ANAESTHESIA FOR EMERGENCY HOSPITALS*

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SINCE THE SUMMER of 1959 the Anaesthesia Department of Canadian Forces Hospital at Rockcliffe (now relocated in the National Defence Medical Centre (NDMC) Ottawa) has been engaged in assessing techniques and equipment applicable to the new Field Medical Units of the Armed Forces. During the past year, the department has accepted the additional responsibility of recommending supplies and equipment for the Emergency Hospital programme. In the latter project, the advice of Dr. Ian MacKay and Dr. R. A. Gordon has been most helpful.

EMERGENCY HOSPITAL PROGRAMME

The Emergency Health Division, Department of Health and Welfare (to whose Director we are indebted for the general information and statistics), has instituted a programme of stockpiling large stores of drugs, supplies, and equipment against the possible catastrophe of all-out total war.

Part of this programme consists of assembling 200-bed surgical hospitals for support of surviving facilities in the weeks and months following disaster. The Emergency Hospital stockpile is authorized presently at 40,000 beds, as the first phase of a 500-hospital (100,000-bed) programme. It is with the anaesthesia for this initial phase that we have been concerned. Many items for many hospitals have already been procured. The first completely packaged units should be available this summer.

A few statistics upon which the programme is based may be of interest, and should orient us to the situation being assumed for planning purposes. There are approximately 100,000 active-treatment beds in Canada today, which gives some indication of the daily work-load of the 20,000 physicians and surgeons in our country. Fifty per cent of these beds are in potential target areas. Incidentally, so are 9,000 of the doctors, including a high proportion of the trained specialists.

If our 12 major cities were attacked, simultaneously, with 5-megaton ground-burst weapons, allowing only 15 minutes' warning, it is calculated that the following situation would apply:

Population at risk	7.1 million
Killed	2-3 million
Injured	1.25 million

It is estimated that approximately 900,000 of the one and one-quarter million would be injured seriously and of these 300,000 would require surgical care urgently, that is, within 48 hours. It is felt that possibly 10 per cent would be

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able to reach a hospital with the assistance of their families or neighbours prior to the commencement of the organized rescue. The responsibility for this organized rescue and for immediate first-aid has been assigned to the Canadian Army, and for this function some 210 mobile survival columns are under training.

THE EMERGENCY HOSPITAL

1. *General Description*

The 200-bed surgical unit will be prepackaged in man-portable units, colour-coded by areas and departments. The unit will consist of ten 20-bed nursing sections including one for preoperative and one for postoperative patients.

The operating section will consist of three operating tables, which should be located in one large room or area if possible.

All equipment requiring sterilization will be packaged and coded for the Central Sterile Supply Service.

Each unit will be provided with generators sufficient to supply adequate power for essential services.

Since blood transfusion service from standard Red Cross sources may be inadequate in the immediate postattack period, it is planned to supply each hospital with equipment sufficient for collecting and cross-matching blood from 100 donors.

Dextran and electrolytes will be available in reasonable quantities and limited supplies of serum albumen will also be provided. It does seem regrettable that there are no plans at present to supply safe plasma.

Oxygen will be stored with, and available to, Emergency Hospitals in sufficient quantities that some may be available for use in anaesthesia for selected cases. For the preoperative and postoperative sections, two-cylinder multiple-manifold units have been recommended (see Figure 1).

No anaesthetic gases or standard anaesthetic machines employing carbon dioxide absorbers are provided for the Emergency Hospitals, at least in the immediate post-catastrophe period.

It is planned that Emergency Hospitals be stockpiled, complete, at safe distances from major target areas, near existing buildings such as schools or small hospitals (preferably) where they can be assembled quickly.

2. *Proposed Functions and Staffing*

The Emergency Hospital unit is designed to function as an independent entity in existing buildings suitable for the purpose—or as a supplement to surviving hospital facilities.

The designation of professional staff for these units is not considered to be a responsibility of the Federal Government but rather one that should be accepted by Provincial and Municipal Departments of Health. Obviously a good deal of co-operation in planning must be attained among all levels of government. It would seem that Academies of Medicine might well take a more active role in encouraging proper planning.

The prepackaged hospital unit will be equipped to function medically for a

FIGURE 1 Two cylinder multiple manifold oxygen unit recommended for emergency hospitals

minimum of 48 hours without resupply. After that time it is hoped that some restocking from back up stockpiles would be possible. No new items (with the possible exception of blood) could be anticipated for at least 30 days. The most optimistic estimate anticipates that it would require a minimum of 6 months for the pharmaceutical industry to be restored to useful proportions. Certainly we would likely be dependent to a large extent on the stockpiling programme for at least that long.

