The Effect of Hyperbaric Oxygen on the Mental and Verbal Ability of Stroke Patients

By JOHN E. SARNO, M.D.,* HOWARD A. RUSK, M.D.,† LEONARD DILLER, PH.D.,‡ AND MARTHA T. SARNO, M.A.§

Abstract:
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Based upon the assumption that oxygen under increased atmospheric pressure (OHP) might improve the verbal and mental function of patients who had suffered vascular infarcts, 32 stroke patients were exposed to such an ambient atmosphere and tested under controlled conditions. The results make it clear that a single exposure to 100% oxygen under two atmospheres of pressure, which is productive of high blood oxygen levels, does not improve the communication and cognitive-perceptual function of these patients.

ADDITIONAL KEY WORDS cerebral infarct cerebral vascular accident aphasia psychological test arterial oxygen tension intellectual function

This project was undertaken in order to determine whether the functional residual of patients who had suffered a stroke could be increased by exposure to oxygen under conditions of increased atmospheric pressure. Specifically, it was reasoned that the efficacy of oxygen under hyperbaric conditions (OHP) could be tested by administering certain psychological and communication measures to patients who had sustained a cerebral infarct as a result of thrombosis, embolism or hemorrhage. Improvement in performance on these might justify the expansion of this therapeutic method.

The study required that patients be included only after a lapse of at least three months following the cerebral vascular accident; this was based on the generally accepted notion that spontaneous recovery of function will have occurred during that period. To study patients with more recent onset would have contaminated the effects of OHP through interaction with spontaneous recovery processes. Vignolo1 studied the evolution of aphasia and thought that physiological recovery probably occurred within two months. Culón2 found that patients with aphasia appeared to have reached maximum spontaneous recovery in both communication and intellectual function within 30 days after the onset of brain damage.

The idea that OHP might be of value to this group of patients was suggested by previous studies. Heyman et al.3 found that OHP could restore neurological function and maintain neuronal viability in a small number of acute stroke patients whose lesions were the result of emboli. Haas et al.,4 Ben-Yishay6 and Ben-Yishay et al.1 found that right hemisphere-damaged (RHD) patients improved on the performance of certain mental tasks while inhaling oxygen-enriched air via a nasal catheter. More recently, Jacobs et al.7 reported improvement with OHP in the cognitive function of 13 elderly males presumed to be suffering from senile arteriosclerosis.

Although we were aware that the neuropathology resulting from a cerebral infarct was

*Associate Professor, †Professor and Chairman, ‡Associate Professor, Clinical, and §Assistant Professor, Clinical, Institute of Rehabilitation Medicine, New York University Medical Center, 400 East 34th Street, New York, New York 10016.

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not reversible, it had been suggested that post-stroke patients suffered from respiratory inefficiency and some degree of chronic hypoxemia. In accordance with this idea, improved oxygenation of the cerebrum might ameliorate impaired function based on such hypoxemia.

It was further reasoned that there might be an area of impaired neuronal function in the tissue adjacent to the infarct and that OHP could have a sufficiently beneficial effect on this "damaged" area to result in improved cognitive-perceptual or communication function. In view of the well-known asymmetry of function between the two hemispheres, it was planned to study possible differential improvement associated with given hemispheric lesions.

In this report patients with lesions in the right hemisphere will be identified as right hemisphere-damaged (RHD) and those with lesions on the opposite side as left hemisphere-damaged (LHD).

Methods

Thirty-two post-stroke patients were studied. A total N of 60 was planned but difficulty in securing subjects, resulting from the development of negative patient attitudes, altered this plan. Some patients refused to participate when they learned of the absence of beneficial effects. Sixteen of the patients were right brain-damaged (RBD); 16 were left brain-damaged (LBD) and all of the latter were aphasic. Fourteen patients were rejected for a variety of contraindications.

The 32 patients included in the study ranged in age from 42 to 82 with a mean of 60.5. They were selected from the patient population of the New York University Medical Center, having sustained vascular strokes documented by the usual diagnostic measures. Twenty-nine of the patients were right-handed, two were left-handed and one was ambidextrous. All had a minimum eighth grade education and were native born or known to be fluent speakers of English. In each case the onset of illness was at least three months prior to participation in the study. Table 1 summarizes these and other demographic data by hemispheric site of lesion.

Prior to admission to the study each patient was examined by a physician on the hyperbaric medicine staff with special reference to the presence of pulmonary disease, a history or evidence of otolaryngological abnormality, and his general condition, aside from the neurological pathology.

A chest film and routine hematologic and urine tests were required to have been done within three months. Pure tone audiometric testing was performed to exclude patients with hearing loss.

All patients but one had a full battery of pulmonary function and blood gas studies to complete the screening process and eliminate those whose pulmonary status would interfere with the development of high blood oxygen levels.

Each patient admitted to the study was administered a standard battery of communication and/or cognitive-perceptual tests, described below. RBD patients received only the psychological test battery; LBD patients received both.

Patients were tested during and immediately following the administration of the appropriate gas mixture through a face mask.

Because the mask finally chosen for the study obscured the examiner's view of the patient's mouth, making the observation of oral movement and facial expression difficult, the communication test battery was administered without the mask.

