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Influence of Posture on Gas Exchange in Artificially Ventilated Patients with Focal Lung Disease

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Abstract. Six patients were artificially ventilated for a focal lung disease localized to one lung in four cases and to both lower lobes in two. Despite an inspired oxygen concentration of 100% the mean PaO_2 was 115 mmHg. The addition of PEEP slightly improved PaO_2 in two patients but led to deterioration in four. We therefore studied the effects of posture. Patients with unilateral disease were placed in the lateral position with the healthy lung dependent. The two patients with both lower lobes involved were tilted into the Trendelenburg position. The mean PaO_2 rose from 98.4 to 199.5 mmHg. Posture was maintained as long as a beneficial effect was demonstrable. The disappearance of this effect was associated either with recovery (three patients) or with the extension of the pneumonia (three patients). The improvement of gas exchange can be accounted for by the rearrangement of ventilation/perfusion relationships. This management could avoid the need for differential lung ventilation.

Key words: Unilateral pneumonia – Positive end expiratory pressure (PEEP) – Lateral position – Trendelenburg

Artificial ventilation with positive end expiratory pressure (AV-PEEP) is widely used in acute respiratory failure [5, 13, 23]. Nevertheless some adverse effects such as a decrease in arterial oxygen tension have been reported [9] especially in unilateral or focal lung diseases. This is probably related to the overdistension of the healthy and more compliant lung, which in turn favours the perfusion of the diseased and poorly ventilated areas. Therefore, selective lung ventilation with a double lumen tube has been advocated [2, 7, 14, 19, 22]. This procedure is efficient but the insertion of the tube may be hazardous in hypoxic patients. Moreover, due to the small size of the lumen, there is a potential danger of obstruction.

It is known that a lateral position affects the ventilation, perfusion relationship (V/Q) [13, 18]. Furthermore such a posture has been shown to be useful in improving gas exchange in respiratory failure related to unilateral lung disease [18, 24]. Nevertheless, this method has rarely been used in severe hypoxemia [8]. We would like to emphasize the therapeutic use of the position and stress the similar use of the Trendelenburg position in bilateral lower lobe disease.

Material and Methods

Six patients ranging from 23 to 54 years, free of chronic respiratory disease were "positioned" because of severe hypoxemia related to infectious lung disease (two pneumococci, one psittacosis, one tuberculosis pneumonia, one nosocomial infection with Escherichia coli) or to atelactasis [1]. The lung disease was unilateral in four cases and involved the two bases in two (Table 1). All the patients were artificially ventilated because of severe respiratory failure occasionally associated with impairment of consciousness. While breathing 100% oxygen, the mean arterial partial pressure of oxygen (PaO_2) was 115 mmHg (15.3 KPa) in patients under intermittent positive pressure ventilation (IPPB) and 103 and 121 mmHg (13.7 and 15.2 KPa) in two others under AV-PEEP with respectively 8 and 10 mbar of end expiratory pressure. In four patients introducing or increasing the level of PEEP led to a further decrease in PaO_2(Fig. 1). Therefore the overall poor response to AV-PEEP consistent with lung consolidation and localized disease led us to assess the effects of posture. After measurements of PaO_2 in the supine position, patients with unilateral infiltrates were placed in the lateral position with the healthy lung in the dependent position while those with both bases affected were

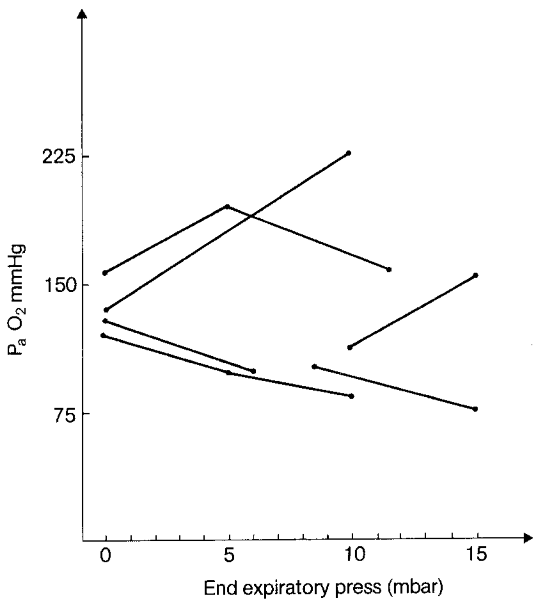


Fig. 1. Effects of PEEP on PaO_2 in supine position. In two patients, the adjunction of PEEP improved PaO_2 but only slightly in one. In the others, PaO_2 decreases under PEEP artificial ventilation, despite an initial improvement in one

