

Haemodynamic effects of the prone position: a comparison of propofol total intravenous and inhalation anaesthesia

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Summary

The haemodynamic changes of the prone position were investigated in 40 ASA I–II patients undergoing lumbar spine surgery. Patients were randomly assigned, following propofol intravenous induction, to receive maintenance of anaesthesia using either isoflurane 1–1.2% in air or target controlled propofol 3 $\mu\text{g}\cdot\text{ml}^{-1}$ infusion. Measurements of non-invasive blood pressure, heart rate and cardiac output were made in the supine position. The patient was then turned prone onto a Montreal pattern mattress and measurements repeated. Cardiac output measurements were made using a non-invasive cardiac output monitor. We found a significant reduction in cardiac index in both groups and a significantly greater change with propofol compared to isoflurane on turning supine to prone (CI change 0.4 vs 0.7 $\text{l}\cdot\text{min}^{-1}\cdot\text{m}^{-2}$ $p = 0.001$ and SVRI change 89 vs 177 $\text{dyne}\cdot\text{s}^{-1}\cdot\text{cm}^{-5}$, $p = 0.041$). We conclude that turning healthy patients prone produces a clinically significant reduction in cardiac output, the change being greater during maintenance of anaesthesia using propofol compared to isoflurane.

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A number of different prone positions have been used for surgical access to the lumbar spine [1]. The considerations that have influenced the choice of position include cardiovascular effects, respiratory compromise [2], surgical conditions/access and intra-operative blood loss [3].

The cardiovascular effects associated with postural changes under anaesthesia can lead to organ dysfunction in susceptible patients. Backofen *et al.* [4] observed a marked decrease in the cardiac index output and stroke volume when patients were turned prone which was associated with a significant rise in systemic and pulmonary vascular resistance. In Yokoyama *et al.*'s study [5] there were no significant changes when patients were turned prone onto a flat surface but there was a marked decrease in cardiac output and stroke volume when they were turned prone onto a convex saddle frame. In their study of four different prone positions, Wadsworth *et al.* [6] found the knee chest position caused the greatest decrease in cardiac index.

In University Hospital of Wales a preshaped Montreal pattern mattress is the support used for prone patients, a widely used device. It is made of plastic coated foam

rubber with a central cavity to allow free movement of the abdomen and covered in a full length jellypad to help distribute the pressure evenly. The operating table is hinged at the centre, to obliterate lumbar lordosis, and to facilitate surgical access to the spine. The head and the lower limbs are then slightly dependent with respect to the heart with the legs bent at the knee over a bolster. The use of this frame has not been previously studied in the literature but would be expected to perform similarly to the other devices (props) described in Wadsworth *et al.*'s study [6].

In the anaesthetic literature, only Ozkose *et al.* [7] have examined whether there is a difference in haemodynamic effects found on turning patients prone depending on the type of anaesthetic technique used. They compared total intravenous anaesthesia (TIVA) and inhalational anaesthesia. The study by Ozkose *et al.* [7] demonstrated a greater reduction in blood pressure in the TIVA group when compared to inhalation anaesthesia with either isoflurane and nitrous oxide or sevoflurane and nitrous oxide; however, it did not investigate changes in cardiac output.

TIVA with propofol is being used more widely following the introduction of target controlled delivery systems. The benefit of minimal pollution to the operating theatre environment and reduced postoperative nausea and vomiting makes TIVA with propofol an attractive option for induction and maintenance of anaesthesia.

The primary objective of this study was to determine the relative cardiovascular stability of propofol TIVA and inhalation anaesthesia with isoflurane in air and oxygen when patients are turned from the supine to the prone position. We used the change in cardiac output measured with the NICO™ system (Novamatrix Medical Systems Inc., Wallingford, CT) as the primary measure of cardiovascular stability.

Methods

Following Bro Taf Local Research Ethics Committee approval and written informed consent, 40 ASA grade I–III patients, aged 18–75 years, undergoing lumbar spinal surgery at the University Hospital of Wales, were recruited. We excluded pregnant women and patients who were grossly obese (BMI > 35), patients with untreated or uncontrolled severe cardiovascular disease, patients with fixed cardiac output and patients receiving treatment with beta-blockers.

All patients were premedicated with 20 mg temazepam 30 min pre-operatively. Non-invasive monitoring was established according to the Association of Anaesthetists of Great Britain and Ireland guidelines. Prior to induction of anaesthesia, patients were randomly assigned to either the TIVA or the inhalation anaesthesia group using a programme written in LABVIEW version 2.1 (National Instruments, Austin, TX).

Group TIVA: Group TIVA patients received 2 µg.kg⁻¹ fentanyl and then a propofol target controlled infusion (TCI) induction with an original target concentration of 6 µg.ml⁻¹. Anaesthesia was maintained with a 3 µg.ml⁻¹ propofol concentration. The patients were ventilated with air/O₂ (F_iO₂ 30–50%).

