

Effect of Prone Position on Respiratory Dynamics During Posterior Spine Surgery

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Abstract

Background: The prone position which is used in the posterior approach to the spine has a propensity to compromise respiratory dynamics and increase the risk of poor lung ventilation.

Aim: This study aimed to determine the changes that occur in the respiratory dynamics and arterial blood gases of patients undergoing posterior spine surgery in the prone position from supine position.

Study Design: This was a prospective study of 27 consecutive adult patients scheduled to undergo posterior spine surgery at the Obafemi Awolowo University Teaching Hospitals Complex, Ile-Ife

Materials and Methods: All consenting consecutive patients presenting for posterior spine surgery under general anaesthesia over a six month period were recruited. The peak inspiratory pressure, peak plateau pressure, dynamic lung compliance and arterial blood gases were measured at 10 minutes after induction of anaesthesia in the supine position. These parameters were also measured again, 10 minutes after placing the patient in the prone position. Samples were also taken for arterial blood gases at the same times.

Results: The peak inspiratory and peak plateau pressures in the supine position (Mean (95%CI); 16.0(15.1; 16.9) and 7.3(6.7; 7.9) respectively in cmH₂O) were significantly lower than the values when patients were in the prone position (Mean (95%CI); 19.2(17.9; 20.5) and 9.2 (8.6; 9.8), respectively in cmH₂O), whereas the dynamic lung compliance reduced significantly when patients were turned from supine to prone position.(Mean (9% CI, supine: 39.1 (35.8;42.5) , prone: 29.8 (27.2;32.5) in cm-H₂O),p<0.5.

Conclusion: The study showed that an increase in the peak inspiratory and peak plateau pressures as well as a reduction in the dynamic lung compliance occurred when patients were positioned prone with the aid of chest and pelvic bolsters to keep the abdomen free. These changes were however not significant enough to cause a compromise in ventilation.

Keywords: Prone Position; Spine Surgery; Respiratory Physiology

Introduction

Patient positioning is a very important aspect of any surgery. Anaesthesia care and attention to the physical and physiologic consequences of positioning can help prevent serious adverse events and complications [1]. The prone position is commonly utilized for approaches for the posterior cranial fossa, suboccipital region and posterior spine surgeries. However in this position, providing adequate ventilation while avoiding abdominal restriction, maintaining haemodynamic stability and keeping proper access to intravenous lines and tracheal tube is technically challenging [2].

Results from studies on changes in the respiratory mechanics in the prone position are conflicting. A study by Palmon, *et al.* [3], indicated that the change in the position from supine to prone position may have adverse effects on the peak airway pressure and that the changes in respiratory dynamics in the prone position was due to the difference in the degree to which various types of frames used, prevent abdominal compression. On the other hand, Pelosi and co-workers [4] reported that in anaesthetized normal subjects who have had neuromuscular blockade, the prone position if correctly performed, improves lung volumes and oxygenation and does not alter respiratory mechanics. In their study, upper chest rolls and pelvic supports were employed to allow for free movements of the abdomen. The prone position with these manoeuvres was then reported to have no effect on respiratory dynamics.

The use of the prone position in the management of acute respiratory distress has however been extensively investigated. In a meta-analysis of the effect of prone position on the patients' with acute respiratory distress syndrome by Gattinoni and colleagues [5], the prone position was found to improve oxygenation. Many of these studies did not however comment on the effect of the prone position on ventilation and respiratory dynamics. Also, results of studies carried out on awake, spontaneously breathing patients may not necessarily be extrapolated to anaesthetized and ventilated patients. Despite the wide use of the prone position for the posterior approach to spine surgeries, the modification in respiratory mechanics and gas exchange during anaesthesia in this position has not been extensively investigated.

This prospective study was therefore designed to study the changes that occur in respiratory dynamics of anaesthetized patients when they are placed in prone position for posterior spine surgeries.

Patients and Methods

Setting

This was a prospective single centre study carried out at the Obafemi Awolowo University Teaching Hospitals Complex, Ile-Ife, Nigeria.

