

Use of target-controlled infusion of propofol for military field anaesthesia

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ANAESTHESIA FOR MILITARY CASUALTIES in forward areas presents many challenges to the anaesthetist. Many of the logistic constraints placed on medical practice in this environment are unfamiliar to practitioners more accustomed to First World hospital medicine. For most of the last 150 years anaesthesia has mainly been provided by volatile anaesthetic agents, both for military surgery and for surgery in civilian settings.

Intravenous anaesthesia, which is seeing increasing use in the civilian setting, may also offer some advantages in military surgery. Inaccurate information about the adverse effects following the use of intravenous thiopentone as a sole agent at Pearl Harbor¹ set back intravenous anaesthesia in military medical practice. Bennetts has since comprehensively debunked the myth that “thiopentone killed more at Pearl Harbor than the Japanese”, showing instead that mortality from thiopentone anaesthesia was little different from that which occurred following ether anaesthesia.² However, a reluctance by the United States Navy to release casualty figures for fear of damaging national morale during the war clouded the true situation and allowed Halford’s original claim to go unchallenged for some years.

In recent times interest in intravenous techniques in the field has grown. In the Falklands campaign both draw-over volatile techniques and ketamine-based anaesthesia were used successfully.³ British military anaesthetists described a technique using a combination of ketamine, midazolam and vecuronium shortly after the Falklands War.⁴ A mixture of propofol and alfentanil was employed by British anaesthetists in the Gulf War⁵ and propofol-based anaesthesia has been used in the Balkans.⁶ ADF experience over the past decade in Rwanda, Bougainville, Papua New Guinea and most recently East Timor has seen a variety of techniques used. After the tsunami disaster in Papua New Guinea, with large numbers of casualties, ketamine as a sole agent was used extensively. In other areas of operation a variety of techniques have been employed.

Target-controlled infusion (TCI) was approved by the Therapeutic Goods Administration in 1998 as a method of delivering propofol for general anaesthesia. It uses a well validated pharmacokinetic model of propofol distribution and elimination to control the infusion rate and maintain anaesthetic concentrations of the agent. The target concentration of propofol is chosen and titrated by the anaesthetist in response to

Abstract

- ◆ Intravenous anaesthesia may offer some advantages in military surgery.
- ◆ Target-controlled infusion (TCI) was approved by the Therapeutic Goods Administration in 1998 as a method of delivering propofol for general anaesthesia. It uses a well validated pharmacokinetic model of propofol distribution and elimination to control the infusion rate and maintain anaesthetic concentrations of the agent. TCI involves less complicated calculation than manual infusion of propofol.
- ◆ We tested TCI anaesthesia with propofol in the field (on deployment in East Timor) with five patients. The mean duration of surgery was 35 minutes. The mean time to open eyes after surgery was 6 minutes. The mean time to be ready for discharge from the recovery area was 26 minutes. No patient suffered from severe pain and there were no episodes of postoperative nausea and vomiting.
- ◆ Our results compare favourably with the results of similar short series of patients anaesthetised by a volatile-based technique using a draw-over delivery system, propofol by manual infusion and ketamine-based anaesthesia: recovery time may be shorter and postoperative nausea and vomiting less likely, although the small size of these studies makes comparison difficult.
- ◆ Reducing postoperative nausea and vomiting is particularly important in the military setting, where patients may have to be mobile soon after surgery.
- ◆ TCI anaesthesia does not require compressed gas supplies and carries no risk of anaesthetic contamination of the atmosphere in enclosed surgical facilities. Unlike draw-over systems, however, TCI requires an electrical power supply to operate.

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the normal clinical signs of depth of anaesthesia. This is analogous to the adjustment of vapouriser settings in a volatile-based anaesthetic. This is different to manual infusion techniques, where a typical propofol regimen calls for an initial bolus of 1.5–2 mg/kg, followed by an infusion of 12 mg/kg for 10 minutes, then 10 mg/kg for 10 minutes and thereafter 8 mg/kg. Several benefits are claimed for TCI, such as earlier awakening and reduced postoperative nausea and vomiting, which may offer military and logistical advantages. Propofol infusion is now a mainstream anaesthetic technique and is used widely by many anaesthetists. Manual propofol infusions have been employed in the field, both by us and others within the

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ADF. There is no report in the literature to date of propofol delivered by TCI being used in the field. To establish that this method is suitable for field use, we conducted a brief trial.

Methods

We were posted to the Field Surgical Troop (Heavy) (FST (Hvy)) as part of INTERFET in Dili, East Timor, during February and March 2000. This facility transferred to United Nations control on 23 February 2000 and was then known as the United Nations Military Hospital.

Following Australian Defence Medical Ethics Committee (ADMEC) approval, patients presenting for surgery at the facility were enrolled in a study to determine if TCI was a suitable delivery system for field use.

Patients were eligible for inclusion in the trial if they met the following criteria:

- Aged 18 years or more
- Able to give informed consent
- Weight within the range 30–150 kg
- No administration of propofol within the previous four hours
- Not having obstetric anaesthesia.

