Paediatric Anaesthesia Using the Triservice Anaesthetic Apparatus

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Introduction

The Triservice Anaesthetic Apparatus (TSAA) has remained the mainstay of British military anaesthesia since its development by Houghton in the late 1970s [1] and has been used extensively in a variety of conflicts and environments ever since [2-5]. In recent conflicts, the presentation of multiple paediatric casualties to the Defence Medical Services (DMS) have provided difficulties in the use of equipment designed for an adult population. These difficulties were reviewed in "Defence Medical Services Support to Civilians on Operations" [6] which made some recommendations for enhancements to equipment and techniques for treating paediatric patients. However young children continue to cause concern to military anaesthetists deployed on operations and a variety of circuits and techniques have been suggested and used [7-9].

Traditionally, anaesthetists have altered their techniques for children weighing 20kg or less, which approximates to six years of age in the UK population [10]. Additionally, the manufacturers of the TSAA and the comPAC 200 ventilator [Pneupac Ltd, Luton] recommend that it should only be used for patients weighing greater than 20kg [11]. The number of paediatric patients who fall below this 20kg threshold is extended on current operations where local national children often weigh significantly less then those of similar age encountered in UK practice; UNICEF data suggests that 52% of children under the age of five in Afghanistan are underweight [12].

We present a series of five children weighing 10kg or less who were safely anaesthetised a total of six times during Operation HERRICK 8 using the TSAA and compac200 ventilator, during a period with large numbers of casualties, 10% of whom were children. We discuss the anaesthetic management of paediatric patients using this equipment.

Case series

Five children, weighing between 7 and 10 kg, underwent general anaesthesia for major surgical procedures using an unmodified TSAA. In each case rapid sequence induction was performed with thiopentone [5mg/kg]/suxamethonium [1.5mg/kg] and intubation with a size 4.5 uncuffed tracheal tube. General anaesthesia was maintained with isoflurane delivered from the Triservice Apparatus and ventilation performed with a comPAC 200 [Pneupac Ltd, Luton] minute volume divider ventilator. The ventilator settings were adjusted to the minimum Minute Volume [4 L/min] and maximum Frequency [30 breaths per minute] to minimise the delivered tidal volume (Figure 1). The children were successfully ventilated with tidal volumes of less than 10ml/kg and peak pressures of less than 20 cmH_20 with one exception described below. Monitoring complied with Association of Anaesthetist of Great Britain and Ireland minimum standards throughout, including airway pressure monitoring integral to the ventilator and spirometry on the Datex AS5 monitor [13]. Median end tidal CO_2 measurements are unfortunately not available, but no significant derangements were recorded at the time.

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Figure 1. *Initial ComPAC 200 ventilator settings for the ventilation of children weighing 10kg or less.*

Case 1

An 8kg, 10 month old male was admitted with 6% Total Burn Surface Area thermal burns to the hands and perineum following an explosion. The following day he underwent a general anaesthetic for debridement and dressing of these burns lasting 180 minutes. Post operative recovery was uneventful and the child was discharged to ongoing care six days later.

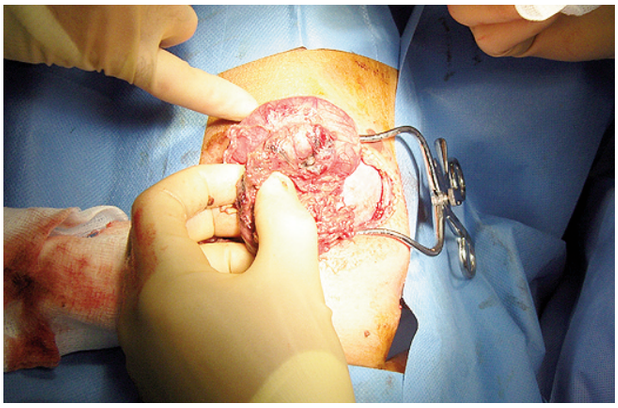
Case 2

A 10kg female child was admitted with multiple injuries following an explosion. She underwent two general anaesthetics for a laparotomy and liver packing, total duration 105 minutes, on the day of admission and a relook laparotomy (100 minutes) three days later following an episode of sepsis. She subsequently made a full recovery.

Case 3

A 10kg female child was admitted following exposure to an explosive device and suffering from multiple fragmentation and blast injuries. After immediate resuscitation in the Emergency Department she underwent laparotomy, thoracotomy, small bowel repair, transverse colon resection, diaphragm repair and left intercostal chest drain under general anaesthetic. This procedure lasted 90 minutes. Initially, the peak airway pressures were high (reaching 30cm/H_20) as the child had a ruptured diaphragm with colon in the chest (Figures 2 & 3). Following replacement of the

colon into the abdomen the airway pressures were reduced to below 20cm/H_2O (Figure 4). The child subsequently developed Abdominal Compartment Syndrome on the Intensive Care Unit and returned to theatre for a laparostomy. Ventilation in this second procedure was performed using the ICU TBird ventilator. The child remained ventilated on ICU and died after 16 days from multi-organ failure.



Figures 2&3. *10kg female child anaesthetised and prepared for a laparotomy and thoracotomy. The figure demonstrates colon prolapsing through a thoracic wall defect.*

Figure 4 . *Monitor screen during laparotomy and thoracotomy of 10kg female.*

Case 4

A 7kg male child was admitted with a fragmentation injury resulting in an open compound fracture of the right femur. The wound was debrided under general anaesthetic during a 90 minute procedure.

