INFANT TRACHEOSTOMY

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THE purpose of this article is to discuss some aspects of tracheostomy in infants and to describe a new type of tracheostomy tube.

Gabriel Tucker (1932), from measurements of infant cadavers, stated that in the normal infant the diameter of the subglottis was 6 to 8 mm. and the trachea was a few millimetres wider. He also stated that a subglottic diameter of 5 mm. was too small and that 4 mm. represented an actual stenosis. It is important to appreciate that tracheostomy tubes are graded as to the sizes of the external diameters and no mention is made of the "airway diameter", that is the internal diameter of the inner tube. This "airway diameter" in infants is very important; thus an 18 French grade tube has an external diameter of 6 mm. but the airway diameter of the inner tube is only 3·5 mm. which is equivalent to an actual stenosis of the trachea. A tracheostomy tube should not fill the tracheal lumen because, firstly, it will cause irritation, and secondly, there must be an adequate airway around the tube on blocking it during decannulation. It is considered that the maximum external diameter of a tube for infants up to six months of age should be 5·0 to 5·5 mm., and from 6 months to 2 years of age 6 to 7 mm. Also the airway diameter up to six months should be 4·0 to 4·5 mm., and from six months to 2 years 5·0 to 5·5 mm. In infants a large airway diameter can only be obtained if a thin single tube is used. This will be illustrated in the accompanying case report.

The metal tracheostomy tube has the following shortcomings:

(1) For a given external diameter the airway diameter is often surprisingly small. Also a small tube is very prone to blockage.

(2) The removal of the inner tube for cleaning may dislodge the outer tube, particularly if it is a tight fit, and the child makes an unexpected movement.

(3) Metal has no elasticity and is likely to cause irritation due to pressure.

(4) The position of the tip of the tube in the trachea depends on the relative position of the flange on the skin, and the trachea. This is variable.

(5) The pull of the tapes is upward and backward, thus tilting the flange.

Most tubes will stay in position unless they become obstructed and are coughed out, or the flange is lifted away from the trachea.

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The main factors involved in the stability of a tracheostomy tube are as follows:

(1) Neck movements. These factors were stressed by Reading (1958). Extension of the neck makes the trachea more superficial and the tracheal rings ascend from the chest. Flexion causes the opposite action. Tapes tied in extension tend to loosen on flexion due to a reduction in the diameter of the neck. Contraction of the sternomastoid muscles tends to lift the flange out from the neck while the chin tends to push the flange down.

(2) Soft tissue swelling of the neck due to post-operative reactive swelling, hæmorrhage or emphysema tends to lift the flange out.

(3) Forceful coughing is an important factor with small or blocked tubes. Also the associated flexion of the neck and contraction of the neck muscles help to force the flange out.

(4) Frequently difficulty is experienced in tying the tracheostomy tapes in adequate tension because of their inelasticity. The tapes also cause an upward and backward pull on the flange with a consequent tilting of the tip of the tube. This causes pressure on the anterior wall of the trachea.

(5) The size and shape of the tracheostomy tube has an important influence on its stability. The acute angled tube such as the Durham Lobster Tail tends to be held in the trachea, but the "segment of a circle type" of tube, although usually easier to insert, does not engage the wall of the trachea so well. If a tube is too short it may slip out, whereas if it is too long it irritates the trachea. The length and shape must be assessed for each individual patient.

