THE POSSIBLE ROLE OF HALOTHANE/ AIR ANAESTHESIA IN MASS CASUALTY SURGERY

Major R. H. ROBINSON, F.F.A.R.C.S., R.A.M.C.

Senior Specialist in Anaesthetics, Cambridge Military Hospital, Aldershot

Introduction

WHEN large numbers of casualties occur in battle or as the result of civilian disasters, the choice of anaesthetic for the surgery required may be limited by the local shortage of compressed medical gases. At the early stages of such situations the bulk and weight of gas cylinders make it impractical for them to be transported in sufficient quantities to fulfil anaesthetic requirements for more than a short time. Because it is impossible to guarantee replacements for empty gas cylinders under these conditions, it is desirable that there should be available some means of vaporizing liquid anaesthetic agents in air. Farman (1962) has pointed out that similar difficulties are faced by anaesthetists in developing countries with skeleton medical organisations.

This problem has been solved to a great extent by the introduction of the Oxford Vaporizer (Macintosh & Mendelsohn, 1941), and the E.M.O. Ether Inhaler (Epstein & Macintosh, 1956). These inhalers give precise concentrations of ether vaporized in air with automatic thermocompensation.

The versatility of both these inhalers is well known, but even in experienced hands, induction of ether anaesthesia may be lengthy and stormy. The dangers of explosion and fire when diathermy is used during ether anaesthesia is a grave disadvantage.

The introduction of halothane, which has none of these disadvantages, has further pushed ether into the background as a routine agent for anaesthesia. In view of the prevalence of halothane as an "all purpose" anaesthetic agent at the present time, halothane/air was clinically investigated. It was anticipated that its rapid induction of anaesthesia, simplicity of administration as regards technique, non irritant action on the respiratory tree and rapid recovery from anaesthesia, would be advantages which were unobtainable from ether/air anaesthesia.

Apparatus

The Gardner Universal Vaporizer was used. This is a new apparatus produced by members of the commercial team which co-operated in the production of the E.S.O. chloroform inhaler and the E.M.O. ether inhaler. The apparatus is suitable for use as a "drawover" inhaler or as a "plenum" vaporizer for use in conjunction with compressed medical gases. The vaporizer is manufactured almost exclusively of stainless steel. It is circular in shape, 17 cm. in diameter, 20 cm. in height, and weighs 5 kg. Mounted on top of the vaporizer is the concentration control unit, consisting of knob, scale and control cam. The control unit can be easily removed and one calibrated for another anaesthetic agent substituted.

The vaporizer delivers predetermined concentrations of volatile anaesthetic agent over a wide range of intermittent or continuous flow rates, and automatic temperature compensation ensures constant concentration of any anaesthetic vapours delivered under any ambient conditions where anaesthesia is envisaged.

Performance of the Apparatus

The following performance data are claimed by the manufacturers:

1. *Change of Flow Pattern.* Change from intermittent "human" pattern to continuous flow, causes no appreciable difference to the vapour concentration output.
2. *Ambient Temperature.* The concentration out-put does not vary more than ± 5% full scale, over the range of ambient temperatures at which surgical procedures may be carried out.
3. *Intermittent Flow through the Vaporizer.* An average accuracy of ± 5% full scale is maintained with flow rates between 3 to 10 litres/minute.
4. *Continuous Flow—Open Circuit.* An average accuracy of ± 5% full scale is maintained with flow rates between 3 to 10 litres/minute.
5. *Continuous Flow—Basal Oxygen.* An average accuracy of ± 7% full scale is maintained with oxygen flow rates between 750 mls. to 3 litres/minute.
6. *Flow Resistance.* At a flow of 40 litres/minute, maximum resistance of the vaporizer at any concentration setting, or any ambient temperature at which anaesthesia is envisaged, is less than 1 cm. water gauge.

In this series, the vaporizer was used as a "draw-over" inhaler with the halothane control unit. An O.I.B. (Oxford Inflating Bellows) was placed between the inhaler and the patient, and on the occasions when controlled respiration was instituted, a Ruben non-rebreathing valve was used. (Fig. 1).

