OBSERVATION ON THE USE OF CUFFED TRACHEOSTOMY TUBES (WITH PARTICULAR REFERENCE TO THE JAMES TUBE*)†

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IN 1869 TRENDLENBURG introduced a tracheostomy tube with an inflatable cuff¹ He advocated that asphyxia and aspiration be prevented in operations in the mouth and pharynx by inserting a cuffed tracheostomy tube prior to the actual surgical procedure In subsequent years this proved a very effective method, compared to the packs, oiled gauze, and rubber balloons placed above the larynx previously used Modern medical dictionaries list this tube as Trendelenburg's cannula,² and it differs little from tubes now in use, nearly one hundred years later (Fig 1)

Apart from surgery of the larynx and pharynx, there was little interest in cuffed tracheostomy tubes until the use of intermittent positive pressure breathing (I P P B) was made popular during the Scandinavian poliomyelitis epidemic of 1952-1953.^{3 4}

FIGURE 1 Trendelenburg's cannula (1869)

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In 1954 Dr Edward James consultant in infectious diseases at Rush Green Hospital of Romford Essex England described a cuffed tracheostomy tube; hence the James Tube⁵ This tube was recommended by Fairley⁶ in his comprehensive account of the management of respiratory insufficiency (Fig 2)

FIGURE 2 James tube (1954)

The James tube manufactured for Medical and Industrial Equipment Limited has a seamless cuff allowing an even inflation The side tube to the cuff can be detached thus the tracheostomy tube can be shortened to fit the individual patient without interference with inflation of the cuff The angle between the two limbs of the tube is slightly greater than 90° which allows for alignment of the tube with the anatomical position of the trachea (Fig 3) Thus the least pressure is brought to bear on the anterior or posterior wall of the trachea The gentle curve of the tube is important for the easy introduction of a suction catheter

The advantage of a cuffed tracheostomy tube is the air tight occlusion of the trachea This makes the use of IPPB possible and protects the lungs against aspiration in patients who have lost their protective laryngeal and pharyngeal reflexes

The disadvantages are⁷

- 1 It is a single lumen tube the lack of a removable inner tube makes obstruction due to inspissated mucus a greater hazard

FIGURE 3 Line drawing from X-ray film of lateral view of James tube in position. Note that the trachea diverges at an angle of 15° from the plane of the skin. Consequently the angle between the two limbs of the tracheostomy tube should be slightly greater than 90° to adapt to the anatomical position of the trachea.

2 Rubber tubes require a thicker wall, thus the diameter of the airway is reduced

3 Rubber tubes may be more irritating than metal tubes

4 The cuff exerts pressure on the trachea and may cause dilation of the trachea and ischaemia of the tracheal mucous membrane

In spite of these disadvantages, we have found that the James tube has gained in popularity in our hospital. In the patients that we have had in our intensive care unit or in the recovery room the following groups of indications could be determined:

1 All patients requiring IPPB (except small children)

2 Patients with borderline respiratory function where respiratory treatment might become necessary

3 Patients with paralysis of the larynx or pharynx

4 Patients in coma with weak or absent protective reflexes

5 Patients for dilatation of tracheal stenosis

The use of the James tube in this last instance is illustrated in the case of a 57-year-old lady in whom a tracheal stenosis developed, for obscure reasons, after a tracheostomy. At one time the patient's tracheostomy tube had been removed on a trial basis, but it could not be reinserted when she experienced respiratory difficulties. She was rushed to the operating room and arrived there unconscious and almost totally obstructed. Intubation was not possible, but a small bronchoscope could be forced past the stenosed area. Subsequent attempts to replace the tracheostomy tube proved unsuccessful. Finally, we succeeded by threading a

No 5 James tube over a No 3 bronchoscope and introducing the tube under direct vision. Increasing inflation of the cuff dilated the trachea sufficiently to accommodate a No 8 tracheostomy tube. Later attempts to produce a permanent dilatation have failed.

PROBLEMS ASSOCIATED WITH THE USE OF THE JAMES TUBE

1 *The Length of the Intratracheal Limb of the Tube*

A high tracheostomy is mandatory for the use of the James tube. The distance between carina and tracheostomy opening must be sufficient to accommodate the cuffed limb of the tube. If the tube is too long it will almost always enter the right main bronchus, the resulting occlusion of the left main bronchus is usually recognized by absent breath sounds, reduced chest movement, and other clinical signs of atelectasis.

A more insidious problem is caused by a tube sitting just above the carina at the entrance of the right main bronchus (Fig 4). Here the air entry is equal in

FIGURE 4 Length of James tube (a) proper position, (b) end of tube close to carina—air entry to both lungs but the suction catheter enters only the right bronchus, (c) tube in the entrance of the right main bronchus—inflated cuff will occlude left main bronchus

both lungs but a suction catheter will only enter the right bronchus. This will lead to accumulation of secretions on the left side and the subsequent problems of atelectasis and infection. Since this position cannot be recognized clinically, we routinely take a chest X-ray within an hour after the insertion of a James tube.

