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## Deep Breathing and Nitroglycerin-induced Hypoxemia

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Arterial oxygen tension ( $P_{aO_2}$ ) decreases after administration of nitroglycerin<sup>1-3</sup> in both normal subjects and in patients with coronary artery disease. Perhaps this decrease in  $P_{aO_2}$  may explain the occasional lack of improvement from the symptoms of myocardial ischemia after sublingual nitroglycerin.<sup>4,5</sup> This lack of improvement may be due to diversion of coronary blood flow away from ischemic zones by vasodilation of normal coronary vessels in nonischemic areas, the "coronary steal syndrome."<sup>4</sup> Another explanation may be that a significant decrease in available oxygen offsets the beneficial hemodynamic effect of nitroglycerin. Although the use of oxygen has been proposed,<sup>3</sup> this may not be a practical solution for ambulatory patients.

Hypoxemia induced by nitroglycerin has been attributed to the redistribution of blood flow to poorly ventilated areas of the lungs.<sup>1-3</sup> If so, deep breathing or hyperinflation may enhance gas exchange in the poorly ventilated regions of the lungs with a concomitant improvement in arterial  $P_{O_2}$ .

We therefore decided to study the effect of deep breathing of room air (four deep breaths in one minute) without a significant hyperventilation on arterial blood gases and hemodynamics in a group of patients with coronary artery disease. We found that the reduced  $P_{aO_2}$  produced by nitroglycerin is completely reversed by deep breathing without changing its hemodynamic effects.

### MATERIALS AND METHODS

*Group I.* Nine patients, seven men and two women, 38-58 years of age, were studied prior to surgery. Each had angiographically proven coronary artery

disease with typical stable exertional angina for at least one year. No patient had clinical evidence of congestive heart failure or valvular disease. All medications, except nitroglycerin, had been discontinued 48 hours prior to coronary artery bypass surgery. Scopolamine, 0.4-0.5 mg, and morphine, 10-15 mg, were given im approximately one hour before the studies.

Arterial blood was obtained for analysis of  $pH_a$ ,  $P_{aCO_2}$  and  $P_{aO_2}$  from a catheter located in the radial artery. A Swan-Ganz thermodilution catheter was inserted percutaneously under local anesthesia into the pulmonary artery via the right internal jugular vein for measurement of pulmonary artery pressure, pulmonary arterial wedge pressure, central venous pressure, and cardiac output. All pressures were monitored continuously with No. 500 Sanborn transducers. ECG lead II was also monitored. Cardiac output was determined by thermodilution with an Edwards CAM model 4510-A<sup>®</sup> cardiac output computer. Patients were asked to take one deep breath every 15 seconds (for one minute only); thus one normal inspiration has been replaced with one deep breath so that the total number of inspirations remained unchanged (mean respiratory rate  $12 \pm 2$ ). All studies were performed before the induction of anesthesia immediately prior to coronary artery bypass surgery with the patient in the supine position breathing room air.

For all patients, the hemodynamic and blood gas values were obtained before nitroglycerin, five minutes after sublingual nitroglycerin, 0.6 mg, one minute after taking four deep breaths, and five minutes after normal breathing.

*Group II.* To evaluate the effect of deep breathing on blood gases in the absence of nitroglycerin, ten additional patients (36-60 years of age) who did not receive nitroglycerin were also studied. Blood gas determinations were performed during the same time intervals as with the patients in Group I, except nitroglycerin was not given. The data collected from these patients were compared with those from Group I using the paired *t* test and Dunnett's multiple comparison procedure.<sup>6</sup> Values  $<0.05$  were considered significant.

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TABLE 1. Cardiorespiratory Response to Nitroglycerin (TNG) and Deep Breathing\*

	Control	0.6 mg TNG	Deep Breathing*	Five Minutes after Normal Breathing
pH <sub>a</sub>	7.35 ± 0.03	7.38 ± 0.15 N.S.	7.39 ± 0.03 N.S.	7.37 ± 0.027 N.S.
Pa <sub>CO<sub>2</sub></sub> (torr)	42.4 ± 4	41.1 ± 3 N.S.	37.7 ± 4†	42.8 ± 4 N.S.
Pa <sub>O<sub>2</sub></sub> (torr)	71.7 ± 12	60.4 ± 11†	78.2 ± 15†	71.4 ± 11 N.S.
HR (beats/min)	62 ± 13	71 ± 14 N.S.	71 ± 14 N.S.	69 ± 13 N.S.
BP (torr)	96.6 ± 15	85.3 ± 10†	85.7 ± 11†	90.8 ± 5 N.S.
CVP (torr)	4.5 ± 2.6	2.2 ± 3.1†	2.3 ± 3.2†	2.6 ± 2.5†
PA (torr)	21.3 ± 9	12.1 ± 5†	10.2 ± 3†	10 ± 2†
PCWP (torr)	7.7 ± 4	4.1 ± 4†	3.2 ± 3.5†	4.5 ± 4.9†
CO (l/min)	5.02 ± 0.54	4.81 ± 0.54†	4.08 ± 0.38†	4.13 ± 0.36†
SVR (dyne-sec-cm <sup>-5</sup> )	1505 ± 381	1657 ± 319 N.S.	1523 ± 261 N.S.	1647 ± 253 N.S.
PVR (dyne-sec-cm <sup>-5</sup> )	232 ± 124	205 ± 116 N.S.	241 ± 87 N.S.	239 ± 79 N.S.