Study Design

This prospective study evaluated the effect of prone position on respiratory dynamics of 27 patients undergoing posterior spine surgeries. All consecutive patients between age 18 years and above, presenting at the health facility during the study period who were in the American Society of Anesthesiologists (ASA) physical status class I or II, scheduled to undergo spine surgery via the posterior approach in the prone position under general anaesthesia, and who consented were included in the study. Patients with restrictive or obstructive airway diseases, chronic smokers and patients with spinal deformities significant enough to impair respiratory dynamics such as severe scoliosis, kyphosis and ankylosing spondylitis were excluded from the study. Ethical approval was obtained from the institutions review board and informed consent was obtained from all patients prior to participating in this study

Study procedure

Patients were evaluated preoperatively, optimized for surgery and their weight, height and level of neurological deficit documented. All anaesthetic procedures were done following our standard of care. Thirty minutes before arrival in the operating room, all patients were premedicated with midazolam 2mg, glycopyrrolate 0.2mg and ranitidine 50mg intravenously. Once in the operating room, patients were positioned supine on a tilting operating table (SCHMITZ, MADE IN GERMANY) and connected to a multiparameter monitor (DASH 400 multiparameter monitor, GE Medical Systems Information Technology, USA) for continuous monitoring of electrocardiography, heart rate, oxygen saturation, non-invasive blood pressure, end tidal carbon dioxide and body temperature by the nasopharyngeal

route. Perioperative antibiotic was given according to the surgeons' preference and the patient was pre-oxygenated for 5 minutes. Anaesthesia was then induced with intravenous fentanyl 1mcg/kg and propofol 2mg/kg. Pancuronium 0.1mg/kg was administered intravenously for muscle relaxation and to facilitate endotracheal intubation. Bag mask ventilation was continued for three minutes after the administration of the depolarizing neuromuscular blocking agent. Intubation was then performed using a wire reinforced nonkinkable endotracheal tube of appropriate size. Anaesthesia was maintained with oxygen in air at 6 litres per minute and 1.0% volume of isoflurane using the anaesthesia delivering system (Datex- Ohmeda Aspire 7100 anaesthetic machine, Sweden). Mechanical ventilation was set to maintain normocarbida using the end tidal carbon dioxide measurement. A radial artery cannula was inserted in all patients for invasive blood pressure monitoring and arterial blood gas sampling.

The values for the peak inspiratory pressure (PIP), peak plateau pressure (PPLAT) and airway resistance (RAW) were recorded 10 minutes after endotracheal intubation to allow for vital signs and changes in the pulmonary compliance and resistance to return to baseline. The dynamic lung compliance (DLC) was derived from tidal volume, peak inspiratory pressure and positive end expiratory pressure. All values were taken three times, each 2 minutes apart, and the average time of the three measurements was used for further analysis. At the same time, samples were taken for arterial blood gas.

The patient was transferred from the operating table unto a trolley. Pelvic and chest bolsters were then placed on the operating table. The patient was then carefully turned prone on these bolsters which kept the abdomen off the table high enough to allow a handshake beneath the patient without any difficulty. The head was placed on a horse shoe shaped head rest in the neutral position. The endotracheal tube was checked again to ensure its correct position and a main stream capnostat was attached to the endotracheal tube for end tidal carbon dioxide measurement. The patient was allowed to stabilize for 10 minutes in the prone position before the respiratory dynamics and arterial blood gases measurements were performed using the same method described above.

Patients were closely monitored in the perioperative and early post-operative period as the departmental protocol.

Data analysis

Data obtained were analysed using Stata 14.0. Descriptive statistics were used to summarize patients' demographics, baseline characteristics, respiratory dynamics and arterial blood gases of the patients' in the supine and the prone position. Changes in respiratory dynamics and arterial blood gases between the supine and prone position were analysed using paired t-tests for normally distributed differences and Wilcoxon signed rank test for non-normally distributed differences. Pearson correlation coefficient was used to assess the association between the patients' body mass index and the change in respiratory dynamics.

Results

A total of 27 patients were included in this study. Patients' demographics, etiology and region affected are summarized in Table I. Age ranged from 23 to 65 years with a majority of male patients. Trauma was the leading cause of spinal surgery occurring in almost half of the patients who were mostly young adults below the age of 40 (9/13). In contrast, 7 of 8 patients with degenerative spine disease were above the age of 40 years (Table 1).

The arterial partial pressure of oxygen (PaO₂) and bicarbonate (Table 2) showed no significant changes between the supine and prone positions. In the prone position, there was a significant increase in the peak inspiratory and the peak plateau pressure when compared to the values obtained in the supine position ($p < 0.001$). The dynamic lung compliance on the other hand decreased when patients were changed from the supine to the prone position. ($p < 0.001$). There was no significant correlation between the patients' body mass index and the change in the peak inspiratory pressure ($r = 0.04$, $p = 0.82$), peak plateau pressure ($r = 0.22$, $p = 0.25$) and dynamic lung compliance ($r = 0.00$, $p = 0.98$). level of neurological deficit showed no relationship to the change in respiratory dynamics from supine to prone position ($p = 0.57$).