Method

The investigation was divided into two parts, the first group contained patients who were not intubated and were breathing spontaneously under anaesthesia. The second group contained patients who were intubated and were breathing spontaneously or whose respirations were controlled under anaesthesia.

Group 1—Not Intubated—Spontaneous Respiration

The operations performed are classified in Table 1. There were 50 patients in this group, 6 of them were female and 44 male. The age incidence was 25.5 ± 10.25 years and the weight incidence was 150 ± 21.2 lbs.

Premedication in all cases was papaveretum (B.P.C.) and hyoscine hydrobromide (B.P.), the dosage scaled to meet each individual patient's requirements.

Induction was with sleep doses of thiopentone sodium. The mask was directly applied to the face and the patient allowed to breathe halothane vaporized in air. On relaxation of the jaw an oropharyngeal airway was inserted and the mask re-applied and kept in place with a Clausen's harness.

Maintenance was carried out using halothane in air only, and average maintenance concentrations of halothane in air were found to be between 1.5 to 2 per cent (Figure 2).

Measurements of blood pressure, pulse rate, respiration rate and minute volumes were carried out pre-operatively, on the completion of induction, post-incisionally and at five minute intervals throughout the course of the operation. The systolic and diastolic blood pressures were estimated using a brachial stethoscope and mercury sphygmomanometer, and the minute volume measured using a Wright Anemometer. Muscle relaxants were not used in Group 1.

Induction

The sleep dose of thiopentone sodium varied between 200 and 350 mgs. of a 2.5 per cent solution. These doses were slightly higher than those commonly used in civilian anaesthetic practice, since most of the patients comprising this series were fit young servicemen and women. The halothane concentration on application of the facemask was 4 per cent and this was easily respired in all cases, there being no instances of coughing or struggling. Breathholding occurred in three cases, and here the sleep dose of thiopentone sodium was deemed to be insufficient. An oropharyngeal airway was easily inserted without attempts at rejection or facial grimaces after approximately two minutes. The too early insertion of the airway emphasised the fact that many a potentially good induction is ruined by this manoeuvre (Guedel, 1951), as induction in four cases took up to three times as long as the average, after premature airway insertion.

Mild cyanosis occurred in six cases during induction, but was rapidly alleviated by adding oxygen to the halothane/air mixture, reducing the halothane concentration or by surgical stimuli on the commencement of surgery.

Clinical Observations

Cardiovascular System

Blood Pressure (Figure 3)

During induction with halothane/air, the average systolic blood pressure fell by approximately 25 mms Hg, with a maximum fall in one case of 45 mms Hg.

The diastolic blood pressure during induction fell on average by 10 mms Hg, a maximum fall in one case was 25 mms Hg.

After incision there was an average rise in systolic blood pressure of 8 mms Hg, and in diastolic blood pressure of 10 mms Hg, which in both cases was only transitory, there being a further slight fall of several mms Hg, during the succeeding minutes.

Thereafter the systolic and diastolic blood pressures both remained well below the pre-operative levels, but gradually rose as the concentration of halothane was reduced during the latter half of the operations, and when skin suturing was performed under the lowest possible halothane concentration necessary to maintain a still patient, systolic and diastolic readings exceeded the pre-operative values.

During maintenance of anaesthesia, the plateau observed by Wyant, Merriman, Kilduff and Thomas (1958) was in evidence (Figure 3). During maintenance 65 per cent of systolic blood pressure readings were 100 mms Hg or more, which is contrary to the findings of Burns *et al* (1957), who reported that 60 per cent of readings were below 100 mms Hg. At no time was respiration assisted, and some degree of respiratory depression leading to carbon dioxide retention may well be responsible for the higher blood pressure readings in this series.

The pulse pressure also fell (Figure 4). After induction of anaesthesia, there was an average fall of 15 mms Hg. with a further slight fall after incision. There was a gradual rise in pulse pressure to the pre-operative value as the concentration of halothane was decreased during the latter half of the operation.