Group inhalation anaesthesia: In this group anaesthesia was induced using 2 µg.kg⁻¹ fentanyl followed by a bolus of propofol 2.5 mg.kg⁻¹. Anaesthesia was maintained with an isoflurane concentration of 0.8–1.2 MAC in air/O₂ (F_iO₂ 30–50%).

Both groups received 0.1 mg.kg⁻¹ vecuronium prior to intubation. The lungs were ventilated with tidal volumes of 7–10 mg.kg⁻¹, a respiratory rate of 8–12 breaths.min⁻¹, PEEP = 0, to maintain an end-tidal carbon dioxide concentration of 4.5–5 kPa.

After the patient was anaesthetised, the cardiac output and systemic vascular resistance were estimated using a

non-invasive cardiac output monitor (NICO™). After allowing the NICO™ monitor to equilibrate following intubation, three consecutive readings were taken, the first measurement being taken approximately 3 min following connection. Measurements were taken before the patient was turned prone and then again after the patient was turned prone. The following variables were recorded: cardiac output, heart rate, blood pressure, systemic vascular resistance and stroke volume. The primary outcome variable was the change in cardiac output in the two positions comparing TIVA with inhalation anaesthesia.

The power calculation was based on previous studies in which the haemodynamics in prone, anaesthetised patients were measured [4, 5]. Yokoyama *et al.* [5] found a mean (SD) cardiac index of 3.1 (0.5) l.min⁻¹.m⁻² and 2.5 (0.3) l.min⁻¹.m⁻² in the supine and prone positions, respectively. A clinically significant difference of 0.5 l.min⁻¹.m⁻² was chosen and consequently 40 patients were required to demonstrate a clinically important difference, with a power of 0.95 at the p < 0.05 level. This power calculation includes an extra 10% for losses and conversions. The data were analysed with an independent Student's *t*-test for between group data and paired *t*-test for differences within groups, using the Statistical Package for Social Services version 11. Data are quoted as mean (SD) [95% confidence limits] and a p-value < 0.05 was considered significant. Data are presented as indices to allow comparison with other studies.

Results

Forty patients were recruited into the study. Demographic data are shown in Table 1.

Changes in haemodynamic variables are shown in Table 2. In both groups the cardiac index was reduced significantly on turning the patient prone (p < 0.05): 0.4 l.min⁻¹.m⁻² and 0.7 l.min⁻¹.m⁻² in the INH and TIVA groups, respectively. In addition, a difference between groups was demonstrated, the cardiac index being decreased to a significantly greater extent in the TIVA group (reduced by 25.9% compared to baseline) than in the INH group (12.9% decrease) following

Table 1 Patient demographics. Data are mean (SD) or ratio.

	INH	TIVA
Age: years	48 (15)	48 (13)
Sex: male : female	14 : 6	11 : 9
Body mass index	29 (4)	27 (3)
Body surface area	2.0 (0.3)	1.9 (0.2)

Table 2 Cardiovascular parameters on turning patients from supine to prone position. Data are mean (SD) [95% confidence interval of difference *between* anaesthetic groups].

	Supine			Prone		
	INH	TIVA	95% CI	INH	TIVA	95% CI
Heart rate: beats.min ⁻¹	84 (18)	82 (11)	[- 7 to 11]	85 (19)	85 (13)†	[- 10 to 10]
Mean arterial pressure: mmHg	92 (17)	81 (17)	[-0.2 to 21]	87 (16)	83 (11)	[- 3 to 13]
Cardiac index: l.min ⁻¹ .m ²	3.1 (0.7)	2.7 (0.7)	[- 0.1 to 0.9]	2.7 (0.6)†	2.0 (0.7)*†	[- 0.3 to - 1.1]*
SVRI: dyne.s.cm ⁻⁵	583 (204)	736 (448)	[- 375 to - 71]	672 (323)	913 (393)*†	[- 471 to - 11]*

*p < 0.001 for difference *between* anaesthetic groups.

†p < 0.05 for difference between supine and prone *within* anaesthetic group.

turning the patient prone ($p < 0.001$). There was also a significant change in SVRI at this point, with SVRI increasing significantly in the TIVA group (24% increase) compared to the INH group (15.3% increase) ($p < 0.05$). No significant change was observed in the mean arterial pressure at this point presumably due to the increase in SVRI.

Discussion

Our results are comparable to those of both Backofen and Schauble's [4] retrospective study of changes in patients with pulmonary and cardiac disease and Yokoyama *et al.*'s study [5]. These studies demonstrated a reduction in cardiac index (24.4% and 17.2%, respectively) and a rise in systemic vascular resistance when the patient was positioned in the prone position. The reduction was similar in magnitude to the propofol group (25.9%) but greater than the inhalational group in our study (12.9%).

