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THE ROLE OF APNOEA IN ANAESTHESIA FOR MAJOR SURGERY

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There has been widespread support for the concept which views anaesthesia as a triad (Rees and Gray, 1950), the components of which, narcosis, relaxation, and analgesia, ideally are produced by specific drugs with selective actions. It is now a generally used method of anaesthesia to induce sleep with thiopentone, to produce muscular relaxation with a relaxant drug, and to reduce the response of the patient to noxious stimuli by the use of nitrous oxide and occasionally a more potent specific analgesic drug such as pethidine.

During the past six years an anaesthetic technique based on this principle has been adopted by us. Thiopentone has been used in minimal doses to produce sleep, a 50% mixture of nitrous oxide and oxygen, if necessary supplemented by pethidine (or, in the earlier years, very minimal doses of ether), to produce analgesia, and a paralytic drug to attain relaxation and initiate the control of respiration. As a result of the respiratory depression subsequent upon adequate doses of the relaxant agents, there has been no hesitation in resorting to completely controlled respiration for the cases in which this technique has been employed. The experience gained during this period led to the conclusion that use of controlled respiration reduced the dose of both relaxant and thiopentone which it was necessary to administer in these cases. The examination and significance of this possibility are the subject of this paper.

Effect of Controlled Respiration on Dosage of Relaxant Agent

It must be remembered that the muscles of the abdominal wall vary their tone during respiratory activity (Best and Taylor, 1945; Lovatt Evans, 1952). Relaxation—that is, the reduction of tonus—of these muscles, like any other muscle group, can be achieved either by diminishing the response of the muscle fibres to activity of their motor neurones, as, for example, by giving a relaxant drug, or by reducing the number of stimuli passing down the motor nerve, and this latter effect can be used to intensify the former.

The activity of the respiratory motor nerve is regulated by the respiratory centre, and any factor which either diminishes or increases the activity of this centre

will correspondingly diminish or increase the tonus of the abdominal musculature. It is presumed in the argument which follows that there will be no "depression" of the respiratory centre either by anoxia or by anaesthetic drugs.

During controlled respiration two factors result in diminished activity of the respiratory centre: they are (a) the rhythmical inflation and deflation of the lungs, and (b) the adequate pulmonary ventilation which maintains a normal blood carbon dioxide level.

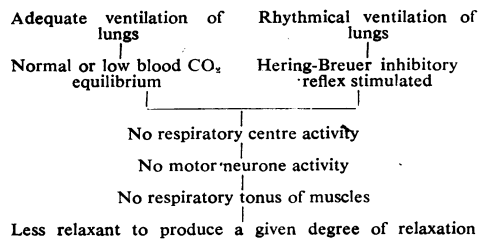
The first of these factors requires little amplification. The establishment of controlled respiration itself tends to prolong the apnoea by overstimulation of the inhibitory Hering-Breuer reflex resulting from the regular cyclical inflation of the lungs (Burstein, 1949). That curarization alone is not responsible for maintaining the apnoea in patients who are anaesthetized by the technique under review is suggested by the fact that they not infrequently move their limbs or the muscles of the face while their respiratory activity is still in abeyance.

The second factor is of the greatest importance. The blood carbon dioxide level plays a dominant part in determining the activity of the respiratory centre, and a consideration of the sequence of events following the administration of a relaxant drug will demonstrate the importance of controlled respiration. The paresis of the muscles of respiration which is an inevitable consequence of injecting any relaxant agent results in a diminished minute-volume of respiration, which in turn is followed by a raised blood concentration of carbon dioxide, because equilibrium between blood carbon dioxide production and excretion takes place at a higher level. Dosage with a relaxant drug therefore produces a state in which the activity of the respiratory motor neurones is increased although the response of the muscles to this activity will be decreased. In other words, a higher dosage of relaxant will be required to produce flaccidity of the muscles. There is here a vicious circle, which can be broken by either "controlled" or "assisted" respiration.

The necessity for assistance of respiration in the curarized patient is universally recognized, but there has been a tendency to regard the persistence of some spon-

taneous respiratory activity as preferable in all cases where there is not an absolute surgical indication for full control of the respiration (as, for example, in open chest surgery). A state of "assisted" respiration in which the blood carbon dioxide level is maintained within normal limits, even if desirable, would seem technically difficult to attain. Even then, however, such a patient, by virtue of the activity of these muscles and the consequent maintenance of tonus, will require more relaxant than the patient in complete respiratory arrest. The probability that this is a valid conclusion is borne out by Dundee (1952).

