The Effect of Lateral Position on Oxygenation in ARDS Patients: A Pilot Study

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Background: *The effect of body position on oxygenation in acute respiratory distress syndrome (ARDS) patients has long been known. Prone position improves the* PaO_2 *in 60-70% of ARDS patients. However, the effect of the lateral positions, which are used in routine critical care, has never been reported.*
Objective: *To determine whether placing the patient in a lateral position has any effect on oxygenation in ARDS.*
Material and Method: *Prospective observational study, comparing oxygenation in ARDS patients between supine, right and left lateral positions (>60 degree).*
Results: *We included 18 ARDS patients, their mean aged was 52.2±19.6 years, 14 were men and the ICU mortality rate was 61.1%. There was no significant change in the mean* PaO_2*, arterial blood gas parameters, respiratory mechanics and hemodynamic parameters between the supine and decubitus positions in the overall group. However, there was a trend toward increasing the mean* PaO_2 *during right lateral position compared with the supine position (90.3±29.0 vs 84.6±20.4, p=0.23). Nine patients who responded to the right lateral position had significantly higher mean* PaO_2 *during the right lateral position than in the supine position (107.8±29.0 vs 85.6±21.8, p<0.0001). In this group, four patients had predominant left pulmonary infiltration and five patients had equally bilateral pulmonary infiltration on chest X-ray. Unfortunately, the* PaO_2 *in three patients decreased more than 10 mmHg during right lateral decubitus.*
Conclusion: *The* PaO_2 *increased while in the right lateral position in patients with predominant left pulmonary infiltration or bilateral infiltration. This effect may be due to the small sample size. A further large-sized randomized controlled study is needed.*

Keywords: *Acute respiratory distress syndrome, ARDS, Lateral position, Decubitus posture*

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Acute respiratory distress syndrome (ARDS), the most severe form of acute lung injury, is characterized by severe hypoxemia and abnormal bilateral pulmonary infiltration without evidence of left ventricular failure[1]. Although, a chest X-ray usually reveals bilateral infiltration, pathology does not show homogenous distribution. There is alveolar collapse primarily in the area of the independent lung regions adjacent to the diaphragm, which produces intrapulmonary venous admixture of blood and severe arterial hypoxemia[2,3]. Mechanical ventilation with positive end expiratory pressure (PEEP) and a small tidal volume (VT) is commonly applied during ARDS to recruit collapsing alveoli for gas exchange without hyperinflation of the lungs[4].

It has long been accepted that placing these patients in a prone position increases oxygenation in 60-70% of ARDS patients[2,5,6]. Several mechanisms have been proposed to account for this effect, including an increase in end expiratory lung volume[6], improved ventilation perfusion matching[7], and a re-

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gional change in ventilation[8] associated with alteration in chest-wall mechanics[9]. A previous report suggested that the lateral position can improve oxygenation in acute respiratory failure patients who have unilateral lung disease where the good lung is in the dependent position[10]. However, in ARDS, there is limited data about the effect of the lateral position on oxygenation despite the fact that during mechanical ventilation, the routine position is right and left lateral decubitus. Wickert et al. studied differential ventilation in the lateral position with PEEP selectively applied only to the dependent lung (DVSP) in ARDS patient[11]. DVSP had been shown to reduce venous admixture and improve oxygenation without compromising cardiac output[12]. However, this method increased demands on staff, required sophisticated respiratory apparatus and there were difficulties with adequate endobronchial suction[11]. There have been no reports about the difference of oxygenation in ARDS patients who received mechanical ventilation with PEEP during the right, left lateral decubitus and supine position.

The aim of this study was to evaluate the change in gas exchange and hemodynamic parameters in both the right and left lateral positions in ARDS patients, who were mechanically ventilated with PEEP.

Material and Method

The authors studied patients who were treated with mechanical ventilation and met the following criteria for the acute respiratory distress syndrome: 1) a ratio of partial pressure of arterial oxygen (PaO_2) to the fraction of inspired oxygen (FiO_2) of or less than 200 while receiving positive end expiratory pressure (PEEP) of at least 5 cm of water, 2) radiographic evidence of bilateral pulmonary infiltrates and 3) absence of clinical evidence of left atrial hypertension or a pulmonary capillary wedge pressure of less than 18 mmHg. The exclusion criteria were 1) aged less than 14 years, 2) evidence of cerebral edema, 3) chest X-ray showed pleural effusion, pneumothorax or atelectasis and 4) contraindication to using the lateral position, such as fracture of the spine (within 2 weeks), thoracoabdominal surgery or severe hemodynamic instability.

