The role of Hyperbaric Oxygen Therapy in Parkinson’s Disease

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Case I

• 64 years old previously relatively fit and healthy female

• History of chronic constipation, gingivitis, anosmia

• Develops tremor, bradykinesia, voice changes, rigid facial expression, stooped posture, loss of swinging of left arm, small cramped writing, intermittent dystonia on hands and feet

• Diagnosed with Parkinson’s disease!
What is Parkinson’s Disease?

Parkinson disease (PD) is a chronic progressive neurodegenerative disease of the nervous system characterized by the cardinal features of rigidity, bradykinesia, tremor and postural instability.
Categories

1. **Parkinsonism**: a group of disorders with Basal Ganglia dysfunction

2. **PD or idiopathic Parkinsonism**: The most common form

3. **Secondary Parkinsonism**: Viruses, toxins, drugs, tumors

4. **Parkinsonism plus syndromes**: conditions that mimic PD, symptoms caused by some other neurodegenerative diseases
Etiology

• The mechanisms of PD remain elusive

• Several genes identified including SNCA, PARKIN, DJ-1, PINK-1, and LRRK2 whose mutations are responsible for rare forms of Parkinson’s disease.

• oxidative stress, mitochondrial and proteosomal dysfunction and inflammatory system involvement

• ? Autoimmune disease
Signs and symptoms

Tremor
Subtle decrease in dexterity
Decreased arm swing on the first-involved side
Soft voice
Decreased facial expression
Sleep disturbances
Decreased sense of smell
Symptoms of autonomic dysfunction (eg, constipation, sweating abnormalities, sexual dysfunction, seborrheic dermatitis)
A general feeling of weakness, malaise
Depression or anhedonia
Slowness in thinking
Diagnosis

PD is a clinical diagnosis

No laboratory biomarkers exist for the condition

Findings on routine (MRI) and (CT) scan are unremarkable

MRI is useful to exclude strokes, tumors, multi-infarct state, hydrocephalus, and the lesions of Wilson disease.

PET and DaT scans
Treatment

Symptomatic drug therapy
- Levodopa/carbidopa: The gold standard of symptomatic treatment
- Monoamine oxidase (MAO)–B inhibitors
- Other dopamine agonists (e.g., ropinirole, pramipexole)
- Anticholinergic agents (e.g., trihexyphenidyl, benztropine)

Treatment for non-motor symptoms
- Sildenafil citrate (Viagra): For erectile dysfunction
- Polyethylene glycol: For constipation
- Modafinil: For excessive daytime somnolence
- Methylphenidate: For fatigue (potential for abuse and addiction)

Deep brain stimulation
Continuing Case I

Investigations

• FBC, U&E, LFT, Bone Profile, CRP: Normal
• MRI: Normal
• Stool comprehensive test: Candida overgrowth, low beneficial bacteria
• Urine organic and amino acids: high benzoic acid, arabinase, Citramalic Acid, Phenylacetic Acid (PAA), α-Hydroxyisobutyric Acid, Pyroglutamic Acid
• Toxicity: PCB, pesticides, mercury, aluminum
Treatment