The foregoing, then, outlines the situation likely to be encountered if the Emergency Hospitals now being stockpiled are ever required to be put into service. From the viewpoint of anaesthesia, the equipment, supplies, and techniques recommended have been selected on the basis of factors which might be summarized as follows:

1. The Emergency Hospital will have an operating capacity of three tables. It is anticipated that they would be used continuously on a 24-hour basis.
2. No anaesthetic gases or standard machines will be available to the unit.
3. The supply of experienced anaesthetists would be very limited. A considerable number would have been victims of the initial attack. Of the remainder, many would be occupied in other roles with units of the militia. Still others would be required urgently to assist in resuscitation duties. Each hospital would be fortunate if it possessed one trained anaesthetist per 8-hour shift.
4. Surgical procedures undertaken initially would likely be of short duration; hence induction of anaesthesia would have to be accomplished as rapidly as possible, compatible with safety.
5. Trained personnel to care for unconscious postoperative patients would likely be scarce; hence recovery from anaesthesia would have to require as little supervision as possible.

Let us now deal with the alternatives available and feasible within the foregoing limitations.

TECHNIQUES, SUPPLIES, AND EQUIPMENT

1. *Local Anaesthesia*

It seems quite likely that a considerable volume of surgical and manipulative work would be performed with the benefit of no more than local and field infiltration—with or without sedation. For this reason, local anaesthetic drugs and the equipment required for their use have been included in the stockpile for each unit. The agent will be provided without epinephrine, but the latter will be available separately if required.

2. *Regional, Epidural, and Subarachnoid Anaesthesia*

The use of these techniques is very limited in Military Field Surgical units. It is felt that there could be some place for them, however, in the management of hospitalized victims of civilian disaster. Limited quantities of equipment and drugs required for these techniques have therefore been included in the stockpiling programme. The epidural catheters will be in sterile packs with sterilizable adapters provided to facilitate administration of the agents. Lidocaine (Xylocaine) has been selected as the agent for local and epidural use. Pontocaine and glucose have been included with subarachnoid anaesthesia in mind.

3. *Intravenous Anaesthesia*

The one limitation which has always applied to the use of intravenous agents has been the requirement for some means of ensuring adequate ventilation. The availability now of ambu-type respirators and of short-acting relaxants has

made the use of intravenous anaesthesia practical for almost any type of surgical procedure. This route of administration is not limited to employment of thio-pentone. Certainly this drug can be used as the induction agent for the anaesthesia for all traumatic surgery, if we recognize that shocked patients cannot tolerate more than minute quantities. With care, and adequate ventilation, it can be used as the principal agent for many surgical procedures.

During the course of our testing programme we have been impressed with the possible uses of a technique which we employed initially for ear, nose, and throat surgery where adrenaline and explosion hazard eliminated most of the potent general anaesthetic agents. This technique involves the administration of a mixture of meperidine (Demerol) and succinylcholine as an intravenous drip, and is described in detail in another paper in this issue of the *Journal*. For purposes of the stockpiling programme, suffice it to say that the many uses of the technique so impressed the testing group that the programme includes these two agents in somewhat larger quantities than might be expected.

The technique obviously demands the use of assisted or controlled ventilation. The requirement for ventilation has been solved, we believe, by the inclusion of six ambu-type respirators for each hospital unit. These kits will have positive-pressure non-rebreathing valves substituted for the standard plexiglass valves normally supplied with them.

Included among the anaesthetist's drugs will be levallorphan (Lorfan), as the narcotic antagonist, and vanillic diethylamide (Emivan) as the respiratory stimulant and arousing agent.

4. *Inhalation Anaesthesia*

It will be appreciated that this area demanded the most investigation and study of any in the testing programme.

Many workers in the past few years have been intrigued by the potentialities of halothane as an excellent anaesthetic agent for use in situations where austerity might be the order of the day. One common factor in all the propositions has been the plea for simplicity of equipment.^{1,2,3}

We have certainly been aware of the requirement for simple techniques. We have also been very much aware of the probable scarcity of experienced anaesthetists in circumstances of disaster, and hence, realized the necessity of providing alternatives to the use of only one agent, particularly when that agent is as potent and potentially dangerous as halothane.

