Taj et al. BMC Anesthesiology (2025) 25:242
https://doi.org/10.1186/s12871-025-03116-9

BMC Anesthesiology

RESEARCH

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Effect of prone position on cerebral hemodynamics and noninvasive intracranial pressure assessed using transcranial Doppler in patients undergoing spine surgeries: a prospective observational study

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Abstract

Background The prone position, frequently used in spine surgeries for optimal surgical access, induces physiological changes in cardiovascular and respiratory parameters. Increased intraabdominal and intrathoracic pressures lead to elevated central venous pressure (CVP). Along with raised intrathoracic pressure, positive end-expiratory pressure (PEEP) results in elevated CVP, impeding venous blood flow from the brain and potentially affecting intracranial pressure (ICP).[1] Transcranial Doppler (TCD) ultrasound is a non-invasive method commonly used to measure cerebral hemodynamic parameters, including peak systolic velocity (PSV/ $MCAv_{peak}$), mean flow velocity (MFV/$MCAv_{mean}$), pulsatility index (PI) and resistivity index (RI), which are associated with cerebral vascular resistance, intracranial pressure, and cerebral perfusion pressure (CPP).

Method Thirty-three patients undergoing spine surgery were assessed. The vital and TCD parameters PSV/$MCAv_{peak}$, MFV/$MCAv_{mean}$, PI, and RI were noted in the supine position. (T_a). General anaesthesia was administered, and TCD measurements were repeated after induction. (T_s). Patients were then positioned prone, and TCD measurements were repeated at intervals T_{p0} - immediately after the prone position, T_{p15} -15 min of the prone position, T_{p30} -30 min, T_{p45} -45 min and T_{p60} – 60 min. Vital parameters were noted at the above-mentioned time points. Non-invasive ICP (nICP) was calculated.

Results There was a statistically significant decrease in the heart rate (HR) compared to the supine position at T_{p45} and T_{p45} as compared to T_{p0}. There was a statistically significant decrease in systolic blood pressure (SBP) as compared to T_a at T_{p0} ($p < 0.001$), T_{p15} ($p < 0.001$), T_{p30} ($p = 0.003$), T_{p45} ($p = 0.001$), and T_{p60} ($p = 0.018$). The study found no statistically significant changes in cerebral hemodynamic parameters (PSV/$MCAv_{peak}$, MFV/$MCAv_{mean}$, PI and RI) and nICP at various time points.

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Conclusion Our findings suggest that the prone position does not cause significant changes in cerebral hemodynamics and nICP.

Trial registration CTRI/2023/06/053677 dated 08/06/2023.

Keywords Transcranial Doppler, Prone position, Spine surgery, Non-invasive intracranial pressure, Pulsatility index

Background

The prone position is the most commonly used position in spine surgery, offering surgeons optimal access to the operative site [1]. However, this position may result in various physiological alterations in cardiovascular, respiratory, and cerebral dynamics. The increase in intraabdominal and intrathoracic pressures during prone positioning leads to a significant rise in venous pressure, thus altering blood flow dynamics and potentially affecting circulation and organ perfusion [2, 3]. The raised intrathoracic pressure due to prone positioning causes a reduction in venous return, leading to increased central venous pressure (CVP). Elevated CVP can impede blood flow from the brain, leading to venous congestion and escalated resistance to blood flow in the cerebral vasculature, which may raise intracranial pressure (ICP) [4, 5]. In addition, the application of PEEP may also result in an increase in ICP and a consequent decrease in CPP [2, 6, 7].

Transcranial Doppler ultrasound (TCD), "the stethoscope of the brain," is commonly utilised to monitor cerebral blood flow velocity (CBFV) in major cerebral vessels [8]. The parameters measured by TCD include mean flow velocity (MFV/$MCAv_{mean}$), peak systolic velocity (PSV/$MCAv_{peak}$), diastolic velocity, pulsatility index (PI), and resistivity index (RI). Among these, PI tends to be more often measured for its association with ICP than RI. This preference likely arises as PI relies on MFV/$MCAv_{mean}$, which considers the flow velocity throughout the cardiac cycle, whereas RI is primarily influenced by systolic velocity [8–13]. A statistically significant correlation was observed between PI and ICP in a prospective observational study by Kaloria N et al. involving 40 patients undergoing endoscopic third ventriculostomy or ventriculoperitoneal shunt surgery [14]. Various studies have been performed to determine the relationship between PI and ICP and to develop a mathematical model for nICP calculation utilising PI [10, 15].

There is a paucity of literature on the effect of the prone position on cerebral hemodynamics. Our study aims to evaluate changes in cerebral hemodynamics (flow velocity, PI, RI, nICP) in supine and prone position in thoracolumbar surgeries. We hypothesised that the prone position alters the cerebral hemodynamics. The primary objective of our study was to evaluate the effect of change in position from supine to prone on PI. The secondary objectives were to assess the impact of change in position from supine to prone on PSV/$MCAv_{peak}$, MFV/$MCAv_{mean}$, RI and nICP. We also evaluated the effects of airway pressure changes on cerebral hemodynamics after changing the position from supine to prone.

