AN IMPROVED ENDOTRACHEAL TUBE FOR PEDIATRIC USE *

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One aspect of anesthesiology in need of additional refinements is pediatric anesthesia. For the past year and a half, we have been engaged in improving apparatus and instruments for pediatric patients. Included in our endeavors has been the development of an endotracheal catheter especially designed for pediatric use. An efficient catheter, particularly for pediatric use, should possess the following features: (1) The wall must be as thin as possible so that the lumen has the maximal cross section attainable without weakness. (2) The catheter should be made of material which is not easily compressed in order to prevent obstruction from kinking or collapse. (3) It should be constructed in such a manner that it does not inadvertently pass down the trachea as far as or past the carina. (4) Its bevel should be placed in such a manner that it does not press against the wall of the trachea, thereby causing obstruction. (5) The catheter should be easily anchored and held in place. (6) It should permit easy attachment of slip joints and be so constructed that these joints remain secure throughout the operation. (7) The body of the catheter should be rigid so that it may be introduced without flexion, bending, and without the use of a stilet. (8) It should be sufficiently pliable that it does not cause trauma. (9) It should not cause allergic reactions. (10) It should be easily cleaned and sterilized. None of the conventional catheters possess all these requirements.

In order to have a better insight regarding the most suitable diameter, length and positioning of endotracheal catheters for infants and children of various ages, a postmortem study was made of the larynx and trachea of premature infants, full term babies and children under 3 years of age. All specimens were fresh and not fixed. The diameters of the trachea and the distance from the vocal cords to the carina were measured in specimens ranging from 700 to 13,500 Gm. The following data were obtained.

Fifty premature infants, whose weight ranged from 700 Gm. to 1,825 Gm., were examined. The average anteroposterior diameter of the trachea in premature infants weighing from 700 to 900 Gm. was 1.5 mm. and the lateral diameter 3 mm. The average distance from the vocal cords to the carina was 4 cm. The difference between the anteropos-

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terior diameter and the lateral diameter is noteworthy. In infants weighing from 900 to 1,825 Gm. the anteroposterior diameter was 2 mm. and the lateral diameter 4 mm. The distance from the cord to the carina was 4.5 cm. In children whose average weight was 5,000 Gm. the anteroposterior diameter was 3 mm. and the lateral diameter 5 mm. The distance from the cords to the carina was 5.5 cm. In children whose average weight was 7,500 Gm. the average anteroposterior diameter was 3.5 mm. and the lateral diameter 7 mm. The distance from the cords to the carina averaged 6.5 cm. In children whose average weight was 13,500 Gm. the anteroposterior diameter was 4 mm. and the lateral diameter 8 mm. The distance from the cords to the carina averaged 8 cm.

A point of interest was noted concerning the relationship of the trachea to the main stem bronchi. Both the right and left main stem bronchi branch from the trachea at an angle of approximately 110 degrees in all children up to 3 years of age (fig. 1). This is in contrast

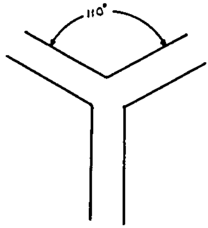

FIG. 1.

to the adult in whom the left main stem bronchus is at a more obtuse angle than the right. It would be of interest to determine at what age this adult relationship of the bronchi is developed. This study will be published later when more material in the older age groups has been examined.

With these figures as a guide we constructed the endotracheal tube to be described. A central core was made of a thin-walled polyethylene plastic tubing with an outside diameter of 4 mm. and an inside diameter of 3.25 mm. This plastic tubing had sufficient resilience to prevent collapse but was soft enough to be nontraumatic when introduced into the trachea. A McGill rubber catheter of standard number 18 French whose internal diameter accommodated the plastic tubing was fitted over the plastic tubing and secured with rubber cement (figs. 2, 3). The plastic tubing extended beyond the rubber tubing at one end for a distance of 3.5 cm. The bevel on the plastic tubing faced the posterior rather than anterior part of the trachea as is the case with the conventional catheter (figs. 3, 4). At the other end the rubber tube extended beyond the plastic tubing for sufficient length to permit the introduction of a standard number 0 slip joint. The over-all length of this catheter was 12.5 cm. This size was introduced with ease in a premature infant weighing as little as 700 Gm. and was found adequate for infants up to 7 or 8 months of age. In only one instance in the past year has there been need for a catheter of smaller diameter. Longer and wider catheters of similar construction were made with larger tubing. The largest size was constructed from plastic tubing with an outside diameter of 6 mm. and an inside diameter of 4.75 mm. and a Magill number 29 French tube for the outer covering. The plastic portion extended 4.5 cm. beyond the rubber tube. The opposite end permitted the introduction of a number 1 slip joint, as in the case of the smaller catheter. The over-all length of this catheter was 20 cm. This size can be used in infants ranging

