MINERVA ANESTESIOL 2001;67:238-47

Pathophysiology of prone positioning in the healthy lung and in ALI/ARDS

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Prone position was initially introduced in healthy anesthetized and paralyzed subjects for surgical specific reasons. Then, it was used during acute respiratory failure to improve gas exchange. The interest on prone position during ALI/ARDS progressively increased, even if the mechanisms leading to a respiratory improvement are not yet completely understood. In normal subjects, during anesthesia and paralysis, prone position determines a more homogeneous distribution of the gravitational gradient of alveolar inflation, a ventilation distributed towards the non dependent lung regions and a reverse of the gravitational distribution of regional perfusion, even if factors other than gravity are involved. Moreover, prone position causes, both in healthy subject and in obese patients, an improvement in oxygenation and in functional residual capacity without affecting respiratory system, lung and chest wall compliance. In ALI/ARDS patients, prone position lead to a reverse of the alveolar inflation and ventilation distribution, due to the reverse of hydrostatic pressure overlying lung parenchyma, the reverse of heart weight, and the changes in chest wall shape and mechanical properties. Little data are available for the modifications in regional lung perfusion. The possible mechanisms involved in oxygenation improvement during prone position in ALI/ARDS patients are: 1) increased lung volumes; 2) redistribution of lung perfusion; 3) recruitment of dorsal spaces with more homogeneous ventilation and perfusion distribution. From a clinical point of view, prone position seems to be a very promising treatment for ALI/ARDS, even if its use is not yet a standard clinical practice. We have recently finished a randomized-controlled trial in order to investigate the clinical impact of this procedure. In the preliminary phase of the study performed in 35 Italian Intensive Care Units, we studied, from 1996 to 1998, 73 patients with a PaO_2/FiO_2 of 123±42 and a SAPS (Simplified Acute Physiology Score) of 38±11. After the first hour of prone positioning, the PaO_2/FiO_2 ratio of 76% of the patients had increased by more than 20 mmHg (responder) with a mean increase of 78±53 mmHg. The proportion of responders increased to 85% after 6 hours of prone positioning. The incidence of maneuver-related complications and severe and life-threatening complications was extremely rare. The overall mortality at ICU discharge was 51% and the ICU stay was similar in survivors and non survivors (17.8±11.6 *vs* 17.8±11.4 days).

Key words: **Prone position - Acute respiratory distress syndrome - Respiratory mechanics - Gas exchange - Computed tomography.**

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The prone position was initially applied in healthy anesthetized subjects to expose the dorsal surface of the body for specific surgical indications. Later on, postural changes were introduced into respiratory therapy to improve the drainage of secretions. In 1974, Bryan [1] suggested that anesthetized and paralyzed patients, in prone position, should exhibit a better expansion of the dorsal lung regions that in supine position, with a consequent improvement in oxygenation. After 10 years from the first description of acute respiratory distress syndrome (ARDS),[2] Phiel and Brown showed, in a retrospective study, that the prone position improved oxygenation in five patients with acute respiratory distress syndrome without any deleterious effects.[3] Their data were confirmed by Douglas *et al.*,[4] who described a significant increase in blood arterial oxygenation in most, but not all, patients studied. Starting from these firsts reports, the interest on prone position in ARDS progressively increased and prone position started to be considered as a simple and safe method to improve oxygenation in severely hypoxiemic patients. However, the physiologic mechanisms that lead to respiratory function improvement are not fully understood yet and randomized clinical studies investigating about the effects on morbidity and mortality are astonishingly lacking.

Here we will present and discuss:

1) the pathophysiological mechanisms leading to alveolar inflation, ventilation and perfusion distribution in supine and in prone position, both in normal subjects, during anesthesia and paralysis, and in patients with early acute lung injury (ALI) or acute respiratory distress syndrome (-ARDS), during mechanical ventilation;

2) lung volumes and respiratory mechanics changes occurring with prone position, either in normal subjects and in ALI/ARDS patients;

3) the mechanisms involved in oxygenation improvement during prone position in ALI/ARDS patients; 4) the possible clinical implication of the application of this maneuver in patients with ALI/ARDS, reporting some preliminary data from an Italian pilot study.

