Decannulation in infancy

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Introduction

Tracheostomy in infancy is still required and can often be a very valuable procedure but the problem of decannulation is ever present. It is of course possible, even when the condition necessitating the tracheostomy no longer obtains, to leave the tube *in situ* until the infant reaches such an age that the size of his trachea eliminates the problems of early decannulation, thus ignoring a compelling number of disadvantages and dangers to the patient. The safety of the infant requires constant supervision, expert care of tracheostomy tubes and catheters, the attendance of someone experienced in the art of atraumatic aspiration of tracheostomy tube and trachea, all this entailing either expensive hospitalization or expensive care at home, involving equipment for home-use, visits by private doctor or district nurse, weekly or perhaps twice-weekly visits to hospital for changing of the tube, management at home presupposing the ability and confidence of the parents, which takes time to develop and time to be assessed by those responsible for the patient in hospital. Parental anxiety too should not be underestimated; the tracheostomy is an awe-inspiring symbol indicating that all is not well even when there is no serious abnormality present. Parents seem to be much happier with an intact neck even if it conceals underlying pathology. Speech articulation is delayed, a disadvantage particularly to the child who would be expressive early but in fact these children develop speech articulation very rapidly when the tube is finally removed. The local disadvantages include further trauma to the trachea from the tracheostomy tube, especially a metal one, and from suction, susceptibility to respiratory infections etc. The problem is therefore not so much one of decannulation *per se* but one of decannulation as soon as possible.

Delayed decannulation

Individual authors define delayed decannulation in terms appropriate to the particular patients being considered. Jaffee (1963), in dealing with patients requiring tracheostomy for obstruction due to acute inflammation considers failure to decannulate within 14 days a significant delay. Jackson (1963) whose series consisted of neonates with tetanus expected to decannulate the infants in 4 or 5 weeks and he considered more than three attempts at this time to constitute a delay while Smythe (1964)

https://doi.org/10.1017/S0022215100071243 Published online by Cambridge University Press

dealing with the same condition regarded failure by the end of the second month as unsatisfactory. The age of the patient, the preceding pathology, the development of pathology resulting from the tracheostomy, and the decannulation technique combine to determine the exact time when decannulation is accomplished. Delayed decannulation may be said to be present when decannulation has failed after a single, adequate, sustained attempt at a time when it would be reasonable to suppose that the condition for which the tracheostomy was required no longer obtains.

Whether a decannulation problem will arise or not is often decided at the outset, with the tracheostomy operation itself. Jackson (1921) found that more than 50 per cent of the cases referred to him as problems in decannulation had in fact a laryngeal stenosis, this being due to the involvement of the cricoid cartilage or crico-thyroid membrane in the 'tracheostomy'. His teaching has ensured that this operation is not now performed deliberately although accidental damage can still occur. Damage to the first tracheal ring can lead to the same result and, nowadays, the operation is usually performed through the second and third rings.

Almost 50 years after Jackson's writing, Sharp (1968) emphasizes that tracheostomy in infants should be avoided if at all possible. When the operation is performed, the opening should be made not higher than the fourth tracheal ring. Crooks (1968) believes that a tracheostomy via the upper tracheal ring is more likely to give rise to decannulation difficulties on account of the greater effect exerted there of the negative pressure developed in the trachea during inspiration. Jackson (1963), too, maintains that a tracheostomy made below the fourth tracheal ring gives less trouble with decannulation and Mann, Jackson and Holloway (1963) advocate a vertical incision of the lower tracheal rings. Putney (1955), however, holds the opposite view maintaining that decannulation difficulties occur more frequently with 'low' tracheostomy than with 'high' tracheostomy but he does not present evidence to support this view.

Some cases of decannulation difficulty have been resolved by making a second tracheostomy opening lower than the first one and allowing the first stoma to close. Decannulation of the second stoma is accomplished without difficulty. Crooks (1968) has used this technique successfully. Diamant *et al.* (1960) has described one case dealt with by this means but the interval between the second tracheostomy operation and the final success in decannulation is not stated. This method may lend support to the suggestion that decannulation difficulty is less likely to occur with a tracheostomy made via the rings below the fourth. The use of the terms 'low' and 'high' in connection with tracheostomy perpetuate the very terminology which Jackson (1921) strove to eliminate.

The incidence of other complications does increase with tracheostomy via the lower tracheal rings and it would appear from the overall point of view that the second, third and fourth rings are the ones of choice.

