"DIFFERENTIAL PRESSURE" RESPIRATION IN THORACIC OPERATIONS

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If two rubber balloons, different in size but of equal thickness of wall, are attached to the two limbs of a “Y” tube, it will be found that any attempt to inflate both balloons simultaneously will be defeated by the behaviour of the larger balloon, which always blows up in preference to the smaller one.

Observations made in the course of a series of 200 resections for pulmonary tuberculosis (to be reported in detail later) suggest that the principle involved in this simple experiment may be utilized to provide a quiet surgical field during intrathoracic operations.

Nitrous oxide-oxygen/thiopentone anaesthesia in combination with relaxants was used in these cases, and artificial ventilation was maintained in the usual way, by rhythmic compression of the breathing bag, up to the moment of pleural incision. The inflationary pressure was then reduced to range from 0 to between 5 and 7.5 cm. of water, until the lung on the operated side was seen to have undergone collapse; a process which was sometimes hastened by the deliberate application of pressure by the surgeon. Experience showed that there was little tendency for the contra-lateral lung to collapse during this interval provided that its pleural space was intact and that the degree of Trendelenburg tilt was not excessive. It was, however,
customary to increase the respiratory rate at this stage in order to minimise the reduction in ventilation resulting from the tidal volume of 150–250 ml. produced by the reduced pressure. After the desired degree of collapse had been achieved, it was observed that it was often possible to raise the inflationary pressure slowly, to range from 0 to between 10 and 15 cm. of water, and so produce a tidal volume of from 250–500 ml. without re-inflating the lung on the operated side. As a result an unimpeded approach and a very quiet field could be provided throughout operation.

Although this “differential” effect could be obtained by manual inflation of the lungs, it was found to be more satisfactory to use a machine for the purpose, since for optimal results it was necessary to maintain a regular respiratory rhythm and consistent pressures; a consistent return to atmospheric pressure at the end of pulmonary diastole (deflation) appearing to be of particular importance (Cournand et al, 1948). The differential effect could not be properly demonstrated when multiple cavities or emphysematous changes were present in the lung on the operated side, nor when an artificial pneumothorax or extensive lung pathology was present on the contra-lateral side.

On no occasion was any difficulty experienced in re-inflating the lung at the end of operation, and no post-operative complications have arisen on the operated side which could be attributed to the technique. In no case, so far as it can be ascertained, has an extension of disease become established in a new area suggesting a spill-over at the time of operation (Bickford et al., 1951).

An explanation of the effect described is appended, but it is felt that it is incomplete and that it probably oversimplifies the mechanisms involved.
Physical Principles (Fig. 1). Two elastic spheres of unequal size are shown connected to a source of pressure.
The same pressure operates over each sq. cm. of the inner surfaces of both spheres. E1 and E2 represent the forces resisting expansion.

The expansion force, or total outward thrust, is in each case a product of the pressure and its area of application. In "B" this product is less than the resisting force and expansion does not occur. In "A" the product is greater and the sphere expands; the disproportionate gain in surface area having outmatched any increase in elastic resistance (Fig. 2).
The increase in the total outward thrust produced by a constant pressure of 10 g. per sq. cm. operating over the inner surface of an elastic sphere of progressively increasing diameter, is indicated by the curve "PP''" (Fig. 2). The ordinates represent the total outward thrust or expansion pressure in grammes on the walls of a sphere at a constant pressure of 10 g. per sq. cm.

The increase in the elastic force resisting the sphere's expansion is shown as a straight line ("EE'") in accordance with Hooke's Law.

If the elastic force resisting expansion is equal to an arbitrary figure of 500 grammes, it is apparent that the sphere must have a surface area in excess of 50 sq. cm. (\(\pi \times 4^2\)) if it is to expand under a pressure of 10 g. per sq. cm., and it will be seen from the graph, in terms of diameter, that this surface area is a critical one below which the sphere will deflate, and above which it will expand ever more freely at the same constant pressure.

SUMMARY

A procedure for maintaining adequate ventilation during thoracic operations with low inflation pressures and collapse of one lung is described. An attempt has been made to demonstrate the rationale and mechanical principles underlying this manoeuvre.

REFERENCES

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