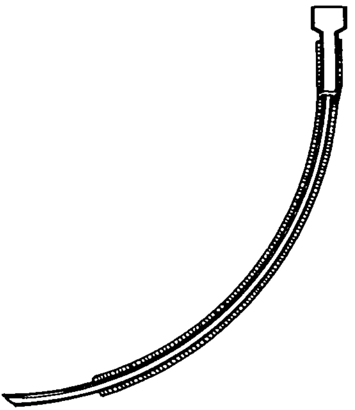

Fig. 2.

from one and a half years to children 2 to 3 years of age. A catheter of intermediate size between these two may be constructed using a 5 mm. plastic tubing and a number 24 French catheter. The plastic portion extended 4 cm. beyond the rubber tube. The over-all length of this catheter was 16 cm. The opposite end, as in the case of the largest tube, permitted the introduction of a number 1 slip joint. Attempts are being made to obtain thin-walled plastic tubing of various sizes and of material that can be boiled in order to have a more varied selection. It was found that the wall of some specimens of tubing was thicker than desired. By placing the tubing over a brass rod it could be thinned down to the desired size on a lathe. When larger catheters are required the conventional, currently available catheters are used.

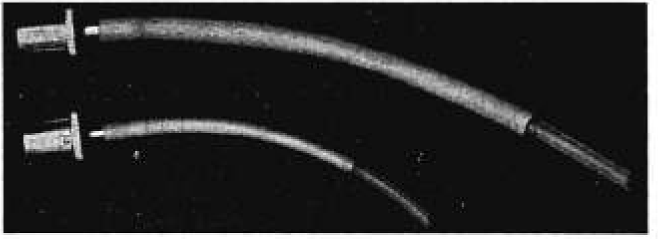

FIG. 3.

This type of catheter satisfies the majority of the requirements for an adequate endotracheal tube. The thin-walled plastic material used gives a maximal possible inside diameter in relation to the outside diameter, thereby decreasing the cross-sectional area which is obliterated by the tracheal catheter wall. Both the plastic and rubber tubing would be compressed if either were used alone but when combined in this fashion the tube is practically noncompressible, and will not kink or twist. The protruding plastic portion is soft and nontraumatic but rigid enough to prevent collapse.

Each time a specimen was dissected at autopsy the larynx was first exposed with a laryngoscope and one of these catheters was placed *in situ*. The position of the catheter and the bevel in the trachea was then noted when the larynx was opened. It was observed in every instance that the bevel came to rest in such a way that the lumen of the catheter was continuous with the lumen of the trachea. With the conventional catheters, which were introduced under the same conditions, the beveled edge was parallel with the tracheal wall and often snugly in contact with it owing to the influence of the curvature of the tube (fig. 4). Obviously, obstruction results with the tube in this position. This has occurred with the conventional catheter on various occasions during clinical anesthesia. The catheter cannot be introduced beyond the junction of the plastic and rubber tube. The larger diameter of the tube prevents passage of the catheter too far into the trachea. At the junction the outer diameter is 6 mm. for the small, 8 mm. for the intermediate and 10 mm. for the largest tube. Kinking at the junction of the slip joint, as well as slipping of the joint, is averted. The inner diameter of the slip joint is the same as or slightly larger than the inner diameter

FIG. 4.

of the plastic tube. Thus obstruction does not occur at the junction of the catheter and the slip joint.

The slip joint is introduced snugly against the plastic core. The extra length of the rubber tube permits a snug nonkinking union. In instances in which the catheter protrudes from the mouth there is sufficient resilience to prevent twisting and collapse. The tube possesses sufficient body to be anchored securely to the face, thereby preventing the catheter from slipping out of the larynx. The catheter is sturdy enough not to yield and kink under the weight of the slipjoints and connectors. It may be anchored with adhesive without damaging the tube. It possesses sufficient body to give it a gentle curve. Angulation, flattening or kicking does not occur in the oropharyngeal position.

Suction catheters of fine plastic tubing 2 mm. in diameter are easily introduced without any obstruction. The tube is sufficiently rigid that a stilet is not required. It is inexpensive and disposable. As many can be made as desired in any length and in any size one chooses. Although Magill catheters were used in the construction, any rigid rubber tubing is satisfactory. The tube is easily cleaned with soap and water and sterilized by the usual method employed for ureteral catheters, that is immersing them in mercuric cyanide solutions. If boilable plastic is available, the catheter may be boiled for sterilization. We do not believe this is necessary and use cold sterilization.

This catheter has been used in our department for the past year. In a number of instances in which the patient died as a result of the disease or operation and permission for autopsy was granted, there was no evidence of local irritation, allergy or trauma. To date, there have been instances in which tracheotomy was necessary because of the development of laryngeal edema after the use of these catheters.