Neurosurgical forum
Letters to the editor

Hyperoxia

To THE EDITOR: We read with great interest the article by Diringer and colleagues (Diringer MN, Aiyagari V, Zazulia AR, Videen TO, Powe WJ: Effect of hyperoxia on cerebral metabolic rate for oxygen using positron emission tomography in patients with acute severe head injury. J Neurosurg 106:526–529, April, 2007).

Abstract

Object. Recent observations indicate that traumatic brain injury (TBI) may be associated with mitochondrial dysfunction. This, along with growing use of brain tissue PO2 monitors, has led to considerable interest in the potential use of ventilation with 100% oxygen to treat patients who have suffered a TBI. To date, the impact of normobaric hyperoxia has only been evaluated using indirect measures of its impact on brain metabolism. To determine if normobaric hyperoxia improves brain oxygen metabolism following acute TBI, the authors directly measured the cerebral metabolic rate for oxygen (CMRO2) with positron emission tomography before and after ventilation with 100% oxygen.

Methods. Baseline measurements of arterial and jugular venous blood gases, mean arterial blood pressure, intracranial pressure, cerebral blood flow (CBF), cerebral blood volume, oxygen extraction fraction, and CMRO2, were made at baseline while the patients underwent ventilation with a fraction of inspired oxygen (FiO2) of 0.3 to 0.5. The FiO2 was then increased to 1.0, and 1 hour later all measurements were repeated.

Five patients were studied a mean of 17.9 ± 5.8 hours (range 12–23 hours) after trauma. The median admission Glasgow Coma Scale score was 7 (range 3–9). During ventilation with 100% oxygen, there was a marked rise in PaO2 (from 117 ± 31 to 371 ± 99 mm Hg, p < 0.0001) and a small rise in arterial oxygen content (12.7 ± 4.0 to 13.3 ± 4.6 vol %, p = 0.03). There were no significant changes in systemic hemodynamics or other blood gas measurements. At the baseline evaluation, bitemporal CBF was 39 ± 12 ml/100 g/min and bitemporal CMRO2 was 1.9 ± 0.6 ml/100 g/min. During hyperoxia there was no significant change in either of these measurements. (Values are given as the mean ± standard deviation throughout.)

Conclusions. Normobaric hyperoxia did not improve brain oxygen metabolism. In the absence of outcome data from clinical trials, these preliminary data do not support the use of 100% oxygen in patients with acute TBI, although larger confirmatory studies are needed.

Diringer and colleagues have used sophisticated 15O-labeled oxygen positron emission tomography (PET) to assess the metabolic effect of 1 hour of an inspired concentration of 100% O2 at normobaric conditions on severe TBI. The results in the five patients studied showed no improvement in brain oxygen metabolism.

We would like to make several comments and observations regarding this paper and the ongoing dialogue as to the role of hyperoxia in the treatment of patients with severe TBI. First, the authors are to be commended for performing this relatively difficult but very sophisticated multimodality 15O-PET imaging study of oxidative metabolism. This type of imaging has the advantage of providing a comprehensive metabolic “picture” of the whole brain as well as of regional areas.

In our view, there needs to be a clear distinction between the potential of hyperbaric hyperoxia compared with normobaric hyperoxia in the treatment of severe TBI. In the introduction, the authors state, “In one series in which the impact of hyperbaric hyperoxia (100% oxygen at 1.5 atm) on cerebral metabolism was studied, investigators found that in the 15% of patients with reduced CBF, there was a modest improvement in global CMRO2, 1 and 6 hours after hyperbaric oxygenation.” A closer reading of our paper, however, shows that patients with “normal” CBF also consistently showed improved CMRO2, 1 hour after hyperbaric oxygenation (HBO) treatment. Thus, 62% of all patients studied showed an improvement in CMRO2, 1 hour after HBO treatment. Only those patients with “raised” CBF did not show significant improvement in CMRO2 after 1 hour. It should be noted that all patient groups showed significant reductions in cerebrospinal fluid lactate levels 1- and 6-hours post-HBO treatment.

The timing of the posttreatment PET imaging is somewhat problematic. For example, in a lateral fluid-percussion injury in rats, mitochondrial function remained depressed immediately after 1 hour of HBO treatment at 1.5 atm. At 3 hours post-HBO treatment, however, during which time the animal received 100% O2 at normobaric pressures, mitochondrial function had recovered to a level similar to that of sham-injured animals. It is also clear from our own work, as well as that of Menzel and colleagues, that brain tissue PO2 increases in a progressive fashion over the first several hours of treatment with normobaric hyperoxia. If the hypothesis is that hyperoxia improves the subsequent ability to use delivered O2, then it may be that the optimal metabolic effect occurs posttreatment.

Our own ongoing prospective clinical trial comparing the effect of hyperbaric hyperoxia to normobaric hyperoxia, as well as work in injured animals, strongly suggests that HBO treatment has a greater beneficial effect. Using the rat model of lateral fluid-percussion injury, Daughtery and associates have documented that HBO produces brain tissue PO2 levels 10 times greater than those induced by normobaric 30% oxygen (30 mm Hg compared with 300 mm Hg, respectively) and three times greater than those generated by normobaric 100% O2 (100 mm Hg compared with 300 mm Hg, respectively). We have demonstrated the same differential brain tissue PO2 levels in humans. It is important to note that HBO at 1.5 atm increases the amount of dissolved O2 in the plasma from 0.3 ml/dl (in air) to 3.2 ml/dl, which is on the order of 10 times more.