Normal subjects

Alveolar inflation in supine and prone position

In normal subjects, the distribution of alveolar inflation follows a gravitational gradient, with the non dependent alveoli, located near to the sternum, being more inflated than the non dependent ones, located near to the vertebra. This is due to the regional elastic mechanical characteristics of the lung: the alveolar dimensions depends to the transpulmonary pressure, *i.e.* the difference between the pressure inside (alveolar pressure) and outside (pleural pressure) the alveoli. Since the alveolar pressure is quite homogeneous among the different alveoli, while the pleural pressure is more negative in the non dependent lung regions compared to the dependent ones, the transpulmonary pressure is more negative in the ventral regions compared to the dorsal ones. The nature of transpulmonary pressure is unclear and it has been attributed to several factors such as: 1) lung weight; 2) cardiac mass; 3) cephalic displacement of the diaphragm; 4) regional shape and mechanical properties of the chest wall, and 5) regional shape and mechanical properties of the lungs. It is likely that the combination of more than one of these factors determines the pleural pressure gradient in supine position.

It is a common belief that in normal subjects the pressure exerted by the heart on the lower lobes has a significant influence on the aeration of the subjacent lung. Experimental evidences suggest that the heart is involved in the genesis of the vertical gradient of the transpulmonary pressure in physiological condition.[5]

Computed Tomography (CT) studies showed that after sedation and paralysis, the more dependent lung regions collapses, with the formation of atelectasis, depending on the kind of the drug, the ventilatory setting, the body mass, and the inspired oxygen concentration.[6] It is likely that the loss of the general muscolar tone, induced by paralysis, is the major cause of the development of atelectasis formation in the dependent part of the lung.[7] This effect is predominant on the rib cage muscles and on the diaphragm, leading to a reduction and changes in the shape of the overall chest volume.[8] Thus, changes in mechanical characteristics of the chest wall are important in atelectasis formation during sedation.

Moving into prone position partly reverse the distribution of the lung weight, *i.e.* more weight is superimposed on the alveoli in the new dependent regions, while less weight is superimposed on the alveoli in the new non dependent ones.[9] Moreover, the pleural pressure and consequently the transpulmonary pressure gradient become more homogeneous, so there is less difference between the non dependent and the dependent regions, since the regional mechanical properties and the lung and chest wall shape are altered. The resulting effect is a more homogeneous distribution of the alveolar inflation in prone position, compared to supine position.

Ventilation distribution in supine and prone position

Ventilation in the spontaneously breathing subject distributes predominantly in the dependent lung regions.[10] This is mainly attributable to the fact that the non dependent alveoli are usually more distended than the dependent ones. It follows that the upper alveoli are closer to the flat portion of their pressure volume curve compared to the lower ones. Since the amount of ventilation depends on the changes in transpulmonary pressure for a given applied transpulmonary pressure, ventilation is greater in the lower lung regions than in the upper ones.

During anesthesia and paralysis, and mechanical ventilation, the diaphragm behaves passively as a flaccid membrane in contact with the vertical gradient of the intra-abdominal pressure which is greater in the dependent part of the lung compared to the non dependent ones. Thus, the mechanical characteristics of the regional lung structures and the intra-abdominal gravitational gradient facilitate a distribution of ventilation more towards the non dependent part of the lung.

Unfortunately, non data regarding the distribution of ventilation in prone position are currently available. However, from the regional data about inflation, we know that in prone position alveolar inflation gradient is partially reversed, with a more homogeneous distribution of alveolar inflation. Moreover, the diaphragm passively moves more efficiently in the non dependent part of the lung. Thus, the ventilation probably is more distributed towards the non dependent part of the lung.