Communication baseline studies were done outside the chamber at least 24 hours prior to the first chamber exposure. Post-exposure speech testing was done immediately after the patient left the chamber since elevated blood oxygen levels could be expected to persist sufficiently long for testing to be done.

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The baseline psychological test battery (administered to both RBD and LBD patients) was given in the hyperbaric chamber, mask in place, at sea-level atmospheric pressure (1 ATA) with 10.5% O2 as the inspired gas.

Each patient was then tested under two additional conditions, as follows:

1. Air under high pressure (AHP) — 10.5% O2 at 2 ATA for one and one-half hours.
2. Pure oxygen under high pressure (OHP) — 100% O2 at 2 ATA for one and one-half hours.
2. Oxygen under high pressure (OHP)—100% O₂ at 2 ATA for one and one-half hours.

According to the study design, each patient acted as his own control. The order of exposure was determined by a randomized, counterbalanced order of selection. Neither patient nor examiner knew which condition obtained during testing.

As noted above, speech testing was done immediately after exposure. The cognitive-perceptual tests were administered one-half hour after the pressure level of 2 ATA was reached and was completed by the end of the one and one-half hour period of exposure. The choice of 2 ATA was based on the expectation that adequately high blood oxygen levels could be achieved at this pressure. Arterial oxygen tension (Pao₂) were sampled throughout the study with the subjects at the required depth (2 ATA = 48 ft.). Determinations were done on blood samples on an instrument within the hyperbaric chamber. Values varied from 1075 to 1420 mm Hg.

During the early phase of the study, a clear plastic hood was tried; it was sealed with tape to the patient's neck and shoulders. This proved to be unsatisfactory since subjects complained of feelings of confinement and claustrophobia and objected to the noise and unpleasant sensation caused by the rapid flow rate of the cold oxygen. After trying a variety of masks, the one finally selected was the Demand Flor Airline Respirator with M-S-A Clearview Facepiece #84304 (Mine Safety Appliances Co., Pittsburgh, Pa.).

The hyperbaric chamber used is a walk-in, three-lock chamber, pressure-rated to 7 atmospheres. It is equipped with physiological monitoring equipment and has facilities for the administration of a variety of respiratory gas mixtures. The operating personnel are experienced diving engineers familiar with Navy diving procedures. A physician with experience in the field of hyperbaric medicine was constantly in attendance.

**Cognitive-Perceptual Test Battery**

**VISUAL CANCELLATION LETTERS (VCL)**
The patient is confronted with a sheet of paper containing six rows of letters totaling 300 letters in all, or 50 letters per row. He is asked to cross out the predesignated letter H, of which there are 80 in all. The task is complex and may be sensitive to a number of factors involved in visual attention and visual scanning in the brain-damaged subject. Subjects are scored for accuracy and time, enabling one to predict different aspects of the learning of functional skills in this group of patients.₁¹

**AUDITORY DIGIT SPAN (ADS)**
The well-known digit span test from the Wechsler Adult Intelligence Scale has been considered to be a test of concentration and attention involving retention of several digits in serial order, and requiring the patient to verbalize his responses. Digits forward are scored independently from digits backward. Pfizer¹² found ADS to be a potent discriminator between patients who showed brain damage and those who did not.

**BLOCK DESIGN (BD)**
This task is administered in accordance with the standard procedure of the WAIS. It has proved to be a useful predictor of success in mastering functional motor skills in RBD, but not in LBD.¹³

**PURDUE PEG BOARD (PPB)**
This well-known dexterity test has been a useful tool in detecting the effect of cerebral pathology on mental performance.¹⁴ Administered in the standard manner, the test is scored in terms of the number of pegs inserted into the left and right sides of a test board during three 30-second periods.

**TWO-POINT TACTILE THRESHOLDS (TPT)**
Following the procedure of Ben-Yishay,⁵ a Bell and Croyden caliper is employed to obtain two-point thresholds for the right and left thumbs. Thresholds are determined by the "serial exploration" method, whereby six thresholds are obtained for each thumb, three of which are in ascending order (in progressively larger increments of 2.5 mm) and three in descending order (progressively smaller increments). Impairment in sensory thresholds is frequent in brain-damaged individuals.¹⁵ The threshold score is expressed in millimeters as the minimum of two-point separation required for two points to be distinguished as separate, with 2.5 being the maximum score.

**MOTOR IMPERSISTENCE (MI)**
Eight tasks of motor impersistence described by Joynt and Benton¹⁰ were administered. These include (a) keeping eyes closed, (b) protruding tongue blindfolded, (c) protruding tongue with eyes open, (d) fixating gaze in lateral visual fields, (e) keeping mouth open, (f) fixating on examiner's nose during confrontation testing of visual fields, (g) head turning during sensory testing, and (h) saying "ah." These tasks have proved to be sensitive to...
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cerebral impairment.\textsuperscript{10, 17} Scoring of this test is based on the number of items passed, the maximum score being 8.

