size their relationships. The assembled spinal cord and nerves were introduced through the inferior end of the canal, which represented the subarachnoid space, and pulled up to the desired height. Because of the grass skirt effect of the trailing nerves and cauda equina, the assembly was removed by pulling it through the superior end of the canal.

**Simulated Cerebrospinal Fluid**

The basic formula for simulated cerebrospinal fluid was calculated from information from Bodansky's textbook. The materials used to make 1,000 cc. of fluid were: NaCl 7.250 g., KCl 0.259 g., CaCl₂ 0.144 g., MgCl₂ 6H₂O 0.231 g., NaH₂PO₄ 0.060 g., urea 0.130 g., glucose 0.510 g., NaHCO₃ 2.250 g., and human albumin 1.25 ml. Except for albumin, this agrees well with that used by Mitchell et al. in his preparation of simulated fluid. It required approximately 0.125 ml. of 85 per cent lactic acid to lower the pH to 7.3. To prevent precipitants, each of the materials was put into separate solution before being added to the mixture. NaHCO₃ was added last and, as soon as sufficient water was added to make up the 1,000 cc. required, oil was layered on top. To prevent escape of CO₂ and pH changes. This fluid compared favorably with cerebrospinal fluid and had an osmolality of 297, a specific gravity of 1.0050, and a pH of 7.30 at 37°. The canal was charged with this fluid from its upper end.

**Use of Model**

This model was used for osmolality, density, refraction, and pH studies of various concentrations and combinations of intrathecal anesthetic agents. Through the multiple access sites, simultaneous sampling could be done and telethermometry facilitated. By coloring the solutions with a drop of methylene blue it was also used to demonstrate to students the movement of injected intrathecal agents. After injection in the vertical (sitting) position, the model could easily be put into the horizontal (lying) position, prone, supine, or Trendelenburg. The effects of positioning, rate of injection, baricity, or other controllable variables to the spread of the injected solution could be visibly shown. An unanticipated dividend of filling the canal and body with water was the optical magnification of the size of the cord. The model was easy to maintain and clean; the most used puncture-site nipples were inexpensive and easily replaced.

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**References**


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**Functional Reduction of Anatomical Dead Space in the Management of Acute Alveolar Hypoventilation**

E. Stresemann, M.D.*

Treatment of acute alveolar hypoventilation with intermittent positive pressure breathing (IPPB) will be ineffective, even on high inspiratory oxygen concentrations, if it does not increase tidal volume and thereby prevent CO₂-retention. If, for example, tidal volume is 250 ml., there will remain, after subtracting 150 ml. of dead space volume, 100 ml. for alveolar ventilation. Given a CO₂ concentration of 5.6 per cent in the alveolar air, a CO₂ output of 200 ml./minute, and a respiratory rate of 20, at each expiration 10 ml. CO₂ are

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contributed to alveolar air, of which only 5.6 ml. can be exhaled during a respiratory cycle. Consequently, 4.4 ml. CO₂ per breath will not be eliminated, thus raising arterial P CO₂. For complete elimination of CO₂ from the alveolar air, tidal volume must be increased to 330 ml., given a constant breathing rate of 20. This may be very difficult, even with the help of IPPB, if mechanical factors restricting lung expansion (such as lung congestion, extensive pleural fibrosis or marked destructive emphysema) are present.¹ Using IPPB, the administration of inspiratory pressures as high as 40 cm. of water in such cases may not improve the acute situation because of adverse effects of high intrapulmonary pressure on venous return ² and, secondly, because such pressure might still be too low to raise tidal volume sufficiently under the given pathophysiologic conditions.

Under these circumstances, a reduction of anatomical dead space becomes very valuable. On intubation of such a patient, a relatively small caliber tube can be inserted and used to blow air into the trachea. If the tube is perforated at several points between the oral

![Fig. 1. Operational design for tracheal intubation in connection with special attachment to respirator (Fig. 2) to reduce respiratory dead space. (Nasotracheal approach for intubation may be used in preference to depicted orotracheal route.)](image1)

![Fig. 2. Diagrammatic representation of respirator exhalation port (Bird respirator) with attached fitting for tracheal tube. Cross shaded spaces comprising exhaled air, not shaded spaces containing air from respirator.](image2)
Cavity and its tip situated above the carina, this part of the dead space can be washed clear of end-expiratory air and filled with fresh air. A functional reduction of dead space of approximately 80 ml may thus be achieved. In the above example, this will raise alveolar ventilation from 100 ml to approximately 180 ml, which means that ventilation then becomes adjusted for complete CO₂ elimination.

A more precise method of dead space reduction would consist of insufflating air through a tube into the dead space during inspiration only, covering the entire inspiratory volume. In this case, the air insufflated must enter the dead space solely at the tip of the tube situated closely above the carina, since expiratory air in the dead space between the end of the tube and the oral cavity must not be rebreathed. The functioning of this principle depends on availability of a mechanism adaptable to various volume requirements of air during inspiration. It is, therefore, preferably to be practiced in conjunction with a pressure-cycled respirator. Such a machine, however, is difficult to operate in an open system as the leak in the airways, represented by the annular aperture at the glottis, might seriously interfere with the proper functioning of the pressure-cycled respirator.

As soon as this working principle is applied to a closed system, however, it can be practiced with accuracy. This can be achieved with a pressure-cycled respirator, where the machine is operated in a closed system represented by tight junctions between the airways and the respirator. On this basis, air can be let into the trachea only during the inspiratory phase. At the same time, due to the arrangement of the valves, no expiratory air will be rebreathed from the dead space between the tip of the air conducting tube within the trachea and the expiratory valve of the respirator (fig. 1). Using a Bird Respirator (e.g., Mark 7), only a slight technical modification of the inlet system, near the expiratory valve, will be necessary. It consists of a short cylindrical adaptor that can be inserted in between the inlet tubes and the exhalation port of this type of respirator. The adaptor bears a nozzle inside to fit a tracheal catheter (approximately 28 Fr.) (fig. 2).

The combination of assisted breathing with the functional reduction of dead space by the insufflation of air into the trachea will be valuable under conditions in which the administration of artificial respiration is unsuccessful because of CO₂-retention due to the inability to raise alveolar volume to required levels.

REFERENCES

Cricothyroid Membrane Puncture with Special Cannula

PETER SAFAR, M.D., AND JEAN PENNINGKX, M.D.

Cricothyroid membrane puncture (cricothyrotomy) (fig. 1) is indicated for the immediate relief of life-threatening airway obstruction in circumstances when backward tilt of the head, forward displacement of the mandible and positive pressure inflation attempts have failed and tracheal intubation is impossible. The latter may be the case in the absence of tracheal intubation equipment, when the operator is inexperienced with tracheal intubation or when there are anatomic abnormalities.

Tracheotomy, i.e., incision of the trachea below the cricoid (fig. 1) is technically more difficult and more time consuming and should, whenever possible, be performed electively under controlled conditions in the intubated patient. Cricothyrotomy is performed more easily and quickly than tracheotomy, since the

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