tilted into a Trendelenburg position. PaO_2 was measured after 30 min without changing the ventilatory features. A paired student test was applied to evaluate the statistical significance of the mean and SE.

Results

Individual results are given in Table 2. In some patients the test was repeated within the following 24 h, thus 12 measures were obtained. Nevertheless, as this work is retrospective the blood gases were measured during non scheduled conditions of ventilation. Patients were sedated and paralyzed. The mean PaO_2 increased from 98.4 ± 26.2 to 199.5 ± 18.7 mmHg ($p < 0{,}001$). The mean carbon dioxide arterial partial pressure ($PaCO_2$) decreased from 28.1 to 26.4 mmHg but not significantly. We assessed daily the effects of posture which was maintained continuously from 2 – 10 days, up to the disappearance of its beneficial effects on gas exchange (Table 1). This was related either to recovery (patients 2, 3 and 6) or extension of the disease to the other lung (patients 1 and 4) or the upper lobes (patient 5).

Table 1

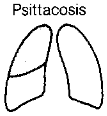
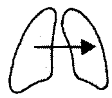
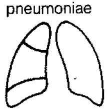
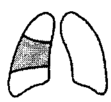
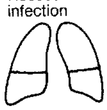
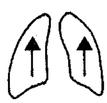
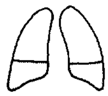
Patients	Age (years)	Diagnosis	$P_a\ O_2$ 100% O_2 on admission in SCU	Duration of posture (days)	Duration of AV-PEEP (days)	Follow-up chestray at the time of posture discontinuation
1	41	Psittacosis 	IPPB 158 mmHg	5	14	Death 
2	28	Pneumococcia 	IPPB 128 mmHg	8	15	Recovery 
3	23	Atelectasis 	IPPB 125 mmHg	2	10	Recovery 
4	29	Tuberculosis pneumoniae 	IPPB 61 mmHg	10	5	Death  Pseudom. aer. nosocomial pneumonia.
5	40	Nosocomial infection 	PEEP 8 mbar 103 mmHg	3	8	Death 
6	54	Pneumococcia 	PEEP 10 mbar 114 mmHg	7	16	Recovery 

Table 2. Effects of posture on PaO_2 and $PaCO_2$

Patients	F_IO_2	End expiratory pressure mbar	PaO_2 mmHg		$PaCO_2$ mmHg		Position
			Supine	Posture	Supine	Posture	
							Unilateral lung disease
1	1	0	97	260	26.3	21	Supine
	1	+10	91.7	147.3	21	18.8	
Psittacosis	1	+6	54.8	109.7	27.8	27	
2	1	+10	218	376	36.8	37.6	
	0.5	+10	66.1	115	36.1	33	
Pneumococcia	0.5	+6	81.2	93.2	29.3	29.3	
3 Atelectasis	1	+6	96.9	310	24	22.5	
4	1	0	112	172.9	27.8	20.3	
Tuberculosis	1	+10	82.7	184.2	32.3	27	
Pneumoniae	0.6	+6	63.1	184.9	24.8	22.5	Lateral decubitus
							2 Bases
5 Nosocomial pulmonary infection	1	+15	81.2	206	29.3	22.5	
6 Pneumococcia	1	+15	154.1	215	22.5	21.8	
mean			98.4 ±26.2[a]	199.5 ±18.7[a]	28.1 ±1.7[a]	26.4 ±2.25[a]	
p			<0.001	<0.001	NS	NS	

[a] Standard error of the mean

Discussion

Although unusual, focal pneumonias and atelectasis occasionally result in severe hypoxemia. This, as well as the deleterious effects of AV PEEP on arterial oxygen saturation are related mainly to inappropriate adjustments of ventilation/perfusion ratio.