- Nutrition: LCHF/ altered with ketogenic diet
- Exercise
- Optimizing gut flora
- Treating candida overgrowth
- Detoxification
- Optimizing methylation pathway
- Supplements (glutathione precursors, antioxidants, anti-inflammatories)
- Low dose naltrexone
- Bioresonance & PEMFR
- Non-laser light therapy
- HBOT x 40 sessions
<table>
<thead>
<tr>
<th>Unified Parkinson’s Disease Rating Scale</th>
<th>At the time of diagnosis in 2012</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Mentation, Behavior and Mood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Intellectual Impairment</td>
<td>Moderate memory loss</td>
<td>None</td>
</tr>
<tr>
<td>• Thought Disorder</td>
<td>Vivid dreams</td>
<td>None</td>
</tr>
<tr>
<td>• Depression</td>
<td>Sustained depression with vegetative symptoms (insomnia, poor appetite, loss of interest)</td>
<td>None</td>
</tr>
<tr>
<td>• Motivation/Initiative</td>
<td>Less assertive than usual</td>
<td>None</td>
</tr>
<tr>
<td>II. Activities of Daily Living</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Speech</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>• Salivation</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>• Swallowing</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>• Handwriting</td>
<td>Moderately slow &amp; small mostly legible</td>
<td>Normal</td>
</tr>
<tr>
<td>• Cutting Food &amp; Handling utensils</td>
<td>Can cut most foods with some difficulty</td>
<td>Normal</td>
</tr>
<tr>
<td>• Dressing</td>
<td>Needs assistance with buttoning &amp; sleeves</td>
<td>Normal</td>
</tr>
<tr>
<td>• Hygiene</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>• Falling</td>
<td>Rare falling</td>
<td>None</td>
</tr>
<tr>
<td>• Freezing when Walking</td>
<td>Occasional freezing</td>
<td>None</td>
</tr>
<tr>
<td>• Walking</td>
<td>Mild difficulty, no swing left arm</td>
<td>None</td>
</tr>
<tr>
<td>• Tremor</td>
<td>Moderate; bothersome to patient</td>
<td>Normal</td>
</tr>
<tr>
<td>• Sensory Complaints</td>
<td>Frequent painful sensations</td>
<td>Left leg-only when anxious</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occasional</td>
</tr>
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<tr>
<td>----------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>III. Motor Examination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speech</td>
<td>Monotone but understandable</td>
<td>Normal</td>
</tr>
<tr>
<td>Facial Expression</td>
<td>Masked face, loss of facial express</td>
<td>Normal</td>
</tr>
<tr>
<td>Tremor at Rest</td>
<td>Moderate in amplitude &amp; present most of the time</td>
<td>Only left leg when anxious</td>
</tr>
<tr>
<td>Action or Postural Tremor of Hands</td>
<td>Slight; present with action</td>
<td></td>
</tr>
<tr>
<td>Rigidity</td>
<td>Marked, FROM full range of achieved</td>
<td></td>
</tr>
<tr>
<td>Finger Taps</td>
<td>Moderately impaired</td>
<td>Normal</td>
</tr>
<tr>
<td>Leg Agility</td>
<td>Moderately impaired</td>
<td>Normal</td>
</tr>
<tr>
<td>Arising from Chair</td>
<td>Frequently unable to arise without help</td>
<td>Normal</td>
</tr>
<tr>
<td>Posture</td>
<td>Moderately stooped posture</td>
<td>Mostly normal</td>
</tr>
<tr>
<td>Gait</td>
<td>Short steps with shuffles</td>
<td>Normal</td>
</tr>
<tr>
<td>Postural Stability</td>
<td>Impaired</td>
<td>Normal</td>
</tr>
<tr>
<td>Bradykinesia</td>
<td>Moderate slowness, small amplitude of movement</td>
<td>Minimal slowness</td>
</tr>
</tbody>
</table>
## Unified Parkinson’s Disease Rating Scale

<table>
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<th>At the time of diagnosis in 2012</th>
<th>2018</th>
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</thead>
<tbody>
<tr>
<td>Dyskinesia</td>
<td>Daily</td>
<td>None</td>
</tr>
<tr>
<td>Early Morning Dystonia</td>
<td>Daily</td>
<td>None</td>
</tr>
<tr>
<td>Insomnia</td>
<td>Severe</td>
<td>Resolved</td>
</tr>
</tbody>
</table>

### In summary:

6 years after diagnosis of PD
- Not on any PD medication
- Disease not progressing
- Significant improvement with complete resolution of majority of the symptoms
Case II

53 years old male, CEO

• 1. Parkinsonism (2005) / 40 years old
• 2. Reduced uptake in the left putamen and minimally reduced uptake in the left caudate and right putamen (DAT scan December 2005)
• 3. Right hip replacement (July 2009)
• 4. Bilateral STN stimulators inserted (November 2012)
• 5. Medtronic ACTIVA PC box replacement (August 2017)

Present complaints: Painful dyskinesia, dystonia, left leg tremor, walking with extreme difficulty, insomnia

Medications: Stalevo 125mg qds and Amantadine 100mg
# Case II, Progress

<table>
<thead>
<tr>
<th>Before HBOT</th>
<th>After 20 sessions of HBOT with no other intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Upper body dyskinesia</em></td>
<td>30% improvement</td>
</tr>
<tr>
<td><em>Left leg tremor</em></td>
<td>50% improvement</td>
</tr>
<tr>
<td><em>walking with extreme difficulty &amp; only short distance</em></td>
<td>30% improvement</td>
</tr>
<tr>
<td>Severe rigidity, full range of motion achieved with difficulty</td>
<td>50% improvement</td>
</tr>
<tr>
<td>Freezing when walking</td>
<td>50% improvement</td>
</tr>
<tr>
<td>Poor quality interrupted sleep</td>
<td>Sleeps well</td>
</tr>
</tbody>
</table>
Numerous in vivo and in vitro studies confirm that HBOT induces neurogenesis


Potential mechanisms of HBOT and HIF-1α.

