THE EFFECT OF HYPERBARIC OXYGEN THERAPY ON IMPROVEMENT OF SPEECH, LANGUAGE, AND COGNITIVE DEFICITS OBSERVED IN A TRAUMATIC BRAIN INJURY PATIENT

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ABSTRACT

INTRODUCTION:

The effectiveness of hyperbaric oxygen (HBO) therapy has been controversial as it concerns traumatic brain injury (TBI) patients. In this report we present the results of HBO treatment of a TBI patient presenting with right side dominant hemiparesis and some speech impairment. MATERIALS AND METHODS: The patient, 15 months post-traumatic brain injury, was treated with HBO at 1.5-2 ATA for 60-90 min once or twice daily for a total of 48 treatments. Prior to and after the course of HBO treatment the patient was evaluated for speech and language deficits with the Boston Diagnostic Aphasia Examination (BDAE) and for the cognitive deficits with the Ross Information Processing Assessment-Second Edition (RIPA-2). RESULTS: The BDAE showed improvements in subtests of Conversational and Expository Speech, 42% proficiency level to 71% in melodic line, 85% to 100% in phrase length, 85% to 100% in grammatical form but no effect (42%) in articulatory agility. In Auditory Comprehension there was a slight deficit in following commands, 93% improved to 100%. In Oral Expression there was improvement in verbal agility, 78% to 93%; in recitation, singing and rhythm, 83% to 100%; and in repetition in words, 80% to 100%. No deficits were observed in Understanding Written Language. In the cognitive deficits testing by RIPA-2 showed improvement in immediate memory, 50% tile to 84% tile; recent memory, 50% tile to 84% tile; orientation to environment, 50% tile to 91% tile; and recall of general information, 84% tile to 95% tile. HBO had no effect on temporal orientation (recent memory, 50% tile), temporal orientation (remote memory, 50% tile), spatial orientation (91% tile), auditory processing and retention (91% tile). HBO had a slight negative effect on problem solving and abstract reasoning, 75% tile to 64% tile and on organization, 84% tile to 63% tile. CONCLUSION: The results of this study suggest that HBO has the potential to improve speech, language and cognitive deficits in TBI patients.

INTRODUCTION:

The etiology of traumatic brain injury (TBI), the circumstances under which injuries occur and the degree of severity of injuries vary significantly, making an effective evaluation of the treatment of an injury difficult. The etiology ranges from all different types of accidental vehicular incidents, falls of varying heights, gunshot wounds, explosions, asphyxiation by various means, including near-drowning and strangulation. In addition the motor, neurological and cognitive deficits differ widely and may or may not manifest themselves immediately but may be delayed for weeks if not longer. Hyperbaric oxygen therapy became a possible treatment modality for these patients when a study in 1969 showed that HBO improved neurological deficits using EEG as a criterion (1). It was observed that 25/51 head injury patients treated with HBO at 0.25 mPa for 60 min once or twice daily (the exact duration of the treatment period was not stated) exhibited varying degrees of clinical improvement in particular “awareness and responsiveness” during the exposure to HBO. However, most of these improvements proved to be temporary and there was regression of these improvements some time after decompression. However, in three of these patients the effects appeared to persist. EEG monitoring of 18 patients showed marked improvement in 6 patients and some improvement in 6 others. As in the cognitive improvements these EEG changes regressed after decompression. It was also noted that the EEG in two patients deteriorated. The results of this study suggested that HBO might be a potential treatment modality in improving the clinical condition of TBI albeit most of the improvements occurred during the HBO exposure, which was lost after decompression.

Subsequently in 1992, a prospective randomized trial of 168 closed-head trauma patients was studied to evaluate the effects of HBO (2). The patients were treated with 100% O2 at 1.5 ATA for 60 min every 8 hours

for 2 weeks with an average of 21 treatments per patient. All patients received 400 mg of tocopheral (vitamin E) every 8 hours and also received prophylactic phenytoin sodium. The patients were followed up at 12 months. HBO did not change the mortality rate for patients with a Glasgow Coma Scale (GCS) score of 3, but significantly decreased the rate of those with a score of 4 to 6. HBO decreased the rate of patients with a score of 7 to 9 but it was not significant. When the overall mortality rate was calculated HBO significantly lowered the rate in the HBO treated patients (17%) as compared to the controls (32%). Unfortunately the patients were not evaluated for the GCS score after the HBO treatment or at the 12 month follow-up.

A study using SPECT/IMP scanning technique suggested an improvement in a 40 year old male TBI patient who was 6-7 months post-closed head injury treated at 1.5-1.75 ATA for 188 treatments. It was stated that the severe neurological deficits for memory, speech, language and cognitive function improved but no data were presented since the results were on videotape (3). In the studies cited above the HBO therapies were performed on acute TBI patients where as in this study the patient was 6 to 7 months post-injury. In addition the effects were not observed unless the number of treatments was increased substantially.

