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Posterior spinal surgery and prone position. Is kneeling better for pulmonary mechanics?

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SUMMARY

Background: For posterior spine surgery prone position is required. The prone position compresses the abdomen and restricts the chest wall movement leading to alterations of the pulmonar mechanics. To solve this problem the use of a free hanging abdomen and kneeling position is proposed, features that are provided by the Andrews surgical chest-knee supportable. **Objective:** To study the changes found on ventilatory variables in patients in three positions: supine (basal), flat prone and chest – knee supported position to prove the efficacy of kneeling position in maintaining proper pulmonar mechanics. **Methods:** We recorded pulmonar compliance, peak airway pressure and airway resistance as ventilatory variables in seventy-six non obese and pulmonar condition free patients during the three positions comparing them using the Student´s t test for statistical analysis. **Results:** With the change from supine to prone position an important increase of peak airway pressure and airway resistance as well as a decrease of pulmonar compliance was noted, situation that was importantly reverted to near basal values with the kneeling position. **Conclusions:** The kneeling position with free hanging abdomen offers better ventilatory environment than the prone position in non-obese and pulmonary disease free patients.

Key words: General anesthesia, posterior spine surgery, atelectasis, prone position.

RESUMEN

Antecedentes: *Para la cirugía posterior de columna se requiere de la posición prona. Esta posición comprime el abdomen, desplazando el diafragma hacia la cavidad torácica, restringiendo el movimiento fisiológico pulmonar y promoviendo atelectasias pulmonares. Para resolver este problema se propone el uso de mesas quirúrgicas con espacio adecuado para dejar libre el abdomen, además de la posibilidad de adoptar la posición de hincado para disminuir aún más la presión abdominal sobre el tórax. La mesa de Andrews con apoyos genupectorales ofrece estas posibilidades.* ***Objetivo:*** *Comparar los cambios en las variables ventilatorias en tres posiciones: supina (basal), prono con abdomen libre y genupectoral con abdomen libre.* ***Material y métodos:*** *Tomamos la adaptabilidad pulmonar, la presión pico y la resistencia de vías aéreas en las tres posiciones como variables ventilatorias en 76 pacientes sanos no obesos, contrastándolas mediante la prueba t de Student.* ***Resultados:*** *De la posición supina a la prona plana hubo incremento notable tanto de la presión como de la resistencia de vías aéreas y disminución también importante de la adaptabilidad pulmonar, cambios revertidos notoriamente con la posición genupectoral.* ***Conclusiones:*** *La posición genupectoral con abdomen libre ofrece un mejor ambiente para la mecánica pulmonar que la prona.*

Palabras clave: *Anestesia general, cirugía posterior de columna, atelectasia pulmonar, posición prona.*

INTRODUCTION

Although advances both in surgical techniques and in anesthetic monitoring and drugs have made surgery extraordinarily safe; even minimized risks still remain latent. In the case of spine surgery patients, the following are usually listed as major risks: pulmonary thromboembolism, increased intraocular pressure, excessive bleeding, medullar damage, etc. However, the effects of both general anesthesia and prone position, especially in extended surgery, are rarely considered risks for pulmonary physiology.

It has been known for decades that general anesthesia is associated with oxygenation abnormalities. Bendixen et al. showed 40 years ago that the decrease of both pulmonary compliance and arterial oxygen pressure returns to normality after providing high positive pressures, which causes suspicion of atelectases[1]. This was subsequently evidenced by the use of computerized tomography, which showed that 90% of anesthetized patients have pulmonary atelectases, especially in dependent lung regions[2]. Two mechanisms have been suggested as causes of this abnormality in patients without previous pulmonary pathology: decreased production of a surfactant factor and external compression. The surfactant factor's function is to lower alveolar surface tension by stabilizing the alveoli, thus preventing them from collapsing. This function is minimized by mechanical ventilation and presence of anesthetics; however, the external compression mechanism seems to be the most important cause, and the abdomen and the diaphragm have been pointed out as the main causes. In a conscious individual, the diaphragm separates the thoracic and abdominal cavities, which allows the former to achieve different pressures in the abdomen and the thorax, during its action as a leading muscle for inspiration. After the anesthetic induction and when muscular relaxation takes place, the diaphragm moves noticeably in the cephalic direction, and it therefore looses its action as a means for differentiating pressures between the two cavities. This phenomenon was brightly studied in the early 70's by Froese and Bryan through serial cineradiography of the upper region of the abdomen. They found two movement patterns of the diaphragm with the individual in supine position: in the anesthetized patient with spontaneous ventilation, the strength of the diaphragm overcomes the pressure of the abdominal contents, and the former has more movement in the lower region of the thorax or posterior diaphragm. Conversely, in the individual with mechanical ventilation and with muscular paralysis, the diaphragm will mostly move in the upper region or non-dependent region. The pulmonary residual functional capacity is thus reduced in the anesthetized patient with muscular paralysis, due to the loss of the diaphragm's typical action and due to its dependency on abdominal pressure[3].

