Preoperative pulmonary blood flow and one-lung anaesthesia

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The distribution of pulmonary blood flow was measured in supine patients before surgery by means of lung perfusion scanning with ^{99m}Tc-macroaggregated albumin in an attempt to predict values of PaO_2 during subsequent one-lung anaesthesia. The PaO_2 values during one-lung anaesthesia were well correlated with the preoperative lung perfusion partition ratios ($r = 0.84$, $p < 0.05$). In 9 of 40 patients, PaO_2 was < 80 mmHg during one-lung ventilation (FiO_2 0.99). In these patients the lung perfusion ratios of the dependent lung were as low as 41.0–48.2 per cent. These results indicate that preoperative measurement of pulmonary blood flow can predict values of PaO_2 during one-lung anaesthesia.

Severe hypoxaemia develops occasionally during one-lung anaesthesia. Peltola[1] reported that during one-lung ventilation, 6 of 32 patients had PaO_2 values less than 70 mmHg, in spite of breathing 100 per cent oxygen (lowest value 52.4 mmHg). Katz *et al.*[2] reported that one-lung ventilation with an FiO_2 of 0.99 resulted in a PaO_2 of less than 80 mmHg in 5 of 17 patients and in two patients PaO_2 was less than 60 mmHg. In this study, the distribution of preoperative pulmonary blood flow was measured by means of lung perfusion scanning with ^{99m}Tc-macroaggregated-albumin (^{99m}Tc-MAA) in an attempt to predict values of PaO_2 during subsequent one-lung anaesthesia.

Methods

The investigation was performed in 40 adult patients between the ages of 27 and 74 years undergoing elective thoracotomy. Surgery was for cancer of the lung in 26 patients, empyema in eight patients and pulmonary tuberculosis in six patients.

Following intravenous injection of approximately 4 mCi of ^{99m}Tc-MAA in 2 ml saline with the patient in the supine position, images were taken in the posterior and anterior projections. The initial posterior image was accumulated for 400 K counts, which usually took one to two minutes. A subsequent scan was taken for the same length of time in the same position. Studies were performed with a standard large field-of-view camera (Nuclear Ohio) centered over the 140 KeV photopeak, using a 20 per cent window with a high-resolution, low-energy, parallel-hole collimator. The distribution of perfusion was evaluated by the mean values of radioactivity counted in two directions (anterior and posterior) over the thorax after intravenous administration of ^{99m}Tc-MAA.

Pulmonary function testing performed preoperatively with the patients seated included vital capacity (VC), forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). No patient had cardiac disease.

All patients were premedicated with 0.5 mg of atropine. Anaesthesia was induced with thiopentone and pancuronium and maintained with halothane and oxygen, delivered through a Robertshaw double-lumen tube. Tube position was confirmed by auscultation and visually at thoractomy. All patients were ventilated mechanically at 12–14 breath·min^{-1} with a tidal volume of 10 ml·kg^{-1}. After thoractomy, one-lung ventilation was begun without alteration in tidal volume or rate.

Blood gas analyses were done before the start of anaesthesia (FiO_2 0.21), during two-lung ventilation in the lateral position, and during one-lung ventilation. The second blood samples were obtained 30 minutes after the start of two lung ventilation in the lateral position. The last blood samples were obtained 30 minutes after collapse of the non-dependent lung. In ten patients, blood samples were obtained directly from the pulmonary artery in the operative field in order to calculate the shunt ratio. All blood samples were taken before either occlusion or division of the pulmonary artery.

Physiological shunt ($\dot{Q}s/\dot{Q}t$) was calculated using standard equations.*

$$*\dot{Q}s/\dot{Q}t = (Cc'O_2 - CaO_2)/(Cc'O_2 - C\bar{v}O_2) \times 100$$

$$Cc'O_2 = Hb \times 1.39 + 0.003 \times P_AO_2$$

(FiO_2 0.99, respiratory quotient 0.8)

Key words

ANAESTHESIA: one-lung anaesthesia; MEASUREMENT TECHNIQUES: regional pulmonary blood flow, lung perfusion scan.

