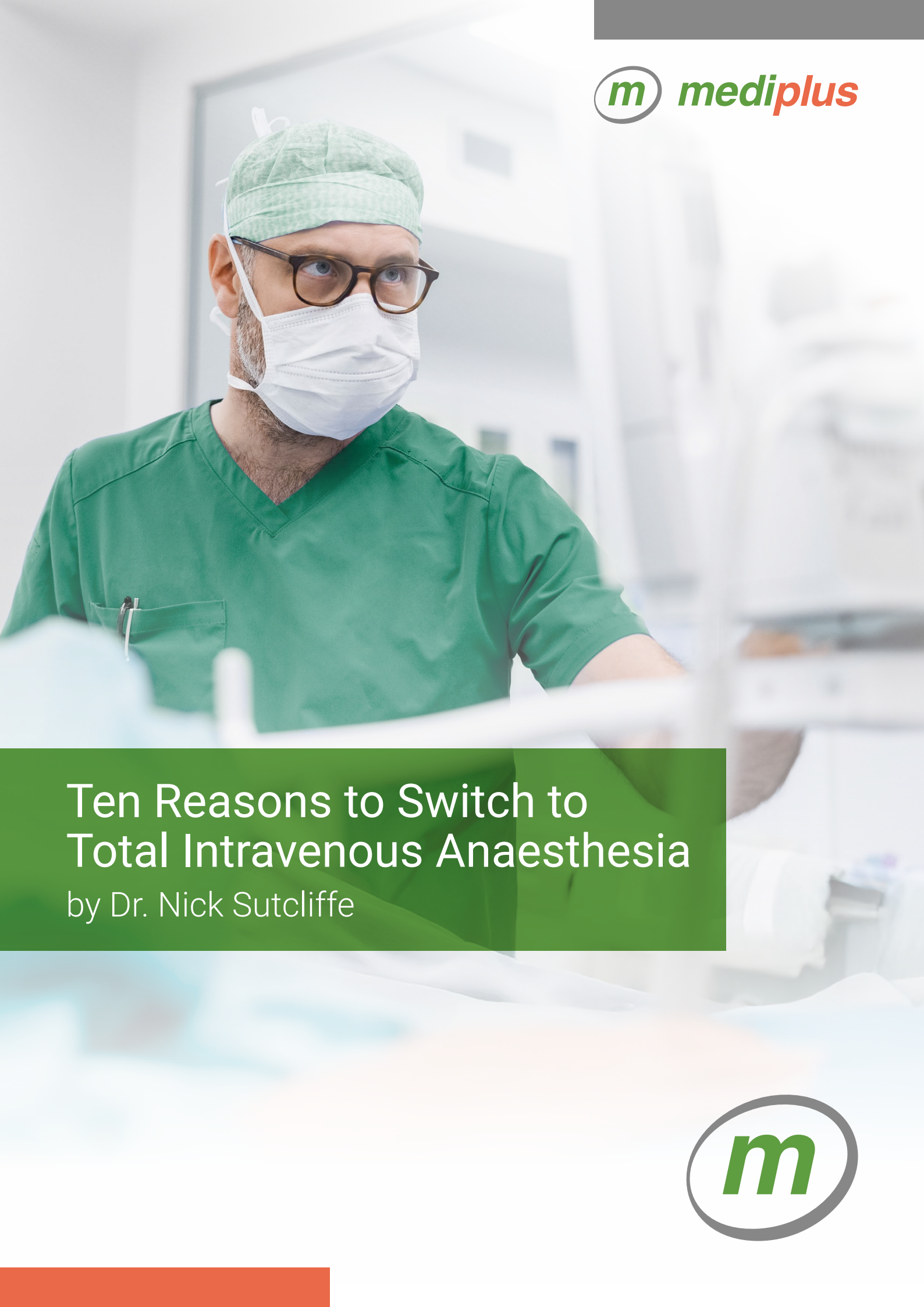

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Ten Reasons to Switch to Total Intravenous Anaesthesia