HR = heart rate; BP = mean blood pressure; CVP = central venous pressure; PA = pulmonary artery; PCWP = pulmonary capillary wedge pressure; CO = cardiac output; SVR = systemic vascular resistance; PVR = pulmonary vascular resistance (dyne-

sec-cm<sup>-5</sup>); N.S. = not significant.

\* Deep breathing = one maximal inspiration every 15 seconds with an overall respiratory rate of 12 breaths/min.

† P < 0.05 vs. control.

RESULTS

*Group I.* Pa<sub>O<sub>2</sub></sub> decreased after nitroglycerin in all nine patients, with the lowest Pa<sub>O<sub>2</sub></sub> being 39 torr (table 1). This patient's control Pa<sub>O<sub>2</sub></sub> was 54 torr. Pa<sub>CO<sub>2</sub></sub> and pH<sub>a</sub> did not change. Mean arterial pressure, central venous pressure, pulmonary artery pressure, mean pulmonary arterial wedge pressure, and cardiac output decreased significantly. Systemic and pulmonary vascular resistance did not change. The heart rate was not significantly altered (table 1).

One minute after deep breathing of room air, the mean Pa<sub>O<sub>2</sub></sub> rose, with the highest Pa<sub>O<sub>2</sub></sub> being 95 torr and the lowest being 60 torr. Pa<sub>CO<sub>2</sub></sub> decreased significantly (table 1). The other variables did not change. Five minutes after normal breathing, Pa<sub>O<sub>2</sub></sub> was still higher than that following nitroglycerin. The other variables did not change.

*Group II.* In patients who did not receive nitroglycerin, Pa<sub>O<sub>2</sub></sub> increased, pH<sub>a</sub> increased, and Pa<sub>CO<sub>2</sub></sub> decreased after deep breathing (four deep breaths in one minute) (table 2). Five minutes after normal breathing, pH<sub>a</sub>, Pa<sub>CO<sub>2</sub></sub>, and Pa<sub>O<sub>2</sub></sub> returned to control values.

DISCUSSION

We found that four deep breaths in one minute (one every 15 seconds) raised Pa<sub>O<sub>2</sub></sub> to its prenitroglycerin

level and, in most patients, even exceeded control values without changing the beneficial hemodynamic effects. The absolute amount of energy required for normal respiration is only 2-3 per cent of the total energy expended by the body to energize the pulmonary ventilatory process.<sup>7</sup> Since the total number of respirations (12 per minute) did not change during deep breathing, we assumed that there was no significant increase in energy expenditure for deep breathing.

Reduction in Pa<sub>O<sub>2</sub></sub> following administration of sub-

TABLE 2. Respiratory Response to Deep Breathing\* without Nitroglycerin

	Control	Deep Breathing*	Five Minutes after Normal Breathing
pH <sub>a</sub>	7.32 ± 0.04	7.36 ± 0.03†	7.33 ± 0.02 N.S.‡
Pa <sub>CO<sub>2</sub></sub> (torr)	44.1 ± 3.5	40.2 ± 3.0†	43.0 ± 2.2 N.S.
Pa <sub>O<sub>2</sub></sub> (torr)	77.7 ± 7.8	90.6 ± 7.1†	76.9 ± 7.8 N.S.

\* Deep breathing = one maximal inspiration every 15 seconds with an overall respiratory rate of 12 breaths/min.

† P < 0.05.

‡ N.S. = Not significant.

lingual nitroglycerin can be attributed to: 1) vasodilation in poorly ventilated areas of the lung; 2) a relative increase in perfusion through the dependent less ventilated area of the lung due to the fall in pulmonary artery pressure; 3) a decrease in cardiac output; and 4) an increase in intrapulmonary shunt.<sup>8</sup>

Since the cardiac output did not increase after deep breathing, increase in  $Pa_{O_2}$  cannot be linked to cardiac output. A small increase in shunt fraction (1.4 per cent) observed in our previous study<sup>9</sup> was not quantitatively sufficient to account for the nitroglycerin-induced decline in arterial  $Pa_{O_2}$ . Presumably then, a rise in  $Pa_{O_2}$  can be attributed to an improvement of ventilation/perfusion ratio produced by deep breaths.

Improvement in  $Pa_{O_2}$  in patients (premedicated, supine, breathing room air) who did not receive nitroglycerin indicates that deep breathing can reverse not only nitroglycerin-induced V/Q abnormalities but also pre-existing ventilation perfusion imbalance.

The clinical significance of the observed changes in  $Pa_{O_2}$  after administration of nitroglycerin is not yet clear. However, in critically ill patients with angina pectoris, a decline in available oxygen may offset its beneficial effect. High-inspired oxygen concentrations probably should be used when nitroglycerin is given for the treatment of anginal pain or when narcotics and nitroglycerin are given to patients with severe coronary artery disease.<sup>2</sup> Although the use of oxygen may be convenient under hospital or intensive care conditions, it is not practical for ambulatory pa-

tients. The present study suggests that a simple method, such as deep breathing, may be an easy alternative to prevent or treat nitroglycerin-induced hypoxemia.

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## The Effect of Method of Radial Artery Cannulation on Postcannulation Blood Flow and Thrombus Formation

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Percutaneous radial artery cannulation is performed to permit continuous monitoring of systemic arterial blood pressure and to facilitate repeated

sampling of arterial blood. The radial artery is chosen because it is accessible, easy to cannulate, and collateral circulation is usually good and easily confirmed. Two methods of cannulation are used: transfixing, in which

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