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Excision of cartilage at tracheostomy is a fruitful source of later decannulation difficulty and there is now considerable feeling that the tracheostomy should consist only of incision of the tracheal rings since the removal of a window of cartilage say 3 mm.×3 mm. from the anterior tracheal wall leaves only two lateral bars of cartilage 2 mm. long by 0·5 mm. broad which have no power to maintain the configuration of the trachea. Jackson (1963) noted an immediate improvement in decannulation difficulties on substituting an incision tracheostomy for a window tracheostomy. He encountered four difficult decannulations out of seven patients with a window tracheostomy while there were only three out of twenty-one cases with an incision tracheostomy. The question as to whether a transverse or longitudinal incision in the trachea influences the course of events was investigated by Nelson (1957) who found that the transverse incision led to an undesirable antero-posterior angulation of the trachea, causing the tracheostomy tube to impinge on the anterior wall, both effects predisposing to decannulation difficulty. He considered whether a transverse skin incision might not have the same effect but did not design his investigation to test this point.

When a tracheostomy tube is *in situ*, it exerts pressure at three particular places on the tracheal wall which undergoes a characteristic distortion. The upper lip of the opening into the trachea is tilted backwards into the lumen of the trachea, the lower lip is pressed downwards and outwards and the posterior wall is displaced backwards in the region of the point where the posterior wall is a tangent to the tracheostomy tube (Fig. 1). This distortion occurs in some measure in all tracheostomies,

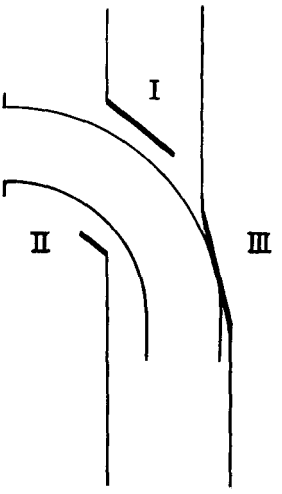


FIG. 1.
Diagram of the three characteristic distortions of the tracheal wall caused by a tracheostomy tube.

https://doi.org/10.1017/S0022215100071243 Published online by Cambridge University Press

being more persistent the longer the tube is *in situ* and causing some degree of obstruction since it is maintained when the tube is removed. This distortion is aggravated by a transverse tracheal incision (Nelson, 1957), by extension of the neck, which leads to posterior tilting of the upper end of the tracheostomy tube and increased pressure on the ring above the stoma (Reading, 1958) and by using a tracheal incision which is too short relative to the size of tube required. The measurements obtained by Gray (1960) are relevant to this question. He found that for a neonate, the tracheal rings are 0·5 mm. wide and that six rings are present in a 10 mm. length of trachea, the corresponding figures for an infant 1 year old being 2 mm. and four rings per 10 mm. of trachea. Calculations based on these figures indicate that the maximum length of an incision via two rings (assuming that the whole of the adjacent spaces above and below the rings divided is available) is $4\frac{1}{2}$ mm. in the neonate and $5\frac{1}{2}$ mm. in the year-old infant. These dimensions are decreased when the presence of soft tissue is allowed for and when allowance is made for the decrease in area which occurs when the vertical incision is dilated to accommodate a tube. Even these theoretical maximum figures barely accommodate the smallest compatible tracheostomy tube and pressure on adjacent tracheal rings is inevitable. There seems to be a sound basis for advocating an incision via three rings, the calculated length of incision being 6 mm. in the neonate and 8 mm. in the year old infant.

The size of tracheostomy tube must be chosen with reference to the lumen of the trachea and the size of the tracheostomy opening available. Corner (1959) recommends that 'the widest bore tracheostomy tube should always be used'. Apart from the increased pressure on and distortion of the anterior tracheal wall there is also the undesirable effect of increased pressure over a greater area of tracheal mucosa and increased friction particularly with I.P.P.R. According to Donaldson and Tompsett (1952), who studied the neonatal trachea radiologically in full inspiration, the average antero-posterior diameter in 350 cases was 4·5 mm. at the level of the fifth cervical vertebra, 3·9 mm. at the level of the first thoracic vertebra and 3·5 mm. at the level of the third thoracic vertebra. In six cases, the antero-posterior diameter was less than 3 mm. in the upper mediastinum. He considered that 3 mm. was the lower limit of normal for the tracheal diameter in the upper mediastinum of the newborn infant. The lateral diameters were 2–7 mm., 1–6 mm. and 1–5 mm. at the levels of the fifth cervical, first thoracic and third thoracic vertebra respectively. The smallest tube which is compatible with adequate respiration is the largest one which need be used and the smallest that can be used. There is really little choice in the matter.