by Dr. Nick Sutcliffe

Contents

When I was first asked to write this document, the given title was "Ten reasons why I switched to Total Intra-Venous Anaesthesia (TIVA)". I soon realised that back in 1994, when I switched to exclusively using TIVA for all my cases, I would have been unable to list ten reasons. At the time, the evidence didn't exist to support the superiority of TIVA over Volatile Anaesthesia (VA). On reflection, the reasons why I started to dabble in the dark arts of TIVA can be expressed in two words: boredom and headaches. When I started my training, I was told that anaesthesia is like flying a plane, 99.9% boredom and 0.1% panic. This was said with a degree of humour, but there is an element of truth that, like aviation, the most interesting and problematic phases of anaesthesia are often induction (take off) and emergence (landing). The bit in the middle is often routine and similar to being on autopilot. During the early days of anaesthesia training, one often had to call upon a senior supervising colleague for help. Once this phase is complete and one becomes experienced, the practice of anaesthesia can become mundane; induction agent, opiate, +/- muscle relaxant and open the vaporiser. Why not add a little bit of interest by trying TIVA? I also noticed that I had headaches towards the end of the working day. No, I wasn't allergic to work, as I didn't suffer the headaches after a day's work in the ICU, or in my previous life as a renal physician. I began to wonder if breathing the contaminated air in the anaesthetic room was responsible. Thus, my journey into TIVA began. Once I started using the technique, I also noticed benefits for my patients in terms of recovery profile. Often, patients would wake up promptly with a clear head, no nausea and a little bit of euphoria that seems to characterise recovery from propofol-based TIVA. However, I digress from the topic of this paper, which is the ten reasons why current-day anaesthetists should consider TIVA for their patients.

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1 TIVA using Target Controlled Infusion (TCI) allows a smooth induction and continuation into maintenance using a single hypnotic agent

Inhalational anaesthesia often involves an IV hypnotic agent for induction and then a switch to a volatile hypnotic agent for maintenance of anaesthesia. The practitioner must balance the dose and timing of both agents and avoid over or underdosing of the combined effect of the two agents. Incorrect management of this process can lead to the potential of transient awareness, if the combined hypnotic effect is too low, or cardiovascular depression, if the hypnotic effect is too high. Figure 1 (upper pane) shows the calculated blood and effect-site concentration in μg/ml after a 2mg/kg bolus of propofol. The evolution of end-tidal volatile concentration over the same period will be dependent on the selected inspired concentration and the efficiency of ventilation. An estimation of the combined effect from the two drugs during this "induction phase" can, at best, only be an educated guess. Given these issues, it's surprising that such a technique so often results in a smooth transition between the two hypnotic agents, without complications. Looking at the lower pane in Figure 1, the situation with a TCI infusion of propofol is, by comparison, more predictable. The effect-site concentration rises progressively and is displayed on the pump. The patient's response can be assessed as the effect-site concentration rises; this allows calibration of the individual patient in terms of sensitivity to propofol. An appropriate maintenance target can then be selected and titrated appropriately as the procedure proceeds.

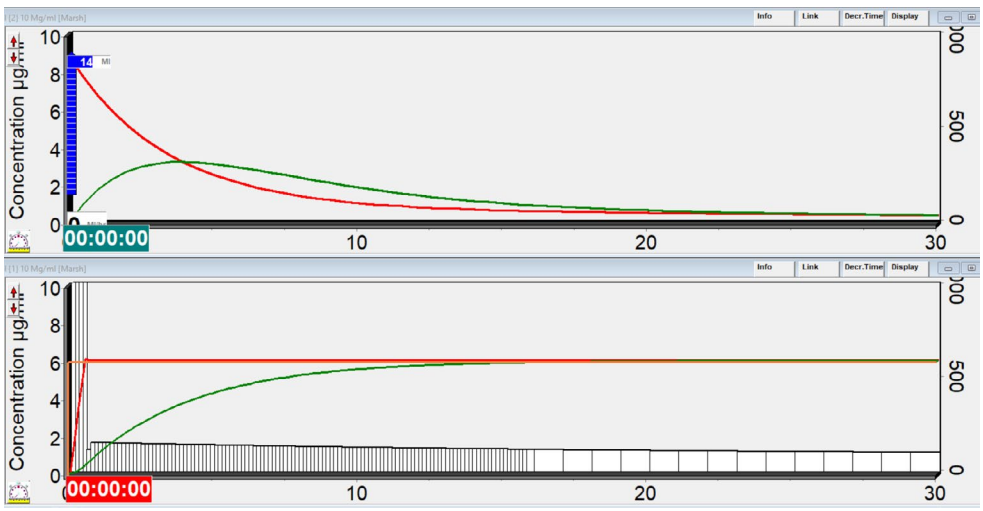

Figure 1: The time course of calculated blood (red line) and effect-site (green line) concentrations of propofol, following a bolus of 2mg/kg (upper pane) and following a TCI infusion set at 6 mg/ml (lower pane), simulated in Tivatrainer using the Marsh model.

