After a sleep dose of propofol, mivacurium 16–20 mg is administered, followed by a propofol infusion. TIVA is supplied by continuing the remifentanil and propofol infusions at a rate that maintains normal pulse rate and blood pressure. Ventilation is conducted initially by hand, with a Mapleson C system. Although the use of forceful and forced inspiration is necessary at times, only extremely rarely has it proved impossible to ventilate at this stage. There is much more danger of resistance to expiration occurring, with the consequence of air trapping being added to the hazards of induction, as a result of over-enthusiastic attempts to create ventilation.[2]

Once muscle paralysis has occurred, a rigid bronchoscope is inserted. A purpose-built jet ventilator, driven by oxygen 100% and developed on the principle of the Sanders technique, is attached to the ventilation port of the bronchoscope and set on automatic.[29] The inspiratory and expiratory controls are set to provide visible and appropriate tidal ventilation. The airway having been secured and maintained, the conduit is then free for the introduction of equipment for end-tidal carbon dioxide monitoring, lasers, balloons, stents and jet ventilation, or for access for dealing with emergencies such as retention of foreign material, aspiration, haemoptysis and distal total obstruction. The ventilator is switched to be driven from an air source if lasers are to be used as part of the procedure.

Alternative techniques

Advances in anaesthesia and airway management and the revolution in fibreoptics have meant that almost any of the standard techniques can be used. Many of the dilemmas facing anaesthetists of past generations do not apply. The advent of self-expanding stents has made it possible for the procedure to be conducted on an awake patient with local anaesthesia, or with TIVA and a variety of other airway-securing devices and techniques, including intermittent tracheal intubation, a laryngeal mask airway (LMA[†]) as a conduit for instrumentation, and ventilating bronchoscopes.[6 9 12 19 20 21 43]

LMAs have increased the number of options for safe anaesthesia and access to the upper airway, and for the insertion of ventilation conduits, such as small-bore catheters through stenoses. But limitations may be set by distal lesions and the type of instrumentation required to facilitate stent insertion or extraction. The patient can be self-ventilating with a volatile anaesthetic or given neuromuscular blocking agents and ventilated with positive-pressure ventilation of various modes, including jet ventilation and high-frequency ventilation, applied with various fine-bore conduits.[6 19 21 43] At the other end of the spectrum of complexity is the use of cardiopulmonary bypass, realistically only sensible in those with benign lesions in whom the potential for total airway obstruction is significant, and which in emergency situations is reported as successful only rarely.[14 21 35]

Authors naturally advocate the technique of securing and servicing the airway with which they are most comfortable and experienced. However, the main disadvantage of the alternatives to the specimen method relates to the handling of complications, which are frequent, sudden and life-threatening. Although the diagnosis of a problem can be made with fibreoptic bronchoscopes and some suction clearance can be conducted, the presence of a rigid bronchoscope is the only sure way of ensuring distal oxygenation and access for the necessary instrumentation at the same time.

Reversing the anaesthetic

Usually, this is more difficult than induction. In our experience, 5–10% of patients require a lot of support through this phase. Stent insertion may not produce immediate relief, and the whole process may down-grade the patients' fitness. However, the commonest problem experienced at this juncture has been the development of a type of acute central airway obstruction.

Acute postoperative central airway obstruction

Clinical presentation

Characteristically, the patient fails to re-establish effective spontaneous ventilation, and has a clinical appearance reminiscent of recurarization, for which the condition may well be mistaken. Respiratory effort is minimal and largely abdominal. Consciousness, initially lightening, becomes obtunded, so that there appears to be little distress and no ability to cough. Cardiovascular deterioration follows, with pallor, peripheral oxygen desaturation, hypotension and cardiac dysrhythmias.

Laboratory findings

In those cases in which blood gases have been done, the invariable finding, besides hypoxaemia, has been hypercapnia [$Pa_{CO_2} \geqslant 10$ kPa (12–18 kPa, local findings)], almost certainly secondary and responsible for the clinical picture of consciousness deterioration and areactivity.

