Chapter 32: Tracheostomy and decannulation

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A tracheostomy involves the construction of a channel between the trachea and the skin surface of the neck in the midline. With time, this channel may acquire an epithelial lining and may then qualify in pathological parlance as a 'fistula'. The alternative spelling of 'tracheotomy' is often employed by etymological discussion is best avoided and in this chapter the more traditional 'tracheostomy' is preferred. The operation is performed at all ages but there are significant differences between children and adults because of the smaller structures involved and the degree of immaturity which may be present in children. With medical progress, the emphasis on these differences becomes greater as the operation is performed on the infant, the neonate and now the preterm neonate.

Historical

Historical accounts of this operation vie with each other in plumbing the depths of antiquity for plausible evidence (Goodall, 1934; Salmon, 1957; Nelson, 1958; Frost, 1976). The operation has been attributed to various oriental potentates who employed the sword as scalpel and hazy descriptions have been given by certain medico-philosophers. No doubt, some fossil-find, decorated potsherd or deciphered hieroglyphic will eventually push its origins even further into prehistory.

Since the Renaissance, this life-saving operation has been better described and certain trends become apparent. Initially, it was performed for choking, caused either by an inhaled foreign body, drowning or trauma to the upper respiratory tract. Indeed, the first successful tracheostomy in a child was reported in 1766 by Caron, a French surgeon who removed an inhaled bean from a 7-year-old boy. Later a common indication was 'croup', a label given by a Scottish physician, Francis Home (Home, 1765) to the combination of sore throat and stridor. Some of these patients would probably have suffered from laryngotracheobronchitis, but more probably from 'diphtheria', a term coined later by a French physician, Pierre Bretonneau. Indeed, the term 'croup' is still reserved exclusively for diphtheria in many parts of western Europe. In the nineteenth century, tracheostomy became widely used in the treatment of diphtheria in children and, by 1998, some 20,000 such operations had been reported in western Europe and the USA. About this time, intubation became a feasible alternative with the appearance of the O'Dwyer tube and the discovery of diphtheria antitoxin in 1895 hastened the demise of diphtheria as the pre-eminent indication for childhood tracheostomy. However, the operation continued to be carried out for various forms of upper respiratory obstruction, although the notoriety resulting from a 30% survival rate caused many parents to refuse the operation. The employment of tracheostomy for the removal of bronchial secretions is a relatively recent innovation and it was first described by Galloway in patients with bulbar poliomyelitis. Subsequently a similar approach was taken for chronic chest disease. The poliomyelitis epidemics of the early 1950s stimulated the use of tracheostomy for positive pressure respiration and this opened the doors for similar treatment in tetanus, cardiac surgery, severe burns and, most recently, the care of the preterm infant. The introduction of active immunization against diphtheria in 1940 and poliomyelitis in 1956 almost eliminated these diseases and left epiglottitis and laryngotracheobronchitis as the principal indications for tracheostomy in children. Over the last 20 years, intubation has taken
over as the treatment of choice in these conditions and the frequency of tracheostomy has, therefore, decreased dramatically in the developed world. In the last decade, the increased skills of the neonatologists have permitted the increased survival of the very preterm infant with its concomitant multiple problems. These infants require prolonged ventilation and the resulting subglottic stenosis and failure of extubation necessitates tracheostomy. However, even in these infants, the need has again decreased as the neonatologists have become more adept in avoiding subglottic trauma.

The historical vista of tracheostomy depicts a life-saving operation which becomes superseded as some less traumatic treatment becomes available. It remains a life-saving operation, but with the associated improvements in anaesthesia, antibiotics and surgical technique, the morbidity and mortality of the operation have been greatly reduced.

**Anatomy and physiology**

In the child, the air passages are both absolutely and relatively smaller than in the adult (Tucker and Tucker, 1979). The cervical trachea usually lies in the midline of the neck and its length varies with body build and the degree of extension. The distance from the cricoid to the suprasternal notch varies from 2.5 cm in neonates to 6.0 cm in the 10-year-old child, but in short, heavy individuals, the cricoid cartilage may be sited almost within the suprasternal notch. The larynx is higher in the child and the cricoid cartilage lies at the level of the third cervical vertebra in the infant and descends to the sixth cervical vertebra at puberty. Since the thyroid cartilage does not take on its adult configuration until adolescence, the larynx is not easily palpable in the infant and the cricoid may be the easiest landmark to identify. The trachea is softer and lies nearest the skin at the cricoid, but it becomes deeper as it approaches the thoracic inlet. The thyroid isthmus varies in size but crosses the trachea at the second, third and fourth tracheal rings. The recurrent laryngeal nerves lie laterally and a pretracheal pad of fat is generally present in the suprasternal notch in infants. In extension, the mediastinal contents may enter the neck so that the surgeon may encounter a high pleural dome, large vessels crossing the midline and, rarely, the thymus. The articulation between the head and neck is considerably more mobile in infants and the chin may easily deviate from the midline during surgery.

The trachea provides an air passage between the larynx and the lungs. Since it needs to maintain its lumen and to remain flexible, it is constructed of incomplete cartilaginous rings. It is lined by respiratory mucosa which continues the process of warming and humidifying the inspired air, and the cilia waft the mucous blanket upwards towards the larynx. The larynx is a valvular mechanism which allows the passage of air but normally denies access to solids and fluids. It also provides a defence mechanism in the form of the cough reflex and it has been adapted to a sophisticated degree for the production of sound.

**Indications for tracheostomy**

The indications for tracheostomy in the past have been largely usurped by the indications for intubation and a tracheostomy may only become necessary when intubation is no longer feasible. In general the indications are conveniently placed in three groups as in the adult, although the specific details are different in the child.
**Airway obstruction**

Obstruction or the threat of obstruction to the upper respiratory tract is an indication for tracheostomy. Apart from laryngeal and subglottic lesions, indications include physical trauma to the face, jaws, oral and pharyngeal cavities as well as burns by corrosive chemicals or the inhalation of smoke or gases.