Methods

Study design

This article adheres to the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines. This single-centre, prospective observational study was conducted after the approval by the Institutional Ethics Committee (letter No. IEC/AIIMS/BTI/301; Dec 2022) and after registration with the Clinical Trial Registry of India (CTRI/2023/06/053677 dated 08/06/2023). Informed consent was obtained from all participants before inclusion in the study. Patients aged between 18 and 65 years of age, belonging to American Society of Anaesthesiologists (ASA) I and II, undergoing thoracolumbar and lumbosacral spine surgeries in the prone position in the department of Anaesthesiology in a tertiary level institute between July 2023 to March 2024 were eligible for inclusion in the study. The exclusion criteria were hemoglobin < 10 gm/dL, previous history of cranial surgery, pre-existing cerebrovascular disease, polytrauma patients, pregnancy, intramedullary spine tumours and spine trauma with dural injury.

Study sample size

The sample size was calculated for repeated measures of ANOVA within factors, taking correlation among repeated measures as 0.5, number of measurements as 6, non-sphericity correction as 0.4, eta squared was taken to detect a medium effect size = 0.06 in PI at 80% power, the sample size was found to be 33. After including 10% dropouts, the sample size was 37. The choice of the effect size was based on the theoretical expectation that should the PI in brains with preserved autoregulation vary with position, the variation should be at best a small to moderate difference from baseline and not by a large extent. This moderate change has not been documented in terms of PI with position change, and hence we chose to use the generic effect size terms (eta squared), and the cut-off of 0.06 was based on Cohen's recommendations [16]. The sample size was calculated using Gpower [17].

Methodology

Patients were enrolled based on the aforementioned inclusion and exclusion criteria. All selected subjects were assessed preoperatively, and the study was explained in their vernacular language. Detailed patient information sheets (PIS) were provided to the patients or to their next of kin, and written informed consent was obtained before enrolment.

On the day of the surgery, patients were shifted to the operation theatre (OT) and placed in the supine position on the transport trolley. Monitors were attached from the anesthesia workstation, and non-invasive blood pressure (NIBP), electrocardiography (ECG), and pulse oximetry (SpO_2) monitoring were initiated. A wide-bore intravenous (IV) cannula was inserted in one of the upper limb veins. Bispectral Index (BIS) monitoring sensors were placed on the forehead after cleaning with an alcohol-based solution. A dedicated study investigator documented the baseline heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and SpO_2.

TCD was performed using a 1.6 MHz probe (Delica, Model: EMS-9 PB). The middle cerebral artery (MCA) was insonated through the transtemporal window, and the best Doppler signal was achieved by fine-tuning the position of the probe, scale, gain, and angle of insonation to achieve the best signal-to-noise ratio. The point of insonation was marked with a pen, and the depth of insonation was noted for subsequent readings. Cerebral hemodynamics, including MFV/$MCAv_{mean}$, PSV/$MCAv_{peak}$, PI and RI, were assessed. All measurements were taken by a single operator on one side only, either the right or the left. Three readings were taken at one-minute intervals, and average values were noted. The first readings were designated as T awake (T_a).

Patients were premedicated with intravenous midazolam 0.01 mg/kg and intravenous glycopyrrolate 10 μg/kg. General anaesthesia was induced with intravenous fentanyl (1.5-2.5mcg/kg), titrated doses of propofol (1.5–2.5 mg/kg), and vecuronium 0.1 mg/kg. Intubation was performed using an appropriately sized cuffed endotracheal tube (7.5 mm and 8 mm for females and males, respectively). After securing the airway, general anaesthesia was maintained with desflurane in a mixture of oxygen, nitrous oxide (50:50), and vecuronium. The depth of anaesthesia was titrated to maintain a BIS value of 40–60. Patients were ventilated using volume control mode with a tidal volume of 6–8 ml/kg, PEEP of 5 cm of H_2O, an inspiratory: expiratory (I: E) ratio of 1:2, and the respiratory rate was adjusted to maintain an end-tidal carbon dioxide concentration ($EtCO_2$) of 30–36 mm Hg. Normothermia was maintained throughout the surgery.

After induction of anaesthesia, patients' HR, SBP, DBP, SpO_2, $EtCO_2$, P peak, BIS, and MAC were noted, and assessment of MFV/$MCAv_{mean}$, PSV/$MCAv_{peak}$, PI, and RI was repeated using TCD through the same point of insonation and depth of insonation, which was used for the initial assessment and was designated as T supine (T_s). Patients were simultaneously preloaded with deficit fluid (body weight X 1.5 ml X hours fasted) to maintain normovolemia before turning the patient to the prone position. Additionally, intravenous fentanyl 0.5 mcg/kg and 1 mcg vecuronium were repeated before positioning the patient prone. 100% Oxygen was administered before disconnecting the circuit. Mean arterial pressure (MAP) was maintained at more than 60 mm Hg. Intravenous Mephentermine 6 mg boluses were used if the MAP decreased to more than 20% from baseline values.

The patient was carefully turned to the prone position on the OT table on two bolsters, one for the shoulder and one for the iliac crests. It was ensured that the abdomen was free. A head-positioning device was used to ensure a head and neck alignment in the neutral position that would avoid neck compression, provide adequate venous drainage, and reduce kinking in the endotracheal tube. The axilla and knees were cushioned appropriately, and eye padding was used to reduce the effects of pressure on the eyes. The arms were positioned at $<90°$ angles at the shoulder and axilla. The position of the table was adjusted so that the heart was above the level of the tragus to improve cerebral venous drainage. This position was maintained throughout the surgery.

