Forum

Field experience with the Triservice anaesthetic apparatus in Oman and Northern Ireland

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Summary

Experience gained by two anaesthetists using the Triservice halothane, trichioroethylene air and oxygen draw-over apparatus in the field and in a sophisticated hospital is described and discussed.

Key words

Anaesthetic techniques; inhalation.
Equipment; anaesthesia machines.

There is a continuing interest in field anaesthetic apparatus,[1] which has recently centred on the Penlon Oxford miniature vaporiser (OMV).[2] This vaporiser, specially modified for the armed services, forms the basis of the Triservice draw-over anaesthetic apparatus (TSA). A full technical description of the apparatus is given by Houghton.[3] This paper describes the clinical use of the TSA apparatus over a period of 3 years during which the TSA was used for both routine pre-planned surgery and for emergency work.

Apparatus

Fig. 1 shows the form in which the Triservice apparatus (Penlon, Abingdon, England) was used for both spontaneous respiration and for manually controlled ventilation. The TSA was also used in the draw-over mode with conventional mechanical ventilators—initially with an electrically driven East Radcliffe ventilator[4] and later with the Penlon Oxford ventilator,[5] which is driven pneumatically. An air compressor was used throughout the trials to drive the Oxford ventilator. The apparatus was on trial for over 3 years although not continuously.

The trials

Techniques The TSA vaporises a volatile agent in ambient air or an air-and-oxygen mixture. Three basic techniques were used during the trials. The apparatus was tested as a simple draw-over system with spontaneous respiration, a manually controlled intermittent positive pressure ventilation (IPPV) system and a mechanically controlled IPPV system incorporating the TSA and the East Radcliffe or the Oxford ventilator.

Geographical locations. The apparatus was used under field conditions with a Field Surgical

Team (FST) in the Dhofar province of Oman and in a modern, well equipped hospital in Northern Ireland.

Oman has an extremely hot, dry and dusty climate (temperature often over 30CC). This environment imposes severe strains on both equipment and personnel. The operating theatre was part of an aluminium Twyneham hut and had one small window-mounted air-conditioning unit which attempted to produce a working temperature of 26°C. The air compressor for the Oxford ventilator, which was fitted with an air filter and water trap and a length of flexible copper tube as a heat exchanger, was outside the hut.

The operating theatre in Northern Ireland had constantly controlled humidity and temperature *(21°C* and relative humidity 70%).

Patients. All the patients in Northern Ireland were members of the British Armed Forces who had either been wounded in the urban warfare in the province or were undergoing elective or emergency surgery.

