Patient-maintained propofol sedation for orthopaedic surgery: patient variability in system use

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ABSTRACT

In the UK, operations not requiring general anaesthesia may be carried out under sedation. This is generally provided by a doctor. As the patient is not controlling the sedation, they may often be either under or over-sedated, due to the doctor misjudging patients' anxiety and sedation requirements. A potential solution is to allow the patient to control their own depth of sedation. We conducted a case series to examine the efficacy of patient-maintained propofol sedation for patients presenting for lower limb orthopaedic surgery under regional anaesthesia. Twenty-six patients undergoing lower limb surgery were given a handheld button to indicate their request for deepening sedation from a baseline propofol concentration of 0.5 $\mu g.ml^{-1}$ by 0.2 $\mu g.ml^{-1}$ increments to a maximum of 2.0 $\mu g.ml^{-1}$. Twelve patients chose not to press their button. The remaining 14 patients pressed the button a median (range) of 6 (1–29) times, obtaining a mean (SD) estimated effect-site blood propofol concentration of 0.91 $\mu g.ml^{-1}$ (0.34 $\mu g.ml^{-1}$). Feedback revealed that patients were satisfied with their sedation, were happy to have control over it, and would use the system again. Despite this consensus, sedation level profiles revealed variability in how patients used the system in terms of button press frequency and timing, associated with their pre-op anxiety and reaction to environmental events during the operation. Whilst this technique can be a safe and effective way of controlling sedation during these types of surgery, future research needs to consider the different ways patients interact with the system.

KEYWORDS

Patient-maintained propofol sedation, user variability, healthcare human factors

Introduction

Over 800,000 operations are performed annually in the UK in the presence of an anaesthetist but without using general anaesthesia (Sury et al., 2014). A substantial number of patients experience anxiety when undergoing awake procedures (Mitchell, 2009). As well as being an intrinsically negative experience for patients, procedural anxiety has been consistently associated with deleterious surgical outcomes such as post-operative pain (Munafò & Stevenson, 2001). A variety of techniques have been shown to be effective at reducing procedural anxiety, including music therapy (Bradt, et al., 2013), visual distraction (Man et al., 2003), patient education (Jlala et al, 2010), and pharmacological sedation (Mackenzie, 1996).

Target controlled infusion (TCI) of propofol, under the direction of an anaesthetist, is a popular choice for intra-operative sedation because of the drug's favourable pharmacokinetic profile; this is how the drug is adsorbed, distributed, metabolised and excreted by the body (Schnider et al., 1998). However, anaesthetists have been shown to be inaccurate judges of pre-operative patient anxiety

(Badner et al, 1990; Fekrat et al., 2006). This could result in either insufficient or excessive dosing of pharmacological sedation in relation to the actual requirements of individual patients. One possibility for overcoming this is allowing patients control over their depth of sedation.

Patient-maintained propofol sedation has been previously tested in endoscopy (Stonell et al., 2006; Campbell et al., 2004), dental (Leitch et al., 2003; 2004) and outpatient surgical (Yun et al., 2008; Alhashemi & Kaki, 2006) settings. While this research has reported back favourably in terms of sedation concentration, patient recovery time and anxiety levels, to date there has not been a truly human-centred approach to the problem that fully considers the opinion and role of the patient within the system. Although previous work has acknowledged the inter-individual variability of patients' propofol consumption (Irwin et al., 1997), there has been little consideration of how patients' differing state of mind influences their interaction with the system for the duration of the process.

The aim of this study was to examine the efficacy and satisfaction of patients using a patient-maintained propofol sedation under anaesthetist supervision in a novel operative setting: lower limb orthopaedic surgery performed under regional anaesthesia. In doing so, we make an exploratory attempt at a more human-centred approach, by considering the varying ways different patients interact with the system and discussing the implications for future patient-maintained solutions.