Diagnosis

This clinical picture is acute central airway obstruction until proved otherwise: the only other condition that has ever appeared similar, albeit much rarer, is tension pneumothorax after a traumatic stent insertion. This is the end result of obstruction in the lower third of the trachea or, more usually, at the level of the carina, in which case the major bronchi may also be obstructed. The most common cause is glutinous secretions, but it can be because of secretions released from previously obstructed bronchi, a malfunctioning stent, blood clot, tissue slough (if laser treatment preceded stent insertion) or stent blockage.

Treatment

Tracheal intubation, positive-pressure ventilation and suction may be life-saving but are not curative. Rigid bronchoscopy is required urgently. Consciousness is so obtunded that these various manoeuvres can be conducted without the use of induction agents and neuromuscular blocking agents, but usually a small dose of induction agent, etomidate or propofol, is administered first. Suction clearance of material in the trachea and adherent to the carina or stents, and some hyperventilation, usually results in a rapid and dramatic improvement in the quality of tidal spontaneous ventilation.

Prophylaxis

Such a scenario was so commonly experienced that now it is local practice and teaching to leave the rigid bronchoscope *in situ* until the patient virtually coughs it out. A useful end-point to signal suitability for discharge to a recovery unit is the presence of all parts of the cough reflex: that is, deep non-stridulous inspiration, active closure of the glottis and an explosive expiration that is free of sounds of laryngeal spasm and that clears secretions.

[†]LMA® is the property of Intavent Limited.

Complications of stents

Stent malposition is not uncommon and is usually treated by insertion of a second or even third stent: some patients have a mixture of types within large parts of the airway. Occasionally, balloon dilatation of the stent may be attempted. Extraction of a broken stent or a badly positioned one can be a long and tense procedure. Under such circumstances, the anaesthetic technique recommended above is often shown to its best advantage.

Apart from the occasional loss of control of the airway as a result of the stent malfunctioning, being malpositioned or disintegrating, and which has produced short-lived but total obstruction, there has only been the tension pneumothorax mentioned earlier and one major perioperative surgical incident in this series. Unlike earlier laser series, there are no immediate perioperative deaths.[8 26]

Airway laceration, total airway obstruction, tracheobronchial wall perforation, stent breakage and erosion into the mediastinum or great vessels are all reported as sequelae to the placement of stents, and are often catastrophic. Many of these have required either interventional radiology or major surgery for cure.[1 15 21 24 26 30 35]

A recent local audit of one type of stent and one surgeon's experience (M. Blacking, S. Barnard, personal communication) reflects the palliative nature of the stenting process. Two-thirds of deaths occurred within 10 weeks of the procedure, and in a subgroup of patients in the terminal stages of cancer. All patients within the benign subgroups were alive.

Conclusions

It is evident that stent insertion is an increasing workload, and locally is fast approaching a weekly exercise. Patients need a lifetime of follow-up and much servicing of the airway. In providing a stenting service and in order to deal with complications, it is necessary to be able to proceed to balloon dilatation and thoracotomy and, on occasion, to have access to cardiopulmonary bypass facilities, even though these have rarely had a successful outcome.

Although it is the period after anaesthesia that has proved the most problematical, it is induction of anaesthesia where practical experience has shown that the models of upper airway obstruction (e.g. epiglottitis, lingual tonsils, supralaryngeal tumours) are not usually appropriate as anaesthetic management templates for central airways obstruction. I.V. induction and tracheal intubation after full neuromuscular block has proved most efficient and safe for central airway obstructive conditions.

Locally, three patients with central airway lesions have now been attending for more than 15 yr, requiring between them more than 50 interventions under general anaesthesia. Perhaps it is a tribute to the advocated techniques that anaesthesia has not been the worst part of their ordeals and has proved adequate and safe for cases of the kind illustrated in Figure 5.

Acknowledgement

I am grateful to Dr M. L. Paes and Dr B. G. Watson (retired), consultant cardiothoracic anaesthetists, who, over the years, have shared the burden of setting up an anaesthetic service for central airway stenting, and to Mr S. Barnard, consultant thoracic surgeon, and Ms M. Blacking, stage 4 medical student, for some data.