The aforementioned measurements were repeated at specific times: immediately after putting the patient in the prone position (T_{p0}), after 15 min of prone position (T_{p15}), after 30 min of prone position (T_{p30}), after 45 min of prone position (T_{p45}), and after 60 min of prone position (T_{p60}). The surgery was not interrupted to perform these measurements. Vital parameters during the surgery were recorded throughout the procedure. The duration of the surgery, intraoperative blood loss, fluid intake, urine output, and intraoperative events were noted at the procedure's completion. Non-invasive ICP was calculated using a PI value obtained through TCD using the formula $ICP = 4.47 \times PI + 12.68$ [15] (Fig. 1).

Statistical analysis

The statistical analysis was performed using the statistical software The Jamovi project (2024) (Jamovi version 2.5). Data collected was presented as tables and graphs. Data was summarised as mean and standard deviation for continuous variables and frequency and percentage for categorical variables. A comparison of continuous variables measured at different time points was performed using Repeated Measures ANOVA. A p-value of <0.05 was considered statistically significant. Linear mixed effects modelling was used to study the effect of gender (fixed effect) on PI, RI and ICP at different positions (random effect) accounting for repeated measures.

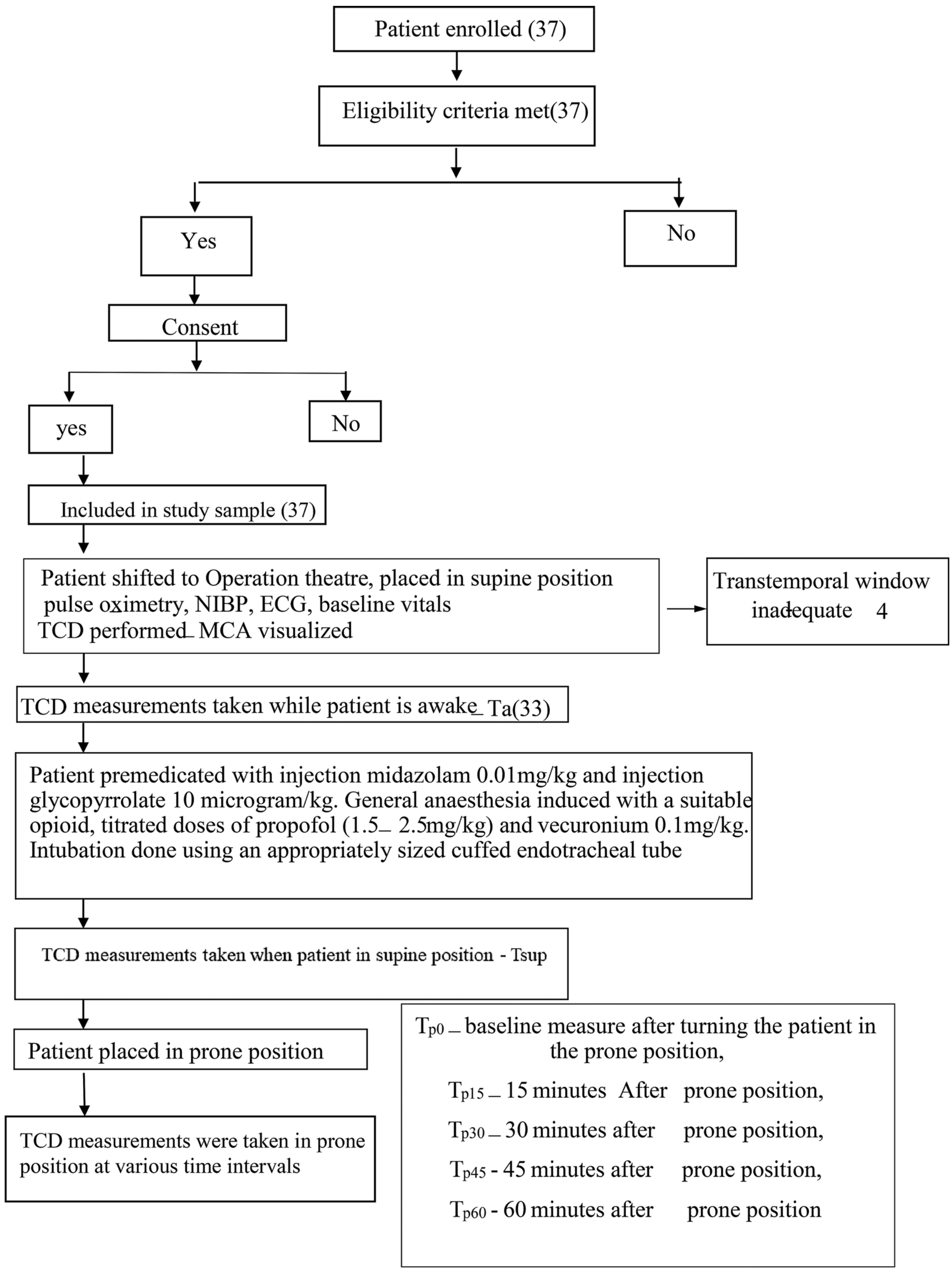

Fig. 1 STROBE flow chart

Results

In this study, 37 participants were enrolled after obtaining informed written consent. Four participants were excluded from the study due to inadequate transtemporal window visualisation (Fig. 1). The demographic parameters and indications for surgery have been mentioned in Table 1.