Table 1: Demographic characteristics of study subjects

Subject Characteristics	N=27
Age (years)	
Mean (SD)	44.3 (16.5)
Body Mass Index (kg/m²)	
Mean (SD)	26.8 (4.9)
Gender, n (%)	
Male	23 (85)
Female	4 (15)
Aetiology, n (%)	
Trauma	13 (48)
Degenerative	8 (30)
Tumor	5 (19)
Infection	1 (4)
Level of Spine Injury, n (%)	
Cervical	12 (44)
Thoracic	4 (15)
Lumbar	11 (41)

Table 2: Arterial blood gases and respiratory dynamics in supine and prone positions (N=27 patients)

	Supine Mean (95% CI)	Prone Mean (95% CI)	Change supine to prone Mean (95% CI)	from pValue
Arterial blood gases				
PaO ₂ (mmHg)	91.7(89.5;93.9)	91.8(89.6;94.1)	0 (0;0)*	0.938 [†]
HCO ₃ (mEq/l)	22.2(21.3;23.1)	22.3(21.7;23.0)	0.1 (-0.3;0.6)	0.537 [‡]
PaCO ₂ (mmHg)	37.7(37.2;38.1)	38.3(37.7;38.9)	0 (0;1)*	<0.001 [†]
Respiratory dynamics(cmH₂O)				
Peak Inspiratory pressure	16.0(15.1;16.9)	19.2(17.9;20.5)	3.2 (2.1;4.3)	<0.001 [‡]
Peak plateau pressure	7.3(6.7;7.9)	9.2 (8.6;9.8)	1.9 (1.4;2.4)	<0.001 [‡]
Dynamic lung compliance	39.1 (35.8;42.5)	29.8 (27.2;32.5)	-9.3 (-12.3;-6.3)	<0.001 [‡]

CI=Confidence interval

*Median (Q1;Q3) presented due non-normality of the difference

[†]P-value from Wilcoxon signed rank test

[‡] P-value from paired t-test

Discussion

In this study of 27 consecutive patients who underwent spine surgery in prone position, changes in respiratory dynamics between the supine and prone position were found. However, the changes were not enough to compromise ventilation and oxygenation. An increase in the peak inspiratory pressures and peak plateau pressures and a decrease in the dynamic lung compliance were observed when the values in the supine position were compared to that in the prone position.

Injury to the cervical and upper thoracic spine is known to cause varying degrees of weakness of the muscles of respiration i.e. the diaphragm, the intercostal muscles, accessory inspiratory muscles and the abdominal muscles, thereby causing a reduction in lung volumes [6] The weakness in these muscles of respiration initially causes an increase in lung compliance. However, within a month of the injury, the chest wall and lung compliance reduces because of the increase in rib cage stiffness. This stiffness has been attributed to ankylosis of the joints due to chronic instability of the patients to inhale deeply and due to

an increase in intercostal spasticity. This is especially true in patients who have cervical spine injuries. However, Scanlon, *et al.* [7] attributed the decrease in the lung compliance after spinal surgery to lung volume loss rather than to intrinsic changes to the chest wall mechanics. In this study, patients were intubated; tidal volumes were fixed and positive end expiratory pressures were applied. Therefore, lung volumes were effectively controlled and atelectatic alveoli recruited. Thus there was no significant correlation between respiratory dynamics and the level of neurological deficit.

The mean peak inspiratory pressure when patients were positioned prone from supine position increased by 3.1 cmH₂O (20%). Despite the significant increase in peak inspiratory pressures in this study, the values still remained within normal limits. It was also noted that on average the peak plateau pressure increased by 1.9 cmH₂O (26%) when patients were positioned prone on the chest and pelvic bolsters with the abdomen free. A concomitant rise in both peak inspiratory and peak plateau pressure was noted in this study. It has earlier been noted that a marked difference in the peak inspiratory and peak plateau pressure reflects an obstruction of the airway by secretion or kinking of the tube [8]. The ideal peak plateau pressure should be <30 cmH₂O to prevent volutrauma i.e lung injury secondary to over distension of the alveoli [9]. In the healthy lungs, there is a direct relationship between the peak inspiratory pressure and the peak plateau pressure. If there is however a rise in the values of the peak inspiratory pressure without a commensurate rise in the peak plateau pressure; a kinked endotracheal tube, the presence of secretions or bronchospasm should be suspected [10]. These changes were not found in this study.