Hyperbaric oxygen therapy promotes neurogenesis: where do we stand?

Jun Mu,1,2 Paul R Krafft,1 and John H Zhang1,2,3

Abstract

Neurogenesis in adults, initiated by injury to the central nervous system (CNS) presents an autologous repair mechanism. It has been suggested that hyperbaric oxygen therapy (HBOT) enhances neurogenesis which accordingly may improve functional outcome after CNS injury. In this present article we aim to review experimental as well as clinical studies on the subject of HBOT and neurogenesis. We demonstrate hypothetical mechanism of HBOT on cellular transcription factors including hypoxia-inducible factors (HIFs) and cAMP response element binding (CREB). We furthermore reveal the discrepancy between experimental findings and clinical trials in regards of HBOT. Further translational preclinical studies followed by improved clinical trials are needed to elucidate potential benefits of HBOT.
"Understanding the Role of Hypoxia inducible factor during neurodegeneration for new therapeutics opportunities".

Merelj A¹, Rodriguez JC², Folch J³, Requeiro MR⁴, Camins A⁵, Lazarowski A⁶.

Abstract
Neurodegeneration (NDG) is linked with the progressive loss of neural function with intellectual and/or motor impairment. Several diseases affecting older individuals, including Alzheimer's disease, Amyotrophic Lateral Sclerosis, Huntington's disease, Parkinson's disease, stroke, Multiple Sclerosis and many others, are the most relevant disorders associated with NDG. Since other pathologies such as refractory epilepsy, brain infections, or hereditary diseases such as "neurodegeneration with brain iron accumulation", also lead to chronic brain inflammation with loss of neural cells, NDG can be said to affect all ages. Owing to an energy and/or oxygen supply imbalance, different signaling mechanisms including MAPK/PI3K-Akt signaling pathways, glutamatergic synapse formation, and/or translocation of phosphatidyserine, might activate some central executing mechanism common to all these pathologies and also related to oxidative stress. Hypoxia inducible factor 1-Δ (HIF-1Δ) plays a twofold role through gene activation, in the sense that this factor has to "choose" whether to protect or to kill the affected cells. Most of the afore-mentioned processes follow a protracted course and are accompanied by progressive iron accumulation in the brain. We hypothesize that the neuroprotective effects of iron chelators are acting against the generation of free radicals derived from iron, and also induce sufficient-but not excessive- activation of HIF-1Δ, so that only the hypoxia-rescue genes will be activated. In this regard, the expression of the erythropoietin receptor in hypoxic/inflammatory neurons could be the cellular "sign" to act upon by the nasal administration of pharmacological doses of Neuro-EPO, inducing not only neuroprotection, but eventually, neurorepair as well.
HIF prolyl hydroxylase inhibition increases cell viability and potentiates dopamine release in dopaminergic cells.


Abstract
Hypoxia-inducible factor (HIF) controls the expression of genes that adapts the cellular condition to accommodate oxidative stress. The potential beneficial effect of HIF up-regulation in ischemia has recently gained interest substantiated by the known HIF-regulation of erythropoietin and other hypoxia accommodating genes. So far the perspectives for HIF up-regulation has been focused on anemia and ischemia related diseases but little information is available about the relevance of HIF biology for neurodegenerative disease like Parkinson's disease. We therefore sought out to characterize the effect of HIF-up-regulation on survival and dopamine homeostasis in dopaminergic cells. We used a low molecular weight HIF prolyl hydroxylase (HPH) inhibitor and lentiviral based shRNA knockdown of HPH subtypes as molecular tools to increase HIF protein level and downstream HIF-regulated genes. We show that HIF induction results in protection against oxidative stress in cellular models based on PC12 cells and LUMHES cells. In addition, HPH inhibition elevates tyrosine hydroxylase expression and activity, which causes increased dopamine synthesis and release in both PC12 cells and a primary rat ventral mesencephalic cell culture. All together these findings suggest that prolyl hydroxylases may represent novel targets for therapeutic intervention in disorders characterized by dopamine homeostasis dysregulation like Parkinson's disease.
Evidence of inflammatory system involvement in Parkinson's disease
## Inflammatory factors involved in Parkinson’s disease