The means of positioning in the prone position will affect the magnitude of the change in cardiac index [6]. Yokoyama *et al.* [5] used a convex saddle frame; no details of the method of achieving the prone position are given in Backofen and Schauble's paper [4]. In our institution the Montreal pattern mattress used produced a change in cardiac index (12% vs 11%) similar to the change with Wadsworth *et al.*'s evacuable mattress [6] but less than with the other devices used props (CI 17%), which resemble the saddle frame used by Yokohoma *et al.* However, in Wadsworth *et al.*'s study [6] they used volunteers who were not anaesthetised and Yokoyama *et al.* included a subgroup who were turned prone with the curvature in the saddle frame eliminated. In both of those cases it was possible to turn the patient prone with little (3%) or no reduction in cardiac index, suggesting that the positioning device rather than the state of anaesthesia was responsible for the reduction in cardiac index.

The reason for an increase in systemic vascular resistance index, and a reduction in cardiac index was

explored by Relton *et al.* [8]. They demonstrated using angiography that the inferior vena cava is compressed, which causes a reduction in venous return, with the concomitant reflex peripheral vasoconstriction maintaining mean arterial pressure. In scoliosis patients, Soliman *et al.* [9] and Toyota *et al.* [10] showed that there was no correlation between transoesophageal echo (TOE) estimation of ventricular volume and measurements of central venous pressure or pulmonary artery occlusion pressure. In fact, pressure measurements showed an increase in pressure when ventricular filling assessed by TOE fell, which they postulated was due to reduced ventricular compliance caused by a raised intrathoracic pressure and reduced venous return caused by compression of the inferior vena cava.

This study has shown that the changes in cardiac index and SVRI were significantly greater if propofol was used instead of isoflurane. No other studies have compared these agents, although Ozkose *et al.* [7] used a three-group study to investigate the blood pressure and pulse rate changes during TIVA anaesthesia with propofol compared with inhalation anaesthesia with isoflurane or sevoflurane. They found a significantly greater decrease in the mean arterial pressure at 1 min postinduction and 1 min postintubation and a significantly lower heart rate for the first 15 min in the TIVA group compared to inhalational agents. There was no difference in the effect of sevoflurane or isoflurane on cardiovascular parameters. We did not measure blood pressure changes at these time points so we would have missed such changes. However, the authors do not specify when the patients were turned and how they were supported in the prone position, which would have affected the magnitude of changes seen and may have explained why we did not see changes in heart rate. Ozkose *et al.* did not measure changes in cardiac output [7].

We were able to measure the cardiac output using a non-invasive technique: partial rebreathing of carbon dioxide. Although the first reference in the literature was 20 years ago [11], it was Capek *et al.* [12] who described a

new revolutionary method of cardiac output measurement. This method was later described as NICO™ (Non-Invasive Cardiac Output monitoring) and it is based on a modification of the Fick Principle using the partial CO₂ rebreathing method [13]. This has been shown to correlate well with little systematic error when 191 paired measurements compared direct ultrasound cardiac output estimation to NICO™ during cardiac surgery [14]. There was a good correlation with thermodilution technique post cardiac surgery in 41 paired measurements [15], the bias being 0.050 l.min⁻¹ (95% CI: -0.024–0.125 l.min⁻¹).

However, it has been suggested that the prone position may increase the $P_{(a-Et)CO_2}$ gradient, which might lead to inaccurate measurements [16], but it would not affect the demonstrated differences between the groups. A further limitation of the technique was that we were unable to obtain a cardiac output reading pre-induction as the mask seal was insufficient to allow stabilisation of the NICO™ device. After conducting this study it was felt the comparison of vapour induction and maintenance compared with TIVA would reflect evolving practice in University Hospital of Wales and may have increased the observed differences between the groups. Possible differences in the depth of anaesthesia and the degree of cardiovascular depression between the techniques could be addressed by using the Bispectral index or auditory evoked response monitoring; this is the focus of ongoing research.

To conclude, our study suggests that when patients are turned into the prone position the cardiac index is reduced due to a reduction in venous return and ventricular compliance, with a secondary rise in SVRI maintaining the mean arterial blood pressure. Evidence from previous studies suggests that an inhalational anaesthetic technique has little effect [5] if the patient is turned to a flat prone position, the changes being related to the degree of compression caused by the supports and the convexity of the frame [5, 6]. The Montreal pattern mattress used in Cardiff seems to cause less compression than props or the knee–chest position and as such may be a better choice of support.

We have demonstrated for the first time that TIVA anaesthesia using propofol causes a significantly greater reduction in cardiac index than inhalation anaesthesia with isoflurane, an effect which merits further investigation in patients with cardiovascular disease.

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