One of the first items made available to us for testing was the C.O.N. (cyclopropane, oxygen, nitrogen) apparatus which uses the "sparklet" cartridges to load the anaesthetic bag. For a variety of reasons, this unit was not recommended for use at the hospital or definitive treatment level. (Incidentally, halothane, employed in a Cyprane Trilene inhaler, will produce just as rapid and safe induction as the C.O.N. unit.)

Limited quantities of Trilene are being scaled for the Emergency Hospitals, however, for self-administration with the Cyprane inhaler.

The so-called Portothane apparatus was also tested on a number of cases. Although it performed reasonably well, we believed it to be much more compli-

cated than necessary as a means of delivering halothane. This unit did, however, arouse our interest in the spring-loaded bellows.

Since the Emergency Health Division had already secured an appreciable number of the Epstein, Macintosh, Oxford ether anaesthesia units, we were able to secure (through the co-operation of the Director and the Supply Section) two of them for trial purposes. Initially we envisaged use of a 'sleep dose' induction of anaesthesia with thiopentone and a gradual transfer to maintenance with ether using halothane only to smooth out the transition. To this end a Fluotec vaporizer calibrated to 10 per cent was obtained. With it as a component, we improvised a unit which has proved eminently satisfactory in every respect, so much so that the role originally assigned to halothane has been largely superseded in our own unit by a technique using halothane and air alone, following the sleep dose of thiopentone.

DESCRIPTION OF THE APPARATUS—NDMC

The basic unit, the EMO apparatus, consists of an Oxford inflating bellows and a modern version of the accompanying ether vaporizer familiar to anaesthetists who served during World War II. Ether vapour in air is drawn from the vaporizer by means of the bellows assembly and delivered through a single, large bore hose to the patient's mask or endotracheal tube. The Oxford inflating bellows is a spring loaded device interposed between two unidirectional flutter valves. As the bellows is expanded either by the spring inside, or by manual effort of the operator, the anaesthetic vapour and air are drawn into it through a connecting

FIGURE 2 EMO bellows unit connected to the ether vaporizer and the Ruben valve for non rebreathing ether-air anaesthesia

FIGURE 3 EMO bellows unit connected to the 10 per cent Fluotec vaporizer and Ruben valve for non rebreathing halothane-air anaesthesia. When using the Ruben valve a small horseshoe magnet is used to inactivate the outlet valve of the bellows unit.

tube and intake valve. Inspiration by the patient or manual compression of the bellows, delivers the air-vapour mixture through the flutter valve (on the outlet side) to the patient. Instructions for operation of the unit will be supplied with it.

Modifications to this unit made for our studies consisted of

- 1 Substituting a positive-pressure non-rebreathing valve (Ruben, Fink, Stephen-Slater, or other) for the simple blow off valve supplied.
- 2 Modifying, by an adapter, the outlet port of a Fluotec vaporizer (either the 10 per cent or AE 5 per cent model) to permit the intake hose from the inflating bellows to be attached securely to either the ether or the halothane vaporizer. The shift from halothane to ether thus involves merely the transfer of the intake hose from one vaporizer to the other (see Figures 2 and 3).

This system can be used for either spontaneous, assisted, or controlled respiration. In practice, however, it has been found that in most instances gentle assistance or controlled respiration is much more satisfactory in ensuring adequate ventilation. Induction by intravenous agents and the use of respiratory depressant drugs for premedication often render spontaneous respiration inadequate, particularly in the first few moments of 'take over' by halothane. Caution in allowing reversion to spontaneous respiration is recommended. Apnoea of even a few moments' duration will produce slight tinges of cyanosis. Presumably dilution of the inspired air by halothane or ether vapour is responsible to some extent for this narrow margin of ventilatory adequacy. Manual operation of the inflating bellows can easily produce tidal volumes of up to 1 litre with only slightly more effort on the part of the operator than is involved in squeezing the

rebreathing bag of a gas machine. Hyperventilation is achieved easily, but during halothane-air anaesthesia it must be gentle and without excessive positive pressure. The "feel of the bellows" in assessing the airway, compliance, relaxation, anaesthetic state, etc., is just as effective as the "feel of the bag" of a gas machine.