The influence of posture on gas exchanges is due to changes in perfusion and ventilation. During spontaneous breathing the dependent regions are ventilated more either in the supine [6] or lateral position [2, 6, 10, 20]. Radiofluoroscopic studies [6] demonstrated that this was related to a greater displacement of the dependent part of the diaphragm attributable to two mechanisms. First the passive expiratory displacement of the diaphragm predominates in its dependent segment because of hydrostatic forces developed by the abdominal contents. Secondly the actively contracting diaphragm generates a stronger force in the dependent segment owing to both a smaller curvature radius and an increased muscular fibre resting length. By contrast, during mechanical ventilation, when the diaphragm is paralysed its displacement is no longer active, but induced by a uniform intrathoracic pressure opposed to the resistance of abdominal contents. As a result the applied positive pressure preferentially displaces the uppermost areas of the diaphragm where the abdominal pressure is least [15, 16]. In addition, in the lateral position, the weight of the mediastinum could contribute to make the dependent lung less compliant. Therefore in artificially ventilated patients the lower lung is less ventilated but the addition of PEEP by gradually overdistending the upper lung could reincrease the ventilation of the lower lung.

Thus, when lying on the healthy lung, AV-PEEP should ensure both a preferential ventilation of the upper lung and a protection of the lower from atelactasis.

During spontaneous breathing and IPPB, pulmonary perfusion increases in the dependent zone [10]. Moreover, if high respiratory pressures or PEEP are used, the distension of the upper lung further impedes its perfusion and contributes to a shift of blood downwards [15]. Thus, patients lying on the healthy lung should increase both the upper lung ventilation and the lower lung perfusion and produce beneficial effects in unilateral pneumonias [5, 8, 15].

With regard to lower lobe pneumonias, similar management has been applied, because the Trendelenburg position is likely to increase upper lobe perfusion. By contrast, however, it probably does not favour reopening of the alveoli in lower lobes. It has been demonstrated that the prone position was the optimum to ventilate the basal and dorsal areas in the lower lobes [4]. This could be due to similar physical features as compared with the lateral position. Therefore in patients 5 and 6, we believe that circulatory effects account for the increased PaO_2.

Posture was maintained over 2 – 10 days. Meticulous care must be taken both in holding the posture and in positioning the arms to prevent peripheral nerve injury. In the Trendelenburg position, dependent oedema can occur. We did not observe any suggestive symptoms of cerebral oedema but this possibility certainly has to be considered. One can also fear the discharge of infected secretions from the upper lung, toward the healthy and dependent regions. This potential risk also depends on the kind of infections and on the outflow of secretions from the damaged lung. In extensive pneumonias, it is difficult to interpret the mechanism of spread. In patients 1, 4 and 5 the infection spread either to the controlateral lung [1, 4] or the upper lobes [5]. In case 1, the type of microorganism with no secretion, and the rapidity of extension make the role of posture unlikely. In case 4 the worsening was related to bilateral nosocomial pneumonia (Pseudomonas aeruginosa). In case 5, the inoculation of the upper lobes in Trendelenburg posture is doubtful.

The need for maintaining the posture depends on the evolution of the disease. In non extensive pneumonias, the beneficial effect of posture on gas exchange usually disappears whereas the X-ray changes either persist or become more dense. This strongly suggests that the diseased areas are no longer perfused. For example patients 2 and 6 exhibited a marked improvement in gas exchange but the opacities persisted. In other instances the posture becomes ineffective because the pneumonia extended to the other side. It is therefore appropriate to reassess daily the effects of posture.

In summary, the previously described improvement in gas exchange with posture may be of therapeutic value in focal lung disease. It is suitable for use in conjunction with PEEP ventilation in order to avoid atelectasis of the healthy dependent lung. Because of its simplicity and safety, this procedure should be considered before differential lung ventilation.

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