Perfusion distribution in supine and prone position

In supine normal subjects, regional perfusion increases progressively from non dependent to dependent regions.[11] The reason for this gravitational distribution has not been yet completely clarified. West proposed that the relationship between blood flow, pulmonary artery pressure, alveolar pressure, and venous pressure return could be modeled by Starling resistor.[12] This is a collapsible tube ("pulmonary vessels") within a closed chamber ("pulmonary alveoli") where the pressure may be modified. When the inlet pressure – the pressure in the pulmonary artery – is lower than that present in the chamber – the alveolar pressure – the blood flow stops. On the contrary, when the inlet pressure is greater than that in the chamber, the blood flow is determined by the difference between the pressure in pulmonary artery and the alveolar pressure, or between the alveolar pressure and the venous pressure. This "gravitational" hypothesis can explain why perfusion is greater in the more dependent lung regions. Other theories do not consider gravity to be the major determinant of perfusion distribution. If these theories were correct, so that gravitational forces would not have any relevant impact on the perfu-

TABLE I.—*Effects of prone position on respiratory mechanics, lung volumes and gas exchange in healthy subjects, obese and ALI/ARDS patients.*

	Normal subjects		Obese patients		ARDS patients	
	Supine	Prone	Supine	Prone	Supine	Prone
Respiratory system compliance (ml/cmH_2O)	80.9±16.6	75.9±13.2	55.4±9.6	59.6±12.1	38.4±13.7	35.9±10.7
Lung compliance (ml/cmH_2O)	150.0±52.3	142.5±36.7	91.4±55.2	109.6±52.4	52.4±23.3	53.9±23.6
Chest wall compliance (ml/cmH_2O)	203.2±72.4	184.3±77.1	199.5±58.7	160.5+±45.4	204.8±97.4	135.9*±52.5
Functional residual capacity (l)	1.9±0.6	2.9*±0.7	0.9±0.3	2.0*±0.9	1.2±0.4	1.3±0.6
PaO_2 (mm/Hg)	160±4	199*±16	130±31	181+±28	103±24	129*±33

sion distribution, the patient positioning would not have any effect on the perfusion distribution.

If the "gravitational theory" is accepted, a perfusion distribution gradient from non dependent to dependent lung regions should exist in prone position. However, few data confirm this hypothesis both in humans and in experimental settings, where a non gravitational gradient in perfusion distribution has been observed in prone position, *i.e.* more perfusion in the lung regions near to the vertebra.[13] Recently, Jones *et al.* studied the regional distribution of lung perfusion in supine and prone position in six healthy subjects, using the electron-beam CT.[14] They found a gravitational gradient of pulmonary perfusion both in supine and prone position, but, in the same way, they found a markedly heterogeneity of lung perfusion between anatomically adjacent lung regions, supporting the hypothesis that factors other than gravity may be at least as important in determining the distribution of lung perfusion in humans.

Lung volumes and respiratory mechanics in prone position

Lung volumes and respiratory mechanics in prone position have not been extensively investigated. Safar *et al.*,[15] in 1959, reported a reduction of 20 to 30% in the compliance of respiratory system with an increase in peak airway pressure when turning anaesthetized and paralyzed subjects to prone position. More recently, Lumb and Nunn [16] reported that prone position did not affect the respiratory function in 13 conscious healthy male volunteers, possibly increasing functional residual capacity (FRC). In 1995 we studied 17 normal subjects receiving general anesthesia for elective surgery requiring prone positioning.[17] We found that the prone position did not significantly affect the compliance of the total respiratory system, neither the lung and chest wall compliance. Respiratory resistance slightly increased in prone position, mainly due to a significant increase in chest wall resistance (about 40%). Both FRC and PaO_2 markedly increased from supine to prone position (53% and 24%, respectively), whereas PaCO2 was unchanged. Similar results have been obtained in obese patients [18] (Table I).

In summary, we found that in anesthetized and paralyzed patients prone position does not alter respiratory mechanics, while it improves arterial oxygenation and lung volumes. Nevertheless, no direct relationship was found between the increase in oxygenation and the increase in lung volumes, suggesting that other mechanisms than lung volumes alone may explain the improvement in oxygenation. A possible explanation may be the relative improvement in ventilation/perfusion ratio within the lungs. In fact, since the heart occupies the anterior mediastinum, there is less lung volume anteriorly than posteriorly and, as a consequence, there is more amount of the lung available for ventilation in the non dependent lung regions in prone position. The decreased lung collapse probably present in the dependent lung regions and the non perfect gravitational distribution of blood flow in prone position may explain the improvement in the relative ventilation/perfusion ratio and in arterial oxygenation. It is worth noting that, in contrast with the previous studies, we positioned our patients as described by Smith,[19] ensuring free abdominal movements with upper chest and pelvic supports. This kind of prone position could explain our different results, since the chest wall is less constricted compared to other proposed prone positions.