Methodology

Prospective NHS Research Ethics Committee approval for this study was obtained (Wale REC 6 Ref: 16/WA/0080) and the study was registered at The Research Registry® (Registration Ref: 2521). Written informed consent was obtained from all subjects. The study methodology reflects the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (von Elm et al., 2014) for reporting of observational studies. The study was designed as a prospective observational examination of the efficacy of a novel sedation technique in a pre-defined sample of patients at a single institution. Review of previously published efficacy studies (Leitch et al., 2003; Campbell et al., 2004) suggested a convenience sample of a minimum of 25 patients would provide adequate data on the feasibility and safety of the sedation technique in our patient population.

Inclusion criteria were adult patients (>18 years) presenting for elective lower limb orthopaedic surgery under regional anaesthesia at Nottingham University Hospitals NHS Trust and expressing a pre-operative preference for surgery to be performed under sedation. Exclusion criteria were: inability to use a patient-maintained propofol sedation button; need for surgery to be conducted under general anaesthesia; contra-indication to the use of propofol; or inability to communicate in written and spoken English.

After routine, non-invasive monitoring was established, an effect-site target controlled infusion was delivered using Schnider modelling (Schnider et al., 1998) by a pharmacokinetic pump (Alaris™ PK Syringe Pump, Carefusion UK, Basingstoke, UK) (Figure 1).

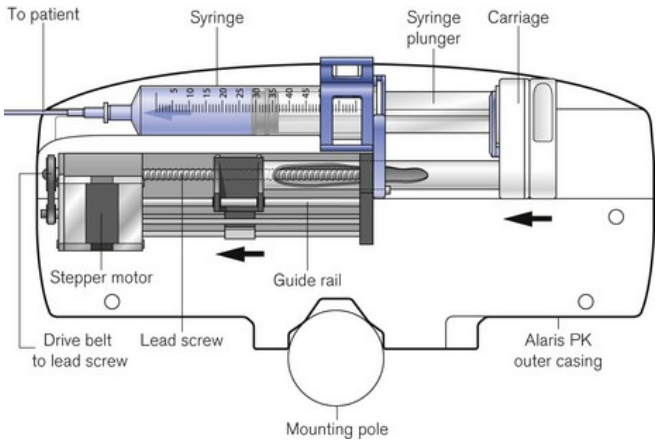

Figure 1: Alaris^{TM} pharmacokinetic pump for administering propofol sedation

Patients were given a hand-held button triggering an audible beep when pressed, indicating a request for deepening of sedation. Subjects were told: *"You will be started on a background level of sedation"* and *"If you feel anxious or want to be more sleepy, press your button to increase the sedation"*. On hearing a beep indicating a button-press, the study investigator manually altered the effect-site target of the propofol infusion according to a standardised protocol. The patient was unaware of the manual nature of the interruption, advised only that the button press was a request for an increase in sedation. Patients were commenced at an effect-site concentration (the estimated concentration of propofol in the brain tissue) of 0.5 $\mu g.ml^{-1}$ and allowed to increment by 0.2 $\mu g.ml^{-1}$ up to a maximum of 2.0 $\mu g.ml^{-1}$. Repeat button-presses were ignored until the calculated effect-site concentration was equal to the target (i.e. the lockout period was equal to the equilibration time). Ignored requests were described as 'failed', and whilst patients were told that the sedation system will not allow them to overdose and has a lock-out time, there was no direct indication whether an individual button press had succeeded or failed. If the patient did not press the button for six minutes the infusion was decremented by 0.1 $\mu g.ml^{-1}$. A minimum effect-site concentration of 0.5 $\mu g.ml^{-1}$, below which the infusion target was not decreased, was maintained throughout surgery.

At the end of surgery, sedation was discontinued and the patients transferred to the post-anaesthetic care unit. After recovery from sedation, a questionnaire was administered seeking feedback on the use of the button and satisfaction with sedation including a 10-point numeric rating scale. After discharge from hospital, patients were contacted by telephone and asked for feedback on their sedation and to provide a narrative evaluation of their experience.