**Dead space and secretions**

Tracheostomy is indicated for improved respiration where a reduction in dead space or the removal of bronchial secretions is considered to be advantageous. This situation is found in chronic lung disease and in certain neonatal chest conditions.

**Ventilation**

The provision of prolonged positive pressure ventilation where voluntary or spontaneous respiration is not possible indicates tracheostomy. The patient with poliomyelitis, tetanus or brain damage may require such assistance, as also will the child with a damaged chest wall. Positive pressure ventilation is also employed as an adjunct to cardiac surgery or in the cases of severe burns and the preterm neonate.

In the first and last groups, intubation may be employed in the short term but, for prolonged treatment, the tracheostomy becomes easier to manage. Until recently, intubation was only employed for periods of up to 3 weeks, but improvements in technique now permit intubation for periods of several months. A tracheostomy, therefore, becomes a necessity whenever prolonged endotracheal intubation poses the threat of laryngotracheal injury.

Several authors have recently reviewed their indications for tracheostomy over the last 10-15 years (Cohen et al, 1977; Rodgers, Rook and Talbert, 1979; Tepas et al, 1981; Gerson and Tucker, 1982; Wetmore, Handler and Potsic, 1982; Carter and Benjamin, 1983; Line et al, 1986; Swift and Rodgers, 1987). There is no purpose in quoting the precise statistics from these reviews because they reflect the different patterns of referral to the centres concerned. Rapid changes have also occurred over the last 15 years and the indications will vary with the precise period under review. The specific indications are, therefore, described below in general terms and in order of decreasing frequency.

**Congenital laryngeal abnormalities**

Although there are variations as described above, this group now accounts for the largest proportion of tracheostomies. In one series (Carter and Benjamin, 1983) laryngeal webs and subglottic haemangiomata account for most cases within this group, but this is unusual and the unit in question attracts these cases from a large area. Bilateral vocal cord paralysis is generally found to be the most common single indication, while congenital subglottic stenosis and cysts come next in frequency. Laryngomalacia or supraglottic floppiness is by far the most common laryngeal abnormality, but tracheostomy is very rarely required for its treatment.
Prolonged ventilation

Trauma to the head or chest continues to be common and is even increasing. Eventually it may, therefore, be the most common indication for tracheostomy. Tetanus occurs intermittently and is still very common in some large rural areas (Mukherjee, 1979). Poliomyelitis has largely been eliminated in the developed world, but continues to be a threat elsewhere.

Supralaryngeal obstruction

This may be present or threatened and is commonly seen in conditions such as the Pierre Robin syndrome, severe sleep apnoea and craniofacial surgery. Advances in the surgical treatment of congenital facial abnormalities are making tracheostomy more common in this latter group.

Acquired laryngeal abnormalities

Ten years ago, acquired subglottic stenosis would have been one of the most common indications for tracheostomy because of the increased resuscitative skills of the neonatologist. Although it is still a very significant problem in those units which attract the worst problems of this nature (Black, Baldwin and Johns, 1984; Quiney et al, 1986), improved intubation skills have in general reduced the necessity for tracheostomy. Indeed, in one series (Carter and Benjamin, 1983), no tracheostomies were performed for acquired subglottic stenosis over a period of 10 years, although some 300 infants were intubated annually in the associated neonatal and intensive care units. Those authors attributed this remarkable success to the use of small-diameter (2.5 or even 2.0 mm) polyvinylchloride (PVC) nasotracheal tubes. Other centres receive patients from areas where such expertise may not be available.

Laryngeal papillomatosis as a cause of tracheostomy is also on the decline. The need in this condition is dictated not only by the virulence of the causative agent but by the degree of oedema and scarring following treatment. The use of the laser has reduced the postoperative oedema and the frequency of removal and has consequently obviated the need for an alternative airway.

Acute infections

Fifteen years ago, infections of the respiratory tract were the most common indication for tracheostomy, but oro- and nasotracheal intubation has changed all that. Intubation is now widely used for acute epiglottitis and laryngotracheobronchitis, although it makes great demands on medical and nursing facilities and is, therefore, not so available in less developed countries (Mukherjee, 1979; Okafor, 1983; Soni, Chatterji and Thind, 1984), where tracheostomy is still widely employed.

Miscellaneous

This review is necessarily based on trends in the developed world but indications differ elsewhere. Diphtheria is an important acute infection and inhaled foreign bodies are a
common indication, particularly where patients may take several days to reach hospital and, if still alive, will, therefore, have considerable oedema around the impacted object.

**The operation of tracheostomy**

The operation is more common in males because of their increased susceptibility to congenital and acquired disorders. The aim of the operation is to construct an airway into the trachea as safely as possible.

Since the emphasis is on safety, the operation should be carried out in an environment where there is complete control of the airway at all times. There are rare occasions when an emergency tracheostomy is life saving but in the hospital environment, intubation or cricothyroidotomy is preferable when that urgent need arises. The technique of emergency tracheostomy will not be described here since, by definition, the facilities available are unknown, but the aim is to provide an airway as rapidly as possible by whatever means possible.

Since more than half of all paediatric tracheostomies are performed on children below the age of one year, it is essential that the operation is carried out in a paediatric unit or hospital where the nursing and medical staff are accustomed to the care of infants and neonates. Details of the anaesthetic and general care of a neonate will not be included here, although these are obviously of the greatest impact.

The operation should be performed electively in a sterile environment under a general anaesthetic administered through an endotracheal tube. The anaesthetic should be given by an experienced paediatric anaesthetist and the operation should be performed by, or supervised by, an experienced paediatric otolaryngologist.