Heart Rate

E.C.G. readings were not taken, but there were no changes in rhythm as a result of halothane/air anaesthesia as far as digital palpation of the pulse could determine. Burns *et al* (1957) and Bryce-Smith and O'Brien (1956) both stress the bradycardia associated with halothane anaesthesia. In this series, however, there was a gradual but definite rise in the average pulse rate throughout the duration of anaesthesia (Figure 5) rising by 24 beats/minute at the end of operation. Some individual cases exhibited a fall in pulse rate.

The tachycardia may be due to surgical stimuli in the presence of inadequate analgesia, this effect being more pronounced than the bradycardia from increased vagal activity which is usually seen with halothane anaesthesia.

Bradycardia would, in any case, be less marked here, since the patients in this series were young, fit servicemen and women with a pre-operative pulse rate of 64 ± 15, which is a much lower value than one would expect from a more generalised cross section of a civilian population.

However, it is more likely that the tachycardia described is associated with some degree of carbon dioxide retention from respiratory depression while using relatively high concentrations of halothane.

Respiratory System

Maximum concentrations of 4 per cent halothane/air were easily respired and no coughing or struggling occurred, and hence smooth inductions resulted.

The respiratory rates increased during induction, the pre-operative values being 15.7 ± 3/minute, and after induction 18.8 ± 1.7/minute. A further increase occurred after incision with values of 25.4 ± 7.4/minute.

The respiratory rates gradually fell during the course of the operations until near the end of the procedures when skin suturing, in conjuction with lowering of the halothane concentrations brought about a further rise. In this series, the average respiratory rates never fell to their pre-operative values during the course of the operations (Figure 6).

The minute volumes were decreased at the end of induction from pre-operative levels of 7.9 ± 2.4 litres/minute to 6.4 ± 1.7 litres/ minute, the lowest recorded value after induction being 3.9 litres/minute. A marked increase occurred following incision with minute volumes of 10.1 ± 3.4 litres/minute and the highest post-incisional reading was 20 litres/minute.

During the course of anaesthesia, there were gentle fluctuations in minute volumes but the average value at no time fell to pre-operative levels (Figure 7). However, there was a disproportionate rise in respiratory rate and minute volume as shown by a falling of the tidal air from an average pre-operative value of 500 mls to an average post-induction level of 340 mls. After incision this rose to an average level of 400 mls, and thereafter gradually fell until the latter half of the operation, when reduction in halothane concentrations initiated a rise in tidal air values, but on average, values did at no time rise to pre-operative levels (Figure 8).

The depression of the respiratory system with high concentrations of halothane/air, gave rise to mild cyanosis in 12 per cent of cases during induction, which were easily relieved by giving oxygen, lowering the concentration of halothane/air, or by commencement of surgery when surgical stimuli brought about an increase in rate and depth of respiration.

Mild cyanosis was also seen in 6 per cent of cases during maintenance of anaesthesia, and this was alleviated by adding oxygen to the inspired mixture or by reducing the concentration of halothane/air when possible.

The onset of cyanosis during maintenance limits the depth of anaesthesia obtainable when respirations are spontaneous and unassisted, as pointed out by Bryce-Smith and O'Brien (1956).

Muscular Relaxation

Muscular relaxation was adequate for the type of operations performed. No added relaxation was necessary for herniorraphy cases, but lower abdominal operations were not performed under halothane/air anaesthesia with spontaneous respiration.

The degree of relaxation obtained was proportional to the concentration of halothane administered. It was not possible to obtain the fullest relaxation of which halothane is capable, due to the marked respiratory depression and cyanosis which occurs using high concentrations of halothane vaporized in air.

Post-operative Period

Recovery of reflexes occurred within minutes of cessation of the administration, and were invariably fully active by the time the patient was returned to bed in the recovery ward.

Most patients rejected their airways within 10 minutes, and most were able to respond to spoken commands within 15 to 30 minutes.

It is the author's impression that these patients are "brighter" post-operatively than following halothane vaporized in nitrous oxide and oxygen, and post-operative headache is a rarity after halothane/air anaesthesia. The incidence of post-operative vomiting does not appear to be greatly influenced by this technique. Shivering occurred in several cases post-operatively.

Volume of liquid halothane used

The average duration of operation was 40 minutes, and the approximate volume of liquid halothane used per minute was 0.46 ml, i.e. 27.8 mls per hour.