Patients were recruited from the medical intensive care unit (ICU) and respiratory intensive care unit (RCU) of Siriraj Hospital, Mahidol University, Bangkok, Thailand. Patients' baseline characteristics, onset of ARDS, initial ventilator setting and hospital outcome were recorded. After diagnosis of ARDS, patients received standard treatment for ARDS using a protective lung strategy with PEEP. Hemodynamic

Fig. 1 Patients were placed in the lateral decubitus position. The pillows were used to support the body position. Both knees and hips were flexed with a pillow between them

monitoring such as a pulmonary artery catheter and arterial line were inserted for routine intensive monitoring. Our study was performed after all hemodynamic parameters were stabilized.

The study protocol was approved by the Institutional Review Board of Siriraj Hospital, Mahidol University in May 2002.

The patients were initially placed in a supine position and then were turned to the right lateral decubitus position (Fig.1). The patients were returned to the supine position for at least 2 hours before being turned to the opposite site. In order to obtain a standard lateral decubitus position, an imaginary line was drawn from the head of the humerous at an angle to the horizontal to obtain a 60^{O} angle. The head was supported by a pillow, both arms were fixed anteriorly and a pillow was inserted between both knees to prevent pressure compression. Change of position was performed manually by four attendants (three nurses and one doctor). The ventilator settings were not changed during the study period.

Measurements were obtained in the supine position (baseline), 30 minutes after changing to the first lateral position, at 120 minutes after returning to the supine position (baseline for second lateral position) and 30 minutes after placing in the opposite lateral position. Arterial blood gas, respiratory mechanics, hemodynamic parameters and complications due to changing position were recorded.

Results

Eighteen patients were studied. Three had predominant right lung infiltration, five had predominant left lung infiltration and ten had homogenous bi-

Table 1. Arterial blood gas during position (n=18)

	Supine 1*	Right decubitus	p-value	Supine 2*	Left decubitus	p-value
pH	7.3±0.13	7.29±0.15	0.43	7.31±0.11	7.32±0.11	0.61
PaO_2	84.6±20.4	90.3±29.0	0.23	77.8±19.6	74.5±15.7	0.45
$PaCO_2$	47.5±19.1	45.1±19.3	0.16	42.3±13.8	42.7±14.9	0.82
HCO_3^-	21.6±7.5	20.4±7.0	0.3	20.9±5.9	20.4±5.8	0.55
O_2 Sat	93.3±4.7	92.7±6.4	0.54	92.5±5.0	92.0±3.9	0.59
PaO_2/FiO_2	138.1±44.0	146.4±54.3	0.29	132.0±51.9	124.9±41.2	0.34
A-a gradient	315.7±88.6	308.1±85.3	0.26	321.2±107.5	322.9±103.5	0.68

* There was no significant difference of arterial blood gas parameters between supine1 and supine2 position. [O_2 Sat = oxygen saturation (%)]

Table 2. Respiratory and hemodynamics parameters during position

	Supine 1*	Right decubitus	p-value	Supine 2*	Left decubitus	p-value
Tidal volume (ml)	452.6±85.1	449.7±110.1	0.80	475.8±93.1	478.0±88.8	0.6.
Respiratory rate (/min)	24.3±5.7	24.4±6.4	0.88	24.6±6.8	25.4±6.9	0.21
Minute Volume (ml)	11.0±2.8	10.9±3.1	0.50	11.3±2.5	11.5±2.5	0.59
Peak airway pressure (cmH_2O)	29.4±4.2	30.6±4.9	0.02	29.8±5.1	30.3±5.7	0.77
Mean airway pressure (cmH_2O)	17.1±4.4	17.0±4.5	0.73	16.7±4.6	16.4±4.4	0.33
Plateau pressure (cmH_2O)	25.9±5.5	26.1±5.5	0.63	26.6±6.1	27.6±5.5	0.08
Dynamic compliance (ml/cmH_2O)	27.0±8.1	25.7±8.8	0.13	28.4±11.0	26.5±9.0	0.09
Pulse rate (/min)	109.9±21.4	109.2±20.2	0.58	112.0±21.1	113.4±19.6	0.40
Systolic BP (mmHg)	114.0±15.4	115.9±15.3	0.58	117.1±16.7	121.0±15.1	0.18
Diastolic BP (mmHg)	63.3±14.8	61.2±13.5	0.23	65.7±14.3	65.0±13.6	0.69