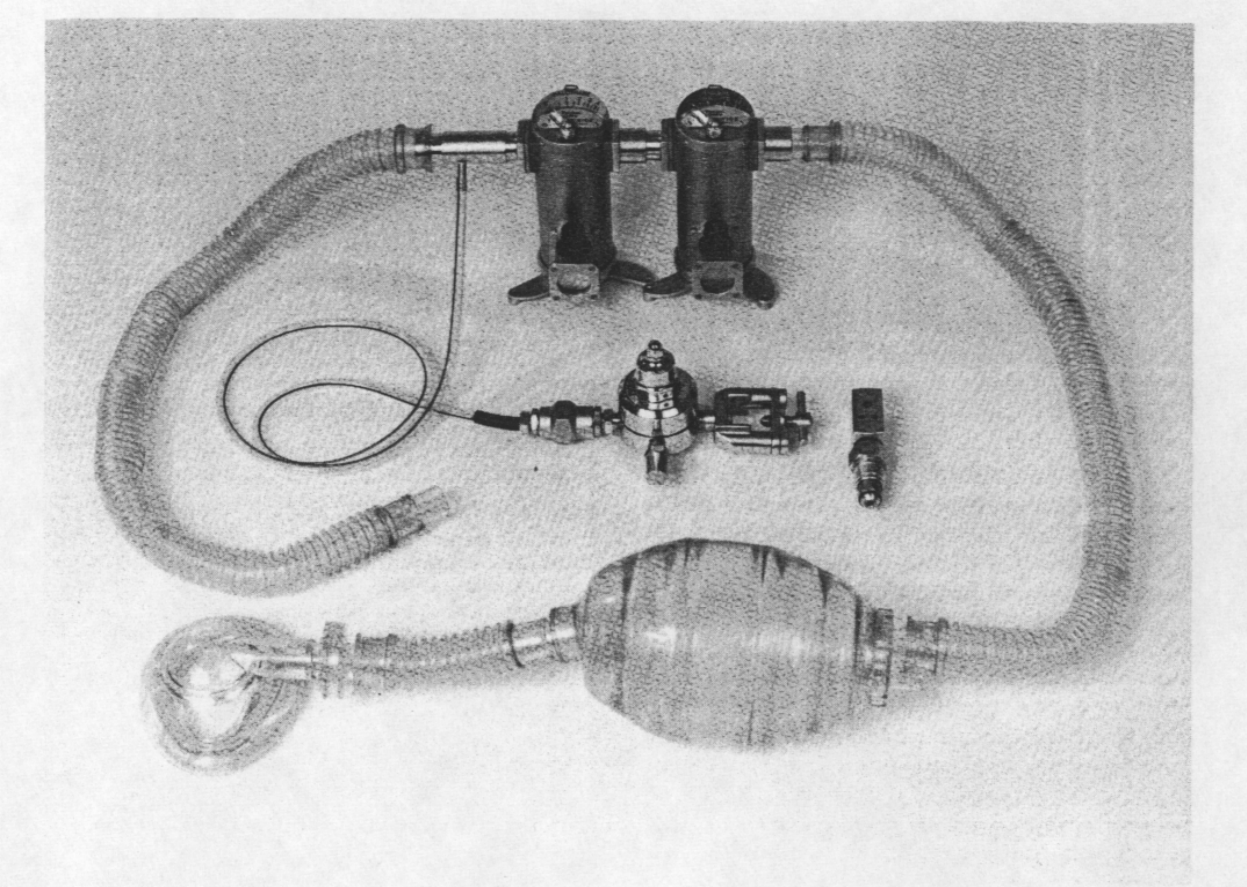

Fig. 1. Form in which the Triservice apparatus is used for both spontaneous and manually controlled ventilation.

The patients in Oman were either arab or caucasian. A wider range of age and pathology was encountered than in Northern Ireland but, as in that Province, a number of cases were suffering from gunshot wounds (GSW). Certain clinical features were shared by the two battle-wounded groups. The GSW were commonly caused by high-velocity weapons of either American or Russian manufacture and all battle-injured patients were assumed to have a full stomach. This latter maxim was rigidly observed and precautions were taken even with those patients who arrived at the FST several hours after wounding; fear, pain and injury are all recognised causes of delayed gastric emptying. Both battle-injured groups were under a degree of psychological stress; this appeared to be borne more easily by the arabs than by the caucasians in either group.

Resuscitative efforts, either by a medical officer or by paramedical personnel, were common to both locations. The extent of these efforts was determined by the expertise and equipment available, the extent of the injury, and the expected evacuation time to skilled surgical aid.
The time between injury and medical aid being available was measured in minutes but, in Oman, this interval was, on occasions, counted in hours. The longest recorded interval for a GSW between wounding and arrival at the FST was 40 hours; this reflected the nature of the confrontation in Oman, the terrain over which it was fought and the difficulty of flying helicoptors at night against an enemy armed with surface-to-air missiles (SAM). It will therefore be apparent that, despite the similarity of their wounds, the fitness of the casualties for immediate surgery in the two trial locations differed considerably.