Thus the approximate cost of halothane/air anaesthesia is 17/– per hour.

Group II. Intubated, spontaneous and controlled respirations

It was intended that this part of the investigation would be concerned only with the maintenance levels of halothane/air necessary to maintain smooth anaesthesia when patients were intubated, and their respirations being spontaneous, or controlled using relaxant drugs.

It was also intended to show the ease or otherwise of tracheal intubation using halothane/air anaesthesia in the absence of muscle relaxant drugs.

Group II. Comprised 30 patients, 9 female and 21 males.

17 cases were intubated and breathed spontaneously, 13 were intubated and controlled respiration instituted. 26 of these cases were intubated without the use of relaxant drugs, and when controlled respiration was necessary, tubocurarine chloride was given.

The average of this group was 20.1 years, the range being 12 to 50 years.

The average weight was 145.6 lbs, the range being 98 to 189 lbs.

Classification of the operations performed can be seen in Table 2.

Induction in all cases was with sleep doses of 2.5 per cent thiopentone sodium in dosage varying from 200 to 350 mgs, followed by the application of mask and inhalation of 4 per cent halothane/air in 26 cases, 3 per cent halothane/air in one case, and in the three remaining cases in this group, suxamethonium chloride was given to facilitate intubation and controlled respiration commenced from the start.

The average duration of inhalation of halothane/air necessary to produce satisfactory conditions for laryngoscopy and the insertion of an endotracheal tube, was six minutes, the range being three to nine minutes. This agrees with Bryce-Smith and O'Brien's (1952) findings, although in this series there was no prior cocainisation of the vocal chords.

60 per cent of cases showed a marked reaction to intubation with reflex arm and leg movement, and often a short period of apnoea, all of which settled in the ensuing two or three minutes.

The average maintenance concentration of halothane necessary for the intubated cases with spontaneous respiration, was 2 per cent.

Patients with controlled respiration, intubation and relaxant drug therapy were at first maintained with 0.5 per cent halothane/air, but the seventh case in the series, post-operatively complained of "awareness" during abdominal closure following her hysterectory. The appreciation of pain was evident during this "awareness" period.

Since this unfortunate case, a maintenance concentration of 0.75 to 1.0 per cent halothane/air has been used, with no further occurrences of "awareness."

Discussion

Halothane/air induction is smooth, rapid and easy and it is much simpler than induction with ether/air. Recovery from anaesthesia is also quicker and more pleasant than with ether/air.

However, halothane is a poor analgesic (Bryce-Smith and O'Brien, 1956). Following a sleep dose of thiopentone sodium, unconsciousness can be maintained with 0.5 per cent halothane/air only in the complete absence of surgical stimuli, when the patient is breathing spontaneously. Analgesia can be improved by raising the concentration of halothane, and up to 2.5 per cent there is no marked respiratory depression. Nevertheless, there are occasions when the surgical stimulus is so great, that reflex movements occur. If this is to be avoided by increasing the concentration of halothane/air still further, marked respiratory depression may ensue, leading to cyanosis.

These higher concentrations of halothane necessary to maintain anaesthesia in certain cases where the patients are breathing spontaneously, associated with some respiratory depression leading to a threat of carbon dioxide retention and hypoxia, raise the possibility of a risk of liver damage.

The hypotensive effect of halothane/air, on the average, was not excessive, but individual cases showed marked falls of blood pressure. This investigation is concerned with halothane in the role of sole anaesthetic agent for mass casualties, who may have some degree of blood loss without adequate facilities of blood volume replacement. The hypotensive effect might well be potentiated in these cases. Furthermore, blood loss alone leads to hypoxia, and this associated with respiratory depression from halothane/air anaesthesia causing further hypoxia would not seem to offer the patient the best chances of survival (Freeman, 1962).

In spite of the above disadvantages, halothane/air anaesthesia with patients breathing spontaneously would be of value in many cases, where blood loss is not severe, on account of its rapid, pleasant induction, ease of administration, uninflammability, and controllability. Apparatus for its administration can be reduced to the simplest and most highly transportable proportions. Rapid recovery from anaesthesia is an added advantage as this may well simplify the post-operative nursing and facilitate the earlier removal of patients from a battle or mass casualty area.