**Preparation**

Antibiotics are not needed prophylactically but they should be given if there is some medical reason to do so. A sample of sputum should be taken for culture and antibiotic sensitivity in readiness for a possible postoperative infection. Blood loss is minimal during the operation, but since the blood volume of a neonate may be very small it is wise for a sample of blood to be grouped and kept for cross-matching.

The infant, suitably warmed, is laid supine on the operating table. The head is extended to increase the distance between the chin and sternal notch, to smooth out the redundant folds of skin in the neck and to bring the trachea and larynx closer to the skin surface. This is achieved by placing a suitable roll of soft material under the neck and the head is prevented from rolling by using a small head ring. It is important not to overdo the extension as this draws the lower trachea and mediastinal contents into the neck. Not only does this place the lung apices and mediastinal vessels at risk but it may tempt a low tracheal incision, which retreats into the chest on flexion.

The skin of the chin, neck and upper chest is cleaned with a suitable disinfectant and the surrounding area is draped with sterile towels. The chin is left uncovered in order that the surgeon can check the midline and some anaesthetists like to keep the face uncovered. Before
the towels are positioned a little adrenaline (1:80,000 or 1:200,000 if halothane is being used) and local anaesthetic are infiltrated subcutaneously between the cricoid and the sternal notch. This allows the adrenaline to disperse and to exert its vasoconstrictive effect before the incision is made a few minutes later. The local anaesthetic reduces postoperative discomfort. At this stage it is also wise to check that the intended tracheostomy tube is available and that the proper connections are at hand.

**Surgical technique**

Both the vertical and horizontal skin incisions are employed, but there are theoretical and practical reasons for preferring the vertical incision. The horizontal skin crease incision has its supporters in the adult because of the better cosmetic result, but in the infant both incisions are so small that they produce similar scars. The main advantage of the vertical incision is that it runs in the line of the trachea. This is important in the infant since it is often difficult to judge the precise level of the proposed tracheostomy externally and the improved access gives a greater freedom of choice. The midline is also less vascular and for both these reasons the vertical incision is best used by the inexperienced surgeon.

The cricoid cartilage is palpated, often with some difficulty, and a vertical midline skin incision of 1.5 cm is made with the upper end at the level of the cricoid. If a horizontal incision is to be employed, it should be of similar length and sited in a skin crease midway between the cricoid and the suprasternal notch. It is important that the chin and sternal notch are in line when the skin is incised. The bleeding is usually minimal but diathermy should be employed if necessary. An assistant retracts the edges of the incision with a skin hook or small retractor and blunt dissection is carried out in the midline with artery forceps or small scissors. It is important not to open up tissue planes unnecessarily as this encourages surgical emphysema later. As the dissection probes deeper, the assistant repositions the retractors and in this way the strap muscles are separated and the trachea approached. If the surgeon stays in the midline, this procedure can usually be completed without any bleeding, but the degree of difficulty in exposing the trachea varies greatly. Even in the more difficult cases, patient persistence is rewarded as long as the midline is sought and the level of the cricoid checked.

It is difficult to mistake the trachea when it is reached, although the tracheal rings are softer and sometimes a problem to identify an individual tracheal ring and this may be facilitated by exposing the cricoid cartilage and its attached cricothyroid muscle and numbering the rings from that level. The identification of the thyroid isthmus also provides a landmark for the tracheal rings. Although the isthmus varies in width from a tenuous sliver of connective tissue to a more substantial mass, it consistently overlies the second, third and fourth tracheal rings. Some authorities feel that the isthmus should always be cut and sutured (Gerson and Tucker, 1982) in order to facilitate recannulation later, but this is rarely necessary. It is usually simple to free the isthmus from the underlying trachea and to retract it superiorly or inferiorly for the exposure of the relevant tracheal rings. Good access to the trachea is obtained by clearing the fascia from its anterior surface, although care must be taken not to disturb the recurrent laryngeal nerves which lie posterolaterally. The trachea should now be exposed in a small but bloodless field and, after rechecking the tracheostomy tube and its attachments, the anaesthetist is alerted to the imminent incision of the trachea itself.
The tracheal incision

In the adult, there has always been considerable discussion about the best form of tracheal incision but in the infant it is generally agreed that the vertical incision is simplest and best. This is given support by a recent attempt (Fry et al, 1985) to evaluate the relative merits of the vertical slit, the inferiorly based trapdoor and the horizontal H. Using young ferrets as a paediatric model, the authors assessed the tracheal airway after decannulation and healing and demonstrated that the vertical slit resulted in less stenosis and less airway resistance.

It is important that the vertical incision is made at the correct level. If it is too near to the cricoid, it will predispose to subglottic stenosis and the surgeon should, therefore, aim at keeping the upper two tracheal rings intact. Conversely, if the incision is made too low, the tip of the tracheostomy tube may enter the right main bronchus and the tube is more likely to come out accidentally. The tracheal rings are identified again and a vertical incision is made through the second, third and fourth rings. A larger incision should be extended to include the fifth ring. The slit is made from below upwards to avoid damage to the mediastinal contents and it should be made in a controlled manner because a slip will extend the incision into the cricoid. Even in the infant, the tracheal wall is rather thicker than one would suspect but care must be taken not to damage the posterior wall of the trachea with the point of the scalpel. In practice this is most unlikely since the anaesthetist's endotracheal tube lies in the tracheal lumen unless it has become displaced superiorly. There is sometimes a little bleeding from the tracheal mucosa and the perichondrium of the ring, but this is rarely significant.

Some surgeons feel that the procedure is assisted by the insertion of a silk suture, to either side of the midline. Before the vertical incision is made, a black silk suture is introduced to circle the third and fourth tracheal rings on either side. These are left long and initially are held laterally in artery forceps. After the vertical incision has been made between them these sutures are retracted to assist cannulation. Later they are taped to the chest wall for up to one week and may be used for recannulation if necessary. In the author's experience, these sutures are not mandatory since there is rarely any problem in introducing the tracheostomy tube at operation and decannulation is prevented by other means described below. In addition, there is a possibility that the sutures will weaken the anterior tracheal wall and the threads become sodden and something of an obstacle during subsequent care of the tracheostomy.