To overcome such difficulties encountered with standard models, a new type of single polythene tracheostomy tube (Figs. 1 and 2) has been devised at the Princess Margaret Hospital for Children, Perth, Western Australia. It has a relatively large airway diameter, its stability is independent of the position of the flange, the neck or the skin surface, and it is pulled directly backwards by elastic traction. It is semi-rigid, non-irritant and thin walled. The tube remains in position in the trachea and is not easily coughed out because of a flange which is separated from, but loosely attached to the tube, and which is held against the skin by elastic traction. The tube is acutely angled and the middle portion is made thicker by a sleeve of polythene. The sleeve gives strength and some rigidity, prevents the tube from being pushed too far into the trachea, and keeps the tracheostomy track open. A loose metal collar surrounds the tube above the sleeve and the flange rests on the collar. The collar fits in the sulcus below the larynx, and the outer parts of the flange rest on the anterior edges of the sternomastoid muscles. The flange does not press on the collar, its sole function is to prevent the tube from being expelled. The shape of the tube and the constant pull of the elastic prevent the tube from coming out, whilst the sleeve prevents the tube from going too far in.

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Complications of Tracheostomy

The tracheostomy tube to be described does not avoid all the complications of tracheostomy, but one may with advantage summarize those which may still be troublesome and in addition make some suggestions for their control.

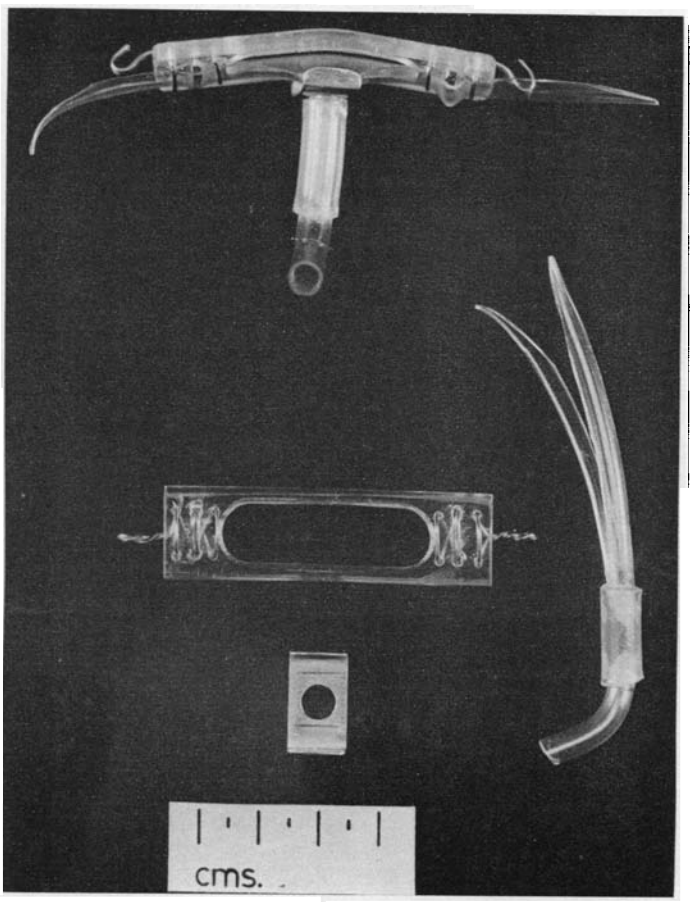


FIG. 1.

The Tracheostomy tube. This demonstrates the tube, collar and flange assembled and separate. Note how the tails of the tube slip under-over-under the wire loops.

The tube may slip out of the trachea depending on the length and shape of the tube, the neck movements, swelling of the neck and coughing. The tube itself with its independent flange has been designed to counteract this eventuality, but in order to minimize the effects of coughing the largest possible airway diameter should be used. This will allow an easy and rapid out-flow of air and secretions. If the tube is too small the high tussive pressure will force it from the trachea.

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Irritation of the tracheal wall may be caused during insertion of the tube and is influenced by the shape, size and position of the tube. The position is a resultant of the pull of the tapes and the push of the chin. Reports of fatalities resulting from faulty positioning have been recorded (Thomson and Negus, 1948, Reading, 1958).

This problem has been controlled by the use of a non-rigid tube which is retained in the trachea uninfluenced by the restraining tapes. With the polythene tube described, the position of least movement is the junction of the tube and sleeve with the anterior wall of the trachea. The tube itself moves with the trachea.