The versatility of the Gardner Universal Inhaler would allow halothane, or any other anaesthetic agent available (e.g. chloroform, ether, azeotropic mixtures) to be used, since only a simple manoeuvre is necessary to change the control unit for one calibrated for another agent. This would allow the anaesthetist in battle or disaster situations to utilise any anaesthetic agent which may be readily available.

Halothane/air anaesthesia is unsuitable as the sole agent for anaesthesia in battle or disaster situations but there is a place for its use in selected cases. However, if the facilities for oxygen administration and controlled respiration are available, it is possible to overcome most of the disadvantages associated with halothane/air. An experienced anaesthetist is necessary for the supervision of its administration if tragedies are to be avoided.

Summary

1. Halothane/air anaesthesia was induced in 50 non-intubated and 30 intubated patients with the object of assessing the possible value of its employment in the surgery of mass casualties in whom respiration was spontaneous.

2. Detailed observations were made on all patients in the non-intubated group on cardiovascular and respiratory functions during pre-operative, induction and maintenance phases.

3. Whilst rapid recovery from this anaesthetic would be an advantage in the removal of treated patients from a stricken area, the anaesthetic could not be considered the method of choice with patients who had suffered from severe blood loss.

4. Under the supervision of an experienced anaesthetist with facilities for oxygen administration and controlling respiration, halothane/air anaesthesia was regarded as safe and useful over a wide range of casualties.

5. Halothane/air anaesthesia does not constitute by itself the most suitable single method for use in the emergency operative treatment of mass casualties in war or civilian disasters.

REFERENCES

BRYCE-SMITH, R., AND O'BRIEN, H. D. (1956): Fluothane: A Non-explosive volatile anaesthetic agent. *Brit. Med. J.*, **2**, 969.

BURNS, T. H. S., MUSHIN, W. W., ORGANE, G. S. W. AND ROBERTSON, J. D. (1957): Clinical investigations of Fluothane. *Brit. Med. J.*, **2**, 483.

EPSTEIN, H. G. AND MACINTOSH, Sir R. (1956): An anaesthetic inhaler with automatic thermo-compensation. *Anaesthesia*, **11**, 83.

FARMAN, J. V. (1962). The problems of anaesthesia in under-developed countries. *Brit. J. Anaesth.* **34**, 897.

FREEMAN, J. (1962). Survival of bled dogs after halothane and ether anaesthesia. *Brit. J. Anaesth.* **34**, 12.

GUEDAL, A. E. (1951). *Inhalation Anaesthesia.* 2nd ed., p. 88. New York, Macmillan.

MACINTOSH, R. R. AND MENDELSOHN, K. (1941). *Lancet.* July 19, p. 61.

WYANT, G. M., MERRIMAN, J. E., KILDUFF, C. J. AND THOMAS, E. T. *Canad. Anaes. Soc. J.*, (1958), **5**, 384.

ORTHOPAEDIC	25
HERNIORRAPHY	6
VARICOSE VEINS	5
ANAL	4
SKIN GRAFTING	4
GENITO-URINARY	3
MASTECTOMY	1
ABDOMINAL WALL	1
GYNAECOLOGICAL	1

CLASSIFICATION OF OPERATIONS PERFORMED IN GROUP I.

TABLE 1

UPPER ABDOMINAL	2
LOWER ABDOMINAL	11
E.N.T.	7
ORTHOPAEDIC	4
DENTAL	5
GENITO-URINARY	1

CLASSIFICATION OF OPERATIONS PERFORMED IN GROUP 2.

TABLE 2

Figure 1. The Gardner Universal Vaporizer with Halothane control unit removed and resting on top of the apparatus.