Anaesthetic management

No attempt was made to sort emergency patients into categories (Triage) in either location. Treatment was started, if indicated, as soon as the casualty entered the resuscitation area. Resuscitation followed the accepted practices of oxygenation, either with a mask or an endotracheal tube, and fluid replacement, Hartmann's solution (compound sodium lactate solution BPC) was used to maintain or replenish intravascular volume until blood became available, except when blood was required urgently, in which case uncrossmatched blood of the same ABO group was transfused. Dehydration was frequently a feature of the battle casualties in Oman. This water deficit was commonly acquired before injury and appeared to be more marked during the Rhamadan fast.

Battle-injured patients from both locations had not uncommonly received one or more doses of an intramuscular analgesic, usually papaveretum (omnopon) from a syrette containing 30 mg. The efficacy of this treatment has been commented on by Beecher.[6] Papaveretum was found to facilitate the induction of anaesthesia in those presenting for surgery within I to 3 hours of being injured.

The two anaesthetists involved in the trial differed slightly in their use of the TSA. One preferred the established technique of thiopentone, halothane or trichloroethylene and, when indicated, tubocurarine with moderate hyperventilation; the other used Althesin as the induction agent, pancuronium as the non-depolarsing muscle relaxant, and intravenous analgesic supplements of fentanyl or phenoperidine to keep the concentration of trichloroethylene in the air-and-oxygen mixture to a minimum.

Intravenous induction of anaesthesia followed routine pre-oxygenation lasting 3 to 5 minutes. The decision whether to intubate or not was easily taken; all emergency cases were intubated to protect the lungs from gastric contents and to reduce the anatomical dead space. The second decision (whether to ventilate following intubation) was more difficult but, despite the assumed changes in pulmonary function and possible reduction in venous return and increases in physiological shunting, most patients who were battle-injured were ventilated mechanically.

The concentration of the volatile agent being vaporised in the air-and-oxygen mixture was slowly increased following induction of anaesthesia to produce satisfactory surgical anaesthesia. The maximum concentration of halothane used was 4.5% and the time taken to achieve surgical anaesthesia seldom exceeded 3 to 5 minutes. If there were no involuntary movements or pupil reactions to incision, the concentration of the volatile agent was reduced for maintenance; 0.5—1% halothane or 0.5—0.75% trichloroethylene were found to be adequate with controlled respiration although with intravenous analgesic supplementation (fentanyl 0.05—0.1 mg or phenoperidine 0.5—2 mg) the level of trichloroethylene required could be reduced to 025—05%. One per cent to 2% halothane was required for maintenance with spontaneous respiration.

Table 2. Use of induction agents and muscle relaxants and duration of surgery

Thiopentone technique			Althesin technique		
Agent	Dose range	Mean	Agent	Dose Range	Mean
Thiopentone (mg)	75 - 600	301	Althesin (ml)	2.5 - 9	4.75
Suxamethonium (mg)	50 - 160	70	Suxamethonium (mg	30 - 100	65
Tubocurarin (mg)	20 - 70	38.5	Pancuronium (mg)	4 - 8	7
Duration (minutes)	2 - 300	40	Duration (minutes)	5 - 150	34

The age and weight of the patient were obtained wherever this was possible. Europeans were asked when they had last eaten. Preoperative blood pressures and pulse rates were taken routinely and any history of drug consumption or drug allergy was noted; however, in Oman, language difficulties, both pre- and postoperatively, sometimes made communication difficult.
The amounts of all drugs given to the patients were timed and recorded on anaesthetic case sheets and during anaesthesia the pulse rate was counted and the blood pressure was measured with a sphygmomanometer.

Table 1. Cases anaesthetised with the Triservice apparatus

Delayed primary suture, debridement and skin graft	70
Manipulation under anaesthesia and orthopaedic procedures	26
Initial operation for gun-shot	23
Perianal procedures	13
Elective laparotomy	12
Dental extractions	10
Burns	9
Others	55
Total	218

Results

There were 218 cases in the trial. The age range was from 6 to 72 years (mean 26.4) and body weights from 18 to 100 kg (mean 784 kg).