More recently 55 TBI patients were evaluated by GCS scores (4). The HBO treated patients were exposed to 100% O2 at 0.25 mPa for 40-60 min daily with a 10 min air break during each treatment. Therapy for 10 days was defined as 1 treatment period. Each treatment period was separated by 4 days. All patients were treated with 3-4 courses of HBO. The GCS scores for the HBO-treated patients increased from a baseline of 5.1 to 10.1 (after 1 course) to 14.6 (after 3 courses), both increases being statistically significant. For the control group the scores were 5.3, 8.1 and 9.5 respectively, but the scores were not statistically different from the baseline score. This study suggested that HBO therapy appeared to improve function, since the GCS which evaluates both motor and cognitive functions were increased. In addition it appeared that as the number of treatments increased the GCS scores improved, demonstrating a kind of dose-response effect. In our study the patient was a 15 month post-injury TBI patient presenting with a right side hemiparesis, speech and language and cognitive deficits. These deficiencies were evaluated before and after 48 HBO treatments. The data suggests that HBO improved some of these clinical deficits.

MATERIALS AND METHODS:

On 7/27/01 this 26 year old male sustained a severe brain trauma injury when he fell approximately 15 feet from a tree. At admission his Glasgow Coma Score was 3. Head computer tomography (CT) showed an acute subdural hematoma (approximately 8mm) predominantly in the left frontal parietal region with additional subdural hematoma in the left posterior parietal lobe. The patient also suffered a nondisplaced fracture of the right temporal bone. He underwent a left craniectomy to evacuate the hematoma. During rehabilitation he underwent extensive physical, occupational and speech therapies. On discharge the patient had mild to moderate cognitive communication deficits characterized by slow processing and increased response latency with flat affect and dysarthria. He had deficits for verbal memory, detailed information, verbal fluency and higher level reading comprehension. The patient was referred to Chico Hyperbaric Center (CHC) in October of 2002. Physical examination by our Medical Director, board certified in Hyperbaric Medicine, found in addition to cognitive and speech and language deficits limited movement of both upper and lower extremities with decreased strength on the right side. He was cleared for HBO therapy. All protocols were followed according to the Declaration of Helsinki and the patient signed an informed consent form detailing the treatment and patient rights. The patient, 15 months post-traumatic brain injury was treated with HBO at 1.5-2 ATA for 60-90 min once or twice daily for a total of 48 treatments. Prior to and after the HBO treatment the patient was evaluated by an outside speech and language pathologist for speech and language deficits with the Boston Diagnostic Aphasia Examination (BDAE) and for the cognitive deficits with the Ross Information Processing Assessment-Second Edition (RIPA-2).

RESULTS:

Boston Diagnostic Aphasic Examination The effects of HBO on conversational and expository speech are shown in Table 1. The melodic line and articulatory agility subtests showed severe deficits. Phrase length and grammatical form subtests showed moderate losses and following commands subtest showed a slight deficit. All of these losses were improved by HBO except for articulatory agility. Melodic line improved from 42%

proficiency to 71% but HBO did not have any effect on articulatory agility. Phrase length, grammatical form and following commands subtests all improved to 100% proficiency from 85%, 85% and 93% proficiencies, respectively. The effect of HBO on oral expression is shown in Table 2. There was a slight loss in nonverbal agility and moderate losses in verbal agility; in recitation, singing and rhythm; and in repetition of word subtests. There was a severe deficit in fluency in controlled association subtest. After HBO therapy verbal agility was improved from 78 % proficiency to 93%; recitation, singing and rhythm and repetition of words to 100% proficiency from 83% and 80%, respectively; and fluency in controlled association improved 75%. Nonverbal agility was not affected by HBO, however the proficiency level was already 91%.

When the patient was tested for understanding the written language (not shown) the subtests symbol and word discrimination; phonetic association; word-picture matching; and reading sentences and paragraphs showed no deficits (100% proficiency). HBO treatment did not result in any loss. There was a moderate loss in mechanics of writing, 80% proficiency, which remained the same after HBO (not shown). The Boston Naming Test showed no loss in word retrieval skills at 98% proficiency and remained the same after HBO (not shown). Ross Information Processing Assessment-Second Edition (RIPA-2) The effects of HBO on RIPA-2 subtests are shown in Table 3. There were severe deficits as a consequence of the brain injury. Particularly affected was memory. Immediate memory, recent memory, temporal orientation (recent memory) and temporal orientation (remote memory) were all at the 50% tile level as was orientation to environment. There were moderate losses in recall of general information (84th % tile); problem solving and abstract reasoning (75th % tile); and organization (84th % tile). Subtests spacial orientation and auditory processing and retention showed slight deficits (91st % tiles). HBO did not change the temporal orientation subtests but did improve both the immediate and recent memory from the 50th % tile to 84th % tile. Improvement was observed on subtests in orientation to environment from 50th % tile to 91st % tile and in recall of general information from 84th % tile to 95th % tile. In addition to the subtests in temporal orientations no changes were observed in spacial orientation and auditory processing and retention after HBO treatment. There were also increased deficits after HBO treatments in subtest problem solving and abstract reasoning from 75th % tile to 63rd % tile and in organization from 84th % tile to 63rd % tile.