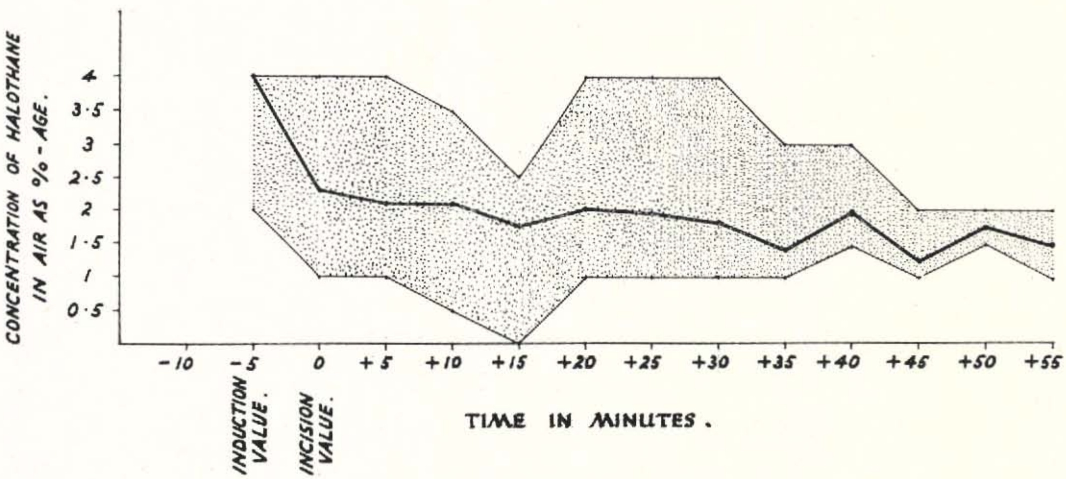

FIG. 2. THICK LINE REPRESENTS AVERAGE CONCENTRATION OF HALOTHANE IN AIR. SHADED AREA REPRESENTS EXTREMES OF CONCENTRATIONS OF HALOTHANE IN AIR.

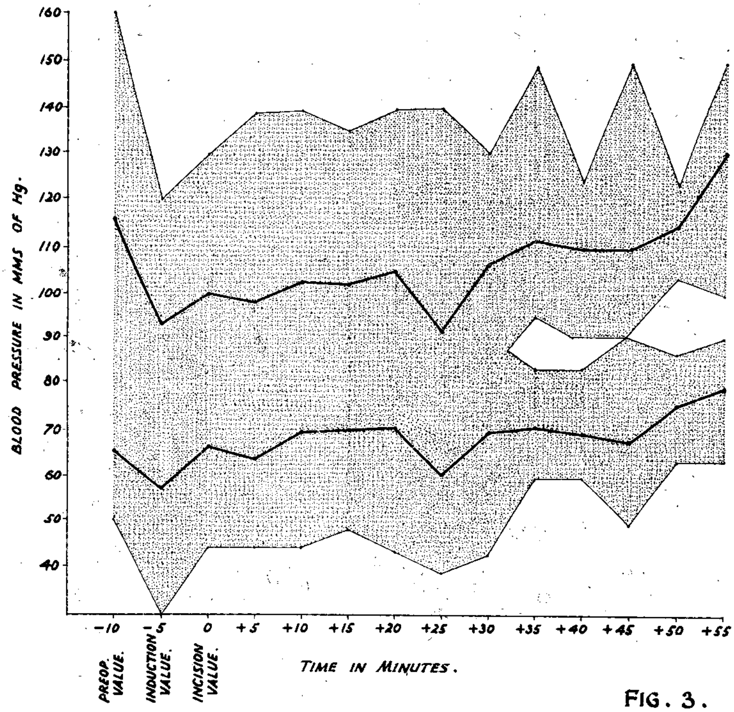

FIG. 3.

UPPER THICK LINE REPRESENTS AVERAGE SYSTOLIC PRESSURE.
LOWER THICK LINE REPRESENTS AVERAGE DIASTOLIC PRESSURE.
SHADED AREA REPRESENTS EXTREMES OF SYSTOLIC AND DIASTOLIC PRESSURES.