Induction of anaesthesia. The mean dose of thiopentone was 301 mg and that for Althesin was 4.75 ml, These values, and the dose ranges, compare well with normal practice (Table 2).

An attempt was made to give suxamethonium on a 1 mg/kg body weight basis. The results show that the dosage of suxamethonium was often underestimated.

The duration and type of surgery. This was from 2 to 300 minutes. The procedures undertaken ranged from a rapid dental extraction to surgery for major trauma.

The time from the induction of anaesthesia to the start of surgery varied considerably. It was 1 - 35 minutes (mean 6 minutes) in the 171 cases in the thiopentone series and 1 - 18 minutes (mean 5 minutes) in the 47 Althesin patients. This time interval included preparatory procedures such as the attachment of monitoring apparatus, tourniquet exsanguination of the limbs and positioning the patient on the operating table.

Respiration during surgery. One hundred and fifty-three patients breathed spontaneously during surgery, 89 with a face mask and 64 after endotracheal intubation. Controlled ventilation was instituted in *65* cases.

Time to waking after anaesthesia. The 171 thiopentone cases awoke in from 1 to 35 minutes (mean 55 minutes) and the 47 Althesin cases in from 1to 18 minutes (mean 35 minutes).

Changes in blood pressure, pulse rate and central venous pressure varied with the nature of the case. It is difficult to compare cold premedicated cases with those of major trauma. Case 2 described below illustrated changes in central venous pressure, blood pressure and pulse rate but these were related to the trauma and surgery rather than to the anaesthetic agents employed.

Case histories

Case 1. A British soldier aged 32 was standing behind a Carl Gustav anti-tank gun at about 2215 hours when it was fired and he was caught in the back blast. He suffered burns and severe trauma to the left shoulder and blast injury to the lungs. He was given morphine 15 mg and evacuated by helicopter to the FST where he arrived at 2320 hours. He was barely conscious and incoherent on arrival and his pulses became impalpable and consciousness was lost during the initial examination. External cardiac massage was started and he was intubated with a 9.5-mm tracheal tube. He was ventilated with an air-and-oxygen mixture by means of the Laerdal resuscitation bag element of the TSA with 4 litres per minute of oxygen flowing into the reservoir tube.

Cannulae were inserted into veins at both ankles by rapidly cutting down, and a 14 swg catheter was inserted at the right antecubital fossa. All three infusions were running by 2330 hours and fluid was pumped into the patient using manual compression of the giving set chambers. Freshly

blood-stained frothy fluid was observed in the lumen of the tracheal tube and the patient was attached to an East Radcliffe ventilator (ERV) via the TSA apparatus and ventilated with an air-and-oxygen mixture.

The patient had received 3 litres of Hartmann's solution, 400 ml of 42% sodium bicarbonate and 3 units of uncrossmatched blood by 2340 hours, and 10 units of uncrossmatched blood had been given by 2350 hours.

The systolic arterial blood pressure (BP) was by now between 100 and 110 mmHg but blood-stained fluid was still frothing out of the tracheal tube. Trichioroethylene 0.5% was introduced into the air-and-oxygen mixture from the TSA and 4 mg of pancuronium was administered intravenously. Surgery began at 2355 hours. The patient continued to produce pink froth from the tracheal tube and pulmonary compliance decreased. The inflation pressure was increased to 60 cmH2O—the maximum recordable on the ERV.

Twenty-nine units of uncrossmatched blood had been given by 0200 hours. The BP was stable between 110 and 120 mmHg and the pulse was steady in a sinus rhythm. The transfusion rate was reduced, and surgical control of the haemorrhage was completed and the trichloroethylene was reduced to 0.25%.