Thus, a TIVA technique using TCI facilitates a smooth induction and transition to maintenance of anaesthesia, whilst allowing the anaesthetist to assess the patient's responsiveness to a given level of anaesthetic agent in a way that no other technique can emulate.

2 Rapid titration of anaesthetic depth to match changes in surgical stimulation

The advantage of VA is its simplicity; the practitioner simply changes the dial on the vaporiser to change the depth of anaesthesia. The development of TCI now means that the delivery of TIVA is as simple as using a vaporiser. The anaesthetist has only to change the target concentration, and the system delivers a complex infusion algorithm, designed to achieve and maintain, each new selected target concentration. The intravenous bolus and infusions associated with TIVA, allow rapid changes in blood agent concentration. This, in turn allows rapid changes in the depth of anaesthesia, particularly when increasing the blood concentration. In contrast, using VA, a change in the vaporiser setting leads to an increase in alveolar agent concentration and subsequently a change in the blood agent concentration. This is a slower process, leading to less rapid changes in the depth of anaesthesia. The rapidity of change in anaesthetic depth offered by TIVA means that anaesthesia can be more closely tailored to the intensity of surgical stimulation. Also, over or underdosing as indicated by EEG markers can be more rapidly corrected. This is particularly important with overdosing, as low BIS values and burst suppression may be associated with poor patient outcomes[1,2].

> Low BIS values and burst suppression may be associated with poor patient outcomes

3 Global environmental effects of anaesthetic agents

All volatile anaesthetic agents are powerful greenhouse gases (GHG). Each agent can be assessed in terms of global warming potential (GWP). This value is dependent on the specific spectrum of radiation absorption of the gas and its half-life in the atmosphere. The GWP value for an agent is expressed with reference to the GWP of CO2 and is also adjusted for time. Thus, 1 kg of a gas with a GWP100 value of 130, captures the same amount of heat, as 130 kg of CO2 over a period of 100 years. The GWP values for the common anaesthetic agents are listed in Table 1. Desflurane and nitrous oxide are the worst offenders, but sevoflurane also has a significant effect. To put this into terms that are more easily understood, a full day of volatile-based anaesthesia with sevoflurane is equivalent to driving a car 200-300 miles. Volatile agents account for 1.7% of all NHS carbon emissions and 5% of emissions from acute hospitals[3]. This figure is even higher if the carbon footprint from volatile agent production is included in the data. Comparing the anaesthetic agent carbon footprint, including both production and direct emissions, propofol-based TIVA emissions are at least an order of magnitude less than those of a "low flow" sevoflurane anaesthetic.

Both the UK and the EU have restricted the routine use of desflurane and nitrous oxide due to their environmental impact. NHS England aims to become net-zero in terms of CO2 emissions by 2040[3]. Clearly, a switch to TIVA from VA anaesthesia represents a significant step towards this goal.

Agent	GWP100	Life in Atmosphere (yrs)
Nitrous Oxide	298	114
Desflurane	2540	14
Isoflurane	510	3.2
Sevoflurane	130	1.1

Table 1: Volatile anaesthetic agents in terms of global warming potential (GWP100). Excluding production emissions.

1 kg of a gas with a GWP_{100} value of 130, captures the same amount of heat, as **130 kg of CO_2 over a period of 100 years**

A full day of volatile-based anaesthesia with sevoflurane is **equivalent to driving a car 200–300 miles**