Communication Tests

1. The Token Test (TT)\textsuperscript{18} is known to be sensitive to deficits in the auditory comprehension of language in brain-damaged adults. First described in 1962, it received support from Orgass and Poeck,\textsuperscript{19} Boller and Vignolo\textsuperscript{20} and Swisher and Sarno,\textsuperscript{21} who reported that its power to detect receptive language disturbances was excellent; this was true even for patients without clinical evidence of aphasia. These studies have also established a systematic relationship between test scores and the severity of aphasia. Contamination of results by the educational level of the patient, often a limitation in clinical testing of aphasics, appears not to be a problem with the Token Test.

Tokens in the shape of circles and squares, varying in size and color, are placed before the patient. He is asked to manipulate them according to instructions which increase in length and complexity as the test progresses. The score is based on the number of correct manipulations in response to the commands.

2. The Functional Communication Profile (FCP)\textsuperscript{22} was designed to measure actual communication residual in aphasic patients. It is a rating scale consisting of 45 communication behaviors considered common language functions of everyday life. Ratings for each behavior are made on a continuum along a nine-point scale, from zero to normal, on the basis of a nonstructured interaction with the patient in a conversational situation. In this near-natural context, the examiner rates the actual use of residual communication skills made by the patient. Based on factor and multiple regression analyses of the ratings, weighted scores are converted to percentages for each of five categories: movement, speaking, understanding, reading and miscellaneous. An overall score reflects the patient's general communication function.

Reported studies have established the inter-rater and test-retest reliability of the FCP as well as its construct and concurrent validity.\textsuperscript{23, 24}

Results

OHP (100\% O\textsubscript{2} at 2 ATA) did not improve cognitive-perceptual function in RHD post-stroke patients or cognitive-perceptual or communication function in LHD patients.

The data did not warrant a detailed statistical analysis; nevertheless, results of the Token Test and FCP were statistically treated to illustrate and confirm the absence of improvement. By means of the Mann-Whitney U Test\textsuperscript{15} changes on the TT and FCP were evaluated as a function of oxygen within each trial condition. Since half of the Ss received 100\% O\textsubscript{2} in Trial 1 and the other half in Trial 2, one could conclude that the findings were not contaminated by a practice effect.

None of the comparisons yielded \(U\) values significant at the 0.05 level on the basis of the two-tailed test. In the case of the TT, \(U\) values of 27 and 18.5 were obtained for Trials 1 and 2 respectively. Similar results were noted for the FCP with \(U\) values of 31.5 and 20. The effects of 100\% O\textsubscript{2} within Ss were also compared regardless of order of administration. Again, no significant effect could be attributed to the high level of O\textsubscript{2} on either the TT or the FCP. The \(U\) values were 122 and 121 respectively.

Looking for the existence of a practice effect, the absence of 100\% O\textsubscript{2} within Ss was evaluated and for each test no significant variation was found, with \(U\) values of 116.5 and 124.5 for the TT and FCP respectively.

Discussion

The results of this study are clear. A single exposure to 100\% O\textsubscript{2} under two atmospheres of pressure does not improve the cognitive-perceptual or communication function of post-stroke patients. This does not preclude the possibility that longer exposure and/or higher pressures might give positive results. However, it would seem wise to postpone such a study until more is known about the cerebral circulation of these patients and in particular whether a state of relative hypoxemia does in fact exist in a significant segment of cerebral tissue.

A recent report\textsuperscript{20} on a single case suggests that OHP in combination with cerebral vasodilator drugs stimulates collateral or neovascular development in ischemic brain tissue. The report warrants attention since treatment was not begun until two months post-stroke and nearly full recovery is said to have occurred by five months after onset. The
authors assume that their patient's hemiplegia syndrome was due to ischemia and that OHP was responsible for revascularization of the area. If this was the case, there may be a place for OHP in the treatment of some strokes. In the cases treated in this study it was presumed that all of the patients had suffered unilateral cerebral infarcts.

The study of Jacobs et al., which reports improvement in cognitive function in a group of senile patients, has not been followed by reports of a persistent beneficial effect and has yet to be replicated. Further, these patients did not sustain cerebral infarcts.

Finally, it must be noted that improvement on specific tests of mental and communication ability can only be considered as indicators. Had the study produced positive results, it would then have been necessary to extend the treatment regimen in order to determine if useful functional improvement resulted. A question frequently asked by patient participants was, "Will the treatment help me to move my arm?" While one would accept a significant improvement in higher nervous functions as well worth the trouble and expense, it must be remembered that the spectrum of motor, sensory, visual, cognitive and language disturbances in this group of patients is wide, and worthwhile treatment must be reflected in improved day-to-day function.

In this respect, neither the research nor the clinical staffs reported behavior changes, positive or negative, in study patients.

Summary
Sixteen RBD and 16 LBD patients with post-acute cerebral vascular disease were treated in a hyperbaric chamber for 90 minutes with 100% O2 at 2 atmospheres of pressure. Each subject served as his own control, undergoing testing in the same atmospheric condition with 10.5% O2. Improvement was measured by a battery of cognitive-perceptual and communication tests. An analysis of the results revealed a total lack of treatment effect. It is concluded that hyperbaric oxygen, as administered in this study, does not improve intellectual or language function in post-stroke patients.

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