Prone position is required for performing posterior spinal surgery. The change from supine to prone position, regardless of the effects of general anesthesia on the diaphragm, increases per se the compression of the abdomen, which causes the diaphragm to move more in the cephalic direction, and it is an added factor increasing pulmonary external pressures, which in turn conditions the decrease of pulmonary compliance and residual functional capacity, which favours the occurrence pulmonary atelectases[4]. With the purpose of reducing the effect of abdominal pressure on the ventilatory mechanics in the patient underwent spine surgery in the prone position, several surgical tables with different positioning options have been designed. One of those surgical tables is Andrews' knee-chest table (Orthopedic System Inc, Union City C.A. USA), which is designed to decrease abdominal pressure as a result of the option to choose the free gravitational positioning of the abdomen. Unlike other surgical tables, the Jackson's table also offers the kneeling position, which must theoretically further decrease abdominal pressure and its effect on pulmonary mechanics. As a part of the usual steps followed in order to position the patient, the latter must be first in supine-prone position, subsequently he must be placed in kneeling position.

In this observational study, we test the hypothesis that abdominal pressure and thus thoracic pressure decrease in kneeling position as compared to supine-prone position, which directly influences on the commonly used variables involved in pulmonary mechanics monitoring.

MATERIAL AND METHODS

In total, 76 patients who underwent thoracic and lumbar spinal surgery, of both sexes, without a history of significant pulmonary disease and with I-II ASA classification were included in the study, they would be placed in knee-chest position by using Andrews' surgical table.

Some demographic variables were included such as age, weight, size, and gender,.

Patients were monitored through pulse-oximetry, neuromuscular transmission quantified by means of the train of four test, non-invasive blood pressure, continuous electrocardiography, capnography, peak airway pressure (PAP) (cm H_2O), airway resistance (AR) (cmH_2O/L/s), and pulmonary compliance (PC) (mL/cmH_2O).

In all cases, total endovenous anesthesia was offered. Anesthetic induction was performed with midazolam (0.05 to 0.1 mg/kg), fentanyl 100 mg, lidocaine 1 mg/kg, and propofol 2 to 2.5 mg/kg. Muscular relaxation was provided through vecuronium 100 μg/kg. Maintenance of anesthesia was carried out with the continuous infusion of propofol and fentanyl. When 100% muscular relaxation was achieved, orotracheal intubation was performed through direct laryngoscopy. Once proper placement of the endotracheal tube is achieved by using both capnography and auscultation of the 2 hemothoraxes, patients were placed under mechanical ventilation by programming a 10 mL/kg tidal volume, a respiratory rate of 10 breaths/minute, and a 1:2 inspiration:expiration ratio. Cardiopulmonary stabilization was allowed for a 5-minute period and subsequently 3 readings/minute was taken of each of the PAP, AR and PC values, making an average and considering them as baseline readings with the patient in supine position. While patient was in supine-prone and knee-chest position, readings were then taken of variables with the same method (Figure 1).

Results of mean variable for each position were contrasted with each other, by applying the Student t statistical test.

RESULTS

In total, 76 patients, 37 male and 39 female –who underwent posterior spinal surgery– participated in this study without showing significant differences related to gender. The age of the study population was 50.32 ± 3.5 years. The average body mass index (25.20 ± 3.54 kg/m^2) places patients within a body weight range between normal weight and lightly overweight.

According to our results, we noted that the position change from supine to prone position causes a significant increase in PAP and AR values, as well as an important decrease in PC. Once a kneeling position was adopted, we found that PAP and AR, despite being statistically different from basal values, go back to values near the previous ones, whereas AR goes back to practically the same levels as the basal values, without a statistically significant difference between both values (Tables I and II).