In the prone position, the dynamic lung compliance of the patients that were studied reduced significantly when compared to the values obtained when the same patients were in supine position. The dynamic lung compliance is reduced in prone position due to the pressure of the ventral chest wall on the chest and pelvic bolsters. In this study, the abdomen was left free so that the pressure from the abdomen does not impede the diaphragmatic excursion. The significant reduction in the dynamic lung compliance and the increase in the peak inspiratory and the peak plateau pressures found in this study may be explained by the restriction in the chest expansion when the patient is in the prone position. Pelosi and co-workers [11] had earlier noted in a study that owing to the pressure on the abdomen, when patients are positioned prone, the internal organs push the dia-

phragm cephalad. In addition, the weight of the trunk decreases the diameter of the chest. A clinical review by Kirkpatrick and colleagues [12] also buttressed this and suggested that a means to achieve adequate ventilation in the prone position is having the abdomen hanging free. When this variable is eliminated, these researchers are of the opinion that the change in respiratory dynamics in the prone position would depend wholly on the degree of movement in the ventral chest wall in the more mobile part when compared to the dorsal portion because of the 'bucket handle' configuration of the ribs in the chest wall [13]. The chest bolsters therefore would restrict the movement in the ventral chest wall and consequently results in a reduction in the dynamic lung compliance. This may explain why a significant reduction in the dynamic lung compliance was found in this study.

Palmon and co-workers [3] studied the extent of change observed in the respiratory dynamics in anaesthetized patients in the prone position and noted that in all of the patients, irrespective of what kind of support was used, there was increase in the peak inspiratory and peak plateau pressure as well as a reduction in the dynamic lung compliance. They indicated that the change in the respiratory dynamics in the prone position was due to the difference in the degree to which the various types of frame used, prevented abdominal compression. Fletcher [14], in a study measured the intraabdominal pressures in the supine and prone position. It was noted that when the abdomen was left free to move with respiration, there was small but significant reduction in the abdominal pressures when the patients were positioned prone. Therefore, as long as the abdomen is left free, it will not impede lung compliance in the prone position.

It was interesting to note from this study that the changes in the respiratory dynamics, when patients were turned prone from supine position, was not significantly affected by the patients' body mass index. The body mass index is known to be an important determinant of respiratory function during anaesthesia [15]. This may manifest as reduction in the lung volumes with increased atelectasis, derangements in the lung and chest wall compliance as well as increased resistance [16]. One will therefore expect that the obese patient will have an increase in the peak inspiratory and peak plateau pressure as well as a more marked reduction in the dynamic lung compliance. Tanskanen and coworkers [17] in a study of 56 patients, despite noting a significant reduction in the lung compliance when patients were positioned prone did not find any correlation between the body mass index and lung compliance. These researchers therefore

concluded that the prone position still remained safe for the patients, irrespective of the body mass index and habitus. However, in this study, it was ensured that the abdomen was free from the operating table to allow for free abdominal wall movement. Therefore, no added resistance to the respiratory mechanics was observed in obese patients.

Positioning patients prone has been shown to improve arterial oxygen levels [18]. This manoeuvre is being used in the management of patients with Acute Respiratory Distress Syndrome to improve oxygenation. In this study of 27 patients without acute lung injuries or chronic obstructive airway diseases, no significant change in arterial oxygenation of the patients, when they were turned prone from supine position was seen, despite a decrease in dynamic lung compliance. This is in keeping with studies by Numa and co-workers [19]. In their study, the arterial oxygen of 30 patients under anaesthesia with neuromuscular blockade in the supine and prone positions was taken. These patients had earlier been divided into three groups of 10 patients each. Ten patients had moderate restrictive lung disease, ten patients had obstructive lung diseases and the last group of ten had healthy patients without significant lung disease. Although, individual patients demonstrated an increase in arterial oxygenation, a significant increase was only seen in patients with obstructive lung diseases.

Lung ventilation and perfusion play a major role in the oxygenation of blood. Studies have been carried out on the pulmonary blood flow when patients were positioned prone from supine position. Nyren and colleagues [20] performed lung perfusion scintigraphy on healthy volunteers in supine and prone positions. They found out that the distribution of blood flow to the lung was more uniform in the prone position than in the supine position. They posited that the intrinsic vascular anatomy and gravity contributed to the more uniform perfusion of the lung in the dorsal and ventral portions of the lung in the prone position. In the prone position, there is a more homogenous regional inflation of the lungs than in the supine position [21]. A combination of the uniform distribution of blood as well as the homogenous ventilation of the lungs in the prone position when compared with the supine position may account for the improvement in arterial oxygenation seen in patients. This thus explains why intermittent prone positioning is useful as a modality for improving oxygenation in patients with Acute Respiratory Distress Syndrome.

Conclusion

In conclusion, this study has focused on the effect of prone position on respiratory dynamics and arterial blood gases. The peak inspiratory and peak plateau pressure increases when patients were positioned prone from the supine position. There was no significant change in the partial pressure of arterial oxygen when patients with healthy lungs, initially ventilated in the supine position, were ventilated in the prone position. It was observed from this study that there were changes in the respiratory dynamics when patients were positioned prone on chest and pelvic bolsters from supine position. However, with proper prone positioning, these changes were not significant enough to cause ventilatory compromise.

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