Among the cerebral hemodynamic parameters and nICP, there were no significant differences in PSV/MCAv$_{peak}$ ($p = 0.423$), MFV/MCAv$_{mean}$ ($p = 0.353$), PI ($p = 0.719$), RI ($p = 0.843$) and nICP ($p = 0.719$) across the various time intervals and positions studied (Table 2; Fig. 2).

The HR was recorded at different positions and time intervals among the hemodynamic parameters. There

Table 1 Demographic parameters

Descriptive	Mean ± SD
Age (years)	40.5 ± 11.4
Male: Female	24:9
Height (m)	1.71 ± 0.07
BMI (kg/m^2)	28.3 ± 1.84
Indication for surgery	
PIVD	18
Spondylolisthesis	6
Lumbar canal stenosis	9
Preoperative parameters	
Haemoglobin (g/dL)	12.8 ± 1.30
Haematocrit (%)	37.9 ± 4.04
Intraoperative parameters	
Blood loss (ml)	349 ± 105
Urine Output (ml)	311 ± 103

BMI: Body mass index; PIVD: Prolapsed intervertebral disc

were significant differences in HR across the various time intervals and positions studied ($p < 0.001$) (Table 2; Fig. 3A). A post hoc test analysis was done, and HR at T_a was compared with HR at T_s, T_{p0}, T_{p15}, T_{p30}, T_{p45}, and T_{p60}. There was a statistically significant decrease in HR with a mean difference of 7 ± 2 beats/min at T_{p45}. There was no statistically significant difference when HR at Ts was compared with HR at T_{p0}, T_{p15}, T_{p30}, T_{p45}, and T_{p60}. When HR at T_{p0} was compared with HR at T_{p15}, T_{p30}, T_{p45}, and T_{p60}., HR at T_{p45} showed a statistically significant decrease in HR with a mean difference of 6 ± 1 beats/min (Supplemental digital content 1; table showing post hoc analysis of HR at different time points). There was a significant difference in SBP across the various time intervals and positions studied. ($p < 0.001$) (Table 2; Fig. 3B). During the post hoc test analysis, there was no statistically significant decrease in SBP at $T'_{s,}$ while at T_{p0}, T_{p15}, T_{p30}, T_{p45} and $T_{p60,}$ a statistically significant decrease in SBP was observed compared to T_a with a maximum mean difference at T_{p45} (12.606 ± 2.70). (Supplemental digital content 2; table showing posthoc analysis of SBP at different time points)

There was a significant difference in DBP across the various time intervals and positions studied. ($p < 0.001$) (Table 2; Fig. 3C) On post hoc test analysis, no statistically significant difference was observed at $T_{a,}$ while at T_{p0}, T_{p15}, T_{p30}, T_{p45} and T_{p60}, a statistically significant decrease in DBP was observed with a maximum mean difference at T_{p0} (10.6364 ± 1.78) (Supplemental digital content 3; table showing post hoc analysis of DBP at different time points).

There were no significant differences in $EtCO_2$ across the various time intervals and positions studied. ($p = 0.672$) (Table 2). The peak airway pressure ($P_{peak)}$ was recorded, and there were no significant differences in P_{peak} across the various time intervals and positions studied. ($p = 0.5498$) (Table 2) There were no significant differences in minimum alveolar concentration (MAC) values across the various time intervals and positions studied. ($p = 0.3535$) (Table 2). There were no significant differences in Bispectral index (BIS) scores at BIS- $T_{p0,}$ BIS- T_{p15}, BIS- T_{p30}, BIS- T_{p45}, BIS- T_{p60} compared to BIS-T_s. ($p = 0.9646$) (Table 2) There was no statistically significant change in the PI, RI or ICP with respect to gender (evidenced by the CIs crossing the line of no difference at 0 in the supplemental digital content 4).

Discussion

We conducted a prospective observational study on the effect of the prone position on cerebral hemodynamics as assessed using TCD in patients undergoing thoracolumbar spine surgeries. The primary objective of our study was to evaluate the effect of change in position from supine to prone on PI. The secondary objectives of

Table 2 Hemodynamic, ventilatory, anesthetic and transcranial doppler parameters at different time points