OPERATING ROOM EXPERIENCE

Experience in the use of this technique has been gained from anaesthetizing males and females of military age, and older DVA patients. The NDMC equipment having been judged satisfactory, it has been used for a wide range of surgical procedures for periods ranging from a few minutes to several hours (see Table I). Because of the lack of opportunity at this Centre, the technique has not

TABLE I
INITIAL SURGICAL LIST IN WHICH THE
ANAESTHESIA WAS PROVIDED BY MEANS
OF NDMC APPARATUS EMPLOYING THE
TECHNIQUE DESCRIBED

Varicose vein stripping	3
Meniscectomy	8
Appendectomy	2
Excision Dupuytren's contracture	3
Exploration cervical cord	1
Discectomy (lumbar)	2
Dental extractions	15
Tonsillectomy	7
Marsupialization pilonidal sinus	4
Cholecystectomy	5
Gastrectomy	4
Haemorrhoidectomy	9
Herniorrhaphy	9
Nephrectomy	1
Bowel resection	1
Radical excision of orbit	1
Wedge resection of lung	1
Miscellaneous	28
Total	104

been used for paediatric surgery. Experience to date, however, has given the impression that the quality of anaesthesia and the controllability and safety of the technique are equal to those of the standard halothane-oxygen technique, provided only that ventilation is maintained carefully.

In our series preoperative medication has consisted of modest doses of sedative 2-3 hours prior to induction and a narcotic plus atropine one-half to one hour before induction. A few cases were induced with halothane-air alone but the usual practice has been to use a "sleep-dose" of thiopentone (followed by succinylcholine where intubation was planned). Fluotec vaporizer settings usually found necessary for surgical anaesthesia are at the 2 to 4 per cent positions, but may be at 5 or 6 per cent in the more resistant patients, or may be as low as 1 per cent when the lightest anaesthesia is sufficient. Because of the intermittent rather than constant air-flow through the vaporizer, we do not accept the scale

settings as indicative of actual concentrations of halothane being delivered to the patient. No attempt has been made to determine the exact concentrations. Once surgical anaesthesia is established, the patient offers no resistance to controlled respiration, and moderate hyperventilation (indicated by evidence of apical expansion) often appears to reduce or eliminate the need for relaxant drugs even in upper abdominal surgery. A drop in blood pressure varying from 10 to 20 per cent below preanaesthetic levels is quite common and seems unavoidable at surgical planes of anaesthesia. There is little doubt that this is due, in part, to the ease with which hyperventilation can be produced. At any rate hypotension due to halothane can be corrected in the usual way, if desired, by judicious use of vasoxylin or similar vasopressor agents.

The pulse rate changes very little once surgical anaesthesia is established but will increase promptly if any degree of hypoxia is permitted or with surgical stimulation if anaesthesia is not sufficiently deep. The pulse "tone" or volume has been found to be a most useful guide in judging the depth of anaesthesia with halothane, as used in this technique. The pulse volume, as felt at the wrist, is increased noticeably as surgical anaesthesia is attained. If the depth becomes excessive, the pulse volume diminishes progressively again from its optimum level. Lowering the halothane vapour concentration or a few gentle inflations with air alone will restore a more satisfactory pulse volume quite readily.

The quantity of halothane used for healthy adults by this method is approximately 30 cc. per hour. During induction, and for a short time thereafter, the rate of administration may be somewhat higher than this. As with other agents and techniques, however, there is a wide individual variation. Caution must be observed with this as with any anaesthetic technique when dealing with the "poor-risk" patient.

Manual operation of the bellows for controlled respiration is a simple rhythmic act requiring perhaps less skill and practice than use of the rebreathing bag of a gas machine. With demonstrations and supervision, this phase of the management can be delegated to an assistant. In situations in which this form of inhalation anaesthesia might be used assistants may be of vital importance, since one qualified anaesthetist may be required to supervise several administrations at once. The margin between adequate oxygenation and hypoxia being very narrow, in the absence of added oxygen, ventilation must not be interrupted for any prolonged period during surgical anaesthesia.

There are two points in the employment of this technique which we feel require special emphasis. First, too rapid filling of the inflating bellows can draw air over the fluothane too quickly with the result that vaporization is inadequate. The filling and compression of the bellows must conform closely to normal breathing at rest. Secondly, manual ventilation of the patient must be gentle in order to avoid excessive positive pressures with consequent risk of sudden inflation with high concentrations of the halothane-air mixture.

While the above technique has been found satisfactory for all anaesthetics given to date, there is at least one way in which greater safety can be achieved. Where indicated, oxygen flow of 1 or 2 litres per minute will raise the oxygen concentration in the anaesthetic mixture to slightly above atmospheric levels.