Results

Between 26/05/16 and 22/03/17, 27 patients received patient-maintained propofol sedation with 26 included in the final analysis. One patient did not complete post-operative follow-up and their data was therefore excluded. Twenty-four of 26 patients used the patient-maintained system for the duration of their surgery. Two patients became restless halfway through surgery and were unable to keep their arms still despite verbal request from the supervising anaesthetist to do so. Their sedation was therefore taken under direct control by the supervising anaesthetist to manage this restlessness. Pre-operative and intra-operative data, up until the anaesthetist took control of their sedation, were included in the study analysis. Postoperative data were also included.

Of the 26, 12 patients did not use the button to indicate a desire for deeper sedation. Therefore, they remained at a baseline effect-site concentration of 0.5 $\mu g.ml^{-1}$. The remaining 14 patients operated the button a median (range) of 6 (1-29) times; successfully 4 (1-9) times and unsuccessfully 5 (1-20) times. Figure 2 shows the number of button demands (successful and unsuccessful) in each five-minute period during the study.

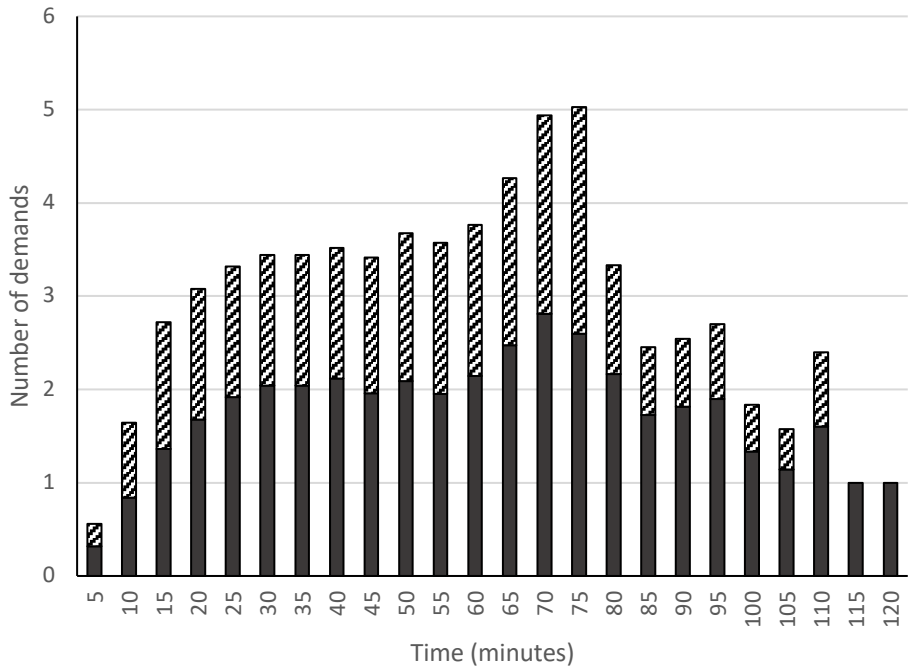

Figure 2: Number of successful (solid bar) and unsuccessful (dashed bar) button demands for increased sedation during the study period

The mean (SD) estimated propofol effect-site concentration obtained by the 14 patients who chose to press the button was 0.91 $\mu g.ml^{-1}$ (0.34 $\mu g.ml^{-1}$). The mean (SD) maximum estimated effect-site concentration during surgery for these patients was 1.2 $\mu g.ml^{-1}$ (0.43 $\mu g.ml^{-1}$). The estimated effect-site concentration of propofol for the duration of the study period for all patients is shown in Figure 3. The mean (SD) estimated effect-site concentration in all 26 patients during surgery was 0.73 $\mu g.ml^{-1}$ (0.32 $\mu g.ml^{-1}$); the mean (SD) maximum estimated effect-site concentration was 0.89 $\mu g.ml^{-1}$ (0.48 $\mu g.ml^{-1}$).