Pneumothorax and mediastinal emphysema are complications which are best prevented by minimal opening of tissue planes and keeping an adequate airway *viâ* the tube so that no undue raising of the tissue tension outside the trachea lumen occurs. In infants, the pleural cavity may bulge into a tracheostomy wound particularly if the trachea is exposed low down. Pneumothorax can follow direct injury or inspiratory mediastinal emphysema (Reading, 1958). Tracheostomy is best performed with a bronchoscope inserted into the trachea.

The use of a small transverse collar incision is strongly recommended. This avoids encroachment on the thorax, causes minimal opening up of the tissue planes, and heals with an inconspicuous soft scar without contractures. Using mainly blunt dissection, a small "post hole" is sunk between the strap muscles onto the trachea, a small portion of the trachea is cleaned and its relative position to the cricoid cartilage is noted. In the newly born the tracheal rings are about 0·5 mm. wide and there are six per 10 mm. of the trachea, while by the age of one year the rings have grown to 2 mm. wide and there are about four rings per 10 mm. of the trachea.

Three rings (usually 2, 3 and 4, as the infant neck is very short) are incised, but no cartilage should be excised. Short lateral cuts are made at each end between the adjacent intact rings. This tracheal opening does not interfere with the blood supply, does not weaken the tracheal wall, allows an adequate opening to be made, and enables the tracheostomy tube to be inserted with minimal trauma, and in particular, allows the tube to take up an optimum position in the trachea in relation to the tracheostomy wound and track. It also reduces the pressure of the tube on the upper rings of the trachea. The opening soon constricts around the tube whatever size is used.

The use of a vertical skin flap incision as suggested by Evans (1958) is valuable especially if the tracheostomy will be required for some time. This flap gives very good epithelialization and closes over the tissue planes of the neck.

Incoordination of the laryngeal reflexes of respiration and deglutition may occur, and is often first noticed a week or so after tracheostomy, when

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a spill over during feeding may result in the appearance of milk in the trachea. This can cause anxiety and may even suggest that a tracheo-œsophageal fistula has been produced. The explanation may be found in the laryngeal reflexes in which the larynx is held open or dilates with inspiration (similar to the external nares) and closes on swallowing with associated inhibition of respiration. These reflexes are closely integrated

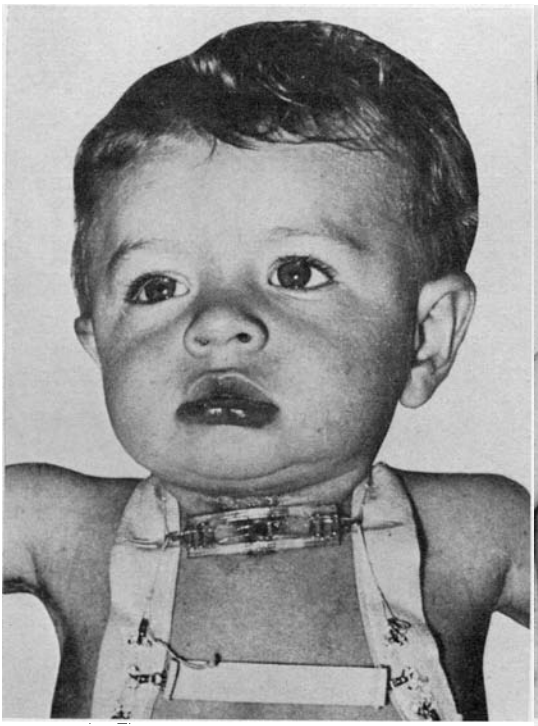




FIG. 2. FIG. 3.

FIG. 2.

The Tracheostomy tube in position. This demonstrates how the flange rests on the collar and how the elastic thread is attached to the hooks on each end of the flange, and the direct pull backward of the thread.

FIG. 3.