The patient was haemodynamically stable at 0300 hours, but a portable chest radiograph revealed severe bilateral pulmonary oedema. It was estimated that the inflation pressure generated by the ERV must have been 75 to 80 cm H_2O but the tidal volume remained between 500 and 600 ml.

The surgery, which included a left forequarter amputation, was completed by 0400 hours, but the compliance was still very poor due to the blast injury to the lung. The patient was electively ventilated with the ERV. Diazepam, pethidine and a trace of trichloroethylene from the TSA were used to provide analgesia and sedation. The patient was conscious and cooperative by 0500 hours and a mannitol infusion was started.

The patient had received 30 units of blood including 24 fresh units; this included 1 unit which was stopped after 100 ml had been administered because it was found to be 35 days post-collection and 1 unit of A positive. The rest of the blood was 0 negative and 0 positive. Fine-screen filtration was not used. Six litres of Hartmann's solution, 2 litres of 5% dextrose, 250 ml of 20% mannitol, 400 ml of 42% sodium bicarbonate, 40 ml of 10% calcium gluconate and 05 g of hydrocortisone were also administered during the resuscitation.

The first stage of an aeromedical evacuation was undertaken from 1000 to 1300 hours. Ventilation was manually controlled with the Laerdal bag with the aircraft pressurised to sea-level. The patient's condition was stable during the flight. The ERV was attached again on landing; the compliance was improving with an inflation pressure of 60 cmH2O, a ventilation rate of 20 per minute and a tidal volume of 700 ml. The second stage of the evacuation to Cyprus began at 1345 hours in an aircraft pressurised to 500 ft (152 m). There was virtually no pulmonary oedema on the radiograph at 2000 hours and the patient had passed 2500 ml of urine since the operation.

Case 2. An Omani officer aged 21 suffered a wound to his left chest and abdomen which was thought to have been caused by mortar bomb fragments at 1100 hours. He arrived at the FST at 1200 hours by helicopter. Analgesia had not been given *en route.*

Examination revealed a sucking wound of the left chest. Resuscitation began. Oxygen was

administered via the TSA and a face mask with 4 litres per minute flowing into the reservoir. Intravenous cannulae were introduced into both antecubital fossae and volume replacement was started with crystalloid solutions. Trichloroethylene was added to the air-and-oxygen mixture at 1230 hours and, by 1300 hours, 3 litres of crystalloids had been administered; the BP was 135 mmHg and the pulse 100 beats per minute.

Induction of anaesthesia began at 1305 hours. The eye-lash reflex was lost after 150 mg of thiopentone had been administered; 80 mg of suxamethonium were given and a medium right-sided Robertshaw tube was introduced. The patient was ventilated with 05% trichloroethylene and tubocurare was administered. The TSA was incorporated into the Oxford ventilator; the inflation pressure was 0 - 22 cmH_2O, the tidal volume 800 ml and the rate 16 per minute. The BP rose to 160 mmHg immediately after induction during positioning for thoracotomy; this was attributed to stimulation of an inadequately anaesthetised patient.

Surgery began at 1340 hours with the BP at 130 mmHg. Central venous pressure monitoring was instituted through the right antecubital fossa. A left thoracotomy and a laparotomy were carried out, the spleen and several metallic fragments were removed and haemostasis was secured. The flow of supplementary oxygen was reduced to 1 litre per minute from 4 litres per minute when the extent of the pulmonary trauma had been assessed and the left lung had been re-expanded. The concentration of trichloroethylene was maintained at 0.5°/

Surgery ended at 1645 hours, the trichioroethylene was discontinued and the muscular paralysis was reversed uneventfully with neostigmine and atropine.

These case histories illustrate the versatility of the TSA system for the administration of oxygen by face mask and endotracheal tube (with and without controlled ventilation, by hand or with a ventilator), the administration of preoperative analgesia for intra-operative analgesia and anaesthesia and postoperative analgesia, and its use in casualty evacuation.