With respect to motor function there was a significant improvement in the movements in his upper and lower limbs on the right side. The weakness and the gait of his right leg were significantly improved. He was able to throw a ball against the wall and retrieve it, which he was not able to do prior to HBO treatment. In addition dysarthria was no longer present.

DISCUSSION:

In this study a 26 year old male TBI patient 15 months post-injury was treated with 48 treatments of HBO. The patient presented with mild to moderate cognitive communication deficits characterized by slow processing and increased response latency with flat affect and dysarthria. He had deficits for verbal memory, detailed information, verbal fluency and higher level reading comprehension. These speech and language losses were assessed by BDAE and the cognitive deficits were assessed by RIPA-2. These assessment measures have been used to determine deficits in TBI, but to the best of our knowledge have not been applied to assess the effectiveness of HBO therapy on TBI patients who had previously undergone all conventional rehabilitation interventions after the acute injury stage. We have previously reported on the effects of HBO on a 36 month post-aphasic stroke patient, utilizing the BDAE (5).

The results of this study suggest that HBO had significant effects on deficits, which were present after the known conventional rehabilitation therapies had been applied. It also shows that not all subtests showed deficits because it would depend upon where the injury had occurred; the degree of severity of the injury; and/or the effectiveness of the rehabilitation program. In the situation where there was near or 100% proficiency, it probably would depend upon the vulnerability of that part of the brain associated with that test and/or TBI does not affect the test. In our patient deficits were not observed in the evaluation of understanding written language (data not shown). We had similar results with our aphasic stroke patient (5). Finally, there were deficits that were not improved by HBO. In this case it is not clear whether that particular deficit was refractory to HBO therapy or whether that deficit was present prior to the injury. There were a few moderate losses in which HBO increased the deficits. This might be important in TBI because the increased deficits were observed in problem

solving and abstract reasoning subtest and in the subtest for organization both of which are probably involved in executive function (6).

What are the possibilities that might explain the HBO effects observed in this study? Any mechanism invoking neuroprotection is probably not a good candidate because it is beyond the acute injury stage. Although preventing further loss would be desirable if such events were still occurring. It is probably reasonable to speculate that there might be more than one explanation. What is clear is that it takes time before one observes improvement in the patient. Coincident with this time element is increased number of treatments over this time period. What is also apparent is that the effect does not require constant elevated levels of tissue O2. The suggestion here is that HBO activates a number of genes, which might be involved in angiogenesis to get better brain perfusion for increased oxygen delivery and/or neurogenesis resulting in new neurons from CNS progenitor cells to replace the old damaged neurons.

One probable mechanism that might be invoked is the involvement of vascular endothelial growth factor (VEGF). HBO has been linked to increased VEGF and wound healing (7). In addition VEGF administered by intracerebroventricular injection into the brain in vivo has been shown to stimulate neurogenesis (8). And finally, VEGF applied directly into the dorsal hippocampus increased neurogenesis and facilitated learning and memory (9). Thus, it is possible that HBO might increase angiogenesis and neurogenesis in the brain via VEGF. Other processes that are likely to be involved might be the process of brain plasticity and/or synaptogenesis to repair previously damaged neurons.

CONCLUSION:

The results of this study suggest that HBO has the potential to improve speech, language and cognitive deficits as well as loss in motor function in TBI patients. Further studies with larger patient population are required to determine whether HBO is beneficial in post-injury TBI. In addition the improvement of cognitive function should be examined with more extensive neuropsychological testing to better assess the deficits before and after HBO therapy.

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Table 1. The Effect of HBO on Conversational and Expository Speech			
BDAE Subtest	% Proficency		
	PreHBO	PostHBO	Change
Melodic Line	42	71	29
Phrase Length	85	100	15
Articulatory Agility	4	24	20
Grammatical Form	85	100	15
Paraphasia in Running Speech	absent	absent	
Word Discrimination	100	100	0
Body-Part Identification	100	100	0
Following Commands	93	100	7
Complex Ideational Material	100	100	0

Table 2. The Effect of HBO on Oral Expression			
BDAE Subtest	% Proficency		
	PreHBO	PostHBO	Change
Oral Agility - Nonverbal Agility	91	91	0
Oral Agility - Verbal Agility	78	93	16
Automated Sequences	100	100	0
Recitation, Singing and Rhythm	83	100	17
Repetition of Words	80	100	20
Repeating Phrases	100	100	0
Word Reading	100	100	0
Responsive Naming	100	100	0
Visual Confrontation Naming	100	100	0
Fluency in Controlled Association	4*	7*	75%
Oral Sentence Reading	100	100	0
*raw scores Subtest			

Table 3. The Effect of HBO on Subtests of Ross Information Processingn			
BDAE Subtest	% Proficency		
	PreHBO	PostHBO	Change
Immediate Memory	50	84	34
Recent Memory	50	84	34
Temporal Orientation (recent memory)	50	50	0
Temporal Orientation (remote memory)	50	50	0
Spatial Orientation	91	91	0
Orientation to Environment	50	91	41
Recall of General Information	84	95	11
Problem Solving and Abstract Reasoning	75	63	-12
Organization	84	63	-21
Auditory Processing and Retention	91	91	0