The Harness. This demonstrates the position of the hooks on the harness. Note how the elastic is pinned to the napkin in the post-axillary line which keeps constant tension on the elastic thread and allows free movements.

and though present at birth, must be reinforced by normal use. The necessity for normal dilatation of the larynx with inspiration disappears on tracheostomy, and also respiration can continue during deglutition. This rapidly causes a breakdown in the swallowing reflex and allows spill over to occur. The infant then has to learn the swallow-closure reflex dissociated from the respiratory reflex and usually does so in 2 to 3 weeks.

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This, however, is a great disadvantage when the time for decannulation comes, particularly if it is delayed, for the laryngeal opening reflex may be very impaired. Thus, as soon as a big inspiratory effort is made, the larynx collapses inwards with stridor and even spasm and a vicious circle may be set up with disastrous results (Venables, 1959).

It is suggested, as a means of stimulating the laryngeal reflex in long-standing cases, that the size of the tracheostomy tube be decreased so as to allow the maximum air entry *viâ* the larynx, leaving the tracheostomy tube as a safety valve. The usual corking should then take place, especially just before and during meals to try to stimulate the normal reflex, but the external diameter of the tube must be small and not fill the trachea. If there is a tendency to impaired airflow around the tube, increase in respiratory work occurs and apprehension causes spasm and much incoordination.

Collapse of the trachea above the tracheostomy opening may be another worrying complication. Crooks (1954) suggests that this may be due to a loss of strength of the trachea after one or two of its soft rings have been divided and to the negative pressure in the larynx and upper trachea which is present during inspiration. Reading (1958) reports a case in which this complication was due to the pressure caused by tilting of the tube.

As a means of control, the negative pressure is decreased by a large airway diameter allowing easy air entry and less strain. Later there must be adequate air flow around the tube. The incision of 3 rings, as mentioned previously, allows a strong section of the wall to be moved laterally and it also allows the tube to take up its optimum position without buckling the upper rings. The use of a tube with a separate flange prevents the tilting. The sleeve rests on the trachea (Fig. 4), the collar fits into the sulcus between the sternomastoids, while the flange rests on the sternomastoids and does not press on the collar (Fig. 3) its sole purpose is to prevent the collar from coming out.

Report of a Case

T.O., a male baby (Fig. 2), had a tracheo-œsophageal fistula successfully repaired when 1 day old. He then developed severe laryngeal stridor which continued to be troublesome until he was 5 months old, when a respiratory infection necessitated the performance of tracheostomy. A metal tracheostomy tube was used, but this was not very satisfactory as his chin kept tilting it down. He commenced to regurgitate feeds through his tracheostomy and developed some lower respiratory infection. Bronchoscopy then showed an indentation in the posterior tracheal wall due to pressure of the tip of the tracheostomy tube and this looked as if it could easily have progressed to a traumatic tracheo-œsophageal fistula.

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A polythene tracheostomy tube was then used. This was modified on several occasions, the final modification being that described in this report. The child is now 14 months old and is very well. Although decannulation has been attempted, he still has too much stridor to close the tracheostomy. His parents now look after him at home, using a portable mouth sucker, and a sucker adapted to a water tap. The vacuum tube from the