The tip of the tube should be at least one centimeter above the carina and possibly more. In order to correct the position of a tube situated too low a cushion of one half-inch foam rubber is placed under the Horner connector.⁶ This raises the tube, minimizes the effects of changing the alignment between the tube and trachea, and is comfortable for the patient.

2 *Obstruction of the Lumen of the Tube*

In metal tracheostomy tubes, an inner cannula can be removed in case of obstruction with inspissated mucus. Rubber tubes have no inner cannula, consequently obstruction is more serious and the patient requires close supervision by experienced nurses. We insist that a patient with a rubber tracheostomy tube must not leave the recovery room or intensive care unit. The most important

factor to prevent the formation of crusts is the continuous humidification of the inspired air. We have modified the Bird micronebulizer by inserting a No. 30 gauge needle into the inlet and attaching it to a single intravenous set running continuously. The overflow is carried away by a small outlet, being inserted just off centre in the bottom of the nebulizer to allow about a $\frac{1}{4}$ -in pool of water to collect. A 500-ml flask of distilled water will supply the nebulizer for about twelve hours. Prior to this change, we invariably found these nebulizers dry.

Recently we have also used the Puritan nebulizer, which appears very efficient and requires little maintenance. It adapts readily to a disposable plastic tracheostomy cover. The nebulizer should be kept below the level of the patient to allow condensed water to drain back into the reservoir. Since we have used continuous humidification of the inspired air routinely, crust formation in the trachea and the accumulation of inspissated secretions in the tracheostomy tube have ceased to be a problem.

3 Tracheal Dilatation

Adriani⁸ demonstrated for the cuff of the endotracheal tube that most of the pressure is expended to overcome the elasticity of the rubber (Fig. 5). The same data should apply for the cuffed tracheostomy tube. To show that the elastic properties of the cuff do not change during usage we have tested a number of

FIGURE 5 The relationship between intracuff pressures and lateral pressures exerted by the cuff on the wall of the airway as the volume of air distending the cuff is increased (From Adriani and Phillips⁸) (By permission of the Editor of *Anesthesiology*)

FIGURE 6 Pressure-volume curve of James tube

tubes after several weeks of inflation. The pressure-volume curve (Fig 6) was found to be unchanged before and after the use of the tube and no difference was found after an additional three weeks of continuous inflation with 8-10 cc of air.

While little pressure on the tracheal wall is necessary to occlude the trachea, IPPB will require cuff pressures close to the inspiratory pressures used to prevent an air leak. With the pressures ordinarily used for IPPB a slight degree of tracheal dilatation can be expected. A reduced pulmonary compliance makes it necessary to use higher inspiratory pressures, and a greater volume of air must be inflated into the cuff to prevent an air leak. This will increase the diameter of the cuff and exert greater pressure on the tracheal wall. Once the trachea is stretched by this larger balloon, a subsequent increase in compliance will not readily reverse the situation, a large cuff is still required to fill the trachea. Thus the diameter of the cuff as seen in the chest X-ray film can become an indication of the patient's respirator problem (Fig 7).

In six suitable patients we have measured the diameter of the cuff from chest X-rays during the course of their respirator treatment (Fig 8). To avoid an error due to different projections, the diameter of the tube was also measured. At first we expressed the diameter of the cuff in relation to the diameter of the tube, but the use of different sizes of tubes presented difficulties. However, the X-ray projection as judged from the diameter of the tubes was sufficiently constant that we decided to use the diameter measured on the X-ray film expressed in millimetres.

FIGURE 7 Tracheal dilatation the broken line indicates the circumference of the cuff The degree of inflation of the cuff was required to maintain an air tight seal for IPPB

Of the patients illustrated in Figure 8 numbers 3 and 4 had no serious pulmonary problems While on the respirator patients numbers 2 and 6 showed a rapid increase in dilatation both required high inflation pressures because of low compliance and both succumbed to their pulmonary pathology

FIGURE 8 Relationship of the diameter of the cuff (as measured in chest X-rays) and the duration of IPPB. A solid or broken line connects the various measurements in any one patient whose number appears at the end of the graph.

Patients numbers 1 and 5 showed a more gradual but significant increase in tracheal dilatation associated with pulmonary infection, but both patients were able to breathe spontaneously before the problem of the dilated trachea reached major proportions. In all cases reported Bird respirators Mark 7 and 8 have been used.

That tracheal dilatation reflects changes in compliance is demonstrated in a comparison of two cases who were totally dependent on the Bird respirator for over three months (Fig 9). One patient had no pulmonary complications, and consequently the cuff volume changed little. The other patient showed a stepwise increase in cuff volume and each step represented a bout of severely reduced compliance, although there were intervals when a good exchange could be obtained using inflation pressures near normal, there was no reduction in the volume of the cuff.