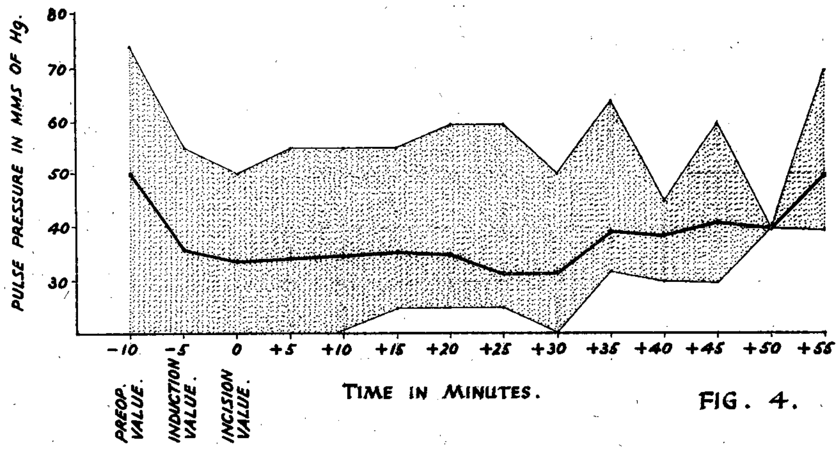

FIG. 4.

THICK LINE REPRESENTS AVERAGE PULSE PRESSURES IN MMS OF Hg.
SHADED AREA REPRESENTS EXTREMES OF PULSE PRESSURES IN MMS OF Hg.

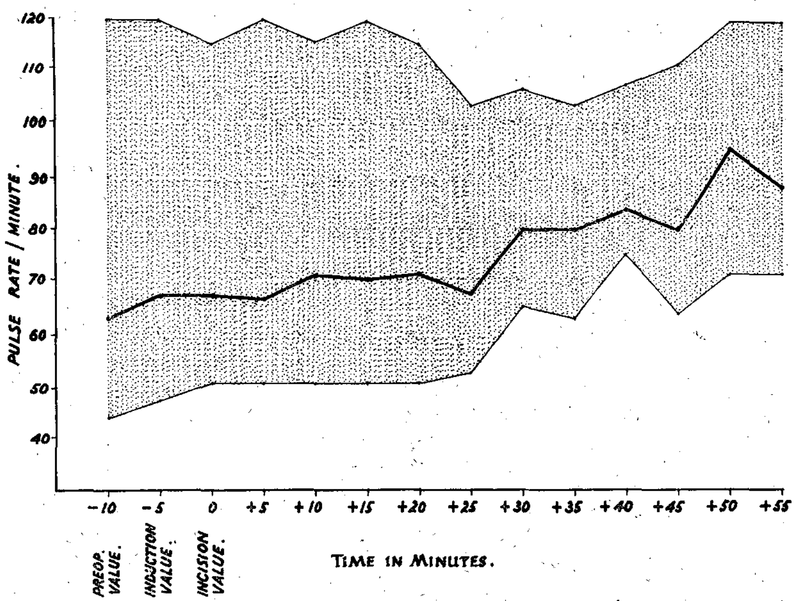

FIG. 5. THICK LINE REPRESENTS AVERAGE PULSE RATES / MINUTE.
SHADED AREA REPRESENTS EXTREMES OF PULSE RATES / MINUTE.