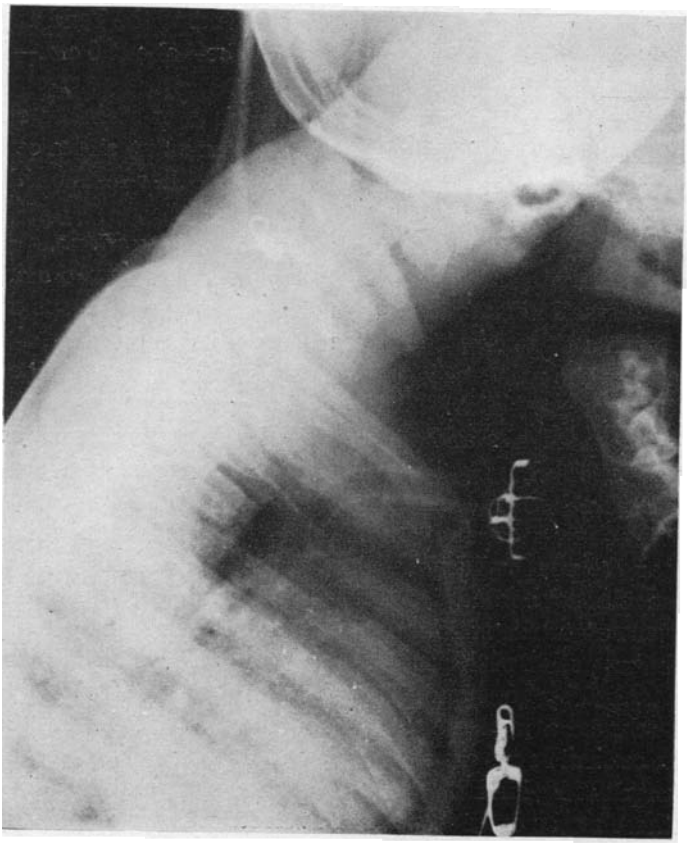


FIG. 4.

Radiogram showing tube in position. Note how the sleeve rests just external to the trachea. On bronchoscopy there was no sign of tracheal compression above the tracheostomy.

windscreen wiper of certain makes of motor car has been used for suction during car journeys by some parents allowing them freedom of movement without fear. (Venables, 1959, personal communication.)

The polythene tracheostomy tubes have been used with complete satisfaction on two other short term cases including an infant 3 weeks old with a congenital laryngeal web. They do not irritate, have a large airway diameter and are very stable.

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Description of the Appliance

The appliance (Fig. 1) is now described in detail.

The Tube. The tube is made from P.V.C. Insulation Tubing (Nylex) of 3·5 to 5·0 mm. internal diameter and with a wall 0·5 mm. thick. The bend is nearly a right angle, the section in the trachea is 10 to 15 mm. long, and the tip is cut in a gentle curve directed upwards and backwards. This prevents the posterior wall of the trachea being scratched during insertion. A sleeve of thick tubing 15 to 18 mm. long is next to the bend and is about 7·5 mm. in diameter. The remainder of the tube—about 6 cm.—is divided in a vertical direction into two tails.

The Collar. The collar is a rectangular piece of stainless steel about 9·5 mm. wide by 17 mm. long with the ends turned up and a central hole. The tails are inserted through the hole and the collar rests on the outside end of the sleeve.

The Flange. The flange is a slightly curved Perspex frame, 5·5 cm. long by 1·5 cm. wide with a central hole 3·5 cm. long and 1·0 cm. wide. At each end is a small hook, and underneath are two small loops of stainless steel wire with a ridge of wire between. The tails are inserted through the loops and over the ridge which hold them securely, so that the centre of the flange sits on the collar.

The Harness (Figs. 2 and 3). A strip of soft material such as doubled unbleached calico about 35 cm. long, with a piece of soft elastic about 15 cm. long attached at each end by hook and eye, is placed behind the neck, passing down in front of the chest. The elastic is pinned to the child's napkin near the post axillary line under slight tension. It is important to attach the elastic behind the mid-axillary line as this ensures fairly constant tension of the strip independent of body movement. To prevent the strip being pulled under the axilla a small piece of elastic (about 7 cm. long) is attached by hook and eye across the chest.

Two hooks are attached about 11 cm. apart on each half of the harness, so that the central hooks are about 3·5 cm. from the middle of the harness. A short length of Nylon Elastic Thread made into small loops is stretched between these hooks on each side. The selected elastic loop is slipped over each hook of the flange, exerting a direct pull backward, thus allowing a small range of movement of the flange and keeping it centred over the collar.

