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REVERSIBLE DECREASE OF OXYGEN CONSUMPTION BY HYPEROXIA

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Introduction. Preoxygenation is routinely used prior to intubation and trachea suctioning in critically ill patients to increase alveolar O_2 in periods of hypoventilation. In preliminary work, however, we found with O_2 breathing for 10 min a decrease in oxygen consumption ($\dot{V}O_2$) resulting from decreases in both cardiac output and arteriovenous O_2 content difference ($avDO_2$). This study further explored this O_2 supply/demand paradox, particularly the time course and reversibility of 100% O_2 ventilation on O_2 delivery and uptake. As an indication of how microcirculatory changes might be coupled to metabolic changes, we also measured tissue PO_2 in leg muscle.

Methods. 20 critically ill, ventilated patients requiring monitoring with pulmonary artery catheters were studied. O_2 content in arterial (CaO_2) and mixed-venous blood was derived from Hb concentration, O_2 saturation (IL-282 Co-oximeter) and PO_2 (PaO_2, $P\bar{v}O_2$). Cardiac output was measured in triplicate by thermodilution. O_2 delivery ($\dot{D}O_2$) was calculated as the product of cardiac index (CI) and CaO_2. $\dot{V}O_2$ was calculated as the product of CI and $avDO_2$. Measurements were taken at 30 min intervals during hemodynamically stable periods in the following stages: 1) baseline, FIO_2 < 0.50 but sufficient to maintain PaO_2 > 100 mmHg; 2) 90 min at FIO_2 = 1.0, and 3) 30 min with FIO_2 at baseline values. Tissue PO_2 values were obtained from the quadriceps femoris muscle using a fast responding polarigraphic-type hypodermic needle probe (response time 90-500 ms). 200 samples at each stage were displayed as a PO_2 histogram. Data were analyzed with paired Student's t-test.

Results. Hemodynamic and O_2 transport variables are shown in the table. With 100% O_2 ventilation, PaO_2 increased and CI was unchanged, thus $\dot{D}O_2$ increased. However, O_2 extraction ratio (O_2e.r.) was reduced, particularly during the first 30 min. Thus $\dot{V}O_2$ was decreased 12% at 30 min of hyperoxia. Mean tissue PO_2 increased gradually in hyperoxia, but the difference from baseline did not reach significance until 90 min. Upon return to normoxia, CI and $\dot{D}O_2$ increased, O_2e.r. remained constant, and $\dot{V}O_2$ and tissue PO_2 returned to baseline. Systemic vascular resistance (SVR) was decreased.

Discussion. The paradoxical decrease in $\dot{V}O_2$ despite an increase in $\dot{D}O_2$ suggests maldistribution of blood flow and functional O_2 shunting. This is substantiated by an increase in $P\bar{v}O_2$ and a decrease in O_2e.r. Similar findings have been found in an animal model.[1] Increased PO_2 causes vasoconstriction and reduction of capillary density and flow in muscle preparations.[2] If microcirculatory control mechanisms protect tissue PO_2 during hyperoxia, overshooting of such response might lead to areas of relative tissue hypoxia. This hypothesis is supported by the finding that mean tissue PO_2 did not increase after 30 min hyperoxia. This resulted from a less normal distribution of the tissue PO_2 values: incidence of both low and high extremes increased during early hypoxia. This has been seen by others.[3,4] Some escape from this over-compensation to hyperoxia was evident by 60 min when $\dot{V}O_2$, O_2e.r., and tissue PO_2 increased. A decrease in SVR and an increase in CI during return to normoxia indicate release of constriction of the resistance vessels whereas an increase in $\dot{V}O_2$ and a decrease in $P\bar{v}O_2$ to baseline suggests improvement of blood flow at the distribution vessels. We conclude that in patients with PaO_2 > 100 mmHg, ventilation with 100% O_2 does not improve whole body oxygenation over a time span of 90 min. These findings do not imply, however, that brief preoxygenation prior to short periods of hypoventilation is useless or dangerous.

	Normoxia	Hyperoxia			Normoxia
Time (min)	0	30	60	90	120
PaO_2 (mmHg)	113±25 *	398±95	395±101	386±103*	100±14
$P\bar{v}O_2$ (mmHg)	41±5 *	53±7	50±7	50±7 *	41±5
PO_2tissue (mmHg)	27±8	28±10	33±10	37±12	29±11
CI ($ml\cdot min^{-1}\cdot m^{-2}$)	4.0±1.1	3.9±1.0	3.9±1.0	3.9±0.9*	4.4±0.7
$\dot{D}O_2$ ($ml\cdot min^{-1}\cdot m^{-2}$)	573±165*	609±157	607±190	597±199	624±175
$avDO_2$ (vol%)	4.2±1.1*	3.7±1.2	4.2±1.3	4.1±1.0	3.8±0.5
$\dot{V}O_2$ ($ml\cdot min^{-1}\cdot m^{-2}$)	155±31 *	137±33	147±28	143±27 *	154±25
O_2e.r. ($avDO_2/CaO_2$)	.28±.07*	.23±.05	.26±.06	.26±.06	.26±.04
SVR ($dyne\cdot cm^{-5}\cdot m^{-2}$)	977±265	980±235	1017±195	1017±205*	843±145

*=p<0.05 between consecutive measurements
all values are mean ± SD

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