Parameters	T_a	T_s	T_{p0}	T_{p15}	T_{p30}	T_{p45}	T_{p60}	*P* Value
HR (bpm)	81.5 ± 16.3	80 ± 17.0	80.8 ± 16.2	75.3 ± 12.1	75 ± 10.7	74 ± 11.8*	74.7 ± 9.39	< 0.001
SBP (mm Hg)	128 ± 12.4	121 ± 15.7	117 ± 13.1*	118 ± 12.6*	118 ± 12.4*	116 ± 12.4*	120 ± 10.3*	< 0.001
DBP (mm Hg)	80.4 ± 9.12	69.8 ± 9.94	69.8 ± 9.94*	70 ± 9.54*	71.2 ± 7.42*	70.1 ± 8.08*	72.1 ± 7.92*	< 0.001
$EtCO_2$ (mm Hg)		33.4 ± 3.39	33.4 ± 3.59	33.2 ± 3.03	33.3 ± 2.95	33.1 ± 2.95	33.3 ± 2.93	0.672
P peak (cm H_2O)		16.90 ± 0.26	17.51 ± 0.27	17.51 ± 0.27	17.51 ± 0.27	17.51 ± 0.27	17.51 ± 0.27	0.5498
MAC		0.93 ± 0.0120	0.96 ± 0.0086	0.94 ± 0.0088	0.95 ± 0.0088	0.93 ± 0.0086	0.94 ± 0.0088	0.3535
BIS		45.93 ± 0.53	46.06 ± 0.59	45.81 ± 0.56	46.33 ± 0.50	45.96 ± 0.59	46.45 ± 0.56	0.9646
PSV/ $MCAv_{peak}$ (cm/s)	74.7 ± 18.5	71.5 ± 18.9	69.8 ± 16.5	70.5 ± 14.5	70.6 ± 15.9	70.2 ± 15.3	69.8 ± 13.1	0.423
MFV/$MCAv_{mean}$ (cm/s)	46.5 ± 13.5	43.4 ± 13.7	42.2 ± 12.1	43.1 ± 10.9	43.2 ± 9.99	42.9 ± 11.5	42.9 ± 9.46	0.353
PI	0.948 ± 0.225	1.02 ± 0.309	1.02 ± 0.286	1.01 ± 0.271	0.964 ± 0.228	0.985 ± 0.296	0.988 ± 0.265	0.719
RI	0.576 ± 0.0835	0.595 ± 0.105	0.599 ± 0.0943	0.592 ± 0.0948	0.577 ± 0.0816	0.591 ± 0.102	0.588 ± 0.0968	0.843
nICP (mm Hg)	16.9 ± 1.01	17.3 ± 1.38	17.2 ± 1.28	17.2 ± 1.21	17 ± 1.02	17.1 ± 1.32	17.1 ± 1.18	0.719

T_a– awake and not anaesthetised, T_s– supine under general anaesthesia, T_{p0}– immediately after turning the patient in the prone position, T_{p15}– 15 min after the prone position, T_{p30}– 30 min after the prone position, T_{p45} – 45 min after the prone position, T_{p60} – 60 min after the prone position. *- statistically significant; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; $ETCO_2$, end-tidal CO_2; P peak, Peak pressure; MAC, Minimum alveolar concentration; BIS, Bispectral index; PSV/$MCAv_{peak}$, Peak systolic velocity; MFV/$MCAv_{mean}$, Mean flow velocity; PI, Pulsatility index; RI, Resistivity Index; nICP, noninvasive Intracranial pressure