The anaesthetist now withdraws the endotracheal tube just proximal to the upper end of the incision under the guidance of the surgeon. The trachea is sucked out and a tracheostomy tube of suitable design and size is inserted under direct vision. This is done in a calm, unhurried way since the anaesthetist still has full control of the airway. If any difficulty is experienced in introducing the tube the following points may be helpful. It should be checked that the incision is long enough and stay sutures should be retracted if they are available. If the tube is a metal one then the introducer should be properly in place while, if it is plastic, the ends can be compressed in an artery forceps and inserted through the incision (Pracy, 1979). The tracheostomy tube can also be 'railroaded' down a fine catheter which has been passed through the tube and the tracheal incision.
Unless there is some good reason, a synthetic plastic or silicone tube should be used for the initial intubation. The standard tube used by the author is the Great Ormond Street pattern of the Aberdeen tube made by Franklin, but other models are available and are described below. The standard size used for a 3-month-old baby is the 3.5 mm (internal diameter), but the tube should obviously be measured for the patient in terms of its lumen and length.

The correct position of the tube in the tracheal lumen is checked and the anaesthetist makes the attachments for continued ventilation. Once the anaesthetist is satisfied that both lungs are being ventilated, the endotracheal tube is withdrawn. No sutures are placed in the edges of the skin incision which usually fits comfortably around the tube and a tight fit is to be avoided since it predisposes to surgical emphysema.

The tube is now held in place by suturing the flange to the neck skin and by tying tapes around the neck. The importance of securing the tube cannot be overestimated since accidental decannulation is avoided if it is done properly. Silk sutures are placed through the flange and adjacent skin just lateral to the opening of the tube. This positioning prevents the substantial tube movement which can occur if the sutures are placed towards the tip of the flange. A tape is then tied from one side of the flange to the other around the back of the neck. One end of the tape is knotted to one side of the flange while the other is passed through a piece of tubing of suitable length. This tubing conforms to the convexity of the baby's neck and protects the skin from the rubbing of the tape. The free end of the tape is then knotted to the other end of the flange and is adjusted so that the tube is held firmly, but not tightly, in place. It is most important that these adjustments to the tape are carried out while the neck is in slight flexion. If they are done while the neck is extended, the tube will loosen on subsequent flexion and accidental decannulation will be encouraged. It is, therefore, important that the tape adjustments are made by the surgeon or the anaesthetist and the task should not be delegated to an inexperienced member of the team. Children above the age of 6 months are given sedation, but those younger babies are best left without to discourage apnoeic attacks. The child is now moved from the operating table and care is taken to avoid traction on the tube while this is being carried out.

**Postoperative care**

For the first few days, the child should be in an intensive care unit where there are adequate trained nursing and medical staff on duty for 24 hours of the day. As soon as the infant arrives on the ward, an X-ray of the chest and neck is taken to confirm that the tip of the tracheostomy tube is not so low that it impinges on the carina or enters the right main bronchus. The X-ray may also demonstrate surgical emphysema in the superficial tissues or in the mediastinum. Initially feeding is via the intravenous drip which is established during the operation, but within a few hours, the baby is able to feed by mouth. The maintenance of adequate hydration is important since it contributes to the prevention of tracheal crusting.

If the baby has previously suffered from chronic airway obstruction, the sudden relief may produce apnoea and it may be wise initially to increase the dead space by a suitable attachment. In the preterm baby, positive end expiration pressure may be necessary to maintain lung stability. The chin may also obstruct the stomal opening in the small baby, but
this can be avoided by choosing a suitable tube (as described below), or by inserting a segment of plastic tubing into the opening of the tracheostomy.

Since the tracheostomy has bypassed the nose, it is essential that humidified air is supplied to the infant, but care must be taken to avoid overhumidification. Particle size is not as important as was previously thought but cold humidity is probably best and an ultrasonic humidifier may be necessary to provide a sufficient volume. The glottis is also bypassed by the operation and the cough reflex is therefore lost. The trachea and bronchi respond to the surgical insult by an increase in mucus secretion and, because the cough reflex is lost, suction is essential. Regular aseptic suction is required but the frequency varies and must be assessed by the experienced attendant staff. The suction catheter is inserted without suction and the negative pressure is exerted as the catheter is withdrawn. The size of the catheter is most important. The external diameter of the catheter should be less than half the internal diameter of the tracheostomy tube because, if not, hypoxia or, at worst, lung collapse may occur.

At first a careful watch must be kept for surgical emphysema or pneumothorax but these are unlikely to occur after 12 hours. It is not usually necessary to place a dressing between the peristomal skin and the tubal flanges, but a barrier cream is helpful if skin excoriation threatens.

The parents of the child are encouraged to take an active role in the routine care from the outset. In the neonate, this is important for bonding, but it is particularly important in the older child because speech will now be impossible and a parent must be immediately available for reassurance and communication. Both parents should initially observe the routine procedures of tracheostomy care and should then be supervised in doing it themselves to overcome their natural fear. At this stage they should also be introduced to the idea of contacting one of the relevant parental organizations such as 'Aid for children with tracheostomies'.

One week after the tracheostomy, the track will be well formed. The tube can now be changed although this is not mandatory and it can be left longer if it is clean and well positioned. The first change is best done in the intensive care unit or in the operating theatre where emergency facilities are available. An endotracheal tube, spare tracheostomy tube and tracheal dilators are essential and the change is done after cutting the flange suture by an experienced doctor, whether surgeon or anaesthetist. The tapes are again tied with great care and the position of the tube is checked. The baby can now be returned to a normal ward but only if the staff are accustomed to dealing with a patient with a tracheostomy and are capable of continuing with the training of the parents. Regular aseptic suction and humidification are continued and the necessary equipment is ordered for the home care of the child. Before a return home is contemplated, both parents should be able to change the tracheostomy tube and the surgeon must be happy that they are confident about the routine daily care.