NHS England aims to become net-zero in terms of CO_2 emissions by 2040

4 Local environmental effects of anaesthetic agents

Volatile anaesthetic agents (VAA) escape into the operating room (OR) environment, due to leakage during mask ventilation, leaks from circuits, spillages and exhalation from patients following extubation. VAA are controlled in the UK under the control of substances hazardous to health (COSHH) regulations and limits are in place. However, they are rarely checked, never enforced and probably regularly breached. I have already alluded to my own experience of minor symptoms related to working in an environment contaminated with volatile anaesthetics. Nausea, headaches, dizziness, fatigue and irritability are seen in excess in OR staff. Such nonspecific symptoms could be attributed to stress or other factors. However, there is evidence that OR staff may also suffer from an excess of more severe pathologies. Studies have shown an excess of spontaneous abortion, congenital abnormalities in offspring, and liver and kidney disease in OR staff[4]. There is also evidence of a higher degree of genetic damage in OR staff compared to controls. A systematic review published in 2016 concluded that "In almost all data, occupational exposure to anaesthetic gases has been associated with statistically significant genotoxic damage among operating room personnel"[5]. There is also evidence from animal studies that VAA can produce changes in the brain, similar to those seen in Alzheimer's disease6. Given this data, why would any anaesthetist expose themselves and colleagues to such risks?

Nausea, headaches, dizziness, fatigue and irritability

Occupational exposure to anaesthetic gases has been associated with statistically **significant genotoxic damage**

5 Post-operative nausea and vomiting (PONV)

It has long been recognised that propofol-based TIVA is associated with a lower incidence of PONV than VA. A recent meta-analysis including 229 randomised controlled trials showed a 39% reduction in PONV during propofol-based TIVA compared to VA[7]. Unlike VAA, propofol does not cause emesis. At sub-anaesthetic concentrations, propofol appears to have an antiemetic effect and has been used to reduce the incidence of emesis following chemotherapy[8]. The following is anecdotal, but I think instructive. I joined a group of 4 other consultant anaesthetists in 1994, at a new hospital in Glasgow. We all used TIVA exclusively for all cases. A few years later, when I was clinical director, one of the recovery nurses came to report some problems in the recovery area. We had a visiting anaesthetist (Dr. X) covering for a colleague on annual leave. Dr X was using VA, and the nurse came to ask me to speak with him, as she was having to recover patients who were vomiting and drowsy. I had to explain to her that I couldn't force Dr X to use TIVA, as VA was a recognised technique and in fact, the normal practice in the UK. She was most upset and couldn't understand why anyone would want to use such a substandard anaesthetic. I have to say I did agree and we removed Dr. X from our backup list.

Controlled trials showed a **39% reduction in PONV** during propofol-based TIVA compared to VA

6 In some circumstances, TIVA is the only viable option for anaesthesia

The safe delivery of VAA requires a complex anaesthesia workstation and an appropriate scavenging system. Some locations outside the OR do not have this infrastructure, and TIVA is the only option for the delivery of procedural sedation and anaesthesia. Likewise, anaesthesia for the transfer of patients from the OR to intensive care can only be achieved using intravenous agents. Bolus dosing of agents to "cover the transfer" can lead to overdosing with cardiovascular compromise or underdosing, risking patient movement, cardiovascular stress and awareness. This is particularly the case when doses of muscle relaxant are given to "cover the transfer", a practice which I have witnessed in my training. A much better technique is to use TIVA with TCI of propofol and opioid in the OR, which can be titrated down at the end of surgery and adjusted during transfer to maintain the appropriate level of anaesthesia. VAA are trigger agents for malignant hyperthermia. Propofol-based TIVA is the only potential option for those known cases, requiring general anaesthesia. I would also suggest that using TIVA for all cases, mitigates the risk of triggering malignant hyperthermia, in those patients where the diagnosis is not known prior to surgery.

> I would also suggest that using **TIVA** for all cases, mitigates the risk of triggering malignant hyperthermia

7 Special circumstances where TIVA is particularly indicated

I would say that TIVA is a better option for all cases, but there are certain situations where it is universally recognised as a superior technique. I have already mentioned the lower incidence of PONV associated with TIVA. A patient with a history of severe PONV requiring GA should have propofol-based TIVA. One lung anaesthesia and patients with severe V/Q mismatch are better managed with TIVA, as VAA abolish the hypoxic pulmonary vasoconstrictor reflex, which may result in hypoxia. Likewise, cerebral autoregulation is maintained, and intracranial pressure is lowered by propofol, in contrast to VAA and is therefore preferred in neurosurgical procedures. Day-case surgery requires prompt discharge from hospital. The superior quality of recovery seen with TIVA, particularly in respect of PONV, can help in this respect.