References

1 Alfaro J, Varela G, De-Minguel E, *et al.* Successful management of a tracheo-innominate artery fistula following placement of a wire self-expandable tracheal Gianturco stent. *Eur J Cardiothorac Surg* 1993; **7**: 615–16
2 Biro P, Layer M, Becker HD, *et al.* Influence of airway-occluding instruments on airway pressure during jet ventilation for rigid bronchoscopy. *Br J Anaesth* 2000; **85**: 462–6
3 Boyd AL, Brown BR. Fiberoptic bronchoscopic placement of self-expandable metallic airway stents for the treatment of tracheobronchial obstruction and fistulas. *J Oklahoma State Med Assoc* 1999; **92**: 568–72
4 Burden RJ, Shann F, Butt W, *et al.* Tracheobronchial malacia and stenosis in children in intensive care: bronchograms help to predict outcome. *Thorax* 1999; **54**: 511–17
5 Callanan V, Gillmore K, Field S. The use of magnetic resonance imaging to assess tracheal stenosis following percutaneous dilatational tracheostomy. *J Laryngol Otol* 1997; **111**: 953–7
6 Catala JC, Pedrajas FG, Carrera J, *et al.* Placement of an endotracheal device via the laryngeal mask airway in a patient with tracheal stenosis. *Anesthesiology* 1996; **84**: 239–40
7 Colt HG, Harrell JH. Therapeutic rigid bronchoscopy allows level of care changes in patients with acute respiratory failure from central airways obstruction. *Chest* 1997; **112**: 202–6
8 Conacher ID, Paes ML, McMahon CC. Anesthetic management of laser surgery for central airway obstruction. *J Cardiothor Vasc Anesth* 1998; **12**: 1–5
9 Dasgupta A, Dolmatch BL, Abi-Saleh WJ, *et al.* Self-expandable metallic airway stent insertion employing flexible bronchoscopy. *Chest* 1998; **114**: 106–9
10 Ducic Y, Khalafi RS. Use of endoscopically placed expandable nitinol tracheal stents in the treatment of tracheal stenosis. *Laryngoscope* 1999; **109**: 1130–3
11 El-Baz N, Holinger L, El-Ganzouri A, *et al.* High frequency positive pressure ventilation for tracheal reconstruction supported by tracheal T tube. *Anesth Analg* 1982; **61**: 796–800
12 Filler RM, Forte V, Chait P. Tracheobronchial stenting for the treatment of airway obstruction. *J Pediat Surg* 1998; **33**: 304–11
13 Grillo HC, Donahue DM. Postintubation tracheal stenosis. *Chest Surg Clin North Am* 1996; **6**: 725–31
14 Guha A, Mostafa SM, Kendall JB. The Montgomery T-tube: anaesthetic problems and solutions. *Br J Anaesth* 2001; **87**: 787–90
15 Ishikawa S, Yoshida I, Otani Y, *et al.* Intratracheal stent intubation under extracorporeal lung assist. *Surg Today* 1995; **25**: 995–7
16 Jacobs JP, Quintessenza JA, Botero LM, *et al.* The role of airway stents in the management of pediatric tracheal, carinal and bronchial disease. *Eur J Cardiothorac Surg* 2000; **18**: 505–12
17 Mather CM, Sinclair R, Gurr P. Tracheal stents: the Montgomery T-tube. *Anesth Analg* 1993; **77**: 1282–4

18 Martinez-Ballarin JL, Diaz-Jimenez JP, *et al*. Silicone stents in the management of benign tracheobronchial stenoses. *Chest* 1996; **109**: 626–9

19 McRae K. Anaesthesia for airway surgery. *Anesthesiol Clin North Am* 2001; **19**: 497–541

20 Milner QJW, Abdy S, Allen JG. Management of severe tracheal obstruction with helium/oxygen and a laryngeal mask airway. *Anaesthesia* 1997; **52**: 1087–9

21 Narang S, Harte BH, Body SC. Anaesthesia for patients with a mediastinal mass. *Anesthesiol Clin North Am* 2001; **19**: 559–79

22 Nesbitt JC, Carrasco H. Expandable stents. *Chest Surg Clin North Am* 1996; **6**: 305–28

23 Neville WE, Bolandowski PJ, Kotia GG. Clinical experience with silicone tracheal prosthesis. *J Thorac Cardiovasc Surg* 1990; **99**: 604–12