Later, if decannulation has not been achieved, questions will arise concerning the development of speech and the proposed nature of future education. The problem of speech is linked to the type of tracheostomy tube to be used and this is discussed in a separate section below. It is imperative to seek the aid of an experienced speech therapist and every effort must be made to enrol the, otherwise normal, child in a normal school although this may prove to be difficult.
Complications

Since the tracheostomy is now the main route for respiration, any complication which interferes with this route may be fatal. The mortality and morbidity following the tracheostomy itself (as opposed to the associated disease) is now much less than it was 10 years ago (Fearon and Cotton, 1974), although results still vary from different centres. The improvement is attributed to the avoidance of emergency tracheostomies where possible and to the emphasis on basic surgical technique as described above. If these guidelines are followed, complications are infrequent although the vulnerability of the tracheostomized child must never be forgotten. Complications are conveniently considered as being early or late, the dividing line being about one week into the postoperative period. Some problems such as crusting and granulation formation are so common that they may be regarded as the normal consequences of the operation, but if these are exaggerated, they qualify as complications.

Early complications

Apnoea

Apnoeic attacks are more likely to occur in the small infant with chronic airway obstruction. Such a child should not be given postoperative sedation and the dead space can be increased temporarily by a suitable attachment to the tracheostomy tube.

Air in the tissues

A little surgical emphysema is commonly seen immediately after the operation and it may only be recognized on the postoperative X-ray. Usually the emphysema resolves without any treatment but the position of the tube and the tightness of the skin around the stoma should be checked. Pneumomediastinum presents in a similar manner and should be treated in the same way but a pneumothorax is more serious and is treated on its merits. A low tracheostomy predisposes to a pneumothorax and a tight stoma aggravates the situation. Prevention is, therefore, the best form of treatment. The neck should not be over-extended during the operation and blunt dissection in the midline will avoid the opening-up of lateral tissue planes.

Accidental decannulation

This can be a serious complication in the first 2 or 3 days after surgery because the fistula track will not have formed and the slit incision in the trachea will make recannulation difficult. If the tracheostomy has been performed at the right level and the tube has been sutured and taped accurately, it should not occur. In this situation, stay sutures come into their own, but, even in their absence, the experienced staff of an intensive care unit should be able to recannulate or pass an endotracheal tube and the necessary instruments should always be immediately available.

Creation of a false passage

The changing of the tube or its reinsertion following accidental decannulation may lead to the creation of a false passage. It is particularly likely to occur before the track is well

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formed and the tube should not normally be changed until this has occurred. The false passage may lead to obstruction or to a pneumothorax and the position of the tube should always be carefully checked after recannulation.

**Obstruction**

This is obviously a potentially fatal complication. If the tube is the correct length and is positioned correctly, the most common cause is the accumulation of mucus and crusts in the tube or the tracheal lumen and it is best prevented by adequate humidification and suction. Intermittent obstruction by the baby's chin is prevented by a suitable restraining attachment to the tube and this is discussed below.

**Haemorrhage**

Blunt dissection in the midline during the operation will often result in a bloodless field but a little bleeding may occur from the skin edges, the tracheal perichondrium and the tracheal mucosa. Such bleeding is usually trivial and will stop after an hour or two. Serious haemorrhage from the erosion of a large vessel is often fatal but rarely occurs in the first week since the most common cause is secondary infection.

**Chest infections**

Even with strict attention to aseptic technique during suction, pulmonary infections occur, particularly in the infant with previous lung problems. In this latter group, prophylactic antibiotics should be given preoperatively and in all cases the appropriate medical treatment is commenced. The choice of antibiotic is aided by taking a sample of sputum or tracheal aspirate at operation and sending it for culture and sensitivity.

**Late complications**

All the complications mentioned above may occur later but their importance varies. The most common and, therefore, the most important fatal complications, are accidental decannulation and obstruction and these are particularly likely to happen at home.

**Accidental decannulation**

Accidental decannulation at this later stage is less dangerous because the tube can be easily replaced into the established track within a few minutes of decannulation. However, the track can stenose rapidly and tracheal dilators may be required even within 10 minutes of the decannulation. The avoidance of decannulation at home is most important and the parents must be instructed to tie the securing tapes firmly. To counteract the efforts of an active child, it may be necessary to have tapes which are tight enough to mark the neck, but a marked neck is preferable to a decannulated child.

**Obstruction**

This may be caused by a granuloma or by a mucus plug. Granulations almost always appear at the site of the stoma, particularly within the tracheal lumen above the stoma. They
may obstruct the tracheal lumen following elective or accidental decannulation, but may also block the tube or cause bleeding during recannulation. Granulations are very likely to occur when a metal tube is used and this tendency has led the metal tube into disrepute. The characteristics of the various tubes and the management of granulations are discussed below. Obstruction of the tube or the tracheal lumen by a mucus plug is best prevented by adequate humidification and suction. Such humidification is provided by a plastic humidifier in the home but also by a heat-moist exchanger (of which there are several models), which is easily connected to the tube. This latter device allows freedom in the open air without the encumbrance of a standard humidifier and may even permit the child to play in sand under supervision.

Haemorrhage due to the erosion of a large vessel is usually fatal and can only be prevented by the proper positioning of the tracheostomy and by attention to operative technique and the prompt treatment of infection. Haemorrhage and mediastinitis have also been caused by an erosion of the tracheal wall by the tip of a badly positioned tube. Chest infections continue to be more frequent than in the normal child and are treated symptomatically.

