The Journal of
Laryngology and Otology
(*Founded in* 1887 *by* MORELL MACKENZIE *and* NORRIS WOLFENDEN)
July 1974

Laryngo-tracheoplasty

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Introduction

IN the past year, five patients with tracheostomies, which were necessary because of severe subglottic stenosis, have been successfully decannulated following a new technique of laryngo-tracheoplasty. The results to date have been so encouraging that we felt this preliminary report justified.

The management of infants and children with tracheostomies presents two main problems. First, there is the treatment of the underlying pathological condition, and second, the prolonged hospitalization. If the patient is cared for at home, the resulting strain on the parents may present many difficulties.

The children in this series all had subglottic stenosis which was sufficiently severe to require a tracheostomy within the first nine months of life. It is our policy to treat all patients with subglottic stenosis conservatively in the first instance, and, in general, surgical treatment is only considered if no improvement in the airway is noted after a period of several months. It is said that most patients with subglottic stenosis will eventually grow out of it with the passage of time, but unfortunately this has not been our experience. Indeed, the complications of prolonged use of tracheostomy tubes may themselves be serious (Cundy and Bergstrom, 1973).

Excision of the thickened tissue via laryngo-fissure, followed by grafting the raw area (with skin or buccal mucosa) and applying a splint for six weeks is sometimes effective (Montgomery, 1968), but the results are commonly complicated by granulation tissue formation and stenosis of the graft, and it should not be performed in children (Conley, 1953). Moreover, the physiology of this area must be affected adversely in that

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columnar ciliated epithelium is replaced by stratified squamous epithelium.

Possibly more applicable in children are the operations described by Aboulker (1968) and Lapidot *et al.* (1968). In the former operation, the larynx and upper trachea are split longitudinally anteriorly and posteriorly, with excision of the stenosis. While the anterior incision is sutured, the posterior one is held open by a teflon prosthesis which protrudes through the vocal cords and is held in place by a silver tracheostomy tube. The widened airway is allowed to heal, the prosthesis being left *in situ* for four months, and the results in seven patients (aged 1–3 years) were good (Grahne, 1971). One disadvantage of the procedure, however, is the possibility of damage to the vocal cords by the prosthesis (Louhimo *et al.*, 1971). In the operation of Lapidot *et al.* (1968), which was first carried out in piglets, the skeleton of the cricoid is widened by inclusion of a flap of thyroid cartilage turned down from above, but still attached to the thyroid by perichondrium. There is, however, no attempt to enlarge the internal diameter of the airway by grafting, or by incising the mucosa and holding it open with a splint.

Intermittent dilatation of the stenosis is unsuccessful. The complete cartilaginous ring of the cricoid is not amenable to dilatation, and the patient is submitted to a large number of general anaesthetics. As Conley (1953) pointed out, dilatation is only effective for thin to moderate web deformity.

Recently, treatment of subglottic stenosis by prolonged endotracheal intubation for weeks or even months has been enthusiastically reported (Finney *et al.*, 1970; Bos *et al.*, 1973). Even where this treatment has been successful, management of the patient, necessarily in hospital throughout, is difficult. Humidification of the inspired air has to be carefully regulated. the child may encounter difficulties with feeding (due to inability to occlude the laryngeal inlet) and damage to the larynx or trachea may be caused by the indwelling tube (Bos *et al.*, 1973). Moreover, it seems illogical to use as a form of treatment a method which itself may cause damage to the larynx or trachea, as fibrotic subglottic stenosis may occur after prolonged intubation in children (an incidence of 2–8 per cent is recorded in most series) and may occur after as short a period as 23 hours (Louhimo *et al.*, 1971).

Widening of the subglottis has recently been carried out in a different way in this hospital, whereby the cricoid ring is split anteriorly and a graft from rib costal cartilage inserted to widen the cricoid ring (Doig *et al.*, 1973). Difficulties with accurate maintenance of the graft in the correct position have been encountered. A surgical approach is here described for the relief of subglottic stenosis (devised by J.N.G.E.). In this the laryngofissure incision is modified such that it is stepped, passing through the substance of the cricoid and, if necessary, the upper tracheal rings (Fig. 1). The cartilaginous interdigitations are distracted and the skeletal frame-

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work held open, externally by suturing of the cartilage and internally by a piece of silastic sheeting rolled on itself like a swiss-roll. This acts as a splint with a constant tendency to expand. The operation is carried out in two stages six weeks apart, the roll being removed endoscopically at the second operation. Extubation has been successfully accomplished in all cases within two weeks of the removal of the silastic swiss-roll.