> For patients with a history of severe PONV, propofol-based **TIVA is the preferred choice**

- **History of PONV**
- **One-lung ventilation**
- **Neurosurgery**
- **Day-case surgery**

8 Post-operative cognitive dysfunction (POCD) and delirium

As the safety and efficacy of anaesthesia have improved, more attention has been focused on the quality of postoperative recovery. Postoperative cognitive dysfunction (POCD) and postoperative delirium (POD) can be a problem, particularly in the elderly. Evidence is accumulating that TIVA with propofol has a lower incidence of these complications[9,10].

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9 Postoperative recovery and enhanced recovery after surgery (ERAS)

ERAS is a package of treatments and measures designed to promote rapid recovery and discharge from hospital following surgical procedures. It has been shown to be of benefit to patients in terms of morbidity and beneficial to the institution in terms of cost-effectiveness. The anaesthetic aspect of ERAS focuses on optimal recovery, to avoid delayed discharge from the recovery area and delayed hospital discharge. Factors affecting recovery following anaesthesia include PONV, POCD, POD and postoperative pain. All these factors are improved with TIVA vs VA[7,9,10]. Thus, TIVA has a prominent role in facilitating ERAS, particularly in patients with a history of PONV and for day-case surgery cases.

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10 General anaesthesia for major surgery and cancer surgery

Surgery elicits a neurohumoral mediated inflammatory response proportional to the degree of tissue damage. It is thought that this inflammatory response can lead to postoperative complications due to immunosuppression. Such complications include infection and metastatic cancer spread. VAA and propofol both have anti-inflammatory properties, which could, in theory, mitigate these issues. However, VAA also suppress natural killer cell activity and white cell function, which are important in suppressing tumour activity and fighting infection. There is considerable in vitro evidence to support the superiority of propofol over VAA in this respect. Also, **numerous retrospective studies show less post-procedural tumour recurrence, using a propofol-based TIVA technique**[11]. Other studies have shown TIVA to have a lower incidence of postoperative pulmonary complications[12]. Large prospective studies are ongoing to try to confirm these interesting findings.

> I am sure if you do persevere, you, like me, will never return to inhalational anaesthesia once you have mastered the art of TIVA.

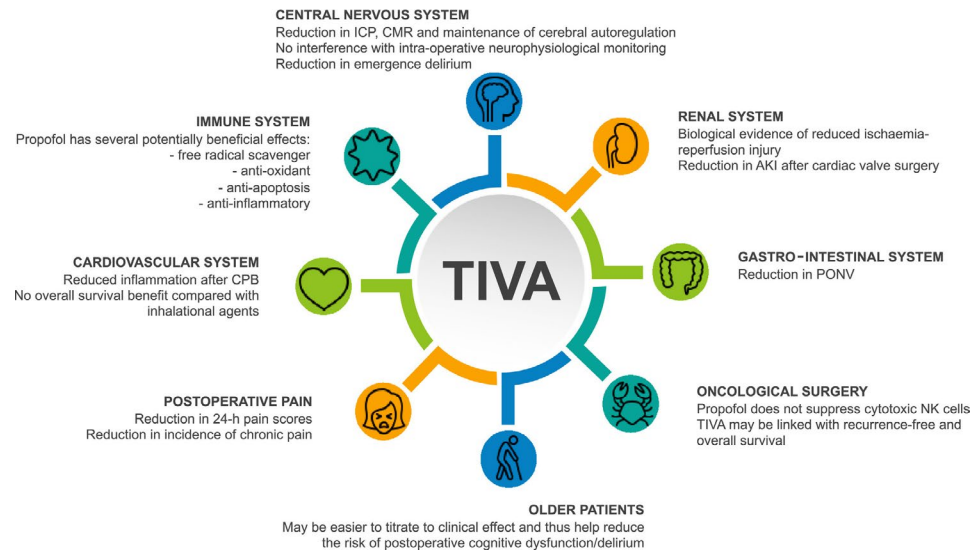

Figure 2: The beneficial physiological effects of propofol-based TIVA from Irwin et al[13].

In summary, there are many potential benefits from the use of TIVA, for both the patient, the OR staff and the global environment. I hope this paper will encourage you to try TIVA for yourself or increase your practice of the technique if you are already a user. Like any skill, it will take time and practice to become familiar with the technique. It is helpful to spend some time in the OR with a colleague experienced with its use. However, I am sure if you do persevere, you, like me, will never return to inhalational anaesthesia once you have mastered the art of TIVA.

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