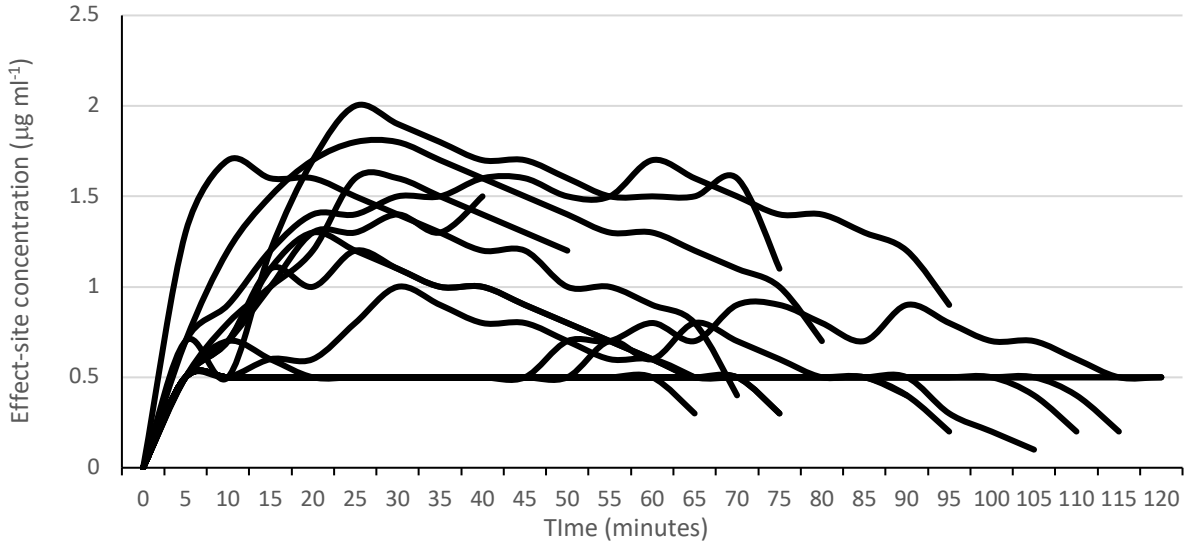

Figure 3: Effect-site concentration of propofol during sedation for all patients.

The design of the experiment allowed patients to alter their depth of sedation accord to personal preference. This revealed the various ways patients interacted with the system - Figure 4 highlights four different patterns of use.