Tracheostomy tubes

Every otolaryngologist must have wished many times that an available tracheostomy tube could be modified to suit the problem of the patient in hand. The perfect tube does not exist but successive modifications have occurred with advances in medical knowledge and in the science of materials (Pracy, 1976).

The early tracheostomy tubes were made of bone, rubber or metal and the paediatric tube was a smaller version of the adult model. The tubes were of varying curvature with a flange around the external opening for the attachment of stabilizing tapes. Latterly, these tubes were made of silver and incorporated an inner tube, which was longer than the outer and could be easily removed when blockage occurred. Later a valve was fitted to the tube by Negus to allow inspiration through the tube and expiration through the glottis for phonation. Thirty years ago, Wilson introduced a silver tube for children with a funnel-shaped projection, which could be easily attached to a respirator. This tube also had a window in the shoulder of the outer tube to allow transglottic breathing prior to decannulation. The addition of a window and a valve to the inner tube produced the Alder Hey tube, which has been widely used in the UK for many years.

A great advance was made with the discovery of flexible plastics such as polyvinylchloride and silicone rubber. Since several of these are thermoplastic, the initial curvature of the tube is not so important because the shaft conforms to the shape of the track as the material warms. Unfortunately, the wall of these tubes needs to be thicker in order to preserve sufficient rigidity. This reduces the size of the lumen and makes the use of an inner tube impracticable in the smaller, paediatric models. The theoretical characteristics of an ideal tube are discussed in detail elsewhere (Pracy, 1976), but a few factors are summarized here. The design of the tube should permit an optimum flow of air, a situation which is favoured by a shorter shaft, a greater radius of curvature and a smooth inner surface (Yung and Snowdon, 1984). The material should be non-toxic and should possess minimal tissue reactivity demonstrated by implantation tests. It is probable that various chemicals are leached
out from these plastic tubes while they are in use and that their tissue reactivity changes. However, it is no known if, or how rapidly, these occurs and, therefore, how long to leave a tube in place before disposing of it (G. H. Bush, 1986, personal communication).

There are also desirable practical considerations. The tube should be comfortable, easy to clean and easy to change. It must be easily connected to ventilation equipment and attachments should fulfil standard international requirements. At present it is agreed that the external opening of the tube, known as the collar, should have an internal diameter of 15 mm. In babies and small children it is helpful to have a projection from the opening of the tube, a chin restrainer, which will prevent the chubby chin of the baby from occluding the tube. It would also be most desirable if the measurements of the tubes were easily accessible and expressed clearly. The choice of an ideal tube would be facilitated by a knowledge of the internal and external diameters of the tube and the length of the shaft. In practice there are two groups of tubes: the metal tubes and the synthetic tubes. The characteristics of those in common use are described.

**Metal tubes**

The Alder Hey tube is typical of this group and is described above. It has an inner tube which means that it is easily cleaned and it inspires confidence in the inexperienced parent who, initially, does not need to change the complete tube. It has a large radius of curvature and its smooth surface encourages laminar air flow (Yung and Snowdon, 1984). Both the inner and outer tubes are fenestrated and a valve is available to allow transglottic expiration and speech. Similar, but not identical, paediatric metal tubes are those of Jackson and Holinger, but all are durable and may last for several years.

There are also disadvantages. They are said to be less comfortable than the synthetic tubes and cosmetically they are less satisfying. The edges of the fenestra and the shaft-tip are sharp and it is the impression of the author and others (Quiney et al, 1986) that granulations are more likely to occur in the trachea and around the stomal skin. The tracheal granulations are sited above the stoma, at the level of the tube tip and at the level of the fenestra on the posterior wall. The fenestrated tube was designed for transglottic air flow. This was thought to be of major importance for the continued development of the child's larynx, as a prelude to decannulation (Pracy, 1976) and in the production of speech. This theory of laryngeal development is no longer thought to be true and it is now known that an adequate air flow through the glottis can be achieved by employing a smaller tube. In addition, it has proved difficult to site the fenestra at a suitable point on the curvature. The tube sits differently in different patients and the opening of the fenestra often impinges on the posterior tracheal wall.

**Synthetic tubes**

Those commonly used in the UK are the Franklin tube of Great Ormond Street pattern, the Portex paediatric tube and the Shiley paediatric or neonatal tube. The Great Ormond Street tube is a winged tube which sits comfortably on the infant neck. Its external opening does not project and lies flush with the winged flanges. The outer section of the lumen expands to an opening of constant size and this is convenient for the attachment of anaesthetic or ventilation equipment. An attachment is now available which provides a projecting connector of international standard diameter. This projecting connection doubles as a chin restrainer but,
if no such attachment is available, a suitable length of tubing can be inserted to achieve the same effect.

The Portex tube is not winged but it has square-ended flanges and a projecting collar connector of international standard dimensions. This connector is sometimes found to be rather bulky. Unlike the Great Ormond Street tube it does not have a bevelled tip and it is, therefore, a little more difficult to introduce through a vertical slit in the trachea. The quoted size of this and the Great Ormond Street tube refers to their internal diameter.

The Shiley tube comes in a paediatric or neonatal size. It has a large winged flange with a standard projecting connector and both structures make an effective chin restrainer. A recent investigation (Yung and Snowdon, 1984) into the respiratory resistance of these tubes showed that resistance to air flow was greater in the Shiley tube owing to the rougher inner surface. However, it is doubtful whether this is of practical importance.

Although the metal tubes still have their use, many practitioners (Line et al, 1986; Quiney et al, 1986) including the author have virtually ceased to use them routinely over the last 2 years. The synthetic tubes are cosmetically better and parents seem to have little trouble in cleaning them and changing them. Obstruction of the tube at home is the most common fatal complication, but it does not appear to be more common with the use of synthetic tubes. Indeed, the standard connectors now available for the synthetic tubes allow the attachment of a heat-moist exchanger with consequent avoidance of dry mucoid plugs. Until recently the metal tubes were valuable in the provision of speech by means of the fenestra and the valved inner tube. However, an effective phonation valve as made by Rusch is now available and can be simply attached to a standard connector. The use of a tube of lesser diameter provides an adequate expiratory flow through the cords.