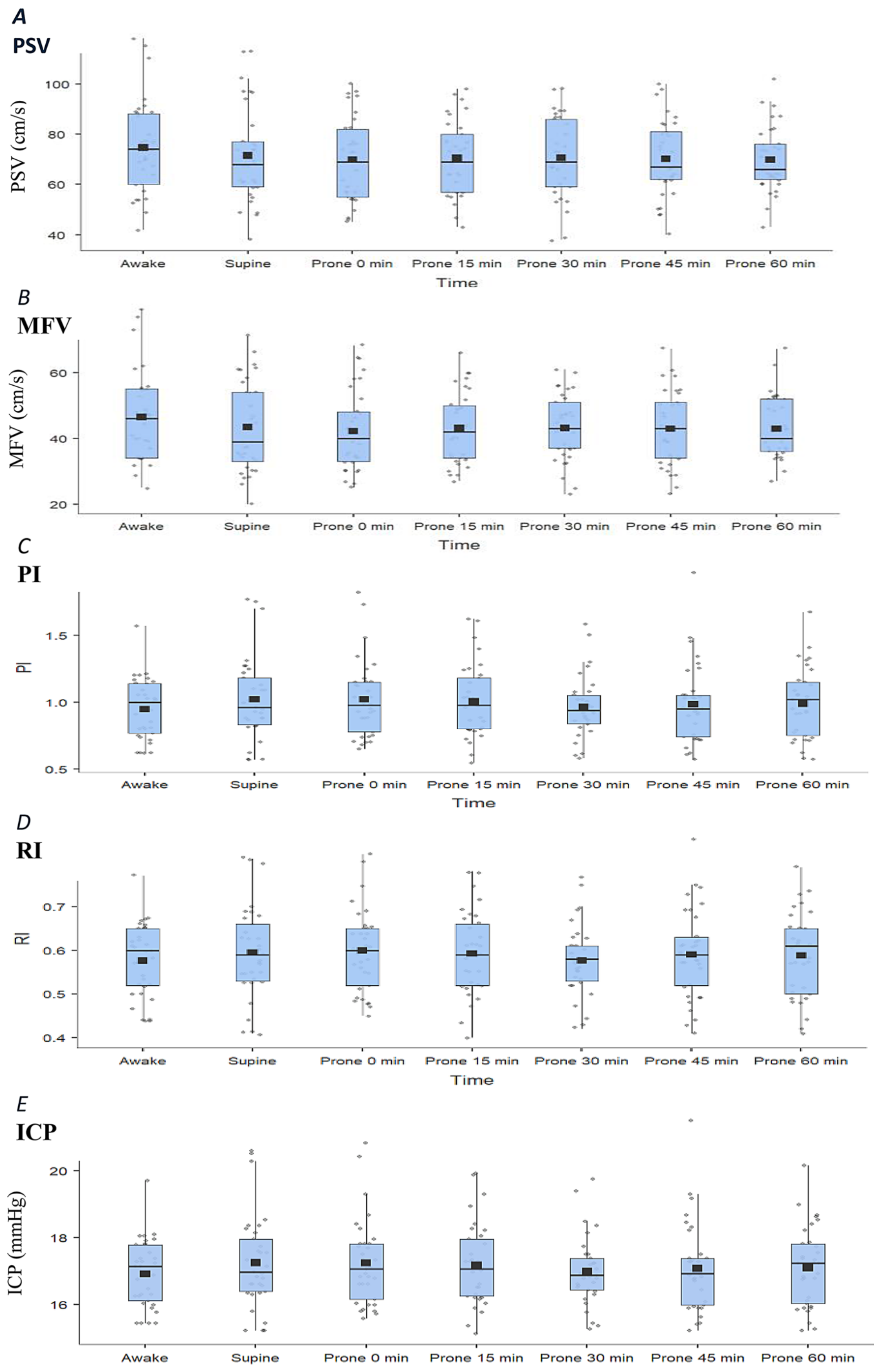

Fig. 2 Peak systolic velocity (PSV), Mean flow velocity (MFV), Pulsatility index (PI), Resistivity index (RI) and Noninvasive Intracranial pressure (nICP) at different time points. Boxplot of TCD parameters: **A**: PSV, Peak systolic velocity; **B**: MFV, Mean flow velocity; **C**: PI, pulsatility index; **D**: RI, resistivity index; **E**: nICP, non-invasive Intracranial pressure at various time points. (Black squares represent mean values, Grey dots are individual data points)

our study were to assess the change in CBFV, RI and the effect of the prone position on nICP.

Thirty-seven patients satisfied the inclusion and exclusion criteria. Among these, four patients were dropouts due to an inadequate temporal window. Thus, the data of 33 participants was analysed. The mean age of the participants was 40.5 ± 11.4 years. There were 72.7% males and 27.3% females in our study.

There was no statistically significant difference in parameters of cerebral hemodynamics, including PSV/MCAv$_{peak}$ ($p = 0.423$), MFV/MCAv$_{mean}$ ($p = 0.353$), PI ($p = 0.719$) and RI ($p = 0.843$). Bombardieri AM et al. also