DISCUSSION

Pulmonary atelectasis is the most frequently referred cause of hypoxemia observed early during general anesthesia. Since 1964 Nunn already had proved that during anesthesia and spontaneous ventilation, gas exchange was altered by increased pulmonary short-circuit and a inadequate ventilation – perfusion relation, and he suggested an increase in the alveolar oxygen pressure up to 200 torr as a solution[5]. Bendixen et al. postulated that spontaneous ventilation without periodic sighs could lead to progressive atelectasis, increased short-circuit and decreased pulmonary compliance, these changes can be reverted by the lung hyperinflation[1]. It was in the 80's when the presence of previously assumed atelectasis was indisputably proved by means of computerized tomography; it was also found that it forms in both lungs and dependent regions, moreover it appears during the first 5 minutes of anesthesia with muscular relaxation[6]. Since then, atelectasis secondary to general anesthesia was widely studied and the following data have been obtained: it is found in 90% of patients receiving general anesthesia[2], it is developed both with intravenous and inhalation anesthesia, regardless of

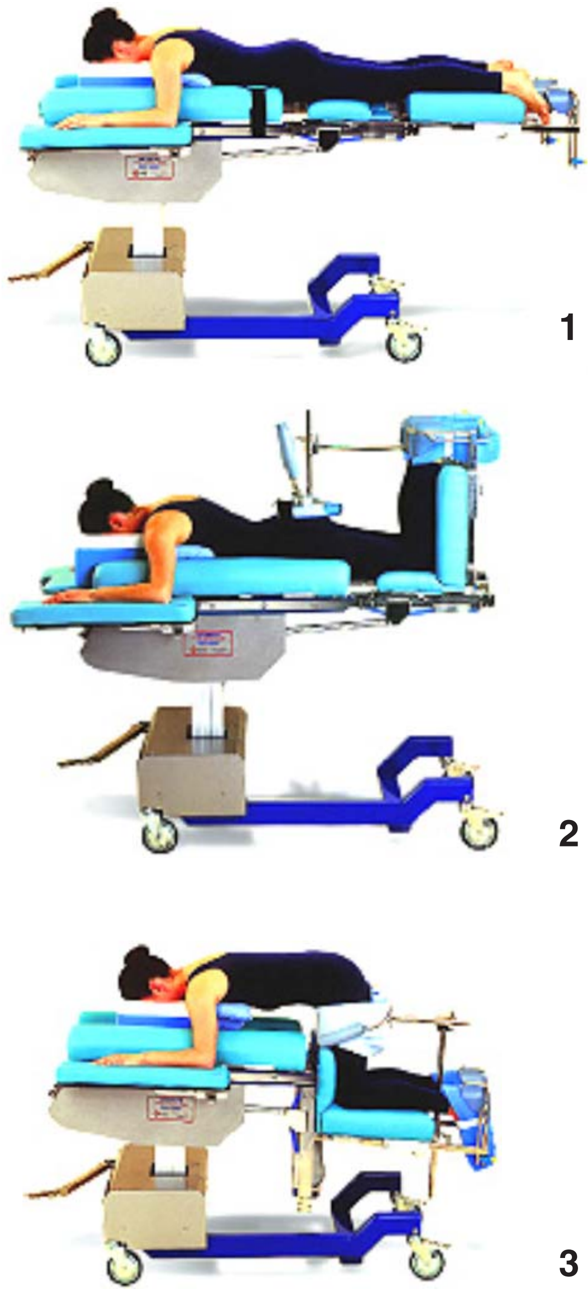

Figure 1. Positioning in the surgical table of Andrews in three times. The studied variables were obtained in the marked postion 1 (prone position) and 3 (kneeling).

Table I. PAP, AR and PC in the three positions.

Position	Supine	Prone	Kneeling
PAP (cm H_2O)	13.88 ± 5.22	17.99 ± 6.55*	15.79 ± 5.42* ¶
AR (cmH_2O/L/s)	10.53 ± 4.52	12.59 ± 6.23*	10.91 ± 5.31 ¶#
PC (mL/cm H_2O)	58.82 ± 15.87	38.96 ± 9.54*	51.13 ± 12.87* ¶

PAP = Peak airway pressure, AR = Airway resistance, PC = Pulmonary compliance, * $p < 0.01$ between the position and the supine, ¶ $p < 0.01$ between the kneeling position and prone, # Without statistical difference with supine position.

Table II. Percentage changes by position in relation to basal values.