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Data are expressed as means ± SE. Statistical analyses were done with Student's t test and the level of significance was defined as $p < 0.05$.

Results

Preoperative distribution of pulmonary perfusion

The ratio of perfusion partition between the dependent and the non-dependent lung was 64.9 ± 2.9 per cent. Twenty-six patients had the abnormality in the right lung and in these patients the ratio of perfusion partition was 61.0 ± 4.2 per cent. In patients with cancer of the lung, the ratio of perfusion partition was 56.9 ± 2.6 per cent. In empyema, the ratio was as high as 85.2 ± 4.9 per cent, probably because the effective pulmonary alveolar area was small in the non-dependent lung and in some the blood flow was almost immeasurable.

Blood gas analyses

Preoperative values of pH and PaO_2 were 7.38 ± 0.01 and 40 ± 1 mmHg, respectively. These values during two-lung ventilation were 7.38 ± 0.02 and 40 ± 2 mmHg, during one-lung ventilation were 7.37 ± 0.01 and 39 ± 1 mmHg. None of these variables changed significantly throughout the subsequent study periods.

The mean value of PaO_2 was 79 ± 4 mmHg preoperatively (FiO_2 0.21), 385 ± 9 mmHg during two-lung ventilation (FiO_2 0.99) and 211 ± 19 mmHg during one-lung ventilation (FiO_2 0.99). In patients with empyema, higher PaO_2 values (269 ± 22 mmHg) during one-lung ventilation were noted than in patients with cancer of the lung (171 ± 21 mmHg). In 9 of 40 patients, PaO_2 was less than 80 mmHg during one-lung ventilation and the lowest values was 53 mmHg. In these cases the lung perfusion ratios of the dependent lung were as low as 41–48 per cent.

The shunt ratio obtained in ten cases by blood sampling from the pulmonary artery, averaged 41 ± 4 per cent during one-lung ventilation.

Correlation coefficients

The values of PaO_2 during one-lung anaesthesia were well correlated with the preoperative lung perfusion partition ratios as shown in Figure 1 ($r = 0.84$, $p < 0.05$). An inverse correlation was noted between PaO_2 during one-lung ventilation and both the preoperative percentage of predicted VC (%VC, $r = -0.59$, $p < 0.05$) (Figure 2) and the percentage of predicted FVC ($r = -0.68$, $p < 0.05$). No significant correlation of PaO_2 during one-lung ventilation was noted either with preoperative PaO_2 or preoperative FEV_1/FVC. A highly significant inverse correlation was noted between preoperative lung perfusion partition ratios and $\dot{Q}s/\dot{Q}t$ during one-lung ventilation ($r = -0.86$, $p < 0.05$).

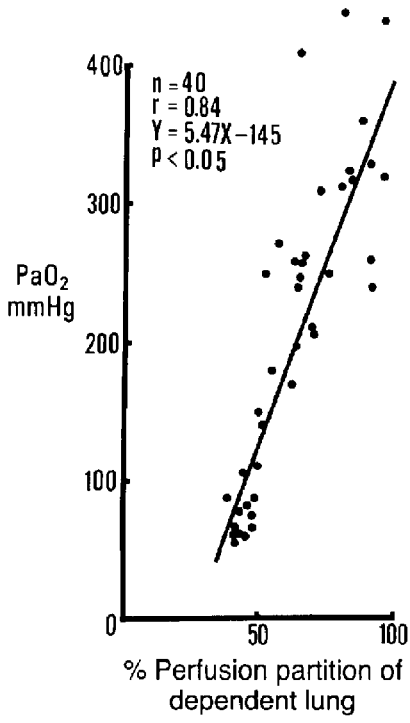

FIGURE 1 A significant correlation was found between the perfusion partition of the dependent lung and PaO_2 during one-lung anaesthesia. In 9 of 40 patients, PaO_2 was less than 80 mmHg during one-lung ventilation and in these cases the lung perfusion ratios of the dependent lung were as low as 41–48 per cent.