24 Niwa H, Masaoka A, Yamakawa Y, *et al.* Esophageal tracheobronchoplasty for membraneous laceration caused by Dumon stent. *Eur J Cardiothorac Surg* 1995; **9**: 213–5

25 Noppen M, Schlesser M, Meysman M, *et al.* Bronchoscopic balloon dilatation in the combined management of postintubation stenosis of the trachea in adults. *Chest* 1997; **112**: 1136–40

26 Nouraei SM, Pillay T, Hilton CJ. Emergency management of aorto-bronchial fistula after implantation of a self expanding bronchial stent. *Eur J Cardiothorac Surg* 2001; **20**: 642–4

27 Obana N, Komatsu K, Komoda S, *et al.* The anesthetic management of tracheal T-tube exchange using Patil–Syracuse mask. *Jpn J Anesthesiol* 1999; **48**: 386–9

28 Pagliero KM, Shepherd MP. Use of stainless steel wire coil prosthesis in treatment of anastamotic dehiscence after cervical tracheal resection. *J Thorac Cardiovasc Surg* 1974; **67**: 932–5

29 Paes ML Conacher ID, Snellgrove TR. A ventilator for carbon dioxide laser bronchoscopy. *Br J Anaesth* 1986; **58**: 663–9

30 Puma F, Farabi R, Urbani M, *et al.* Long term safety and tolerance of silicone and self-expandable airway stents. *Ann Thor Surg* 2000; **69**: 1030–4

31 Rafanan AL, Mehta AC. Stenting of the tracheobronchial tree. *Radiol Clin North Am* 2000; **38**: 395–408

32 Sabnathan S, Mearns AJ, Richardson J. Self-expanding tracheobronchial stents in the management of major airway problems. *J R Coll Surg Edinb* 1994; **39**: 156–61

33 Scherer TA. Nd YAG laser ignition of silicone endobronchial stents. *Chest* 2000; **117**: 1449–54

34 Shah R, Sabanathan S, Mearns AJ, *et al.* Self expanding tracheobronchial stents in the management of major airway problems. *J Cardiovasc Surg* 1995; **36**: 343–8

35 Scherhag A, Hafner B, Dick W, Mann W. High-frequency jet ventilation for placing tracheal stents—a case report. *Anaesthesiol Reanim* 1999; **24**: 164–6

36 Sherry KM, Keeling PA, Jones HM, *et al.* Insertion of intratracheal stents. *Anaesthesia* 1987; **42**: 61–6

37 Sheski FD, Mathur PN. Long-term results of fiberoptic bronchoscopic balloon dilation in the management of benign tracheobronchial stenosis. *Chest* 1998; **114**: 796–800

38 Song HY, Shim TS, Kang SG, *et al.* Tracheobronchial strictures: treatment with a polyurethane-covered retrievable expandable nitinol stent. *Radiology* 1999; **213**: 905–12

39 Sonett JR, Keenan RJ, Ferson PF, *et al.* Endobronchial management of benign, malignant and lung transplantation airway stenosis. *Ann Thorac Surg* 1995; **59**: 1417–22

40 Spittle N, McCluskey A. Tracheal stenosis after intubation. *Br Med J* 2000; **321**: 1000–2

41 Susanto I, Peters JI, Levine SM, *et al.* Use of balloon expandable metallic stents in the management of bronchial stenosis and bronchomalacia after lung transplantation. *Chest* 1998; **114**: 1330–5

42 Teh J, Platt H. Inhalational induction with sevoflurane in central airway obstruction. *Anaesth Intensive Care* 1994; **26**: 458–9

43 Van de Putte P, Martens P. Anaesthetic management for placement of a stent for high tracheal stenosis. *Anaesth Intensive Care* 1994; **22**: 619–21

44 Watters MP, McKenzie JM. Inhalational induction with sevoflurane in an adult with severe complex central airways obstruction. *Anaesth Intensive Care* 1997; **25**: 458–9

45 Weber AL. Radiologic evaluation of the trachea. *Chest Surg Clin North Am* 1996; **6**: 637–73

46 Wood DE, Reynolds B, Vallières E. Percutaneous placement of tracheal T tube. *Ann Thorac Surg* 1998; **65**: 557–8