Position	Supine	Prone	Kneeling
PAP (cmH_2O)	–	+29%*	+13%* ¶
AR (cmH_2O/L/s)	–	+19%*	+3% ¶#
PC (mL/cmH_2O)	–	-44%*	-14%* ¶

PAP = Peak airway pressure, AR = Airway resistance, PC = Pulmonary compliance, * $p < 0.01$ between the position and the supine, ¶ $p < 0.01$ between the kneeling position and prone, # Without statistical difference with supine position.

if breathing is spontaneous or mechanical with or without applying a muscle relaxant[7]. In the anesthetized patient in supine position, most of atelectases appear near the diaphragm and more rarely towards the apex[8]. Disappearance of atelectases by applying positive pressure at the end of expiration indicates that they are secondary to the compression of lung tissue, which in turn indicates the loss of diaphragm tone –it allows for a higher abdominal pressure to be easily transmitted to the thoracic cavity– as the cause[6]. This is a transient pulmonary dysfunction and most atelectases are resolved around 24 hours after surgery. However, they are a very probable cause of mild to moderate hypoxemia during surgery[9]. By considering pulmonary complications, it is also known that persistent atelectasis may cause a predisposition to pneumonia, which has a high mortality rate[10].

It has been proved for years that prone position per se alters pulmonary dynamics by decreasing pulmonary compliance, which may demand the application of high airway pressures in order to maintain an adequate ventilation of the patient, which in turn it may significantly reduce venous return, decrease cardiac output and increase systemic venous pressure. This increase may be reflected in profuse intraoperative bleeding due to ingurgitation of epidural plexuses, and it may in turn compromise spinal cord irrigation[11].

Due to the above, it is convenient to take measures leading to minimize deleterious physiological changes typical of the surgical position, in search of one allowing the pulmonary mechanics closest to normal.

The studied variables provide an overview of the pulmonary status in relation with external pressures experienced as a result of changes in position. Two aspects are outstanding in our results: pulmonary compliance, which is substantially affected in the decubitus position with a noticeable decrease of approximately 50%, was evidently improved when the patient was placed in the kneeling position, showing a 30% recovery from basal values. The other outstanding aspect is the return to values very near to basal AR values, without a statistically significant difference.

In conclusion, according to our results in non-obese patients without a serious pulmonary pathology and in a non-compressed abdomen situation, the kneeling position preserves pulmonary constant variables measured better than prone position.

REFERENCES

1. Bendixen HH, Hedley-Whyte J, Chir B, Laver MB. Impaired oxygenation in surgical patients during general anesthesia with controlled ventilation. N Engl J Med 1963;269:991-6.
2. Lundquist H, Hedenstierna G, Strandberg A, Tokics L, Brismar B. CT-assessment of dependent lung densities in man during general anesthesia. Acta Radiol 1995;36:626-32.
3. Froese AB, Bryan AC. Effects of anesthesia and paralysis on diaphragmatic mechanics in man. Anesthesiology 1974;41: 242-55.
4. Krayer S, Rehder K, Vetterman J, Didier EP, Ritman EL. Position and motion of the human diaphragm during anesthesia-paralysis. Anesthesiology 1989;70:891-8.
5. Nunn JF. Factors influencing the arterial oxygen tension during halothane anaesthesia with spontaneous respiration. Br J Anaesth 1964;36:327-41.
6. Brismar B, Hendenstierna G, Lundquist H. Pulmonary densities during anesthesia with muscular relaxation-a proposal of atelectasis. Anesthesiology 1985;62:422-8.
7. Strandberg A, Tokics L, Brismar B, Lundquist H, Hedenstierna G. Atelectasis during anaesthesia and in the postoperative period. Acta Anaesthesiol Scand 1986;30:154-8.
8. Reber A, Engberg G, Sporre B. Volumetric analysis of aeration in the lungs during general anaesthesia. Br J Anaesth 1996;76:760-6.
9. Eichenberger AS, Proietti S, Wicky S. Morbid obesity and postoperative pulmonary atelectasis: an underestimated problem. Anesth Analg 2002;95:1788-92.
10. Pedersen T, Viby-Mogensen J, Ringsted C. Anaesthetic practice and postoperative pulmonary complications. Acta Anaesthesiol Scand 1992;36: 811-18.
11. Smith RH, Gramling ZW, Volpitto PP. Problems related to the prone position for surgical operations. Anesthesiology 1961;22:189-93.