MANAGEMENT OF THE ENGSTRÖM RESPIRATOR IN EARLY INFANCY*

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High tracheostomy through the second or third tracheal cartilage is performed using the widest possible silver cannula, i.e. usually 3 to 4 mm. in diameter at the distal opening, to fit tightly into the tracheal lumen.

The cannula is double-lumen unfenestrated and protrudes beyond the guard plate so that the small standard tubings of the respirator can easily be connected to it.

The patient is intubated, if necessary under general anaesthesia given with the respirator. Thus respirator treatment is instituted even before tracheostomy.

The respirator treatment is started with an approximate volume for alveolar ventilation, which is determined from the size of the child's body, i.e. for a case in early infancy about 0.5-1.0 l./minute.

The total volume of the tubings, etc., of the apparatus is a known constant, and the compressible gas volume of the apparatus which does not reach the lungs can easily be determined for each case from the actual peak pressures in the airways. This volume will increase the total volume in the average case by 1.7-2 l./minute.

The settings on the respirator are the sum of the alveolar ventilation, the anatomical dead space and the compressible volume of l./min.; this is the total volume and is usually 2.2-3.5 l./minute.

At the same time, the rate of ventilation is chosen and is usually kept around 26-28/min., which has been shown by experience to be best, despite the fact that the infant's respiratory rate is higher. This frequency has given good results, because it allows sufficient time for physiological expansion and gas exchange in the alveoli.

Finer adjustments are made by a further control of the rate and volume. The peak insufflating pressure in the patient's airways is usually around 25-30 cm. H₂O, but occasionally the peak pressure

is as high as 40-45 and more rarely pressures of 70 cm. H₂O have been noted.

The main principle is to adjust the ventilatory volume exactly so that the patient gives up his spontaneous breathing completely and the respiratory work is given completely to the respirator.

In some cases it is necessary to use the negative suction venturi. The negative pressure varies from a few cm. H₂O to 15 cm. H₂O, and in a few cases it is even lower. The negative venturi suction is of the venturi type and does not begin to act before an essential part of the tidal volume has been passively expired by the patient. This timing prevents bronchial collapse and thereby aids in completely evacuating the insufflated gas.

With the proper application of negative suction a hyperinflation of the lungs is prevented. The suction effect is adjusted by watching the position of the thorax and ensuring that the chest moves properly through the normal mid position, which is a sign that effective gas exchange can take place.

The period immediately following consists of watching and judging the ventilatory needs of the patient.

After a short time, 15 to 20 minutes, the settings are controlled by the apnoea-duration test. The respirator is turned off and opened to the atmosphere and the apnoea duration is measured, i.e. the time taken after turning off the apparatus for the first spontaneous breath to be taken by the patient.

Our experience has shown that 15 seconds apnoea indicates that the respirator settings are adequate. If the apnoea is of shorter duration the volume should be increased a little, and if the duration is longer the volume should be decreased.

During the course of the basic disease, the ventilatory needs, especially during the acute phase, are altered owing to disturbances in metabolism and to other reasons that will be discussed later. In some cases the metabolism may be high and in others it may be low. Therefore, it is necessary to repeat the test frequently during the early stages

* From the panel discussion at a meeting of the British Association of Paediatric Surgeons in Stockholm, September 1961.

FIG. 1.—In order to maintain a constant adequate alveolar ventilation against increasing respiratory resistance, the respirator's compressible volume and the respirator's 'emptying' pressure must be greatly increased. As a consequence the total ventilatory volume is correspondingly increased.

of the respirator treatment until the patient's condition is stabilized.

Pathologically increased resistance and decreased compliance demand higher 'emptying pressure' on the respirator's ventilatory bag which contains the total ventilatory tidal volume. This 'emptying pressure' must always be about 20 cm. H₂O higher than the contrapressure in the bag, which is identical to the actual resistance for insufflation in the lungs. When the resistance in the airways is greater than 35 cm. H₂O, then the water safety trap must be shut off in order to make possible the administration of the required volume of gas for proper lung ventilation.

From Fig. 1 it can be seen that if the airways pressure rises, then the 'emptying pressure' on the bag must also be increased sufficiently to overcome this resistance. This means that the

respirator's compressible volume will also be increased and as a consequence the total ventilatory volume is correspondingly increased.

The mean tracheal pressure is kept at a low level because the positive pressure progresses to a peak pressure of short duration. In addition, the mean tracheal pressure can be reduced by proper use of the negative venturi suction.

When the intratracheal pressure in this case was 48 cm. H₂O (Fig. 2), the oesophageal pressure was found to pass from the negative to the positive side of the zero line with only a short peak and was negative for almost the whole cycle.

From experience, a mean tracheal pressure of 5 cm. H₂O was found to be acceptable. In some cases this pressure can be maintained at a low level with this respirator without the use of the negative suction phase.

FIG. 2.—Tracings showing tracheal and oesophageal pressures during the use of the Engström respirator in early infancy, in which there was great lung-airways resistance.

Because the patient's airways are in direct connexion to the preset gas volume in the respirator's ventilatory bag, it is possible for the patient to breathe quite freely without interference with the respirator frequency. In fact, the remaining part of the preset tidal volume is then administered by the apparatus, ensuring that the patient is sufficiently ventilated.

When the patient is well controlled by using the

apnoea-duration test properly, he may be allowed to leave the respirator's rhythm for a short time. This may happen if he becomes disturbed, for example, crying because of hunger; once the cause of the disturbance is remedied, the child falls into step again with the respirator, so that for practical reasons the settings are left unchanged once basal conditions have been reached.

To date, laboratory analyses of the serum bicarbonate substantiate how steadily the bicarbonate level is maintained by the respirator.

As infants are very sensitive to rapid electrolyte variations, a sudden release of carbon dioxide in acidosis through late interference can lead to tetany.

Thus it is possible to treat respiratory distress in infancy of various aetiology for a long time. From our experience the following characteristics of the distribution of the preset ventilatory volume are a necessary prerequisite for the success of the treatment:

- (1) The respirator must be able to give a constant measurable volume no matter how small this volume may be.

- (2) The gas flow must continuously accelerate and adapt itself proportionately to the varying resistance in such a manner that the tidal volume causes an even and normal expansion of the lungs including the pathological parenchyma.

- (3) Enough contact time, i.e. time for gas exchange, must be achieved without change in the necessary respiratory rate and inspiration-expiration relationships.

- (4) No depressant drugs should be used if they can be avoided.