<table>
<thead>
<tr>
<th>Cytokines and other soluble molecules</th>
<th>IL-1, IL-2, IL-4, IL-6, IL-10, TNF-, IFN-, TGF-, IL-6, MMP-3, IL-17, and IL-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern recognition receptors (PRRs)</td>
<td>TLRs (TLR-1, -2, -3, and -7), NLRs, and complements</td>
</tr>
<tr>
<td>Immune cells</td>
<td>Microglia, monocyte, NK cell, T-cell, and B cell</td>
</tr>
</tbody>
</table>
Hyperbaric oxygenation in the complex treatment of Parkinson disease.

Abstract

Hyperbaric oxygenation (HBO) was used for the treatment of 64 patients suffering from parkinsonism of different etiology. HBO sessions were provided daily, 8-12 per course, the treatment pressure amounted to 1.3-2 atm exposure to 40-60 minutes. The beneficial effect was marked in 55 patients. The results of the treatment turned out better in vascular parkinsonism, in patients under 65 years, with a disease standing of 1-5 years. The akinetic-rigidity syndrome regressed to a greater degree, whereas in trembling hyperkinesis, HBO turned out to be less potent.

Hyperbaric oxygen treatment for Parkinson's disease with severe depression and anxiety: A case report.

Xu JY, Yang ST, Sha Y, Ge YY, Wang JM.

Hyperbaric oxygen therapy promotes neurogenesis: where do we stand?

Jun Mu, Paul R Krafft, and John H Zhang

Mild hyperbaric oxygen inhibits the decrease of dopaminergic neurons in the substantia nigra of mice with MPTP-induced Parkinson's disease.

Kusuda Y, Takemura A, Nakano M, Ishihara A.
Potential benefit of HBOT

- Inhibits neutrophil adhesion to endothelium cells
- Decreases IL-8, TNF-α and MMP-9; increases IL-10
- Enhances Nrf2 and HO-1
- Inhibits the expression of TLR4 and NF-κB
- Increases brain tissue pO₂
- Induces Bcl-2 and Bcl-xI, decreases Cas-3
- Inhibits permeability of mPTP
- Decreases endothelin, improves blood velocity; improves tissue metabolism
- Wnt, HIFs, cAMP, and CREB

Reduces inflammation

Inhibits apoptosis

Reduces ICP

Promotes neurogenesis and angiogenesis
Gut-Brain Axis

Increased intestinal permeability correlates with sigmoid mucosa alpha-synuclein staining and endotoxin exposure markers in early Parkinson’s disease.

Gut microbiota are related to Parkinson’s disease and clinical phenotype.

The gut-brain axis in Parkinson’s disease: Possibilities for food-based therapies.

Enteric glial cells: new players in Parkinson’s disease?

Stomaching the Possibility of a Pathogenic Role for Helicobacter pylori in Parkinson’s Disease.
Lewy pathology has been described in neurons of the enteric nervous system in nearly all Parkinson’s disease (PD) patients at autopsy.

The enteric nervous system not only contains a variety of functionally distinct enteric neurons but also harbors a prominent component of glial cells, the so-called enteric glial cells, which, like astrocytes of the central nervous system, contribute to support, protect, and maintain the neural network.

recently shown that enteric glial cell dysfunction occurs in PD.
Combining HBOT with other treatment modalities

- Nutrition: Ketogenic Diet?
- Optimizing gut microbiome
- Tailored supplements, vitamins and minerals
- Cannabidiol
- Low dose naltrexone
- Near infrared light therapy
- Repetitive transcranial magnetic stimulation
- Pulsed electromagnetic field therapy
- Exercise
PD depletes
- L-tyrosine
- L-dopa
- L-tryptophan
- 5-HTP
- Vitamin B6

L-dopa depletes
- L-cysteine (thiol)
- L-methionine (thiol)
- Glutathione (thiol)
- S-adenosylmethionine (thiol)
- Serotonin
- Dopamine
- Norepinephrine
- Epinephrine

Carbidopa depletes

The relative nutritional deficiencies of PD, L-dopa, and carbidopa
Cannabidiol

• Two studies presented at the 21st International Congress of Parkinson’s Disease and Movement Disorders further explored this possibility and assessed the effects of oral cannabidiol (CBD) and inhaled cannabis in patients with Parkinson’s disease.