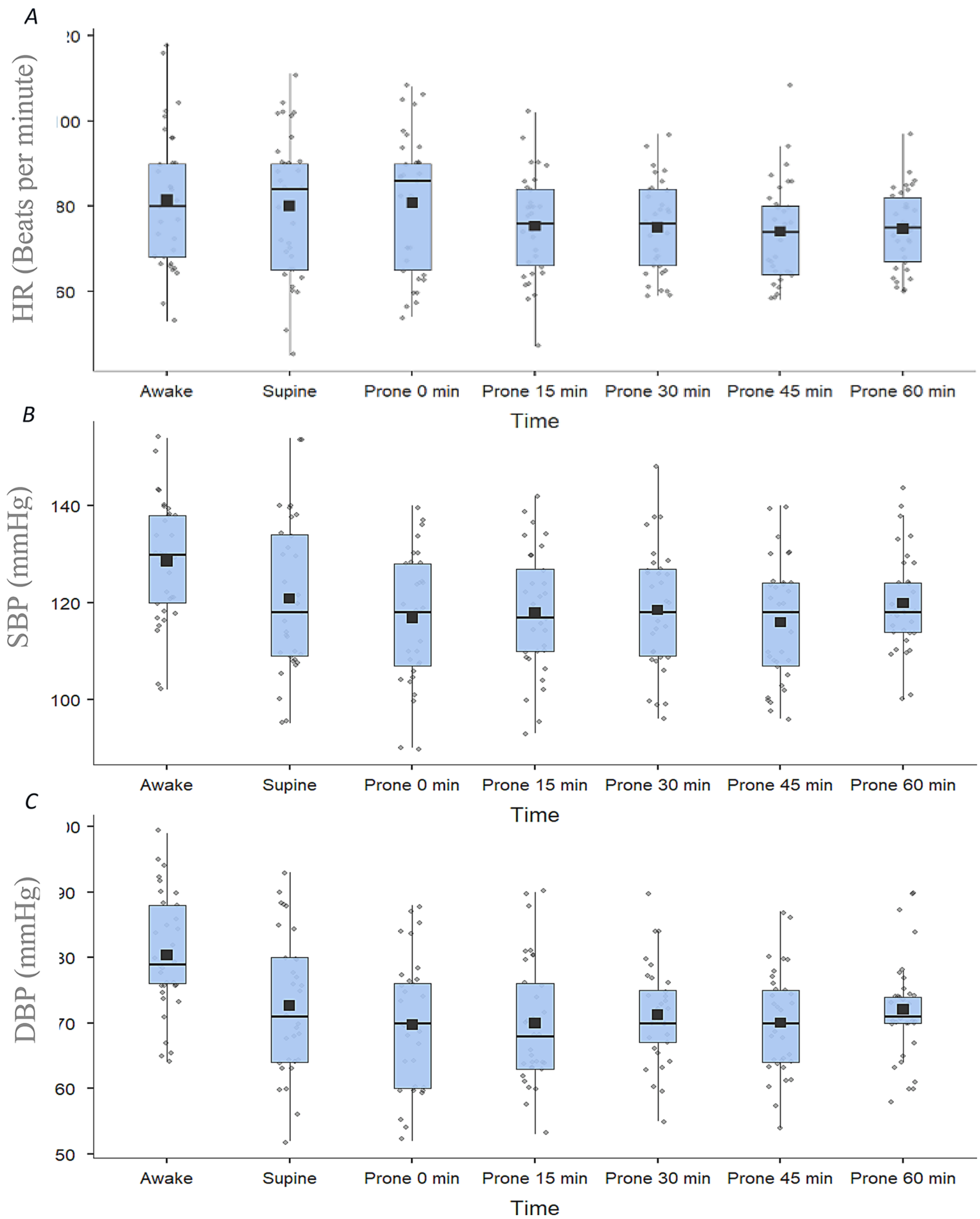

Fig. 3 Heart rate (HR), Systolic blood pressure (SBP) and Diastolic blood pressure (DBP) at different time points. Boxplot of hemodynamic parameters: **A**: HR, Heart rate; **B**: SBP, Systolic blood pressure; **C**: DBP, Diastolic blood pressure at various time points. (Black squares represent mean values, Grey dots are individual data points)

found no statistically significant difference in cerebral blood flow $CBFV_{syst}$ (the maximal CBFV during the systolic phase of a cardiac cycle) and $CBFV_{mean}$ (the time-averaged value of the maximal velocity envelope over one cardiac cycle) when the patient's position changed from supine to prone position and at different time intervals after prone position. There was no statistically significant difference in PI immediately after the prone position, 15 min after the prone position, 30 min after the prone position and 45 min after the prone position. However, there was a statistically significant increase in PI observed 60 min after the prone position ($p < 0.05$) in the study by Bombardieri AM et al. They attributed this increase in PI to the older mean age (mean age = 58 ± 13 years) of patients in their study. They stated that the cerebral arteries may become more rigid with age, leading to higher pulsatile flow and PI [18]. Our study had a relatively younger population (mean age = 40 ± 10 years), which might explain the absence of a statistically significant change in PI at various time points in our patients.

We found no statistically significant difference in nICP between supine and prone positions at various time points. We also observed that the addition of PEEP (5 cm H_2O) did not alter PI and nICP in our study. On the contrary, a study by Robba C et al. estimated the change in ICP when the patient was in the prone position by TCD analysis of PI (ICP_{PI} = 4.47·PI + 12.68 mm Hg) and found a significant increase in the mean values of ICP_{PI} after a change from supine position to prone position in patients undergoing spine surgeries. They also found a further increase in ICP_{PI} after applying PEEP (8 cm H_2O) in the prone position [6]. This increase in ICP_{PI} could be due to the patients' older mean age (mean age = 54 ± 16.4 yrs) in their study. Secondly, they applied a higher PEEP in their patients (PEEP of 8 cmH_2O) than in our study, wherein a physiological PEEP of 5 cm of H_2O was used [6]. This higher PEEP could have led to increased ICP through an increase in intrathoracic pressure and CVP, resulting in reduced cerebral venous return. Secondly, increased PEEP can increase spinal pressure, reduce cerebrospinal outflow, and increase ICP. Thirdly, a higher PEEP can cause a reduction in MAP, leading to cerebral vasodilation and increased ICP. We found no statistically significant difference in nICP, which could be attributed to the relatively younger mean age in our study (40 ± 10 yrs) and consistent application of physiological PEEP (5 cm H_2O) throughout the procedure. The changes in ICP primarily depend on cerebral autoregulation, defined as the ability of the cerebral vasculature to maintain constant cerebral blood flow despite the change in systemic blood pressure [19, 20].

In our study, the hemodynamic parameters (HR, SBP, DBP) during awake, supine under anaesthesia and in the prone position at various time intervals showed statistically significant differences with a p-value of HR ($p < 0.001$), SBP ($p < 0.001$) and DBP ($p < 0.001$). On Post Hoc analysis, the statistically significant decrease in the HR was observed at T_{p45} compared to the baseline, i.e. T_a (mean difference = 7 ± 2 bpm) and at T_{p45} compared to T_{p0} (mean difference = 6 ± 1 bpm.); the decrease in HR was around 10%, hence not clinically significant. The statistically significant decrease in SBP as compared to baseline, i.e. T_a was observed at T_{p0} ($p < 0.001$). However, this difference in SBP was not clinically significant (mean difference < 20% from baseline). A statistically significant decrease in DBP as compared to baseline at T_a was seen in all the time points (< 0.001) after prone positioning and had no major impact clinically, as the difference was < 20% from the baseline. Bombardieri AM et al. found a statistically significant decrease in MAP after 60 min of the prone position (70 ± 9 mm Hg) as compared to baseline i: e before the prone position (80 ± 18 mmHg) ($p < 0.05$).[18,] but it was < 20% from baseline and hence was not clinically significant [18]. Another study by Robba C et al. demonstrated no statistically significant difference in SBP when a patient's position was changed from supine to prone [6]. This lack of clinically significant change in haemodynamic parameters in our study, as in the study by Bombardieri AM et al., can be explained by the administration of an adequate amount of fluids before turning the patient prone. It was then followed by administration of an adequate amount of maintenance fluids.

