TITLE: THE CEREBRAL METABOLIC RATE FOR OXYGEN IS NOT DEPENDENT ON CEREBRAL OXYGEN DELIVERY IN CRITICALLY ILL PATIENTS

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Introduction: Normally, systemic oxygen consumption (VO_2) is not altered by changes in systemic oxygen (O_2) delivery, except at very low levels of O_2 delivery (DO_2). However, in ARDS,[1] and below a critical threshold in anesthetized man,[2] VO_2 does appear to be flow-limited. The relationship between regional O_2 consumption and delivery has not been studied in critically ill patients. We performed studies of cerebral blood flow (CBF) and the cerebral metabolic rate for O_2 ($CMRO_2$) in six critically ill patients to determine whether systematic changes in cerebral oxygen delivery (CDO_2) would produce corresponding changes in $CMRO_2$.

Methods: After approval by the Clinical Research Practices Committee, written consent was obtained. CBF was determined by the clearance of intravenous 133Xenon (133Xe) measured by 16 gamma detectors. End-tidal 133Xe concentration was measured to correct for recirculation. CBF was calculated by the CBF_{15} technique, corrected for temperature and hematocrit. Mean global CBF was determined by averaging CBF from all detectors. In each patient a right jugular bulb catheter was placed. An initial measurement of CBF was then made. After this, CBF was increased or decreased so that $CMRO_2$ was calculated for each patient at a lower and higher CDO_2 ($CBF\ CaO_2$). CBF was altered by increasing or decreasing $PaCO_2$ by changing mechanical ventilatory rate so as to result in the safest change in systemic pH. CBF measurement was repeated 30 minutes after changing the ventilatory rate. One minute after injection of 133Xe, systemic blood pressure was recorded, and samples were drawn for measurement of arterial and jugular venous partial pressures of O_2 and carbon dioxide, O_2 saturation (SaO_2, $SjvO_2$), and hemoglobin (Hb). From these data were calculated arterial and jugular venous O_2 contents (CaO_2, $CjvO_2$), arteriovenous O_2 content difference ($Ca\text{-}jvDO_2$), $CMRO_2$ ($CBF\ Ca\text{-}jvDO_2$), and CDO_2. Mean $CMRO_2$ and CDO_2 data were compared using paired two-tailed t tests, significant at $p<.05$.

Results: At a mean lower CDO_2 of 3.8±1.8 (SD) ml/100g/min, $CMRO_2$ was 1.2±0.6 ml/100g/min. At a mean higher CDO_2 of 5.1±2.5 ml/100g/min, $CMRO_2$ was 1.4±0.9 ml/100g/min. While the difference in CDO_2 was significant, the difference in $CMRO_2$ was not. Mean arterial pressure, SaO_2, hemoglobin, and temperature were not significantly different between data points. Before CDO_2 was experimentally altered, CDO_2 averaged 4.4±1.9 ml/100g/min, and $CMRO_2$ averaged 1.3±0.5 ml/100g/min (normal: CDO_2 = 7-10 ml/100g/min; $CMRO_2$ = 3-3.5 ml/100g/min). The figure shows data for six subjects, two of whom were studied on two different days. Patients 1, 2, and 3 were septic, and patients 4, 5, and 6 had closed head injuries without intracranial hypertension. Triangles indicate CDO_2 and $CMRO_2$ obtained before alteration of CDO_2. Circles indicate CDO_2 and $CMRO_2$ obtained after alteration of CDO_2.

Discussion: O_2 consumption is not normally limited by O_2 delivery, except at very low levels of O_2 delivery. Changes in O_2 consumption, systemic or cerebral, are primary determinants of systemic or cerebral blood flow. In some critically ill patients this relationship is abnormal, and oxygen delivery becomes a primary determinant of oxygen consumption. In this series of critically ill patients, changes in CDO_2 did not change $CMRO_2$. Before experimental alteration of CDO_2, both CDO_2 and $CMRO_2$ were approximately half normal. The failure of $CMRO_2$ to change in response to alteration of CDO_2 suggests that reduced utilization was not due to a primary CBF reduction. Efforts to improve $CMRO_2$, and inferentially neurologic outcome, by increasing CDO_2 may be ineffective in some critically ill patients. However, in two of the head-injured patients, an increase in CDO_2 increased $CMRO_2$. In such cases an increase in CBF could be beneficial, or hyperventilation could further impair O_2 utilization. More studies are needed to define subsets of patients in which an increase in CDO_2 produces an increase in $CMRO_2$. It is also necessary to determine the most effective means of increasing CDO_2, and to determine whether this improves neurological outcome.

References:

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