Case 5

A 10kg male child was admitted after a fragmentation injury to his foot. The wound was debrided under general anaesthesia during a 60 minute procedure. Recovery was uneventful and he was discharged to ongoing care.

Discussion

A significant proportion of casualties encountered on current and recent operations are children. Many of these children weigh considerably less than children of similar age normally encountered in UK practice and consequently weigh less than 20 kgs which is the traditional cut off for paediatric anaesthesia [12]. The standard British Military anaesthetic equipment, the TSAA, and ventilator, the Pneupac compPAC 200 [11], are recommended for use by the manufacturers for adults and children greater than 20 kgs. The comPAC ventilator is a minute volume divider which can deliver a minute volume of 4 – 14 L/min and a frequency of 10 – 30 breaths per minute.

Anaesthetising these young children with the equipment provided has caused concern to military anaesthetists, especially those not performing paediatric anaesthesia in their routine clinical practice. A variety of circuits and techniques have been developed and described to anaesthetise these children.

However clinical experience and recent work suggests that simple drawover anaesthetic systems, such as the TSAA, may be suitable for much smaller children. Bell et al [14] have shown that the TSAA is suitable for spontaneously breathing patients down to a weight of 10 kgs. As they state most children weighing less than 10 kgs will be intubated for anaesthesia and their ventilation controlled. For the few small patients who are allowed to breath spontaneously, the Mapleson F remains superior because of the ease of application of continuous positive pressure.

The problem then becomes how to manage children weighing less than 10 kgs who require intubation and controlled ventilation for surgery. Use of the Mapleson F is possible but has a number of problems. Flow rates of greater than 5 $Lmin^{-1}$ are often required; these can only be obtained with the equipment available by using oxygen cylinders rather than concentrators, which is wasteful of scarce resources, or using improvised flow restrictors at the inspiratory limb of the TSAA. Also the anaesthetist is then responsible for manually ventilating the patient and therefore restricted when many of these cases are major trauma, staffing levels are limited and other tasks need to be done.

The compPAC ventilator has a minimum Minute volume of 4 $lmin^{-1}$ and maximum frequency of 30 breaths per minute which would deliver a tidal volume of approximately 130 mls. These respiratory parameters would be suitable for a child down to a weight of 20 Kgs [15]. However the compPAC ventilator can be very easily changed from a minute volume divider type ventilator into a pressure generator type by the introduction of a leak either by the use of an uncuffed endotracheal tube, as would be normal practise for prepubertal children, or the insertion of an Adjustable Pressure Limiting [APL] valve into the circuit [Figure 5]. The tidal volume delivered then depends on the lung compliance and degree of leak. The delivered Minute Volume can be set and adjusted by setting a suitable respiratory rate and then adjusting the set Minute Volume and therefore delivered tidal volume until an appropriate airway pressure, usually approximately 20 cm H_2O, is achieved. If an APL valve is placed in the circuit this may also need adjusting to obtain suitable airway pressures.

We would recommend that children less than 10 Kgs can be anaesthetised safely using the TSAA and compPAC ventilator with minimal adjustment to the equipment and sound application of basic principles.

Preoxygenation can be performed using the TSAA itself but many anaesthetists may prefer to use a Mapleson F circuit and an oxygen cylinder. This provides high FiO_2, the ability to provide continuous positive pressure and a good respiratory feel. Following induction of anaesthesia and securing of the airway with an uncuffed endotracheal tube anaesthesia can be maintained using oxygen, air and isoflurane through the TSAA with the compPAC ventilator in the pushover mode [16]. In particularly small children, or if there is concern about the degree of cuff leak, an APL valve can be placed in the circuit between the ventilator and the Oxford Military Vaporiser (OMV) to ensure that the ventilator is functioning as a pressure generator.

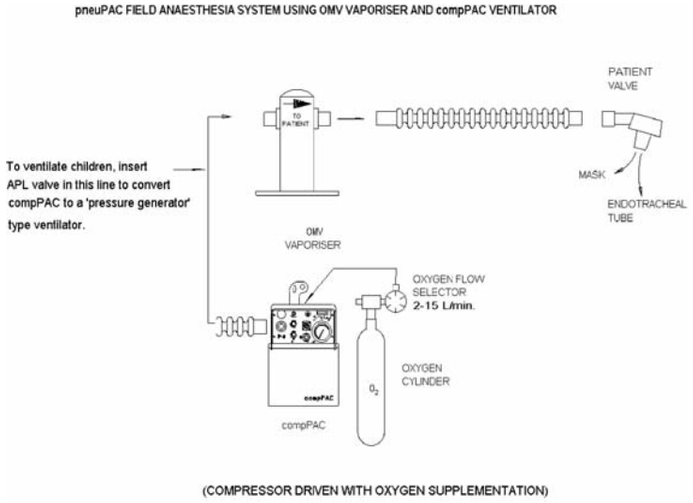


Figure 5 . *Anaesthesia circuit using ComPAC 200 and OMV for paediatrics. Reproduced with permission of Smiths Medical International.*

Paediatric anaesthesia will continue to be a challenge to military anaesthetists, who may not have regular paediatric sessions. We need to ensure that we endeavour to maintain our paediatric skills, especially airway management and vascular access. Military equipment modules need to be regularly reviewed to ensure they contain appropriate paediatric equipment for use by the non specialist. However we believe that we have shown that children weighing less than 10 Kgs can be safely anaesthetised using the standard TSAA and compPAC ventilator with the minimum of adjustments to the equipment and techniques. We hope this will help to relieve some of the difficulties in these challenging cases.

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