* There was no significant difference of respiratory and hemodynamic parameters between supine1 and supine2 position. [BP = blood pressure (%)]

Table 3. The effect of the lateral decubitus position on oxygenation in ARDS patients

	Right lateral position (n=18)	Left lateral position (n=18)	p-value
Increased PaO_2	9	8	1.0
Decreased PaO_2	9	10	1.0
PaO_2 decrease < 10 mmHg	6	3	0.137
PaO_2 decrease $\geq$ 10 mmHg	3	7	0.137

Table 4. Arterial blood gas values while in the right decubitus group. (only responders are shown)

	Supine	Right decubitus	p-value
pH	7.28$\pm$ 0.13	7.25$\pm$0.13	0.028
PaO_2	85.6$\pm$21.8	107.8$\pm$29.0	<0.001
$PaCO_2$	51.8$\pm$22.3	48.8$\pm$22.6	0.311
HCO_3^-	22.5$\pm$8.5	19.5$\pm$7.3	0.081
O_2 Sat	93.7$\pm$3.7	96.0$\pm$2.6	0.018
PaO_2/FiO_2	134.6$\pm$51.3	169.3$\pm$64.4	<0.001
A-a gradient	332.8$\pm$116.9	314.7$\pm$120.9	0.004

Table 5. Clinical characteristics of responders and non-responders to the right decubitus position

	Responders (n=9)	Non-responders (n = 9)	p-value
Age (years)	54.6$\pm$20.0	51.6$\pm$20.8	0.76
Sex (male/female)	7/2	6/3	1.0
APACHE II score	22.7$\pm$7.6	25.6$\pm$11.1	0.53
Lung injury score	2.78$\pm$0.63	2.97$\pm$0.34	0.43
Onset of ARDS (days)	2.2$\pm$1.9	2.3$\pm$1.9	0.90
Chest X-ray			0.09
Right predominant	0	3	
Left predominant	4	1	
Equal both sides	5	5	
FiO_2	0.67$\pm$0.16	0.61$\pm$0.08	0.32
PaO_2/FiO_2	134.6$\pm$51.3	141.7$\pm$38.2	0.74
PEEP	8.8$\pm$3.3	9.3$\pm$2.9	0.71
Cause of ARDS			
Community acquired pneumonia	3	2	
Hospital acquired pneumonia	2	4	
PCP	3	0	
Sepsis	0	1	
Leptospirosis	0	1	
Tuberculosis	0	1	
ICU mortality rate	5/9 (55.6%)	6/9 (67%)	1.0

PCP = Pneumocystis carinii pneumonia (*Pneumocystis jiroveci*) lateral infiltration. In the overall population, the mean PaO_2 increased after turning from the supine to the right lateral position. However, this was statistically not significant (84.6±20.4 versus 90.3±29.0, p=0.23). The mean PaO_2 returned to the baseline level during the change to the supine position and slightly decreased during the left lateral position (77.8±19.6 vs 74.5±15.7, p=0.45). The mean $PaCO_2$, respiratory parameters and hemodynamic parameters were unaffected by the right or left lateral position (Table 1 and 2). After turning from the supine to the right lateral decubitus, there were nine patients who had an increase in PaO_2 (50% responder) and nine patients with no change or a decrease in PaO_2 (50% non-responder). Of the non-responders in the right lateral position, only 3/9 patients showed a decrease in PaO_2 of more than 10 mmHg. Whereas with left lateral decubitus positioning, 7/18 patients had an increase in PaO_2 (39% responder) and 10/18 patients showed a decrease in PaO_2 (61% non-responder). Of the non-responders in the left lateral position, 6/10 patients (60%) demonstrated a decrease in PaO_2 of more than 10 mmHg (Table 3).

Among the nine patients who responded to the right lateral position, the PaO_2 significantly increased during the change from supine to right lateral decubitus (85.6±21.8 vs 107.8±29.0, p<0.0001). In this group, O_2 saturation and PaO_2/FiO_2 were also significantly increased while the A-a gradient significantly decreased during the period in the right lateral decubitus position compared with supine position (Table 3). Other arterial blood gas parameters, respiratory mechanics and hemodynamic parameters are summarized in Table 4.