We used the volume control mode of ventilation in all the patients. A PEEP of 5 cm H_2O was applied. There was no significant change in peak airway pressure (P_{peak}) between the supine position (T_s) and the prone position ($T_{p0,}$ T_{p15}, T_{p30}, T_{p45} and T_{p60}) (p = 0.549). This was achieved by adequately placing bolsters and ensuring the abdomen was free. A straight head and neck alignment was maintained to avoid neck compression and kinking of the endotracheal tube. There was no significant change in $EtCO_2$ between the supine position (T_s) and the prone position (p = 0.672). There was no significant change in MAC between the supine position (T_s) and prone position (p = 0.3535). There was no significant change in BIS scores between the supine position (T_s) and prone position.

In our study, we maintained adequate oxygenation (PaO_2) and ventilation (tidal volume 6-8 ml/kg) ($EtCO_2$) by using VCV mode of ventilation. There was no significant change in $EtCO_2$ and P_{peak} when the position changed from supine to prone. The haemodynamic parameters, i.e. HR and MAP, were maintained within 20% of baseline using adequate fluid resuscitation and the use of anaesthetic agents titrated to BIS. Depth of anesthesia was comparable in both supine and prone positions after the patient was anesthetised. Normothermia was maintained throughout the surgical procedure. These factors might have helped to maintain cerebral hemodynamics in our patients. These findings also suggest that in patients undergoing anesthesia for surgeries in the prone position, the hemodynamic parameters, cerebral hemodynamics, and nICP can be maintained if adequate fluid balance, oxygenation and ventilation (target $EtCO_2$ of 30–36 mm Hg) are maintained.

The limitation of our study was the small sample size, which could have affected its generalisability. Secondly, we did not follow the patients throughout the surgery, so we could not evaluate the hemodynamic changes that can possibly happen with longer surgical times and their effect on cerebral hemodynamic parameters (PSV/$MCAv_{peak}$, MFV/$MCAv_{mean}$, PI, and RI). Thirdly, we did not include ASA 3, 4, or 5 patients where a change in position could have significant changes. Fourthly, we used TCD and measured CBFV, which is only a surrogate marker of cerebral blood flow.

Conclusion

Our findings suggest that the prone position does not cause significant changes in cerebral hemodynamics, provided adequate fluid resuscitation before turning the patient to the prone position, and adequate oxygenation (PaO2) and ventilation (PaCO2) are maintained.

Abbreviations

CVP	Central venous pressure
PEEP	Positive end-expiratory pressure
ICP	Intracranial pressure
TCD	Transcranial Doppler
MCA	Middle cerebral artery
PSV/$MCAv_{peak}$	Peak systolic velocity in the Middle cerebral artery
MFV/$MCAv_{mean}$	Mean flow velocity in Middle cerebral artery
PI	pulsatility index
RI	Resistivity index
CPP	Cerebral perfusion pressure
nICP	Non-invasive intracranial pressure
HR	Heart rate
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
MAP	Mean arterial pressure
BIS	Bispectral Index
$EtCO_2$	End-tidal carbon dioxide concentration
CO	Cardiac output
IVC	Inferior vena cava
PaO_2	Partial pressure of oxygen
$PaCO_2$	Partial pressure of carbon dioxide

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-025-03116-9.

Supplementary Material 1: Supplemental digital content 1: Post-hoc analysis of Heart rate (HR) at different time points. Supplemental digital content 2: Post-Hoc Analysis of Systolic blood pressure (SBP) at different time points. Supplemental digital content 3: Post-Hoc Analysis of Diastolic blood pressure (DBP) at different time points. Supplemental digital content 4: Coefficient plot of linear mixed-effects models (repeated measures) assessing the impact of gender (Male vs Female) on PI, RI and ICP; numbers represent coefficient values; all Bonferroni adjusted p values were not significant.

Acknowledgements
Nil.

Author contributions
Y.T., N.S. and A.D. wrote the main manuscript text. V.G. did the statistical analysis. V.G., S.P., A.D. and V.A. prepared the figures and tables. All authors reviewed the manuscript.

Funding
Nil.

Data availability
The datasets used and/or analysed in the current study are available from the corresponding author on reasonable request.

Declarations

Human ethics and consent to participate
This study was approved by the Institutional Ethics Committee of AIIMS Bathinda (letter No. IEC/AIIMS/BTI/301; Dec 2022) and commenced after registration with the Clinical Trial Registry of India (CTRI/2023/06/053677 dated 08/06/2023). (Letter attached). All study related procedures were performed in accordance with relevant guidelines and regulations. Written informed consent was taken from all patients willing to participate in the study.

Consent for publication
Not applicable.

Details of previous presentation of the work
Presented at 12th EURONEURO - Brussels November 5–7, 2023 as a poster titled "Effect of prone position on cerebral hemodynamics assessed using transcranial doppler in patients undergoing thoracolumbar spine surgeries: a preliminary analysis.". Presented at SNACC 2024 Annual Meeting (Virtual presentation) held from September 12–14 in Denver, Colorado, as a paper titled "Impact of Prone Position on Intracranial Pressure in patients undergoing Thoracolumbar Spine Surgeries as Assessed by Transcranial Doppler."

Competing interests
The authors declare no competing interests.

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Received: 2 October 2024 / Accepted: 6 May 2025
Published online: 15 May 2025

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