Crooks (1954 and 1968) maintains that some collapse of the trachea occurs during inspiration and adds to the difficulties of decannulation. The negative pressure developed in the trachea during inspiration could

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easily result in the complete apposition of anterior and posterior tracheal walls partly opposed by the various distorting influences already considered. The changes in the lumen of the trachea due to pressure variations are less at the level of a low tracheostomy than at the level of a tracheostomy via the higher rings.

Granulation tissue at the stoma can of itself prevent decannulation but usually it is only one factor to be considered along with others. Pearce and Walsh (1961) describe two cases, one a child aged 4 years and the other an adult of 19 years of age, in which decannulation was prevented solely by the presence of granulation tissue arising from the upper lip of the tracheostomy.

Tracheomalacia may be present and cause increased effects as far as distortion and inspiratory collapse are concerned (Bigler *et al.*, 1954).

The presence of oedema at the site of the tracheostomy tube, even when not marked and scarcely apparent at endoscopy, can be of great significance. Toremaln (1960) points out that subglottic oedema of 1 mm. depth causes a 50 per cent reduction in the tracheal lumen of a year-old-infant.

Some degree of emotional dependence on the tracheostomy tube is encountered in patients generally and even in the very young infant this can play an important role among the decannulation difficulties. In the mentally retarded infant, this psychological difficulty is less well developed and may be absent at the particular age at which the decannulation occurs, as in Case no. 1. Toremaln (1960) stresses that moving the increased volume of dead-space air and overcoming the increased airway resistance give a feeling of dyspnoea.

Other factors thought to play a part in decannulation difficulties but which are more nebulous include the impairment of the laryngeal opening reflex mentioned by Gray (1960) and the impairment of development of the larynx in patients who have a tracheostomy for a prolonged period of time as suggested by Putney (1955).

Decannulation procedure

Decannulation is not a procedure to be undertaken without full preparation and arrangements and, in fact, there is much to be said for dealing with these cases in a unit geared to the essential requirements. However, at the same time, there is no reason why any surgeon should not deal with his own cases provided he is able to expend a considerable amount of time and patience on the individual case. The most satisfactory accommodation is a cubicle immediately adjacent to the operating theatre. The attempt at decannulation should be started early in the morning to ensure that complications or reinsertion of the tube can be dealt with while all the appropriate staff are still readily available. The

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essential personnel consists of the special nurse well known to the infant. the anaesthetist and the ear, nose and throat surgeon. The same nurse should remain with the infant constantly, the anaesthetist, experienced in intubating infants and children must be readily available and the surgeon should preferably be in constant attendance. The infant is fed about an hour to an hour and a half before the decannulation. This increases the possibility of his sleeping after the tube is removed and avoids the difficulty of deciding whether crying is due to anoxia or simply to hunger. A sedative is given at an appropriate time before the attempt. An oral sedative is adequate and the actual choice of preparation does not matter a great deal. Pethidine Co. may cause a marked pallor which cannot easily be distinguished from the pallor of anoxia. There is a great variation in individual susceptibility to sedation and several attempts may be required before an appropriate preparation and dose are found. This, however, is time well spent. While most authors recommend sedation for a decannulation attempt, Mann *et al.* (1963) indicate one of its disadvantages, viz. the anterior and posterior tracheal walls may be only partly apposed while the infant is sleeping under the influence of the sedation, providing an adequate airway, but on wakening he may make more powerful inspiratory efforts which can convert the partial apposition into a complete apposition and respiratory obstruction.

The necessary equipment for oral intubation, suction, oxygen and humidification, polythene tracheostomy tubes and silver tracheostomy tubes with appropriate introducers should all be available. If a tracheostomy has been allowed to contract down for a few hours it is usually not possible to reinsert a polythene tracheostomy tube but usually a lubricated silver tube with introducer can be inserted with gentle but definite and steady pressure.