ALI/ARDS patients

Alveolar inflation in supine and prone position

It has been reported that the ARDS lung is characterized by an increased amount of extra-vascular water, mainly due to an increased pulmonary vasculature permeability.[20] Using conventional chest X-ray, the increase in extra-vascular lung water appears as diffuse pulmonary infiltrates. However, this concept has been challenged since CT scan shows the radiographic densities prevalently located in the dependent lung regions, while the non dependent ones appear, at least to visual inspection, quite normal [21] [22] (Fig. 1). The radiographic densities may account for up to 70-80% of the lung field, depending on the severity of respiratory failure, and the size of the ventilable lung is reduced to almost 20 to 30% of a normal lung.[23] Applying a regional CT analysis of the lung, we found that alveolar inflation is markedly reduced both in the ventral regions (near to the sternum in supine position) and in the dorsal ones (near to the vertebra in supine position), following a gravitational gradients.[24] Thus, the non dependent alveoli are more expanded than the dependent ones. In contrast, the distribution of edema is uniform throughout the lung parenchyma, suggesting that the disease process is uniformly distributed. As the total mass of the ARDS lung is increased, the lung progressively collapses under its own weight, squeezing out the gas from the dependent lung regions with the formation of compression atelectasis. Therefore, it is possible to describe the ARDS lung as composed by three different zones: 1) a pathologic ventilated one ("open gas zone"); 2) a pathologic one, but without any possibility to be ventilated ("a consolidated zone"),

End Expiration

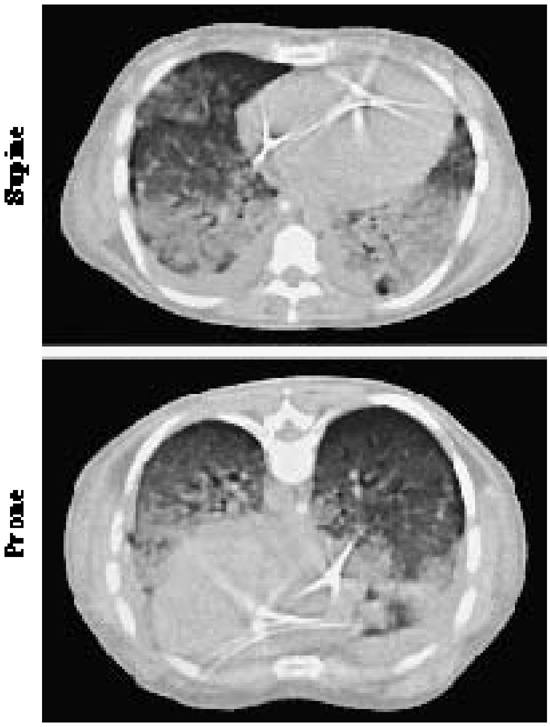

Fig. 1. — Effect of supine and prone positioning on lung densities in a patients with acute respiratory distress syndrome, at end expiration. In supine pulmonary densities are prevalently located in the dependent lung regions. Turning the patients in prone position, pulmonary densities redistribute from the dependent lung regions in supine (near to the vertebra) to the dependent lung regions in prone (near to sternum).

and 3) a pathologic one, but recruitable and ventilable with appropriate airway pressure ("a recruitable zone").

As the alveolar inflation distribution in normal subjects, also in ARDS patients others factors seem to play a relevant role in determining the alveolar inflation distribution. Recently it has been found that in ARDS patients the cardiac mass is increased compared to normal subjects. As a consequence, the increase in cardiac mass would result in an increase of pleural pressure in the dependent part of the lung, contributing to the alveolar collapse observed in the lower lobes.[25]

As in supine position, alveolar inflation likely depends on transpulmonary pressure. Prone position causes a more homogeneous distribution of transpulmonary pressure compared to supine position.[26] We observed, first, a movement of the densities, *i.e.* lung inflation from dorsal to ventral regions, when turning the patients from supine to prone position, as shown in Figure 1, and second, a more homogeneous distribution of alveolar inflation in prone than in supine position.