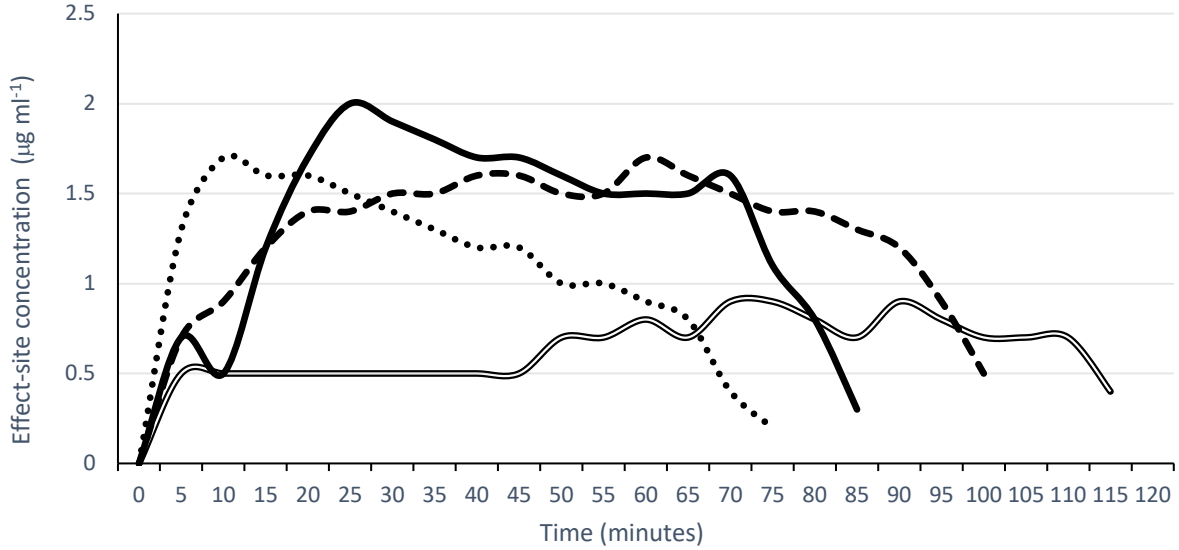

Figure 4: Effect-site concentration of propofol during sedation for four patients. Patient 1 (dotted line), patient 2 (solid line), patient 3 (dashed line), and patient 4 (double line).

Through combining the quantitative button usage and effect-site concentration data with observational evidence provided by the attending anaesthetist, the patterns of use described in figure four can be expanded on as follows:

Patient 1 (dotted line): Appeared anxious pre-operation in the anaesthetic room, and therefore chose to obtain a relatively deep level of sedation as soon as given the button to press (as shown by steep increase in concentration over first 10 minutes in figure 4).

Patient 2 (solid line): Initially chose not to press the button when first available, but when surgery had commenced, due to associated noise decided to deepen their sedation (between 10-15 minutes on figure 4). From then on sedation slowly decreased due to the systematic degradation built into the system, until ~70 minutes where the button was pressed again.

Patient 3 (dashed line): Button usage was the most regular throughout the surgery, achieving a relatively steady state of sedation throughout (shown by the shallower curve up to ~1.5 $\mu g.ml^{-1}$ and the shallower degradation after ~80 minutes).

Patient 4 (double line): Patient appeared relaxed for most of the surgery and did not press the button until a major part of the surgery commenced with its associated noise caused by hammering (~45 minutes on figure 4). At this point they deepened their sedation, but at no point did the effect-site concentration of propofol exceed 1 $\mu g.ml^{-1}$.

Considering the post-operative questionnaire results, when asked to what degree they liked/disliked having control over their sedation, 24 out of 26 patients recorded *"I liked it"*, two patients recorded *"I neither disliked nor liked it"* and therefore no patients recorded *"I disliked it".* Adding context to these results, narrative responses included:

> *"It was comforting to know that you could do it if you wanted to…"*

And:

> *"Although I didn't use the button I liked knowing that I could have if I had wanted to."*

There were no perceived negative responses regarding sedation control. When asked whether they felt they were sedated to the right level, 25 of 26 patients recorded: *"I felt I was sedated at the right*

level". One patient recorded: *"I cannot remember"*. No patients recorded that they felt *"too sedated"* or *"not sedated enough".*

Twenty-four of 26 patients were *"satisfied"* or *"very satisfied"* with their sedation; the two remaining patients were *"neither dissatisfied not satisfied"*. Median (range) ten-point numeric rating scale response was 10 (5-10) for satisfaction with sedation. When asked if they would use the same sedation technique again, 25 of 26 patients responded with *"very likely"* or *"likely",* one patient responded *"unsure".* No patients responded *"unlikely"* or *"very unlikely".*

Discussion

In this study of patients undergoing lower limb orthopaedic surgery, we used effect-site targeted, patient-maintained propofol sedation in 26 patients to obtain personalised sedation levels. By applying patient-maintained propofol sedation in the setting of orthopaedic surgery without general anaesthesia, we have shown that the technique is a legitimate alternative to current anaesthetist-controlled TCI. Twenty-four of the 26 patients successfully maintained their own sedation levels throughout the procedure without any intervention from the attending anaesthetist. However, two patients did experience physical and verbal disinhibition; a common and well-recognised occurrence during propofol sedation. On both occasions, the patient's sedation was deepened by the anaesthetist to terminate this side effect. Both events coincided with the 'decremental' phase of their sedation, one patient decrementing from a peak effect-site concentration of 1.6 $\mu g.ml^{-1}$ to 1.2 $\mu g.ml^{-1}$ at the point of disinhibition, the other from a peak of 0.7 $\mu g.ml^{-1}$ back to 0.5 $\mu g.ml^{-1}$. This serves as a reminder of the importance that the attending anaesthetist can easily and effectively take control of the system when required during a patient-maintained propofol sedation procedure.