• Maureen A. Leehey, MD, Professor of Neurology and Chief of the Movement Disorders Division at the University of Colorado in Aurora, and colleagues conducted a phase II, open-label, dose-escalation study to evaluate the safety and tolerability of CBD (Epidiolex) in Parkinson’s disease.

• Over a 31-day treatment period, patients received 5-, 7.5-, 10-, 15-, and 20-mg/kg/day doses of CBD.

• 13 patients, mean total UPDRS score significantly decreased from 45.9 at baseline to 36.4 at the final visit. UPDRS motor score decreased from 27.3 to 20.3. Mean rigidity from 9.14 to 6.29.

• Laurie K. Mischley, ND, PhD, MPH, Associate Clinical Investigator at Bastyr University Research Institute in Kenmore, Washington, and colleagues evaluated the effect of inhaled cannabis on Parkinson’s disease tremor using motion sensors and qualitative interviews.
LDN

• low-dose naltrexone blocks opioid receptors in the brain for few hours and creates a “rebound effect,” resulting in up-regulated production of the endogenous opioids beta-endorphin and met-enkephalin, as well as increased expression of opioid receptors

• both endogenous and exogenous opioids immune modulators

• suppress microglial activation via its antagonistic effect on toll-like receptor 4 (TLR4), a non-opioid receptor that is found on macrophages such as microglia
Neuron Photomodulation-light therapy

Turning On Lights to Stop Neurodegeneration: The Potential of Near Infrared Light Therapy in Alzheimer’s and Parkinson’s Disease

Daniel M. Johnstone, 1 Cécile Moro, 2 Jonathan Stone, 1 Alim-Louis Benabid, 2 and John Mitrofanis 2 *

Abstract

Alzheimer’s and Parkinson’s disease are two of the most common neurodegenerative disorders. They develop after a progressive death of many neurons in the brain. Although therapies are available to treat the signs and symptoms of both diseases, the progression of neuronal death remains relentless, and it has proved difficult to slow or stop. Hence, there is a need to develop neuroprotective or disease-modifying treatments that stabilize this degeneration. Red to infrared light therapy (λ = 600-1070 nm), and in particular light in the near infrared (NIR) range, is emerging as a safe and effective therapy that is capable of arresting neuronal death. Previous studies have used NIR to treat tissue stressed by hypoxia, toxic insult, genetic mutation and mitochondrial dysfunction with much success. Here we propose NIR therapy as a neuroprotective or disease-modifying treatment for Alzheimer’s and Parkinson’s patients.
Monitoring the progress of PD patients before, during and after HBOT

Unified Parkinson’s Disease Rating Scale

I. Mentation, Behavior and Mood

1. Intellectual Impairment
   0 = None.
   1 = Mild. Consistent forgetfulness with partial recollection of events and no other difficulties.
   2 = Moderate memory loss, with disorientation and moderate difficulty handling complex problems. Mild but definite impairment of function at home with need of occasional prompting.
   3 = Severe memory loss with disorientation for time and often to place. Severe impairment in handling problems.
   4 = Severe memory loss with orientation preserved to person only. Unable to make judgements or solve problems. Requires much help with personal care. Cannot be left alone at all.

2. Thought Disorder (Due to dementia or drug intoxication)
   0 = None.
   1 = Vivid dreaming.
   2 = “Benign” hallucinations with insight retained.

4. Motivation/initiative
   0 = Normal.
   1 = Less assertive than usual; more passive.
   2 = Loss of initiative or disinterest in elective (nonroutine) activities.
   3 = Loss of initiative or disinterest in day to day (routine) activities.
   4 = Withdrawn, complete loss of motivation.

II. Activities of Daily Living
   (for both “on” and “off”)

5. Speech
   0 = Normal.
   1 = Mildly affected. No difficulty being understood.
   2 = Moderately affected. Sometimes asked to repeat statements.
   3 = Severely affected. Frequently asked to repeat statements.
   4 = Unintelligible most of the time.
Thank you