Management. The customary routine management of tracheostomy tubes is required. Fine polythene tubes make excellent suckers, and rarely is it necessary to suck further than just past the tip of the tracheostomy tube. A small piece of cotton tied firmly around the sucker about 4 cm. from the end will remind the nursing staff, or the parents, of this distance and so save a lot of unnecessary irritation of the trachea or carina.

Inspissated secretions can usually be liquified by instilling sodium bicarbonate solution or a wetting agent such as "Alevaire". Postural

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drainage preferably under the supervision of a physiotherapist, can greatly assist in keeping the chest clear and should be included in routine infant tracheostomy care.

No difficulty has been experienced in changing the tubes (usually twice a week) because the sleeve keeps the track well open down to the trachea. It is advisable to have a fresh tube, collar and flange assembled for the replacement. The importance of pinning the harness behind the mid-axillary line is stressed. It is the gentle constant pull of the elastic which allows free neck movement with no real change in the tension.

Summary

1. A new polythene infant tracheostomy tube is described. The stability of the tube is independent of the position of the flange or of the neck, due to the flange being separate from the tube. The tube is non-irritating, semi-rigid and has a large lumen compared with the external diameter. A polythene tube of 6 mm. external diameter has an internal diameter of 5 mm. which is twice the area of the similar sized 18 French grade metal tube in which the internal diameter of the inner tube is only 3·5 mm. Elastic traction from a harness allows free neck movements, but keeps constant tension on the flange. Tubes can be readily made in varying sizes to suit individual cases.

2. The case history of an infant on whom such a tube was used successfully is recorded.

3. Suggestions are put forward to prevent some of the complications of tracheostomy.

Acknowledgement

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Appendix

Technical details in the manufacture of the apparatus are as follows:

The Tube. About 10 cm. of P.V.C. Insulation Tubing (Nylex) of the required diameter is pulled over a metal rod, one end of which is bent at right angles. Paraffin is used as a lubricant. The rod must fit snugly, otherwise the polythene will blister at the bend when heated. The bend is inserted for about 10 seconds into paraffin heated to about 160°C. It is removed and immediately placed in ether for the same time. The polythene is rapidly removed from the rod—at times the end must be twisted to unstick it—and then replaced in the ether for a short time, keeping it bent to a right angle. The sleeves—15 to 18 mm. long—have been made from P.V.C. Blood Tubing (Nylex) or P.V.C. Tubing (Portex) H.E., whose

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internal diameter is the same or slightly less than the external diameter of the thin tubing. The edges are bevelled off and, as with all the polythene used, the edges are made smooth by passing them through a small flame. The sleeves are placed in "Dilating Fluid" and when sufficiently dilated are slipped over the tubes nearly to the bend. These shrink firmly onto the tubes and do not slip or narrow the lumen.

When dry, the ends of the tubes are cut down each side on the vertical line to within about 12 mm. of the sleeve, and then a narrow V-shaped piece is cut down to the sleeve on each side and removed. This ensures that when the ends or tails, which are about 6 cm. long, are pulled sideways they do not kink or bulge into the lumen.

The tracheal section is made 10-15 mm. long (for a long piece is unnecessary in the trachea) and cut in a gentle curve directed upwards and backwards.

The Collar is made from 26 gauge stainless steel, is rectangular about 9·5 mm. by 17 mm., with the ends turned up about 3·5 mm., that is, the thickness of the flange. A central hole is made slightly larger than the tube. Collars with different sized holes have been made to fit their respective tubes.

The Flange is a slightly curved frame made from "$\frac{1}{8}$ inch" Perspex Sheet 5·5 cm. long, 1·5 cm. wide, with a central hole 3·5 cm. long by 1·0 cm. wide. On the lower surface near each end, two small loops of 24 gauge (B.W.G.) hard drawn stainless steel wire are made by threading through holes, and a ridge of wire made between them. At each end of the flange is made a small hook. The holes are filled with "plastic filler" which prevents debris collecting and assists cleaning.

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