The comparison of responders and non-responders to the right lateral decubitus position is shown in Table 5. There was no difference in clinical characteristics; age, sex, APACHE II, number of multiple organ systems failure (MOSF), lung injury score and onset of ARDS between responders and non-responders. However, CXR findings revealed a difference between responders and non-responders. Responders had predominantly left lung infiltration while non-responders had predominantly right lung infiltration. The PaO_2 increased in 4/5 patients (80%) with predominantly left lung infiltration, but decreased in 3/3 patients (100%) with right pulmonary infiltration on chest x-ray. Five of ten (50%) patients with bilateral alveolar infiltration responded to the right decubitus position in terms of oxygenation.

The mortality rate of ARDS patients in our study was 61.1%. Only one complication occurred during lateral positioning. This was an intravenous line disconnection (peripheral line). Other complications as the result of re-positioning, such as hemodynamic or respiratory mechanic disturbance, endotracheal tube displacement or decubitus ulcer did not occur in this study.

Discussion

Our findings suggest that the mean PaO_2 might be increased after turning from supine to the right lateral decubitus position, although this was not statistically significant. There was no change in the other arterial blood gas parameters, respiratory mechanics or hemodynamics. This suggests that the improvement in oxygenation did not depend on the other beneficial factors of ventilation. When the group of patients who responded to the right lateral decubitus position is considered, the PaO_2 increased significantly from the baseline value during the supine position. There was no difference in clinical characteristics between responders and non-responders excepted in the chest X-ray features. Eighty percent of patients with predominantly left side pulmonary infiltration responded to the right lateral decubitus position. While the PaO_2 of patients with predominantly right pulmonary infiltration decreased during the right lateral decubitus position.

In unilateral lung disease patients when the unaffected lung was turned to the dependent position, there was an improvement in the PaO_2. The mechanism of improvement of oxygenation during positioning may be due to improvement in the ventilation: perfusion mismatch[10]. Gravitational influence causes an increase in blood flow through the well-ventilated non-pathologic dependent lung, whereas there is a decrease in blood flow to the poorly ventilated pathologic lung. This improves the ventilation perfusion mismatch. It can also be applied to the prone position in ARDS patients[3], with non-homogeneous bilateral lung infiltration.

The explanation for the improved PaO_2 when turned to the right lateral position in patients with predominantly left pulmonary infiltration is similar to unilateral lung disease. Increased perfusion to the relatively well-ventilated right lung and increased ventilation to the predominantly infiltrated left lung while in the right decubitus position resulted in a match between perfusion and ventilation. However, there is evidence that the dependent lung in the decubitus position is associated with a reduction in functional residual capacity when PEEP was no used[13]. PEEP as used in the study played a major role in maintaining small airway patency in the dependent lung and preserved alveolar patency.

In the group with equal pulmonary infiltration, 50% showed an increase in PaO_2 (increase > 10 mmHg), 30% showed a slight decrease in PaO_2 (decrease<10 mmHg) and 20% showed a marked decrease in PaO_2 (decrease > 10 mmHg) while in the right lateral decubitus position. This evidence suggests that the right lateral decubitus position tends to increase PaO_2 in equal pulmonary infiltration. The right lung volume is greater than the left lung volume (55:45). When the right lateral decubitus position was applied, blood flow to the right lung had a tendency to increase and may have improved the ventilation-perfusion mismatch.

We found only 1/3 patients showed an improvement in PaO_2 in the left lateral position when the CXR showed predominantly right lung infiltration. This may have been due to the small sample size, and it is not possible to draw a conclusion from this finding.

Conclusion

The lateral decubitus position may affect the PaO_2 in ARDS patients. The PaO_2 increased during the right lateral decubitus position in patients with predominantly left pulmonary infiltration even though there was no change in respiratory mechanics or hemodynamic parameters while in the lateral position. These results need more investigation from an ongoing study that includes a larger sample size before a firm conclusion can be made about the effects of right lateral position on the oxygenation in ARDS patients.