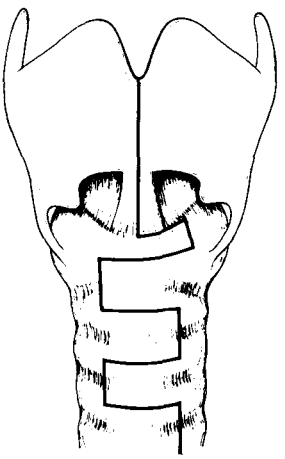


FIG. 1.
A–P view of larynx and upper trachea showing stepped incision.

The operation

The operation is carried out under general anaesthesia with the head extended. A horizontal skin incision is made at the level of the cricoid cartilage. The strap muscles are separated in the midline and the laryngeal cartilages and first two rings of the trachea identified. The operating microscope is then used and the thyroid cartilage is split along the keel. This incision is carried in a step-wise fashion through the cricoid, and if necessary, the upper tracheal rings (Fig. 1). The mucosa of the larynx and upper trachea is incised at the same time. The stenotic mass is excised by sharp dissection in the submucosal plane, and by blunt dissection just internal to the surrounding cartilage. A piece of silastic 5001 sheeting is cut, as shown in Figure 2. The size of each upper flange corresponding to the antero-posterior length of the true vocal cord. The silastic sheeting is curled upon itself like a 'swiss-roll' and inserted into the upper trachea. The flanges are positioned so they project through the glottis and prevent adhesions forming between the vocal cords anteriorly (Figs. 3 and 4).

The cartilaginous interdigitations are distracted and sutured in their new position using 50 stainless steel wire (Fig. 5). The 'swiss-roll' is held in position by a transfixion suture which passes through the trachea and the roll (Fig. 6), and which is then threaded through a small polythene

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tube external to the cartilage. The skeletal framework is thus held open externally by the wire sutures and internally by the 'swiss-roll.' The silastic 'swiss-roll' has a constant tendency to uncurl. It, therefore, exerts a gentle pressure upon the tracheal mucosa obliterating any dead space and allowing mucosal regeneration to occur. The subcutaneous tissue and skin are closed in layers and the wound is drained. A nasogastric tube is not necessary and, if thought desirable, the patient can go home to await the second stage.

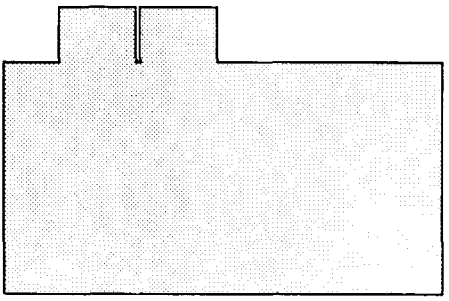


FIG. 2.
Approximate dimensions of silastic sheeting.

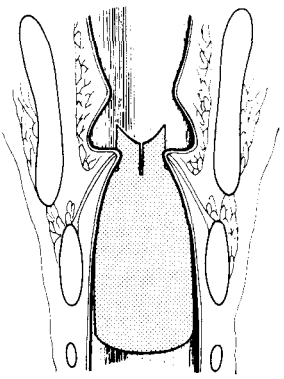


FIG. 3.
Coronal section through larynx with silastic roll *in situ*.

This is carried out through the same incision six weeks later. The transfixion suture is cut, external to the larynx, and the roll removed endoscopically. We have found that the post-operative oedema usually subsides after about fourteen days, and the patient can then be extubated.

Complications

(1) The silastic roll may sometimes be placed too high and lie in the supraglottis, leading to incompetent closure of the laryngeal inlet with consequent aspiration problems. Accurate positioning and stitching of the

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'swiss-roll' is important and particular care should be taken to ensure that one flange of almost half the circumference is free so that the tendency of the 'swiss-roll' to uncurl can thereby exert a gentle but even pressure over the inner surface of the subglottis and upper trachea (Figs. 3 and 6).

(2) It is often difficult to locate the wire external to the larynx at the second operation. Threading the wire through a small polythene tube assists in location and protects the cartilage.

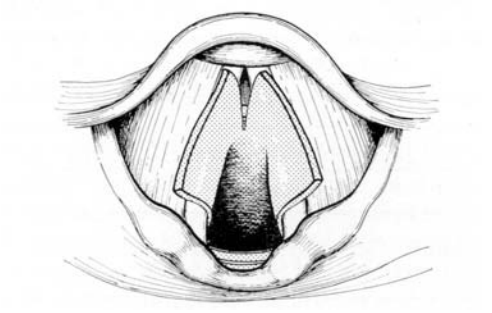


FIG. 4.
View of larynx from above showing flange of silastic projecting through glottis.