Discussion

One-lung anaesthesia has the disadvantage of producing impaired pulmonary oxygen exchange and an increase in the alveolar-to-arterial oxygen pressure difference $P(A\text{-}a)O_2$.[3–5] In this study, one-lung anaesthesia with an FiO_2 of 0.99 resulted in PaO_2 values of less than 80 mmHg in 9 of 40 patients. As expected, a high correlation between preoperative blood flow to the dependent lung and PaO_2 during one-lung ventilation was noted. Also, there was a high inverse correlation between preoperative blood flow to the dependent lung and $\dot{Q}s/\dot{Q}t$ during one-lung ventilation. Our data suggest that preoperative measurement of pulmonary blood flow can help predict values of PaO_2 during one-lung anaesthesia.

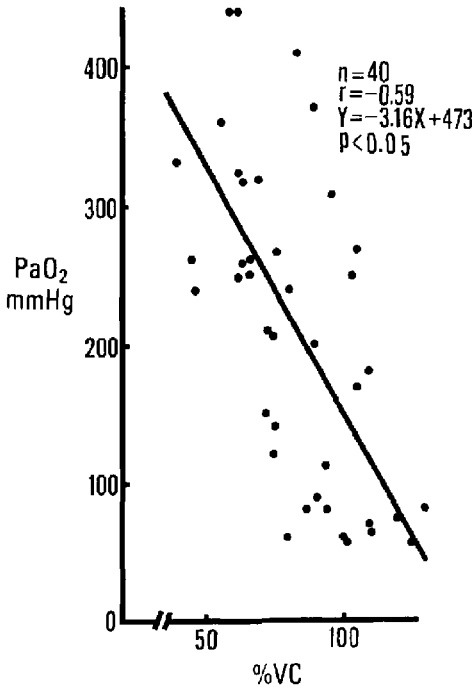

FIGURE 2 An inverse correlation was noted between the preoperative percentage of predicted VC (%VC) and PaO_2 during one-lung anaesthesia.

Flacke *et al.*[6] reported a significant positive correlation between PaO_2 during one-lung ventilation and both the preoperative FVC and PaO_2 during two-lung ventilation as well as an exponential relationship to preoperative PaO_2. However, Katz *et al.*[2] reported that PaO_2 during one-lung ventilation correlated inversely with the percentage of predicted FEV_1 ($R = -0.66$, $p < 0.005$) and the percentage of predicted FVC ($r = -0.51$, $p < 0.05$), but did not correlate significantly with FEV_1/FVC, preoperative PaO_2, or PaO_2 during two-lung ventilation. The findings in the present study of an inverse correlation between PaO_2 during one-lung ventilation and both the %VC and the percentage of predicted FVC and absence of correlation between PaO_2 during one-lung ventilation and FEV_1/FVC or preoperative PaO_2 agree with the report of Katz *et al.* It is possible that some patients with a low %VC had this reduction because of unilateral restrictive pulmonary disease and the preoperative pulmonary blood flow to the operative side was less, therefore values of PaO_2 remained high during one-lung ventilation. There are, however, so many factors affecting oxygenation that frequent monitoring of blood gases is mandatory.

Acknowledgment

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Résumé

On a mesuré, avant la chirurgie, la distribution du débit sanguin pulmonaire en utilisant un balayage de perfusion pulmonaire avec de l'albumine ^{99m}TC-macroagrégé chez un patient en décubitus dorsal, afin d'essayer de prédire les valeurs de la PaO_2 durant une anesthésie à un poumon subséquente. Durant l'anesthésie à un poumon, les valeurs de la PaO_2 correspondaient bien à celles des rapports de partition de la perfusion pulmonaire préopératoire ($r = 0.84$, $p < 0.05$). Neuf des 40 patients ont eu une PaO_2 de moins de 80 mmHg durant la ventilation à un poumon (FiO_2 0.99). Dans ces cas là, les rapports de perfusion pulmonaire du poumon dépendant étaient aussi peu élevés que 41.0–48.2 per cent. Ces résultats indiquent que l'on peut prédire les valeurs de la PaO_2 durant une anesthésie à un poumon en mesurant le débit sanguin pulmonaire en période préopératoire.