Discussion

All battle-injured patients were resuscitated prior to surgery using crystalloids, colloids and blood. A clinically adequate intravascular volume was considered to be essential prior to the induction of anaesthesia.

Pre-oxygenation with the TSA aided the safety of the induction of anaesthesia. It allowed more time, and therefore more care, to be taken over intubation; this proved to be of considerable value in the more severely wounded.

The intravenous induction of anaesthesia proved uncomplicated and similar to routine hospital practice. The time taken to reach satisfactory surgical anaesthesia varied with several factors. Opiate premedication was of value and most of the patients who were not battle casualties were fit young men in their twenties - some with a considerable ethanol intake. These patients required more thiopentone or Althesin and a higher concentration of the volatile agent than did the injured

patients.
During spontaneous respiration, a higher concenttion of volatile agent was required in the period leading to stable anaesthesia than was needed with controlled ventilation. The manufacturer had increased the output of the Triservice vaporiser compared with the original OMV from 1% to 1.5% for trichloroethylene and from 3% to 4.5% for halothane to aid this aspect of field anaesthesia. Once anaesthesia was stable the output of the vaporiser was reduced to 0.5 - 0.75% for trichloroethylene and 0.75 – 1.5% for halothane. These concentrations are higher than those required when nitrous oxide is used in combination with these agents.

It was soon appreciated that using either halothane or trichloroethylene alone for spontaneous respiration was not entirely satisfactory, whereas a combination of the two produced an acceptable level of anaesthesia more smoothly and more rapidly, but for maintenance of anaesthesia during controlled ventilation, either volatile agent alone proved suitable. The TSV operates for about 4 hours without refilling the 50-ml reservoir at these concentrations. A small 300-litre oxygen cylinder using a flow of 1 litre per minute lasts about 5 hours. The longest case in the series (case 1) lasted for this length of time.

The concentration of the volatile supplementation was slowly reduced as the surgery proceeded but it was not possible to discontinue either halothane or trichloroethylene for more than 2 or 3 minutes before the procedure ended.

Awareness using this anaesthetic technique proved to be merely a theoretical consideration. One European very early in the series admitted to recall on direct questioning; consequently the maintenance level of trichloroethylene was increased from 0.5% to 0.75%; at this concentration no further episodes of recall were encountered despite direct questioning.

Non-depolarising muscle relaxants were reversed with atropine sulphate 1.2 mg and neostigmine 2.5 - 5 mg; reversal was uncomplicated. Narcotic antagonists were not used.

The mean time intervals between ending surgical anaesthesia and the patient being fully awake (55 minutes for thiopentone induction and 35 minutes for Althesin) show that rapid recovery with the TSA is possible with consequent minimal, immediate postoperative patient care, so freeing theatre or nursing personnel for more pressing tasks. This becomes more important if the casualty load increases.

In the injured patients who were not battle casualties, changes in pulse rate and blood pressure were as expected after intravenous induction. An initial fall in blood pressure was recorded, this being more marked in those patients receiving halothane for maintenance of anaesthesia than in those for whom trichloroethylene was used. Changes in blood pressure and pulse were minimal once anaesthesia was stable. The battle casualties sometimes showed BP rises which were interpreted initially as reflecting the adequacy of resuscitation and later as indicating the requirement for further analgesia during surgery.

Vomiting was not a postoperative problem with these ISA techniques. Jaundice was not detected in those patients receiving repeated halothane anaesthetics, nor in those receiving group compatible blood transfusions; no haemolytic reaction was precipitated nor was any infection

transmitted by this transfusion technique.
The results obtained with the TSA were considered to be satisfactory and suggest that the TSA is reliable, simple to use, versatile and safe for all age groups and all types of surgery.

Acknowledgments

The authors wish to thank Brigadier CD. Sanders QHS for his help and guidance in the preparation of this report.

Anaesthesia, 1981, Volume 36, pages 1127—1129

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