Given the fact that there are diffusion barriers to oxygen delivery to brain tissue, the brain tissue PO2 levels achieved may be critical to mitochondrial function. Hyperbaric O2 greatly increases the oxygen diffusion gradient from the lungs to blood to brain tissue. Nonhemoglobin O2 transport may be more significant than previously believed. If, as it appears, the presence of O2 induces the mitochondria to begin to function, brain tissue PO2 levels may be critical. This finding could explain the more robust effect of HBO in the model of lateral fluid-percussion injury to the brain compared with normobaric 100% O2.
Neurosurgical forum

We will conclude with a question for the authors: Was there any attempt to analyze the metabolic response to 100% O\textsubscript{2} in pericontusional areas as compared with noninjured areas? We congratulate the authors on a very important study.

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References


RESPONSE: We thank Drs. Rockswold and Rockswold for their interest in our recent publication. We agree that a clear distinction needs to be made between normobaric and hyperbaric hyperoxia. We chose to focus on normobaric hyperoxia for practical reasons—the limited availability of hyperbaric chambers and the current suggestions that normobaric hyperoxia should be used to treat patients with head injuries.

The timing of the PET studies is described as “somewhat problematic” in their letter. We would have preferred to make two measurements over a longer timeframe, but practical considerations and regulatory limits on patient exposure to radiation made that impossible. In addition, as pointed out in their letter, Drs. Rockswold and Rockswold found a rise in CMRO\textsubscript{2} at 1 hour after treatment. Finally, we know of no mechanism to explain why transient hyperoxia would result in either a delayed or a sustained metabolic response. The increase in partial pressure of O\textsubscript{2} and O\textsubscript{2} delivery to the brain is limited to the time that the patient is subjected to hyperoxia.

In response to the authors’ question, the two patients with contusions had multiple, small contused areas (< 1 cm) in both hemispheres. Because of the small size and configuration of these lesions we felt we could not clearly identify and analyze regions that were entirely pericontusional. In addition, the small size of those contusions limited our ability to make reliable measurements due to the low number of PET counts and the inability to correct for the effects of partial volume averaging in those regions.

We agree that the use of hyperoxia in TBI requires further study. The use of hyperbaric O\textsubscript{2}, unlike normobaric hyperoxia, can significantly increase O\textsubscript{2} delivery and achieve a much higher PO\textsubscript{2} level, and thus may have different effects. Yet we stand by our conclusions that our data do not support the use of normobaric hyperoxia in patients with acute TBI. Finally, neither of these studies takes into account the potentially detrimental effects of hyperoxia on the brain (through free radical mechanisms) or the lungs.

We look forward to seeing more data from the authors’ ongoing prospective trial comparing normobaric and hyperbaric hyperoxia. (DOI: 10.3171/INS-07/10/0898)

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Suprapetrosal Craniotomy


Abstract

Object. The primary aim of this study was to establish standard sites for bur holes that maintain constant anatomical relationships with the skull base and neural structures and can serve as the basal aspect of supratentorial temporococcipital craniotomies.

Methods. To determine cranial–cerebral relationships, the authors created bur holes in 16 adult cadaveric skulls. Three bur holes were made on each side of the skulls (32 cerebral hemispheres). The authors then introduced plastic catheters through the bur holes to evaluate pertinent cranial and neural landmarks. The first bur hole, located anterior to the auricle of the ear, appeared to have a particular anatomical relationship with the anterior aspect of the petrous portion of the temporal bone and the most anterior aspect of the midbrain. The second bur hole, whose base was located 1 cm above the interface of the parietomastoid and squamous sutures, had a particular relationship with the posterior border of the petrous portion of the temporal bone and with the posterior aspect of the midbrain. The third bur hole, whose base was located 1 cm above the asterion, was mostly supratentorial and particularly related to the preoccipital notch.

Conclusions. The preauricular bur hole and the bur hole whose base was located 1 cm above the interface of the parietomastoid and squamous sutures delimit anteriorly and posteriorly the external projection of the petrous bone and the midbrain. The middle fossa floor is located anterior to the site of the preauricular bur hole, and the superior surface of the tentorium is posterior to the bur hole located above the parietomastoid–squamous suture interface. Together with the bur hole whose base is located above the asterion, these bur holes can be considered standards for temporococcipital craniotomies.

I wish to bring to the reader’s attention the strikingly similar work that my colleagues and I published about a decade ago that was unfortunately overlooked in the authors’ bibliography.1,2

In our work, the focus was to reliably locate the underlying transverse sinus, transverse–sigmoid junction, posterior fossa dura, and supratentorial dura above the transverse sinus, based on external landmarks as a guide to postero-lateral skull base approaches. We reliably determined the level of the distal transverse sinus to be located beneath a line of projection between the root of the zygomatic process and the inion. As Ribas and Rodrigues also found,

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