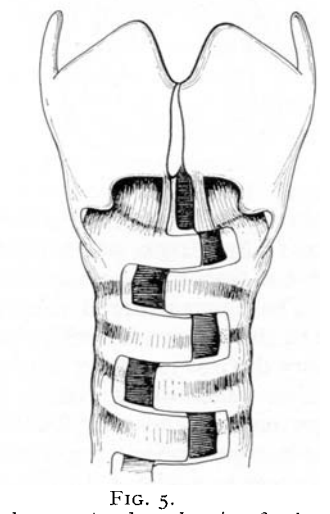


FIG. 5.
A–P view of larynx and upper trachea showing final position before suturing.

(1) An 18-day-old male child, born 28 March 1970, was admitted to hospital with stridor. A direct laryngoscopy revealed a laryngeal web and subglottic stenosis, and a tracheostomy was performed. The web was divided but an attempt to divide the stenosis endoscopically failed, and this was then followed by seventeen dilatations under general anaesthetic every four days. A laryngofissure with insertion of a plastic intralaryngeal prosthesis was then carried out, but the prosthesis had to be removed because of suppuration. The child was then admitted to the Hospital for Sick Children, Great Ormond Street. A

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granuloma above the tracheostomy stoma was later excised, and on 13 June 1972 the patient had a further laryngofissure with insertion of the silastic swiss-roll. This was removed six weeks later and the child successfully extubated at the first attempt. He had had a total of twenty-seven anaesthetics. One year after the operation, he was fit and well, and his total respiratory resistance using the forced oscillation technique (Cogswell, 1973) was normal.

TABLE I.

	Time spent in hospital		
	Prior to laryngo-fissure (months)	Following laryngo-fissure (months)	No. of general anaesthetics
Case 1	26	3	27
Case 2	18	2	11
Case 3	13	2	10
Case 4	7	2	5
Case 5	5	2	11

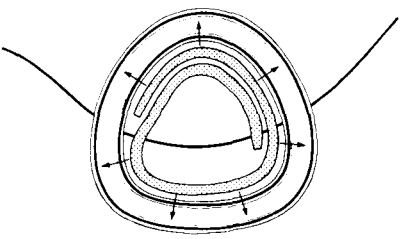


FIG. 6.
Cross-section of trachea showing relation of silastic roll and transfixion suture.

(2) A male child, born on 18 April 1970, was noted to have grunting respirations immediately after birth. A tracheo-oesophageal fistula was diagnosed and repaired the following day. The repair required re-exploration six weeks later as cyantoic attacks persisted, but even after this second operation the child still had periods of respiratory distress requiring intubation. Tracheostomy was eventually necessary and, after failure of extubation, a subglottic stenosis was found on direct laryngoscopy and bronchoscopy. The child at that time (August 1970) was considered to be too young for surgical correction of the stenosis. A year later a laryngofissure was carried out. In this the cartilaginous incision extended from the tracheostomy to the upper edge of the thyroid cartilage, the subglottic stenosis was divided and the trachea and larynx grafted with a wedge of costal cartilage in order to widen the airway. In spite of subsequent dilatations, extubation was not possible and part of the graft had to be removed. A further graft to the trachea in February 1972 did not allow successful extubation. Laryngofissure employing the stepped incision and the silastic swiss-roll, with excision of the cricoid stenosis, was carried out in September 1972 and the patient extubated, after subsequent removal of the silastic, within two months. He has had no further respiratory problems and is free of stridor at the present time.

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(3) A female child, born 21 September 1971, suffered two cyanotic attacks during feeds shortly after birth. Six weeks later, she was admitted to hospital with stridor and a croupy cough, and eventually required tracheostomy. A direct laryngoscopy showed no abnormality in the glottis or supraglottis, but the subglottis was not clearly seen. However, a haemangioma of the lower neck just superior to the sternum was noted at this time. Three attempts at extubation failed so a further direct laryngoscopy was performed. This revealed a large subglottic haemangioma, which did not shrink after treatment with prednisolone and four separate injections of hypertonic saline. Laryngofissure with excision of the haemangioma and insertion of the silastic roll was carried out. The silastic was removed on 30 January 1973, and the child extubated successfully at the first attempt a few days after that. She has remained well on follow-up.