Charts should be kept showing accurate recordings of the quarter hourly respiratory rate, pulse rate, and heart apex rate, counted on auscultation, the latter being particularly important with rapid heart rates which are always underestimated by measuring the peripheral pulse rate. Restlessness should be noted and evaluated carefully against the background of sedation administered. It is an important sign of anoxia in the infant. When an infant has been coping with an inadequate airway for some time, he becomes tired and finally exhausted. In these circumstances, it is important to distinguish between the effects of sedation and the inactivity due to exhaustion. The response to painful stimuli can be helpful in elucidating the difference. An infant who is merely sedated will respond vigorously to painful stimuli while the exhausted infant hardly responds at all, this being a very clear indication for replacing the tracheostomy tube. It is important to make regular observations of the infant's colour. Pallor is an important sign of anoxia.

When a decannulation trial proceeds for several hours, further useful

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information in helping to decide whether to continue or abandon the attempt may be obtained from estimation of the blood *p*H, pCO^2 and pO^2.

There are several methods of gradual decannulation e.g. using successively smaller tracheostomy tubes over a period of several days and corking the tube for increasing periods of time as advocated by Jackson (1942) or the use of fenestrated tracheostomy tubes. The latter are impracticable and dangerous since it is impossible to maintain the fenestra opposite the tracheal lumen. Gradually decreasing the size of tracheostomy tube obviously does not arise if one adheres to the principle of using the smallest tube compatible with adequate respiration. There seems little to be gained by gradual decannulation. The tube should be removed completely under the conditions described. The cases decannulated present no further problems and the time thus saved can be devoted to the important investigation of those cases which fail at the first attempt.

The special problem of anterior tracheal wall dislocation

The condition of anterior tracheal wall dislocation must be clearly distinguished from other forms of subglottic and tracheal stenosis, the term 'stenosis' being used to denote any type of 'narrowing'. The condition is not a stricture, a term which implies a more or less circumferential change in the tracheal wall resulting in a rather fixed narrowing of the lumen requiring some degree of force to dilate it. In anterior tracheal wall dislocation, the deformity is confined to the anterior wall. The narrowed part will accept a bronchoscope or endotracheal tube larger than the apparent lumen without the use of any significant dilating force. The displaced segment can easily be moved forward by gently passing a bronchoscope or endotracheal tube and at bronchoscopy, the anterior segment can be seen to spring backwards like a trap-door when the bronchoscope is slowly withdrawn.

In this connection, it is important to be aware of the dimensions of the normal tracheal lumen and here Tucker (1932) gives some guidance. He suggests that 6 mm. or greater is the normal diameter of the subglottis in the well-developed infant, that 5 mm. is abnormally small but not incompatible with life and development, but that 4 mm. must be regarded as indicative of stenosis. The tracheal lumen is several mm. greater than that of the subglottis.

Many methods of dealing with the decannulation problem are described. However, they all attempt to be of general application. Success in a few cases is taken to mean that the method advocated will be universally successful. The truth lies at the other extreme, there being almost as many methods as there are patients. If the problem is tackled from this standpoint, and the individual circumstances of each patient accurately

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assessed beforehand, success will come more readily. One must always ask oneself at the outset 'Why is this infant difficult to decannulate?' and one always answers the question in accurate terms.

It is difficult to prove that the method one advocates materially affects the progress of the decannulation but one must at least make an attempt. I would suggest the following principles. There should be a sound theoretical basis and this should be related to a given set of circumstances which have been evaluated by accurate observation. There must be a convincing demonstration of the failure to manage without a tracheostomy tube during a sustained and adequate attempt at decannulation and this to be followed within as short a period of time as possible by a successful decannulation using the method being advocated. One must beware of attributing success to various charms—obturators, stopples etc., placed around the neck. Obturators placed in the tracheostomy track cannot increase the tracheal lumen. Their main purpose is to keep the track open so that in the event of obstruction developing, the airway can quickly be restored. They have the theoretical and probably real disadvantage that they maintain or cause distortion of the anterior tracheal wall and on this basis they should not be used when the problem is one of anterior tracheal wall dislocation.

To deal with the problem of anterior tracheal wall dislocation, some form of splinting is required. This may be internal, in the lumen of the trachea, or external, between the anterior tracheal wall and the skin. Ardran and Caust (1963) recommend inserting a wire suture at the tracheostomy operation. This can be used post-operatively to pull the anterior tracheal wall forward if X-ray examination shows that it is being distorted by the tube. Fennell (1962) suggests inserting a deep suture through the anterior wall and the skin at the time of decannulation. Venables (1959) excises the tracheostomy scar down to the trachea immediately prior to the decannulation attempt in cases where the tracheostomy has been present for more than a few days since scar tissue contracts down rapidly and prevents reinsertion of the tracheostomy tube. It is possible also that the scar tissue is partly responsible for maintaining the segment of anterior tracheal wall in its dislocated position. Sercer (1952) employs tracheofissure or laryngofissure, elevating the depressed anterior wall and fixing it to the skin. After this operation he inserts a special straight short and narrow cannula which is less likely to distort the trachea to the extent that the quarter-circle tubes do.