Several factors could contribute to this differential ability of prone position to alter dorsal lung transpulmonary pressures.

We found that modification of hydrostatic pressures can explain, at least in part, the redistribution of intra-pulmonary gas.[27] The hydrostatic pressures, in supine position, cause alveolar collapse in the dorsal lung regions, which are the most dependent ones. In prone position, the most dependent lung regions, with higher hydrostatic forces, are the ventral ones which, hence, become collapsed.

More recently the role of cardiac mass in determining changes in densities in prone position has been emphasized.[28] As discussed above for supine position, a fraction of both lungs are located underneath the heart and, as such, would be subjected to the compressive forces resulting from the weight of the heart and blood contained therein. On the contrary, in prone position only a very small fraction of either lung would be similarly affected.

The regional mechanical properties and shape of the lung and chest wall are likely modified by prone position. We found that the distribution of alveolar inflation in prone position was more homogeneous in patients with a more "triangular" shape (-apex on the top and base on the bottom) in supine position.[29] Thus, it is evident that the shape of the lung and thorax may deeply influence the alveolar inflation distribution in prone position.

Ventilation distribution in supine and prone position

The distribution of alveolar ventilation roughly follows the alveolar inflation distribution. In sedated and paralyzed ARDS patients in supine position, the ventilation at zero positive end-expiratory pressure (ZEEP) is preferentially distributed in the upper lung, and the ratio between the amount of ventilation in the upper and lower lung is approximately 2.5:1. Increasing PEEP, the distribution of ventilation becomes progressively more homogeneous and the ratio is approximately 1:1 at 20 cmH_2O of PEEP.[30] This implies that modifications on regional compliance occur with PEEP increase, with a decrease in compliance of the upper lung due to the relatively amount of possible recruitment, and an increase in the lower lung, due to a relatively high amount of possible recruitment. During mechanical ventilation and tidal volume breath, the lung continuously collapse and decollapse in its dependent part, especially at low levels of PEEP. At higher PEEP levels, the reopening and collapsing tissue is decreased, because the amount of collapsed tissue at end-expiration is decreased.

Unfortunately, few data are available regarding the distribution of ventilation in prone position. However, since alveolar inflation appears to be more homogeneous and ventilation is usually proportional to alveolar inflation, we expect a prevalent distribution of ventilation towards the non dependent lung regions at relatively low PEEP levels, with a more homogeneous distribution of ventilation at relatively high PEEP levels.

Perfusion distribution in supine and prone position

In ARDS, regional lung perfusion may be affected by different factors, including: 1) hypoxic vasoconstriction; 2) vessels obliteration, and 3) extrinsic vessels compression. However, the relative importance of these factors is not clear. Using a selective angiography, we documented prevalent perfusion in the non dependent lung regions, suggesting an important role of extrinsic compression and hypoxic vasoconstriction during ARDS.[31] On the contrary, recent data, obtained with more sophisticated techniques, suggest a perfusion distribution prevalently located in the dependent atelectatic lung regions.[13]

To our knowledge no data regarding the distribution of perfusion in prone position are available. However, experimental data suggest that perfusion is prevalently located in the non dependent lung regions even in prone position, and factors other than gravity may explain this behavior.[13]

Lung volumes and respiratory mechanics in prone position

We recently studied the modifications in respiratory mechanics and lung volumes in ARDS patients in prone position.[32] We found that prone position did not affect the respiratory system compliance, lung volumes and intra-abdominal pressure (Table I). On the contrary, prone position markedly reduced chest wall compliance, while slightly improved lung compliance. The reduction in chest wall compliance may be attributed to a reduction in the rib cage and/or abdominal compliance. Since intra-abdominal pressure was unchanged between supine and prone position, we may reasonably assume that the compliance of the thoraco-abdominal compartments was not greatly modified. Thus, the change in chest wall compliance may be explained by an increase stiffness of the anterior part of the rib cage, *i.e.* lying on the rigid surface of the bed in prone position, while the posterior part, *i.e.* near to the vertebra, did not modify its mechanics due to its own stiffness. Moreover, we found that respiratory and lung compliance were improved in supine position after pronation, suggesting that prone position per se not only produced "cosmetic effects" on oxygenation but also structural modifications in the lung parenchyma.