In terms of feedback from the patient, the consensus agrees with previous research. Overall, patients liked having control over their own sedation and were happy with their sedation level (Leitch et al., 2003). They were also satisfied with their sedation and would use the same sedation technique again (Campbell et al., 2004; Irwin et al., 1997). The verbal reports from patients also suggest a degree of empowerment, i.e. the patients found it reassuring to be able to control their level of sedation. This empowerment may reduce anxiety and the level of sedation that the patients felt they required. Indeed, some patients indicated in the free responses that they liked knowing they had the option to press the button, even though they did not use it. There was also a noticeable lack of negative responses - this is perhaps surprising considering the lock-out period of button, and the associated unsuccessful button presses. Whether this is due to the patient being unaware of their failed button presses or accepting that it is for good reason requires further investigation.

Although feedback from the patients suggests a strong positive consensus regarding controlling the sedation process, this did not translate to uniform behaviour when using the system. When and how often a request for an increase in sedation occurs can be attributed to a several factors. Aspects such as the pre-op anxiety, the stage of the operation and associated environmental effects (noise, vibrations etc.), and individual sensitivity to propofol can all influence the number of button presses, when they occur and ultimately the maximum depth of sedation the patient reaches during the procedure. It is also worth noting that a large proportion of patients (12, ~46%) did not request an increase in sedation at any point during the operation. Whether this would have been the case if the sedation process was anaesthetist-led is unknown, however there is a possibility that patients could be sedated to levels higher than they would wish.

The results of this study demonstrate insights uncovered by a human-centred approach when considering patient-maintained propofol sedation. Whilst the importance of the system delivering sedation successfully and at dosages that are safe for the patient is apparent, it is also important to recognise the differing ways the system is utilised. If patient-maintained propofol sedation is to be successfully adopted as an alternative to anaesthetist-led practices, the system needs to be robust to

the different ways patients' use it, and in turn used to inform the anaesthetist when to be vigilant (early in the procedure for anxious patients and during decremental periods when considering potential disinhibition etc.).

Beyond the potential impact that this research could have when informing future patient-maintained sedation solutions, a number of the findings could be applied to current anaesthetist-delivered TCI sedation. For example, although the time with the patient afforded by this study did not allow for a formal appraisal, consideration of patients' pre-operative anxiety and mental state could inform selection of the baseline effect-site concentration of the sedation. More anxious patients (patient 1 in Figure 4), may therefore benefit from a higher baseline concentration. Similarly, the decrement rate of sedation needs consideration. Since the lower limb orthopaedic surgery considered in this study is often longer in duration, more research is required to examine if longer decrement times would reduce the potential for disinhibition as suffered by the two patients discussed.

This work has demonstrated that effect-site targeted, patient-maintained propofol sedation in patients presenting for elective lower limb orthopaedic surgery under regional anaesthesia can be safe and effective, provided that the system is used under the supervision of an anaesthetist. It has also revealed a variety of ways patients interact with the system in terms of sedation request timing and frequency, and how factors such as patient pre-op anxiety and events during the operation influence this interaction. The outcomes of this study support a hypothesis that a patients' differing mental state could affect their use of self-sedation. The next step for patient-maintained propofol sedation research is to consider this question, investigating system designs that are flexible to differing patient profiles and to develop reliable ways of assessing pre-op personality trait and anxiety to help inform the anaesthetists of when intervention might be required.

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