Tracheal cartilages are "U" shaped, the open end of the "U" is closed by the fibres of the musculus trachealis.⁸ While the cartilages resist the pressure there is some degree of lateral dilatation, the main effect from pressure will be seen posteriorly where the tissues can stretch. This can produce a tracheal diverticulum.

Unfortunately an inexperienced pathologist attacked the patient whose dilatation curve was presented in Figure 9 and left for us to photograph the ruins of

FIGURE 9 Diameter of cuff in two patients dependent on the respirator for three months. Note the stepwise increase of the diameter in the patient with pulmonary complications.

what might have been a superb specimen. Although the posterior wall of the tracheal diverticulum is missing, the loose wrinkled tissue of the tracheal wall and the opening of the saccular dilatations can be seen (Fig 10). The patient suffered from an irreversible lesion in the spinal cord at the level of C2. The lungs at autopsy showed diffuse patchy consolidation separated only by small patches of air-containing tissue.

Tracheal dilatation can be minimized by the use of large tubes and by keeping the amount of air used to inflate the cuff as low as possible,⁹ a tolerable degree of air leak, for which the respirator can compensate, may be preferable. A record of the amount of air introduced into the cuff should be kept and any increase in the volume required should be given serious consideration.

SUMMARY

Of the many modifications of the cuffed tracheostomy tube, introduced by Trendelenburg in 1869, the "James Tube" manufactured for Medical and Industrial Equipment Company has been used frequently in our hospital in association with IPPB and for protection against aspiration. The angle and the smooth curve of the tube facilitate adjustment to individual patients and suction.

The length of the tube may present problems and we prefer an X-ray control of its position. Minor adjustments are made by placing a foam rubber cushion under the connector.

FIGURE 10 Tracheal diverticulum The trachea is opened from the front The posterior wall of the diverticulum had accidentally been removed (*a*) The loose wrinkled tissue of the tracheal wall indicates the stretching by the inflated cuff (*b*) The tube had been positioned well above the bifurcation (*c*)

Continuous humidification is essential to avoid obstruction of the lumen by inspissated mucus patients with rubber tracheostomy tubes require expert supervision and care

The pressure in the cuff necessary to prevent an air leak is related to the inspiratory pressure required in I.P.P.B. Tracheal dilatation was found to be associated with the use of high inflation pressures, and the volume of air used in the cuff as well as the diameter of the cuff seen in a chest X-ray appears to be related to pulmonary complications

RÉSUMÉ

Parmi les nombreuses variétés de tubes avec ballonnet utilisés dans les trachéotomies et introduits par Trendelenburg en 1869, nous avons souvent utilisé, pour la respiration sous pression positive intermittente et comme protection contre la régurgitation, le tube de James fabriqué pour la "Medical and Industrial Equipment Company". L'angulation et la courbe douce du tube en facilitent l'ajustement à chaque malade et à chaque genre de succion.

La longueur du tube peut présenter des problèmes, et nous préférons contrôler sa position par une radiographie.

Une humidification continue est nécessaire si l'on veut éviter l'obstruction de la lumière par du mucus, les malades porteurs d'un tube à trachéotomie en caoutchouc doivent faire l'objet d'une surveillance et de soins spéciaux.

La pression requise dans le ballonnet pour empêcher les fuites d'air est en rapport avec la pression inspiratoire requise pour la respiration sous pression positive intermittente. On a trouvé de la dilatation trachéale associée à un gonflement exagéré du ballonnet, et le volume d'air utilisé dans le ballonnet de même que le diamètre du ballonnet, visibles aux rayons-X, semblent être en rapport avec les complications pulmonaires.

REFERENCES

1. TRENDLENBURG, F. Beitrage zu den Operationen an den Luftwegen. Archiv f. klin. Chirurgie 12: 112 (1871).
2. DORLAND, W. A. The American Illustrated Medical Dictionary, 22nd ed. Philadelphia: Saunders (1951).
3. LASSEN, H. C. A. A Preliminary Report on the 1952 Epidemic of Poliomyelitis in Copenhagen. Lancet 264: 37 (1953).
4. IBSEN, B. The Anaesthetists' Viewpoint on the Treatment of Respiratory Complications in Poliomyelitis during the Epidemic in Copenhagen 1952. Proc. Roy. Soc. Med. 47: 72 (1954).
5. JAMES, E. Positive-Pressure Respiration in Bulbo-Spinal Poliomyelitis. Brit. Med. J. 1: 726 (1955).
6. FAIRLEY, H. B. The Management of the Patient with Respiratory Insufficiency. Canad. Anaesth. Soc. J. 7: 447 (1960).
7. MORCH, E. T., SAXTON, G. A., & GISH, G. Artificial Respiration via the Uncuffed Tracheostomy Tube. J. A. M. A. 160: 864-867 (1956).
8. ADRIANI, J. & PHILLIPS, M. Use of the Endotracheal Cuff. Some data pro and con. Anesthesiology 18: 1 (1957).
9. LLOYD, J. W. Tracheal Dilatation. Lancet 1: 83-84 (1964).