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การเปลี่ยนแปลงของระดับออกซิเจนในเลือดแดงของผู้ป่วยกลุ่มอาการหายใจลำบากเฉียบพลัน: การศึกษานำร่อง

สุรัตน์ ทองอยู่, วรการ วิไลชนม์, รณิษฐา รัตนะรัต, ไชยรัตน์ เพิ่มพิกุล

การเปลี่ยนแปลงท่านอนของผู้ป่วยกลุ่มอาการหายใจลำบากเฉียบพลันมีผลต่อระดับออกซิเจนในหลอดเลือดแดงดังจะเห็นได้จากการศึกษาโดยการจัดท่าให้ผู้ป่วยนอนคว่ำพบว่า 60-70% ของผู้ป่วยมีระดับออกซิเจนในหลอดเลือดแดงสูงขึ้นได้ อย่างไรก็ตามยังไม่มีการศึกษาเกี่ยวกับการเปลี่ยนแปลงของระดับออกซิเจนในหลอดเลือดแดงของผู้ป่วยกลุ่มอาการหายใจลำบากเฉียบพลัน ขณะจัดให้อยู่ในท่านอนตะแคงขวาและซ้าย ทั้งที่เป็นท่านอนปกติที่ใช้ในการดูแลรักษาผู้ป่วยกลุ่มดังกล่าว

วัตถุประสงค์: *เพื่อประเมินความเปลี่ยนแปลงของระดับออกซิเจนในหลอดเลือดแดงของผู้ป่วยภาวะหายใจลำบากเฉียบพลันขณะอยู่ในท่านอนตะแคง*

วัสดุและวิธีการ: *เป็นการศึกษาโดยการเปรียบเทียบความเปลี่ยนแปลงของระดับออกซิเจนในเลือดของผู้ป่วยกลุ่มอาการหายใจลำบากเฉียบพลันขณะจัดให้นอนตะแคงขวา และซ้ายทำมุมประมาณ 60 องศาจากแนวระนาบเทียบกับขณะนอนหงาย*

ผลการศึกษา: *จากการศึกษาผู้ป่วยภาวะหายใจลำบากเฉียบพลันจำนวน 18 ราย อายุเฉลี่ย 52.2±19.6 ปี ส่วนใหญ่เป็นผู้ชาย พบว่าไม่มีความเปลี่ยนแปลงอย่างมีนัยสำคัญของระดับออกซิเจนและคาร์บอนไดออกไซด์ในหลอดเลือดแดงรวมทั้งระบบไหลเวียนโลหิตและการหายใจในผู้ป่วยระหว่างเปลี่ยนจากท่านอนหงายเป็นนอนตะแคงขวา และซ้ายตามลำดับ อย่างไรก็ตามในผู้ป่วยจำนวน 9 ราย ที่ตอบสนองต่อการนอนตะแคงขวาจะมีระดับออกซิเจนในเลือดขณะนอนตะแคงขวาสูงกว่าขณะนอนหงายอย่างชัดเจน (107.8±29.0 vs 85.6±21.8, $p < 0.001$) โดยผู้ป่วย 4 ใน 5 รายที่มีภาพรังสีทรวงอกผิดปกติในปอดด้านซ้ายมากกว่าด้านขวา และผู้ป่วย 5 ใน 10 รายที่มีภาพรังสีทรวงอกผิดปกติเท่ากันทั้ง 2 ข้าง เป็นผู้ป่วยที่ตอบสนองดีต่อการนอนตะแคงขวา ในขณะที่ผู้ป่วยที่มีภาพรังสีทรวงอกของปอดขวาผิดปกติเด่นชัดกว่าปอดซ้าย 3 ราย ตอบสนองไม่ดีต่อการนอนตะแคงขวาทั้ง 3 ราย*

สรุป: *ระดับออกซิเจนในหลอดเลือดแดงสามารถเพิ่มขึ้นในขณะเปลี่ยนท่าจากนอนหงายเป็นนอนตะแคงด้านขวา ได้โดยเฉพาะในผู้ป่วยที่มีความผิดปกติของภาพรังสีทรวงอกด้านซ้ายเด่นชัดกว่าด้านขวา และมีแนวโน้มว่าผู้ป่วยที่มี ความผิดปกติของภาพรังสีทรวงอกพอๆกันทั้ง 2 ข้างจะมีระดับออกซิเจนในเลือดเพิ่มขึ้นขณะนอนตะแคงขวาเช่นกัน อย่างไรก็ตามประชากรที่ทำการศึกษายังมีจำนวนจำกัด จึงยังไม่สามารถสรุปความเปลี่ยนแปลงให้ชัดเจนได้ในขณะนี้*