The vaporizer setting may then require raising to allow for dilution by the oxygen.

The physician familiar with halothane will learn to use the air-vaporization technique very quickly. Our group actually found it difficult to force themselves to employ the ether vaporizer, but did so, in order to test its use. The EMO ether vaporizer may be connected to the bellows unit in place of the Fluotec, in order to deliver an ether-air mixture. In practice it has been found best to stabilize the level of anaesthesia at a light surgical plane (after induction with pentothal) and then to effect a gradual change-over to ether. This may be done by disconnecting the EMO bellows unit from the Fluotec and connecting it to the ether vaporizer for gradually increasing periods and with progressive increases in the ether vaporizer settings.

Variations of technique are many using this equipment. Since additional connecting hoses will be available, both vaporizers can be connected at once to the inflating bellows by means of a Y-yoke. Certainly the inexperienced or "conscripted" anaesthetist should be encouraged to use ether until he can be instructed in the use of halothane. For the purist, who prefers halothane and ether in an azeotropic mixture, he has the agents and the equipment necessary to employ this technique if he so desires.

In the very-poor-risk patient the authors have found the use of a form of combined anaesthesia very satisfactory. This technique employs meperidine-succinylcholine in 1:2 ratio administered as an intravenous drip slowly after a "sleep-dose" of thiopentone. Ventilation by means of the Oxford inflating bellows with minimal concentrations of halothane provides a combined technique which reduces the risk of using excessive quantities of any of the agents.

In the course of our testing programme, extending over a period of some two years, other anaesthetic agents and vaporizers were given a fair trial. They included chloroform in a Chlorotec, and methoxyflurane (Penthrane) in various Fluotecs and a Pentec (this unit develops such excessive resistance at higher settings that it was quite useless for an air-vaporization "draw-over" technique). Neither of these agents appeared to be the equal of halothane, and neither was felt to be an adequate substitute for ether. Chloroform was found to be most disturbing to all concerned during induction (slower than halothane) and recovery, being prone to produce laryngeal disturbances and cardiovascular abnormalities during both periods when used in this way. This agent will be available in the Emergency Hospitals but its use should be restricted to short inductions in a 1:3 mixture with ether, by the open-drop method.

Methoxyflurane (Penthrane) in the absence of nitrous oxide proved much too slow using any vaporizer available to us. As a substitute for ether, relative costs alone would militate against its adoption for stockpiling.

As noted previously, the Emergency Hospitals will be provided with a number of ambu-type respirator units. These, being equipped with positive-pressure, non-rebreathing valves, will be adaptable for employment as "Ambutec" units in the manner described by Macartney (3). This would also permit general inhalation anaesthesia for more than three cases simultaneously by use of the halothane and ether vaporizers for different cases, if necessary.

SUMMARY AND COMMENTS

A general outline of the Emergency Hospital programme and of the individual prepackaged unit has been presented. Techniques, supplies, and equipment for anaesthesia recommended for stockpiling have been reviewed. Particular emphasis has been placed on the use of equipment being stored for inhalation anaesthesia using a "draw-over" technique for administration of air-vaporized halothane.

The equipment for this technique being procured at present includes: (1) the Fluotec vaporizer 10 per cent or AE Fluothane vaporizer 5 per cent; (2) the EMO ether vaporizer; (3) the Oxford inflating bellows; (4) the Ruben non-rebreathing valve.

Some of the other techniques tested in a programme of selection and elimination have been mentioned briefly.

Our studies have certainly confirmed the value of the air over halothane technique for general anaesthesia as a reasonable alternative to use of anaesthetic gases and carbon dioxide absorber units. If the equipment now being stockpiled against a situation of disaster is needed sometime in the future, its use will be much more satisfactory if teaching hospitals will undertake to demonstrate its use now to residents, staff members, and, perhaps more important, to general practitioners practising part-time anaesthesia in hospitals outside the major target areas.

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REFERENCES

1. JOHNSTONE, M. Halothane-Oxygen: A Universal Anaesthetic. *Brit. J. Anaesth.* 13: 29 (1961).
2. PEARSON, J. W., & SAFAR, P. General Anaesthesia with Minimal Equipment. *Anaesth. & Analg.* 40: 664 (1961).
3. MACARTNEY, H. H. Halothane, Air Anaesthesia Using the "Pulmotec" Apparatus. Preliminary Report. *Canad. Anaesth. Soc. J.* 8: 281 (1961).