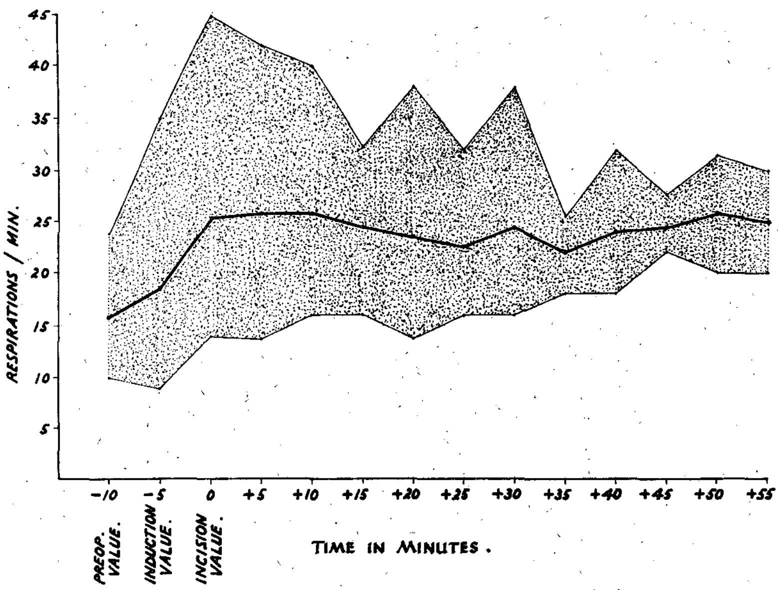

FIG. 6. THICK LINE REPRESENTS AVERAGE RESPIRATIONS / MIN.
SHADED AREA REPRESENTS EXTREMES OF RESPIRATIONS / MIN.

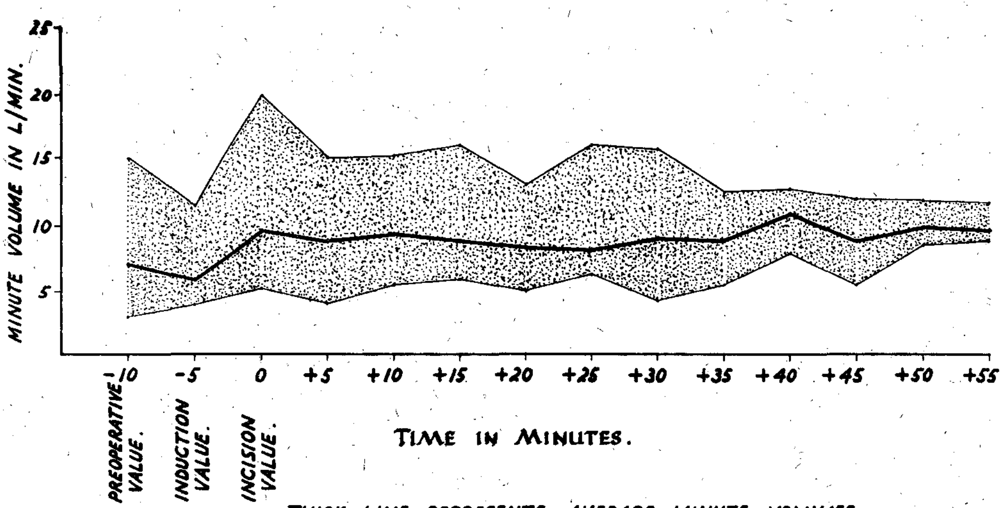

FIG. 7. THICK LINE REPRESENTS AVERAGE MINUTE VOLUMES. SHADED AREA REPRESENTS EXTREMES OF MINUTE VOLUMES.

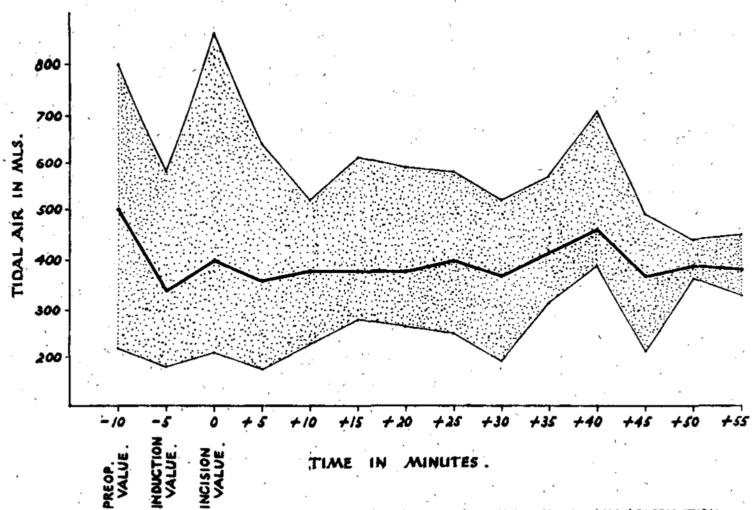

FIG. 8. THICK LINE REPRESENTS AVERAGE TIDAL AIR IN MLS/RESPIRATION. SHADED AREA REPRESENTS EXTREMES OF TIDAL AIR IN MLS/RESPIRATION.