**Decannulation**

It is always hoped that any child with a tracheostomy will eventually be decannulated. The outcome obviously depends upon the original lesion, but fortunately many resolve either spontaneously or with medical and surgical treatment. The time comes when the airway appears to be adequate and it is felt that the patient will manage without the tracheostomy. However, it is well established that the removal of the tracheostomy tube in these circumstances may still result in problems and it is these which are discussed below.

**Assessment before decannulation**

Children with tracheostomies may be in hospital or at home but in both situations they are seen at regular intervals and assessed clinically. The child should appear to be well and show no sign of aspiration during eating and drinking. It should be noted that he has a good voice or cry in the absence of a valved tube and the temporary occlusion of the tube with the finger permits respiration to continue adequately through the glottis. Radiography and particularly xerography of the larynx and trachea will demonstrate any narrowing of the airway and a picture taken during temporary extubation may be particularly helpful. A method for physiological assessment has been described (Mallory et al, 1985) whereby the peak inspiratory flow through the tracheostomy tube is compared with that through the mouth and the authors considered this to be useful. Lastly, endoscopy is carried out and the larynx,
trachea and bronchi are examined with special attention to the sites of the original lesion and the tracheal stoma. The lumen of the subglottis is also measured by the passage of an endotracheal tube of known diameter and the vocal cords are observed for normal movement towards the end of the anaesthetic.

It is advisable to carry out such endoscopic examinations at least every 6 months because a tracheostomy carries a morbidity and mortality rate which justifies decannulation as soon as it is feasible.

In most cases, this assessment will lead to a definite decision with regard to decannulation but there will be some where considerable doubt will remain. The child may suffer from recurrent chest infections or the lumen of the subglottis may be smaller than was expected. There are occasions when the presence of a tracheostomy predisposes to chest infections and to adjacent subglottic oedema. This latter finding is more significant when there is a mild congenital subglottic narrowing which had not previously been diagnosed. In these borderline cases, a trial of decannulation may be necessary.

When the endoscopy is carried out, a suprastomal granulation of varying size is nearly always seen on the anterior tracheal wall. Indeed, this finding is so common that it should be regarded as a normal consequence of tracheostomy rather than as a complication. The suprastomal granulation, which may be mixed with fibrous tissue, is more likely to be present with a long-standing tracheostomy but a substantial granulation can be present after only one week. In the infant, even a small granulation causes a significant blockage of the lumen and it should be removed endoscopically or surgically through the stoma. Endoscopically, the granulation is removed with microscopic cup forceps, diathermy, cryosurgery or the laser. Through the stoma, the granulation is removed at the time of the endoscopy (Reilly and Myer, 1985) or during surgical decannulation as described below. Varying degrees of anterior tracheal wall collapse may also be noted above the stoma at endoscopy.

**The decannulation procedure**

Broadly speaking, decannulation may be performed in two ways. The most common method is to remove the tube and to allow the track to close down and heal. The alternative is to excise the track and allow it to heal by first intention. In both methods, the final decannulation is preceded by various manoeuvres and are aimed at ensuring the safety of the final extubation.

The child is brought into hospital for a period of observation, which need not exceed 2 or 3 days. If there is any choice in the timing, then it is preferable to do it in the early summer when there is a low incidence of respiratory infection. The general health is checked, chest physiotherapy is arranged and a sample of sputum is taken for culture and sensitivity. Although the tube may already have been blocked for a trial period, this period should be repeated and the child should be watched carefully by the ward staff while he/she carries out normal physical activities. Some advocate the use of a fenestrated metal tube such as the Alder Hey tube (Black, Baldwin and Johns, 1984) for this procedure, but a small plastic tube allows an adequate airway around it. Indeed, this latter method is preferable, since the partial blockage of the tracheal lumen by the tube makes the trial more stringent and, if it is well tolerated during the day, then it should be continued at night as long as there are enough
qualified nursing staff to provide a constant watch. If there are still no problems, the tube is removed and the stoma is covered by a sterile dressing. The child is then kept under observation as an in-patient for at least one week before being allowed home. Various other pre-decannulated procedures are practised but they are all variations on a theme of progressive tube blockage with an increase in the dead space.

During the whole of the decannulation and pre-decannulation period, essential emergency equipment must be at the bedside and humidification must be continued. The equipment should include a tracheostomy tube, an endotracheal tube, a laryngoscope, suitable retractor or skin hooks and tracheal dilators. Antibiotics are only given if there is a medical reason for doing so and there is no indication for routine mucolytics or steroids.

**Decannulation problems**

Although the airway is deemed to be adequate or near adequate before the decannulation trial is commenced, significant numbers still have problems. In one recent report (Black, Baldwin and Johns, 1984), 30% had some initial problem with chest infections and respiratory distress but this large percentage is unusual and can be attributed to the large numbers of problem patients with subglottic stenosis who are referred to that centre. Others (Carter and Benjamin, 1983; Line et al, 1986) reported very few problems and the present author shares this experience. When respiratory distress does occur, the causative factors are thought to be as described below.

**Dead space**

An increase in the dead space occurs when the tracheostomy is closed. In addition, the infant's air passages are absolutely and relatively smaller than those of the adult and the airway resistance will, therefore, be relatively increased. An increased oxygen requirement in children will emphasize any airway resistance and further compromise a previously diseased lung. However, these factors should have manifested their effects in the early assessment prior to decannulation and it is doubtful whether they would be very significant after decannulation.