(4) A female child, born 29 June 1972, was noted at birth to have a haemangioma of the right cheek. She had always had some degree of stridor from when she was 6 weeks old and the airway obstruction required two hospital admissions. Direct laryngoscopy revealed a large subglottis haemangioma. Treatment with steroids resulted in temporary improvement but the stridor again became severe and tracheostomy was carried out. A laryngofissure with excision of the haemangioma and insertion of the silastic roll was done on 27 March 1973, but her post-operative course was complicated by episodes of aspiration which required trimming of the silastic under general anaesthetic. The roll was removed on 15 April 1973, and the child extubated at the first attempt eight days later. She has remained well on follow-up.

(5) A female child, born on 8 May 1972, was noted to have a large haemangioma of the lower lip at birth. Four hospital admissions with croup and stridor occurred before tracheostomy was performed on 27 January 1973. A large subglottic harmangioma was noted on direct laryngoscopy and persisted in spite of a course of prednisolone and three injections with hypertonic saline. Laryngofissure with insertion of the silastic roll was carried out on 12 June 1973. The silastic required trimming on one occasion, but was removed after six weeks, and the child subsequently extubated at the first attempt on 16 August 1973. Her post-operative airway resistance was measured and found to be normal.

Discussion

The symptoms in all five cases have been similar, consisting of intermittent attacks of respiratory distress with severe stridor and cyanosis. These attacks have generally, but not always, been associated with an upper respiratory tract infection and of such severity that a tracheostomy eventually became necessary.

Diagnosis of the nature of the lesion is frequently delayed. It is often difficult to see and assess the state of the subglottis accurately in infants, and endoscopy should be performed by a surgeon skilled in this technique. In this series the average length of time spent in hospital directly related to the respiratory condition was fourteen months, but only two months from the time when the first stage of the operation was carried out (Table I).

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Three of the children were aged between 9 and 15 months at the time of the first stage, the other two being slightly older. The latter were the first to be treated by this technique and, in view of the success with these, the younger children were then managed in the same way. However, in all cases the operating microscope was of value, particularly when the stenosed area was being dissected away from the mucosa. We feel that this stage of the operation should be meticulously carried out as preservation of the mucosa substantially reduces the risk of late restenosis.

The good exposure of the subglottis obtained by this method considerably facilitates the removal of benign subglottic tumours or thickenings of the cricoid cartilage. Three of the cases in this series had subglotict haemangiomata. They were initially treated by widely accepted methods including injection of the tumour with hypertonic saline and administration of steroids. There was no reduction in the size of the tumour (in fact, rather the opposite) and the airway remained considerably narrowed. Had the operations not been carried out, it seems likely that the tracheostomies in all three patients would have had to remain *in situ* for some years. Yet they have all been successfully extubated, they all have excellent airways (and voices) and have every chance of leading a normal life.

In addition to the advantage of a more definitive form of treatment, the vocal cords and thus the voice are unlikely to suffer damage as may occur in other laryngoplasties for subglottis stenosis (Grahne, 1971). Moreover, the operation is designed, like that of Aboulkers, not only to remove the stenosis but also to widen the airway by enlarging the skeletal framework and thus allow early extubation. The long-term results still have to be assessed. Grahne (1971) pointed out that growth of the larynx continued normally even when the cricoid ring had been completely divided posteriorly. With partial horizontal splitting of the cartilage and preservation of the perichondrium,we would hope that the skeleton of the larynx would continue to grow and, because of the overlap, not collapse or stenose.

In summary, the advantages of the operation can be listed as follows:

1. Early extubation.
2. Relatively short hospital stay, with reduction in the number of anaesthetics.
3. Excellent approach for benign subglottic swellings.
4. No damage to vocal cords (and hence voice).

We have been successful in extubating all the patients operated upon to date. The operation causes little disturbance to the child, and enables him to lead a normal life thereafter. However, long-term follow-up with regular radiological and endoscopic measurements of the airway, along with assessments of airway resistance, is being undertaken.

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Summary

A new operation for the correction of severe subglottic stenosis of the larynx is described employing a stepped incision which increases the lumen of the cricoid cartilage. An internal splint of silastic sheeting allows mucosal regeneration to occur whilst the prosthesis is *in situ*. Extubation has been possible within two months of the operation in all patients to date.

Acknowledgements

We wish to thank Mrs. G. Oliver of the Department of Medical Illustration, The Institute of Child Health, London, for the illustration of the operative procedure.

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