Sharp (1968) is entirely against any form of reparative operation on an infant trachea. While acknowledging that there are some successes, he is more impressed by the failures considered in the light of the fact that good results can be obtained with more conservative measures and the passage of time.

Crooks (1954) describes the case of a child who had eighteen operations

https://doi.org/10.1017/S0022215100071243 Published online by Cambridge University Press

in 18 months, the anterior tracheal wall finally being splinted by means of a wire bridge in the tracheal lumen.

The external forms of splinting have the common disadvantage that the traction is difficult to arrange accurately, that it is not constant and that in most cases, a tracheostomy tube is still left *in situ*.

Internal splintage by means of a nasotracheal tube seemed, theoretically, to offer the best solution to the problem of anterior tracheal wall dislocation. The tube provides a prolonged, uniform support for the whole area of distorted tracheal wall. The tracheostomy tube can be dispensed with and the nasotracheal tube is easily removed at the appointed time. The exact position of splinting is made possible by the range of available diameters of the nasotracheal tubes. The anterior wall can be held in its definitive position for sufficient time to ensure that it will continue to maintain that position when the support is removed. During the time that the tube is *in situ*, the track formed by the tracheostomy tube contracts down and healing becomes established, thus exerting fixed traction and support for the anterior tracheal wall in its correct position.

A subsidiary effect of the nasotracheal tube occurs by virtue of the fact that it provides an increased airway resistance to which the infant becomes accustomed. When the nasotracheal tube is removed, he breathes through his upper respiratory tract without the feeling of discomfort and panic which can occur when a tracheostomy tube is suddenly removed and the infant has to deal with the upper airway resistance.

When the diagnosis of anterior tracheal wall dislocation has been made, the infant is anaesthetized and the tracheostomy tube is removed. The stoma is inspected for the presence of granulations which may have formed since the last examination and an endoscopic inspection of the trachea is made to check the diagnosis and to ascertain that the situation has not changed. A nasotracheal tube of appropriate length and of a diameter large enough to support the anterior tracheal wall without causing excessive pressure is selected and passed into the trachea. A small safety-pin is passed through the tube just external to the anterior nares. Nothing further is done to the tracheostomy. The infant is allowed to recover from the anaesthetic and thereafter requires constant supervision by the trained nurses whose duty it is to see that the tube maintains its exact position. It may be necessary to restrain the infant's hands, tying them loosely to the sides of the cot. The tube is aspirated every 15 minutes by means of a fine polythene catheter after instilling 1–2 c.cm. of sterile, normal saline. Sedation is not required at this stage. The tube remains *in situ* for 1 week and if carefully looked after, it should not become blocked. Since the cough mechanism is interfered with, frequent physiotherapy is required to prevent stasis of secretions in the chest. When the tube is removed the care of the infant is exactly as that described for ordinary decannulation.

https://doi.org/10.1017/S0022215100071243 Published online by Cambridge University Press

Case reports

Case no. 1

J.H. 377946, a female child, was born at home, the delivery being normal. Stridor was noticed on the first day of life but had not been evident immediately after birth. Respiratory obstruction was progressive and she was admitted to hospital when 2 days old. After observation for 6 hours, it was clear that a tracheostomy was required since there was continuous stridor, intercostal, subcostal and supraclavicular retraction, her colour was grey, the pulse was rising and feeding was impossible. Thereafter, it was noticed that she was irritable and 'jittery'. She was transferred to the Hospital for Sick Children, Great Ormond Street when she was 4 days old for further investigation and supervision of decannulation.

There were repeated episodes of apnoea and cyanosis and she took her feeds slowly and reluctantly and frequently appeared very floppy. At no time, was there any difficulty with the tracheostomy tube. One apnoeic episode which occurred on the 17th day of life lasted over 5 minutes and required artificial respiration. Following this, jerky movements of the extremities occurred. Throughout her admission, she had nystagmus, absence of conjugate eye movements and the state of her vision was in doubt. There were no other focal neurological signs but she appeared to be suffering from a marked degree of brain damage.