**Tracheal narrowing above the stoma**

This is the most probable cause of decannulation problems and there is more than one aetiology. First, a significant granuloma may have been misjudged at the endoscopic assessment, or it may have increased in size or reappeared in the interval between assessment and decannulation. A failed decannulation should, therefore, be followed by a repeated endoscopic assessment and a removal of the granulation if necessary. Second, there may be a flap of fibrous tissue or a displaced anterior tracheal wall above the stoma, which may not be immediately obvious to the uninitiated. In the author’s experience, a flap of fibrous tissue is much more common. It has been claimed that the flap can be repositioned by inserting a nasotracheal tube for 72 hours (Carter and Benjamin, 1983), but it can also be sutured forwards or removed surgically through the stoma (Rogers, 1980). Third, the trachea may be weakened in the vicinity of the stoma by a low-grade chondritis and this may cause collapse of the trachea during inspiration. Lastly, the repeated interference with the larynx, which occurs during the period of assessment and decannulation, may cause oedema in the subglottis where the lumen is critical for decannulation. This is particularly likely to occur where there
was previously some congenital narrowing or where the original problem was one of acquired subglottic stenosis.

**Reduced movement of vocal cords**

It has been reported (Sasaki, Fukuda and Kirchner, 1973) that the reflex abduction of the vocal cords with inspiration is dependent on airway resistance and that this reflex disappears in the presence of a long-standing tracheostomy. Although this had been demonstrated electromyographically and is a possible source of trouble, practical experience shows that it is not of real clinical significance.

All the above may combine to cause trouble but the most likely problems are those of *suprastomal granulations* and *tracheal narrowing* due to tracheal weakness or a displaced anterior tracheal wall. Both these common problems are well treated by surgical decannulation.

**Surgical decannulation**

In this operation, the tracheostomy track is excised and the tracheal stoma is examined under direct vision. A pre-decannulation assessment is carried out as described above and endoscopy is performed immediately prior to the operation to confirm the presence or otherwise of granulations or a displaced anterior tracheal wall flap. A suitable orotracheal tube is introduced for general anaesthesia.

A horizontal elliptical skin incision is made around the external stoma and the resulting island of skin is grasped in an Allis forceps. The track with its surrounding cuff of fibrous tissue is freed down to the trachea with cutting diathermy. It is important not to pull too hard on the fibrous track as the weakened trachea may be tented upwards and damaged when the track is incised horizontally at the tracheal stoma. The tracheal opening and the intraluminal orotracheal tube can now be clearly seen and any visible granulations or excessive fibrous tissue are excised. A small triangular piece of anterior tracheal wall tissue, about 2 mm long, is now excised from the superior border of the tracheal stoma. This piece of tracheal wall is made up of fibrous tissue which may have been displaced posteriorly into the tracheal lumen and it often carries on its internal surface the suprastomal granulation. One horizontal Vicryl suture is now placed in the stoma to reconstruct the tubular structure of the trachea at this level and a repeat endoscopy is performed to ensure that there is no residual granuloma or displaced anterior wall flap. It should also be checked that there is no excessive narrowing of the tracheal lumen as a result of the suture, although this has never been the case. The orotracheal tube is reinserted and two more Vicryl sutures are placed in the tracheal incision to prevent the leakage of air into the neck tissues. After achieving haemostasis, the strap muscles, the subcutaneous tissues and skin are closed in layers. The child is sedated and taken back to the intensive care unit with the endotracheal tube still in place. Adequate humidification is maintained and the endotracheal tube is removed after about 2 hours when the child has sufficiently recovered from the anaesthesia and sedation. Initially, the child sleeps peacefully since he is partially sedated but normal activity is gradually regained and a return to the otolaryngology department is usually possible within 48 hours. Humidification is continued as required and the child is observed for a further 5 days before the skin sutures are removed. The child can then return home if the domestic arrangements are suitable.
There are several advantages in this approach which has been employed by the author for the majority of decannulations:

(1) it allows direct access to the tracheal stoma and permits the removal of any possible obstruction under direct vision;

(2) the suturing of the tracheal stoma reconstitutes the cylindrical wall of the trachea and, therefore, increases the strength of the trachea at this weakened point. In practice, the closure does not produce narrowing of the lumen, which is prevented in any case by the presence of the endotracheal tube;

(3) the removal of the tough fibrous track hastens the healing in the soft tissues and the horizontal elliptical incision produces a better cosmetic result.

An obvious disadvantage of this surgical decannulation is that an operation is required, but other disadvantages encountered have been relatively infrequent. In the author's experience, re-opening of the tracheostomy was necessary on two occasions within 3 days of the closure. In one, there was a residual granuloma and the other developed marked surgical emphysema following inadequate suturing of the trachea. This resolved spontaneously.

This surgical method of decannulation was originally employed by the author to decannulate three children who had resisted all other attempts at decannulation (Rogers, 1980). It was so successful that it is still employed in most cases. However, it is not suggested that others should use this form of closure in all cases, but it is certainly a most useful addition to the methods available for treating difficult decannulation.

**Summary and conclusion**

Tracheostomy in children is no longer the fearsome operation of the last century. There are still occasions when it is the primary treatment of choice, but its position has been largely usurped by intubation, particularly in inflammatory disease. The operation has become much safer by treating it as an elective operation and emphasizing basic principles of surgical technique and aftercare. The mortality as a result of the tracheostomy itself is still around 5% even in the best of hands and the main cause of death is obstruction of the tube at home. Decannulation is no longer a significant problem except in the worst cases of acquired subglottic stenosis and the scar on the neck is often unnoticeable by adulthood.

In the future, the aim should be to eliminate the need for tracheostomy but, with the advances in neonatal medicine, cranial and thoracic surgery and the increase in the numbers and speeds of motor vehicles, this is unlikely. There will gradually be changes in the types of tubes and their attachments and the operation itself may change as the age-old cricothyroidotomy and its successor, the minitracheostomy, are assessed more thoroughly.