Mechanisms of improvement in oxygenation during prone position in ALI/ARDS

From a pathophysiological point of view, hypoxemia in ALI/ARDS patients is a consequence of a reduction in ventilation/perfusion (VA/Q) ratios and of the presence of a true shunt due to alveolar units not ventilated but perfused (VA/Q ratio = 0). The combination of these two factors is called "physiological shunt". Prone positioning can improve oxygenation through different mechanisms which in general improve VA/Q ratio and consequently cause a reduction in physiological shunt.

Increase in lung volume

An increase in lung volume during prone position has been suggested for many years, because of a reduction in intra-abdominal pressure load on the diaphragm. However, this hypothesis has not been confirmed, either in animal [13] and in human studies prevalently including patients with "primary" ALI/ARDS,[32] since the improvement in oxygenation was not correlated with lung volume or alveolar recruitment. On the contrary, in "secondary" ALI/ARDS, the improvement in oxygenation was found correlated with the increased lung volume due to prone position.[33]

Thus, change in lung volumes is not likely the major factor leading to the improvement in oxygenation during prone position in "primary" ALI/ARDS, while an increase in lung volume and alveolar recruitment may explain the improvement in oxygenation in "secondary" ALI/ARDS.

Redistribution of perfusion

This hypothesis is based on the assumption that perfusion follows a gravitational gradient, with regional lung perfusion prevalently located in the dependent lung regions, both in supine and in prone position. Thus, in supine position perfusion is more distributed in those regions more affected by the pathology. In prone position, if the densities do not redistribute, and perfusion redistributed to the dependent regions, the net effect would be an improvement in VA/Q ratio and a reduction of the true shunt. However, this mechanism seems not to be true in clinical practice, since, as we have discussed above, the densities redistribute to the dependent regions. If the perfusion followed a gravitational behavior, we would expect a deterioration and not an improvement in oxygenation.

Recruitment of dorsal spaces with more homogeneous ventilation and perfusion distribution

This seems to be one of the most probable causes of increased oxygenation in prone position. In fact, in prone position, radiological densities in the dorsal part of the lung decrease with a consequent more homogeneous distribution of alveolar inflation and ventilation, while perfusion probably remains most prevalent in the dorsal lung regions. Thus, VA/Q ratio improves with a consequent increase in oxygenation. Recently, we found in a group of patients with "primary" ARDS, that basal chest wall compliance and its changes played a role in determining oxygenation response in prone position (the lower chest wall compliance in supine, the lower the improvement in oxygenation).[32] In addition, the magnitude of the decrease in thoraco-abdominal compliance observed in prone position was related to the improvement in oxygenation. These findings, in patients with ALI/ARDS, are in line with experimental data and highlight the importance of the interactions between rib cage, lungs and abdomen during prone position.[34] Moreover, the greater are the lower lobes compared to the upper ones, more likely is greater the response in oxygenation in prone position.[29] The improvement in oxygenation likely results from a redistribution of blood flow away from unventilated areas to regions with normal VA/Q ratios, most probably resulting from an alveolar recruitment in previously collapsed but healthy and well perfused alveoli.[13] Interestingly, in some studies the improvement in oxygenation was partially maintained even when the patients were repositioned supine.[35 36]

Clinical implications: data from an Italian pilot study

Although the use of prone position is not yet a standard clinical practice, it seems to be a very promising treatment for ALI/-ARDS. Our experience indicates that this maneuver may be useful, with an high chance of success (50 to 80%), and occasionally it has dramatically changed the course of the respiratory failure. Certainly, there are some points that need to be cleared up, such as the long-term impact of this technique, the time frequency of the turns, the impact of prone position on nursing workload, and the intensive care costs, and, finally and more importantly, whether prone position could influence mortality in patients with ALI/ARDS or decrease the frequency with which ALI/ARDS develops.

