THE EFFECT OF POSTURE ON GAS EXCHANGE FOLLOWING CARDIAC SURGERY

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THE CHANGE from the supine to the sitting position is associated with changes in factors which have conflicting effects on gas exchange. Cardiac output is decreased,¹ tending to increase the alveolar to arterial gradient for oxygen ($AaDO_2$).² Functional residual capacity (FRC) increases, however,¹ promoting better distribution of ventilation in the lung. In certain subjects, this enables more airways to remain open during normal breathing, and decreases $AaDO_2$.¹

Patients in the postoperative period after cardiac surgery feel more comfortable in the semi-sitting position. It was the aim of our present study to see whether this is associated with any significant alteration in gas exchange, and whether one of the conflicting factors discussed above has a predominant effect.

METHOD

Nine male and three female patients were studied on the day following their operation. Mean age was 47 years, with a range of 23 to 57 years. The surgery was performed using extra-corporeal circulation and involved valve replacement, aorto-coronary graft or closure of ventricular septal defects.

Cardiac output was measured in triplicate by a dye-dilution method using indocyanine green. The dye was injected through a central vein and sampled from a radial artery. A Waters system (XC 302 cuvette; D 400 densitometer) was used, with a 10-inch recorder (Honeywell Electronik 194). Curves were analyzed using the Stewart-Hamilton semi-logarithmic replot technique.

Expired gas was collected over three minutes in a neoprene bag with a non-rebreathing valve of 35 ml dead space. Arterial blood was collected simultaneously from an in-dwelling catheter in the radial artery into a heparinized syringe. All blood and gas analyses were by conventional electrodes (Instrumentation Laboratories 113 System). Alveolar oxygen partial pressure (PA_{O_2}) was calculated from the following form of the alveolar air equation³:

$$PA_{O_2} = PI_{O_2} - PaCO_2 (PI_{O_2} - PE_{O_2}) / PE_{CO_2}$$

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Supported by MRC (Canada).

TABLE I
GAS EXCHANGE RESULTS IN THE SUPINE, HORIZONTAL POSITION, AND WITH THE TRUNK
AT AN ANGLE OF 35°.

Patient	PaO ₂ mm Hg		AaDO ₂ mm Hg		Cardiac Output L/ min.		PaCO ₂ mm Hg	
	Horizontal	35°	Horizontal	35°	Horizontal	35°	Horizontal	35°
1	123	111	152	163	5.4	4.9	43.5	43.5
2	87	87	159	150	5.5	4.9	50.5	51.0
3	75	74	191	181	3.8	3.8	44.0	42.0
4	75	82	180	180	4.0	4.7	44.0	43.5
5	58	59	208	208	3.8	3.6	46.0	43.0
6	85	102	177	159	3.4	3.4	49.0	43.0
7	82	82	135	128	4.1	3.6	44.5	44.0
8	85	84	118	126	6.5	6.4	40.0	38.0
9	85	79	153	160	7.4	8.1	37.0	33.5
10	88	89	140	148	5.8	5.1	42.0	41.0
11	68	67	169	159	4.5	4.8	39.0	36.6
12	76	74	160	160	3.8	3.4	39.5	37.5
Mean	82	82	162	160	4.8	4.7	43.3	41.4
SD	15	14	25	22	1.3	1.4	4.0	4.5
P =	.9 n.s.		.6 n.s.		.45 n.s.		.004 sig.	

Note: The mean value and the standard deviation are given at the bottom of each column. The significance was tested by the Student's test for paired differences.

The inspired gas was a preformed mixture of 40 per cent oxygen in nitrogen contained in a light-weight Neoprene bag.

Seven patients were studied first in the supine position and then with the patient flexed at the hips so that the trunk made an angle of 35° with the horizontal. In the remaining five patients the sequence was reversed. Fifteen minutes were allowed following a position change before measurements were made.

Systemic blood pressure was measured in each position by a sphygmomanometer.

RESULTS

The change from supine to 35° head up had in each case the effect of making the patient feel more comfortable and less dyspnoeic. The results for the gas exchange data are shown in Table I. Where mean values are given, the figures in parentheses indicate the standard deviation.