Due to an unexpected lull in activity during this period only 12 surgical cases presented to FST(Hvy). Of these, five were obstetric cases not suitable for enrolment. Of the remaining seven cases, five were recruited into the study. ADMEC stipulated that all participants must be presented with the patient information sheet and consent form in their own language. We were unable to have these documents translated into Tetum and so no local person could be recruited into the study.

All patients were anaesthetised with propofol delivered by TCI. The target concentration was titrated up or down based on standard clinical signs of depth of anaesthesia, such as pulse rate, blood pressure, signs of sympathetic activity (eg, lacrimation) and (in non-paralysed patients) respiratory rate. These signs do not differ significantly between patients anaesthetised by total intravenous or volatile techniques. Use of opioids and muscle relaxants was left to the discretion of each anaesthetist, as was the method of airway control.

Both authors have considerable experience as anaesthetists, both in the hospital and in the field. JH had considerable prior experience with TCI, which was a new technique to MW.

At the conclusion of the procedure, time taken for the patients to open their eyes, to obey commands and to be fit for discharge from the recovery area (as judged by the nursing officer using a five-point scoring system) was recorded.^{7,9} The presence of nausea and vomiting and of severe pain in the first 24 hours after surgery was also noted.



1: TCI pump attached under operating table. Note the small amount of space required.

Results

The five patients (four men, one woman) had a variety of surgical conditions. The mean age was 35 years (range, 28–45 years). The mean duration of surgery was 35 minutes (range, 29–45 minutes). The mean time to open eyes after surgery was 6 minutes (range, 4–7 minutes). The mean time to be ready for discharge from the recovery area was 26 minutes (range, 19–44 minutes). No patient suffered from severe pain and there were no episodes of postoperative nausea and vomiting, although two patients were given prophylactic metoclopramide 10mg intraoperatively, as this was the usual practice of one of the authors.

Discussion

Times to be ready for discharge from recovery for these five patients are similar to times to eye opening or to obeying commands recorded in three separate studies for a number of field techniques, including a volatile-based technique using a draw-over delivery system, propofol by manual infusion and ketamine-based anaesthesia.^{5,6,10} This may represent slightly faster recovery with TCI techniques, although the very small numbers in all these studies make comparisons difficult. There appears to be no large, well-controlled study examining any of these techniques in the field setting.

We used a clinically validated objective measure of fitness for discharge; such objective criteria were absent in the other three studies. The scoring system as described by Aldrette and Kroulik^{7,9} is used at the civilian institution where one of us (JH) usually works.

In previous studies, anaesthetists who are experienced¹⁰ and inexperienced¹¹ with the use of manual propofol infusions for general anaesthesia prefer TCI methods to manual methods once exposed to both. These studies have shown that most anaesthetists find that TCI involves simpler calculations than those entailed in manual infusion methods. Anaesthetists soon become proficient in adjusting the target concentration against the usual clinical signs of depth of anaesthesia, in a manner analogous to the titration of anaesthetic concentrations in a volatile-based anaesthetic. The target can vary widely, depending on a number of factors, including the robustness of the patient, the intensity of any noxious stimuli, and the presence of other depressant drugs such as opioids or benzodiazepines. In all such cases the anaesthetist is able to adjust the target and titrate it against the observed clinical effect.

Repeated surveys of patient satisfaction following surgery consistently rate nausea and vomiting as the most unpleasant aspect of their experience.¹² Rapid awakening and freedom

from nausea and vomiting are obvious benefits to individual patients, and in the military setting may have further advantages. Forward surgical facilities are by their very nature lightly staffed and equipped. Nursing officers are few, and medical assistants provide much basic nursing care instead. Patients who have lower dependency states are easier to care for, allowing limited human resources to look after a greater number of casualties. Alternatively, this may enable the facility to function for longer without the requirement for reinforcement or stand-down. Patients who are free from nausea and vomiting and more aware are also more capable of evacuating the facility if the military situation so dictates. Similarly, a lower predisposition to postoperative nausea and vomiting is advantageous in a medical facility at sea, or during evacuation by air.

Most studies of anaesthesia by volatile techniques describe rates of nausea and vomiting between 16% and 30%.^{12,14-16} Published figures for the rate of nausea and vomiting following TCI anaesthesia vary widely from a low of 3%–5% to 15%–18%.^{12,14,16} The anti-emetic effect of propofol appears to be mediated, at least in part, by reducing 5-hydroxy tryptamine levels in the area postrema via a gamma-aminobutyric acid mediated pathway.¹³ Most studies have shown a statistically significant difference in postoperative nausea and vomiting in the first 24 hours after surgery, although this difference diminishes or even disappears on the second and subsequent postoperative day.¹⁴ The reason for this has not been clearly elucidated, but is likely to be due to a combination of effects. A recent German study suggests that volatile agents alone may be the main cause of early postoperative nausea and vomiting.¹⁵ It is likely that the emetic effect of the volatile agent has diminished by the second postoperative day, and also that the emetic effect of opioid analgesia and noxious stimuli, such as pain, is greater. In addition, propofol exhibits a prolonged terminal elimination phase, with an elimination half-life of roughly three hours, so that subhypnotic doses remain within the circulation for up to 18–24 hours. These low levels of propofol are known to be anti-emetic and the termination of such an effect may also explain the convergence of rates of nausea and vomiting beyond the first postoperative day.