Electrolytes, in particular Ca^{++} and PO_4', were studied in her initial 'Jittery' phase and also during fasting and were within normal limits.

E.E.G.s taken at 2 and 10 weeks of age showed a moderate, diffuse abnormality and a slight asymmetry between the activities of the two hemispheres. Chest X-ray, and the barium swallow showed no abnormality.

There were no congenital abnormalities evident on direct laryngoscopy and bronchoscopy but the anterior tracheal wall above the stoma was definitely displaced backwards and as soon as the bronchoscope was drawn proximally past this segment, it sprang backwards to occlude the trachea but the bronchoscope could again easily be passed through the narrowed segment.

Attempts at decannulation at 3 and 12 weeks of age failed completely. At 13 weeks, the method described in this paper was attempted. During the week the nasotracheal tube was *in situ*, there were no problems and when the tube was removed on the 7th day, there was some obstruction but not sufficient to end the trial. Two days later, she developed a 'cold' with slight pyrexia but the chest remained clear. At the worst point, the respiratory rate was up to 60 per min. and the heart rate up to 160 per min. She recovered from the 'cold' within a few days and was discharged 2 weeks after detubation. There has been no airway problem since then, 8 months ago.

Case no. 2

M.S., 377948, a male infant, had been quite well until he was 6 weeks old, when he developed laryngo-tracheo-bronchitis and oral thrush. Despite intensive treatment, he required tracheostomy on the 9th day of the illness. Laryngoscopy at that time showed acute congestion, oedema and extensive monilia plaques. Attempts at decannulation were unsuccessful and he was transferred to the Hospital for Sick Children, Great Ormond Street when he was 10 weeks old.

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Endoscopy showed no abnormality apart from a collapsed segment of erior tracheal wall above the stoma. Decannulation, 10 days after admission, the method described failed. Further attempts at decannulation were ıyed by treatment (requiring general anaesthetic) of a large haemangioma erior to the right pinna. The next attempt was made when he was $6\frac{1}{2}$ months failing after 4 hours after slowly progressive obstruction.

The following day, the nasotracheal method was instituted, the tube remain- *in situ* for 1 week. After removal of the tube, he developed a respiratory ction necessitating reintubation after 30 hours but he responded to intensive apy and the tube was removed for the second time after 3 days. A further piratory infection 2 weeks after detubation necessitated further intubation 3 days, but this time, when the tube was removed there was no further ıble and he was discharged when he was almost 8 months old.

When last seen, he was 13 months old. He has a good strong voice and is inning to speak. He still has a tendency to chest infections and broncho- sm but there has been no further trouble with respiratory obstruction.

In the two cases described, the cause of the decannulation difficulty was efully assessed and found to be due to anterior wall dislocation, other sible causes being absent. It was established on two separate occasions that annulation was not possible even with sustained and adequate attempts. successful decannulation using the nasotracheal intubation method urred only a short time after the failed attempts, viz. 1 week in Case no. 1 1 day in Case no. 2. Both infants developed an upper respiratory infection ch placed an extra burden on the airway but provided a further test of the hod suggested. These cases illustrate convincingly that the success in de- nulation could be attributed to the use of the nasotracheal tube.

Summary

Decannulation in infancy is discussed and the literature reviewed. ticular reference is made to dislocation of the anterior tracheal wall ı cause of difficult decannulation and a method of managing the problem ng nasotracheal intubation is described. Criteria for evaluating the cess of a decannulation technique are suggested and two cases are sented illustrating the method described.

Summary of factors involved in delayed or difficult decannulation

1. Persistence of the condition necessitating tracheostomy.
2. Anterior tracheal wall dislocation.
3. Granulation tissue around stoma.
4. Oedema of tracheal mucosa.
5. Emotional dependence on tracheostomy.
6. Inability to tolerate upper airway resistance on decannulation.
7. Tracheomalacia.
8. Subglottic stenosis resulting from the tracheostomy operation, the sence of a tracheostomy tube or infection (Perichondritis).
9. Incoordination of the laryngeal opening reflex.

https://doi.org/10.1017/S0022215100071243 Published online by Cambridge University Press

10. Impaired development of the larynx as a result of long-standing tracheostomy.

Acknowledgement

My thanks are due to Mr. Henry Sharp, under whose care the patients were managed, for his permission to present the two cases.

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https://doi.org/10.1017/S0022215100071243 Published online by Cambridge University Press