The pilot phase of a large prospective, randomized, controlled, multicentre trial designed to compare a standard therapeutic strategy and a similar strategy in conjunction with the daily use of prone position for the treatment of patients with acute respiratory failure was performed in the period 1995-1997 in 35 Italian intensive care units, asked to apply a standardized protocol to at least two patients with pre-defined criteria. 73 patients (45 M/28 F, 51 with "primary" ARDS) were enrolled. The mean age was 51±17 years, mean SAPS at entry was 38±11, mean time before enrolment was 2.8±3.2 days. After the first hour of prone positioning, the PaO_2/FiO_2 atio of 76% of the patients had increased by more than 20 mmHg (responder), with a mean increase of 78±53 mmHg. The proportion of responders increased to 85% after 6 hours of prone positioning.

The improvement in oxygenation, expressed as a (PaO_2/FiO_2, was greater in patients with "secondary" compared to "primary" ARDS during the ten days period (77±24 *vs* 52±12, $p < 0.01$). The incidence of maneuver-related complications and severe and life-threatening complications was extremely rare.

The overall mortality at ICU discharge was 51% and it was not significantly different between "primary" and "secondary" ARDS. The ICU stay was similar in survivors and non survivors (17.8±11.6 *vs* 17.8±11.4 days).

The global results of the analysis on the entire population (296 patients) will be published in a short time.

Riassunto

La posizione prona è stata inizialmente introdotta nei soggetti sani anestetizzati e paralizzati per specifici motivi chirurgici. Successivamente, è stata utilizzata durante insufficienza respiratoria acuta per migliorare gli scambi gassosi. L'interesse per la posizione prona in corso di ALI/ARDS è progressivamente aumentato, nonostante i meccanismi responsabili del miglioramento respiratorio non siano stati ancora del tutto compresi. Nei soggetti normali, durante anestesia e paralisi, la posizione prona determina una distribuzione più omogenea del gradiente gravitazionale di espansione alveolare, una distribuzione della ventilazione verso le regioni polmonari non declivi ed una inversione della distribuzione gravitazionale della perfusione regionale, ma anche fattori diversi dalla gravità sono implicati in questi processi. Sia nei soggetti sani sia negli obesi, la posizione prona causa, inoltre, un miglioramento dell'ossigenazione e della capacità funzionale residua senza che si modifichi la compliance del sistema respiratorio, del polmone e della parete toracica. Nei pazienti con ALI/ARDS, la posizione prona porta ad un'inversione dell'espansione alveolare e della distribuzione della ventilazione, dovuta all'inversione della pressione idrostatica che grava sul parenchima polmonare, all'inversione del peso del cuore ed alle modificazioni della forma e delle proprietà meccaniche della parete toracica. Pochi dati sono disponibili sulle modificazioni della perfusione regionale polmonare. I possibili meccanismi che contribuiscono al miglioramento dell'ossigenazione in posizione prona nei pazienti ALI/ARDS sono: 1) aumento dei volumi polmonari; 2) redistribuzione della perfusione polmonare; 3) reclutamento degli spazi dorsali con una distribuzione più omogenea della ventilazione e perfusione. Dal punto di vista clinico, la posizione prona sembra essere un trattamento molto promettente per ALI/ARDS anche se il suo uso non è ancora entrato negli standard della pratica clinica. Abbiamo recentemente completato uno studio randomizzato-controllato che ha valutato l'impatto clinico di questa procedura. Nella fase preliminare dello studio condotto in 35 terapie intensive italiane, abbiamo studiato, dal 1996 al 1998, 73 pazienti con una PaO2/FiO2 di 123±42 ed un SAPS (Simplified Acute Physiology Score) di 38±11. Dopo la prima ora di posizione prona il rapporto PaO2/FiO2 è aumentato di più di 20 mmHg (responder) nel 76% dei pazienti, con un incremento medio di 78±53 mmHg. La percentuale di responder è aumentata ad 85% dopo 6 ore di posizione prona. L'incidenza di complicanze dovute alla manovra e di complicazioni gravi e con rischio per la sopravvivenza è stata estremamente rara. La mortalità complessiva alla dimissione dall'ICU è risultata del 51% e la permanenza in ICU è risultata simile nei responder e nei non responder (17,8±11.6 *vs* 17,8 ±11,4 giorni).

Parole chiave: Posizione prona - Acute respiratory distress syndrome - Meccanica respiratoria - Scambio gassoso - Tomografia computerizzata.

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