A recent review suggested that total intravenous anaesthesia is an effective method of reducing postoperative nausea.¹⁶

Another method of reducing postoperative nausea and vomiting is the avoidance of nitrous oxide during anaesthesia. The ADF Anaesthetic Consultative Group has decided to phase out the use of nitrous oxide in land-based forward medical facilities, although this decision was driven by logistical considerations.¹⁷

There are often difficulties with medical resupply in forward areas, as medical facilities have a lower priority than fighting elements. Draw-over anaesthetic techniques have been



1: TCI pump attached under operating table. Note the small amount of space required.

favoured within the Australian Defence Force due to their low logistical burden, including freedom from compressed gas supplies. Gas cylinders are dangerous cargo and pose a considerable risk in a hostile military environment. TCI shares this advantage. It can be used with the same simple breathing circuits as a draw-over technique: the propofol infusion replaces the volatile anaesthetic agent, while the remainder of the technique (opioids and relaxants) and breathing circuit remain the same.

In a fixed facility, scavenging systems, using low pressure suction, are employed to collect waste anaesthetic gases and vent them into the atmosphere in a safe manner. Draw-over systems are unscavenged, and waste anaesthetic gases are vented directly into the theatre environment. This can result in considerable contamination

of the theatre environment. In a tent or open air environment this is unlikely to be a major concern, but may present a potential hazard in an enclosed facility. Yoganathan et al studied the effects of contamination with halothane via a draw-over technique with an unscavenged, passively scavenged and an active absorber system in a chemical warfare-proof operating theatre.¹⁸ When using the unscavenged circuit, atmospheric halothane concentrations were a mean of 15.3 ppm, well in excess of the allowable limit of 2 ppm of halogenated anaesthetic agent.¹⁹ Passive scavenging (as is used in current ADF practice) reduced the levels to 1.9 ppm, but the standard¹⁹ also recommends that levels should be reduced further if possible. TCI overcomes this problem by removing the source of contamination entirely — a significant advantage in any operational environment where a nuclear/biological/chemical threat requires surgical facilities to be strictly enclosed.

One potential drawback to the use of TCI in the field is the bulk of the propofol packaging and prefilled syringes, and the resupply burden these items would place on the logistical system. This can be overcome by using the technique with a standard infusion pump controlled from a laptop computer, using such software as StanPump (Steven L Shafer, Department of Anesthesia, Stanford University, Palo Alto, CA, USA; <http://anesthesia.stanford.edu/pkpd/HTML%20Web%20pages/default.htm>) or Rugloop (Department of Anaesthesia, Ghent University, Ghent, Belgium; <http://allserv.rug.ac.be/~mstruys/rugloop.html>). This in itself poses questions of survivability of the laptop in the field environment. Recent experience in the ADF shows that most modern laptops withstand the hardships of deployment quite well, and they are currently included on the equipment tables of land-based health care facilities. This method also requires the presence of a suitably computer-literate anaesthetist.

TCI pumps have battery backup facilities, but, as with all such equipment, this has a finite timespan. Loss of electrical power is an ever-present problem in forward medical facilities. In this regard volatile-based techniques using draw-over vaporisers have the advantage, as they are independent of all power and compressed gas sources.

There is a learning curve involved with TCI, although, for most trained anaesthetists, this is not a significant hurdle. However, it is not a technique suitable for use by untrained or non-anaesthetist personnel. Similar issues face anaesthetists coming to terms with draw-over systems for the first time.

Conclusion

Use of target-controlled infusion anaesthesia in the field is feasible. Modern infusion pumps are robust enough to withstand the rigours of field deployment. Results obtained in this limited series show comparable results to conventional draw-over techniques in terms of awakening times and better results in terms of postoperative nausea and vomiting. Intravenous anaesthesia has a proven place in military field anaesthesia and this technique may make its adoption more widespread. The options of infusion-based anaesthesia, with a draw-over system as backup in case of prolonged power loss, may be the most flexible combination for use in forward areas. Logistical issues, including bulky packaging, may be the greatest obstacle to the widespread adoption of target-controlled infusion for field use.

Conflict of interest statement

AstraZeneca provided support for this trial in the form of a loan of 2 Alaris TCI pumps. Major Harding received financial assistance from AstraZeneca to attend the Joint Scientific Meeting of the Australian and New Zealand College of Anaesthetists and the Hong Kong College of Anaesthesiologists in Hong Kong, May 2001. Portions of this paper were presented as a poster at that conference.

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