1. *Horizontal position.* Mean arterial oxygen tension (PaO₂) was 82 (±15) mm Hg. Mean alveolar-arterial oxygen tension difference was 162 (±25) mm Hg. This is considerably higher than in normal subjects, but is in agreement with published data for the postoperative period following cardiac surgery.⁴ Mean cardiac output was 4.8 (±1.3) litres/minute. Mean arterial carbon dioxide tension (PaCO₂) was 43.3 mm Hg.

2. *Effect of change to 35° head up.* There was no significant alteration in PaO₂, AaDO₂ or cardiac output, when tested using the Student's t test for paired differences. There was a small but statistically significant decrease in PaCO₂ (P = 0.004) on adopting the 35° head-up posture.

DISCUSSION

It has been postulated that the deficit in gas exchange following cardiac surgery is due to atelectasis.⁵ Beecher in 1933⁶ showed that following abdominal surgery, functional residual capacity (FRC) was reduced. The significance of FRC is its relationship to "closing volume" (CV). In a normal subject, as lung volume is reduced from a total lung capacity (TLC), a volume of the lung is reached where airways start to close – the "closing volume." It has been shown to be of importance to gas exchange that FRC remains above CV during normal breathing.¹ The benefit of continuous positive pressure ventilation (CPPV) is possible by maintaining the lungs at an increased FRC and therefore minimizing atelectasis.⁷ Continuous positive pressure has in some patients the disadvantage of reducing cardiac output,⁸ presumably because of a raised intrapleural pressure. A second important complication of CPPV is the occurrence of pneumothorax.⁷

We wondered, therefore, whether the FRC could be increased by an alternative technique to CPPV – the simple mechanism of tilting the trunk into a head-up position. This would not have the technical problems associated with CPPV, nor the dangers of increased intrapleural pressure, although cardiac output is lowered in the head-up position.¹ During gradual tilting, from supine to standing, the increase in FRC is about linearly related to the angle of tilt from the vertical to the horizontal.⁹

Our results indicated that the manoeuvre of moving the patient from the supine to the 35° position was not associated with a significant decrease in Aa_{DO_2} nor cardiac output.

It is possible that gas exchange fails to improve because the angle of tilt of the patients is insufficient to alter the relationship of FRC to CV. Firstly in the presence of a lung with low compliance, position change will have less effect on FRC. Secondly CV may be so far above FRC that even the normal change in FRC would not place it above CV.

A curious finding for which we do not have an explanation is the small but consistent decrease in arterial carbon dioxide tension in the 35° head-up position.

The subjective benefit which we found in each patient was not, therefore, associated with any significant improvement in gas exchange. Our results indicated that nursing patients in the postoperative period after cardiac surgery in a head-up position at 35° to the horizontal does not impair their cardio-pulmonary status.

SUMMARY

Gas exchange and cardiac output was measured in twelve patients the day after cardiac surgery involving total cardio-pulmonary bypass. Measurements made with the trunk of the patient flexed at 35° to the horizontal were compared with those made in the horizontal position.

There was no significant difference in arterial P_{O_2} , alveolar-arterial oxygen gradient (Aa_{DO_2}) or cardiac output. Arterial P_{CO_2} decreased slightly but significantly in the 35° head-up position.

We concluded that the 35° head-up position could be safely used to make pa-

tients subjectively more comfortable, but there was no evidence of any improvement in cardio-respiratory parameters.

RÉSUMÉ

Chez douze malades, le jour suivant de la chirurgie cardiaque, impliquant une circulation cardio-pulmonaire totale extracorporelle, nous avons mesuré les échanges gazeux et le débit cardiaque. Ces études ont été faites alors que les malades étaient assis à 35° par rapport à l'horizontale et une comparaison a été faite avec les résultats obtenus alors que les malades étaient en position horizontale.

On a noté peu de différence dans la P_{O_2} artérielle, la différence alvéolo-artérielle en oxygène (Aa_{DO_2}) et le débit cardiaque. La P_{CO_2} a diminué légèrement mais de façon valable en position assise à 35°.

Nous concluons que la position assise à 35° peut être acceptée pour le confort subjectif des malades, mais qu'il n'existe pas d'évidence d'amélioration des paramètres cardio-respiratoire.

ACKNOWLEDGMENT

We thank Dr. Ronald Gabel for performing the statistical analyses.

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