A patient, therefore, who is in apnoea and whose respiration is adequately controlled will require less relaxant than a patient with spontaneous respiratory activity, because of the following train of events:



Effect of Controlled Respiration on the "Sleep" Dose of Intravenous Barbiturate

From the earliest days of the use of relaxants there was a strong clinical impression that the dose of thiopentone required to maintain sleep was smaller in patients whose respiration was controlled than in those whose respiration was spontaneous or assisted. It was suggested that this might in some part be due to pharmacological potentiation of thiopentone by D-tubocurarine chloride (Gray and Halton, 1946). A controlled investigation, however, on human volunteers led to the conclusion that there was in fact no such potentiation when the respiration was not controlled (Gray, Gregory, Rees, and Fenton, 1951). Dundee (1952) has (a) established that there is a statistically significant reduction in the dose of thiopentone required by patients whose respiration is controlled, and (b) investigated and indicated the possible factors, other than those suggested by Brennan (1952), responsible for this finding.

Discussion

There are few who would question the desirability of producing maximal effects from minimal doses of relaxant in order to ensure at the end of an operation more complete elimination and ready reversal by antidotes. The maintenance of apnoea during anaesthesia by controlling the respiration contributes towards this end by obtaining the greatest degree of muscular relaxation from a given dose of relaxant. Furthermore, such control of the respiration results in a quieter field of operation, for which the surgeons are undoubtedly grateful.

It is well established that the anaesthetic agents are directly depressant to the myocardium and have, in addition, varying degrees of effect on cardiac rhythmicity and vasomotor control. In addition to these disturbances of the circulation they may impair the function of various parenchymatous organs. The desirability of reducing the dosage of these drugs in clinical practice must be undisputed.

In view of the considerations outlined above it is suggested that apnoea, with controlled respiration, is a valuable means of achieving this and should therefore be looked upon as an integral feature of the technique for anaesthesia in major surgery and not as something to be avoided if possible, or regarded as a nuisance if inevitable.

There is an additional advantage to be gained from controlling the respiration. Breathing into anaesthetic apparatus inevitably places some additional strain upon the patient, although with well-designed anaesthetic machines this may be minimal. Nevertheless it would seem better that this extra energy should be expended by the anaesthetist rather than by the patient, and, as Waters (1942) pointed out, it may be "desirable to relieve a weak patient from the energy output necessary to contract the diaphragm and intercostal muscles."

An objection to the use of controlled respiration for all major surgery which must be considered is the possibility that the efficiency of cardiac filling is impaired by the intermittent positive pressure and that as a result the cardiac output will fall and the circulatory condition deteriorate. It has been shown that the cardiac output depends upon the average intrathoracic pressure, and there is no doubt that certain types of intermittent positive-pressure respiration produce circulatory depression. However, if the pressure at which the lungs are ventilated is applied according to a curve which shows a slow rise to a maximum during inspiration, followed by a rapid expiratory fall to zero pressure and then a pause at least as long as the period of inflation before the next cycle begins, the rise in mean intrathoracic pressure is small and the cardiac output unaffected (Cournand *et al.*, 1948). The knowledge and application of this correct type of intermittent pulmonary inflation are extremely important and an integral part of the technique which is advocated. Moreover, any machine which may be used to maintain artificial pulmonary ventilation must be capable of giving the correct type of respiratory pressure curve (Esplen, 1952a, 1952b; Musgrove, 1952).

Conclusion

In the light of these considerations we suggest that apnoea should be regarded as an essential component of the syndrome which we induce in our patients in order to prepare them for, and to protect them from, surgery. The time has come, in our opinion, to substitute for the triad principle of anaesthesia outlined at the beginning of this paper a tetrad which can be regarded as a pyramid which has as a base apnoea, upon which are constructed the sides of the pyramid—narcosis, relaxation, and analgesia.

Summary

This paper discusses the effects of "controlled respiration" on the dosage of relaxant drug and thiopentone found to be necessary during anaesthesia. As in both cases smaller doses are used in patients whose respiration is controlled than in those in whom there is spontaneous respiration, it is suggested that "apnoea" should be regarded as an important feature of the technique of anaesthesia for any major surgery.

The importance is emphasized of maintaining the correct type of pressure curve of inflation and deflation during controlled respiration.

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