CASE REPORTS

Report on Hyperbaric Oxygen Therapy: An Overlooked Therapeutic Option in Stroke Recovery and a Potential Source of Health Sector Revenue and Health Tourism

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ABSTRACT

This is a special case report on Jamaica's first use of hyperbaric oxygen therapy (HBOT) in stroke recovery, presented at the 56th Annual Conference of the Association of Surgeons in Jamaica, Kingston, Jamaica. The literature and story behind the trial – covering case history, diagnosis and discussion of outcome – technical issues, costing, insurance and possibilities for income earning and health tourism are explored.

Keywords: Cerebrovascular accident recovery, health tourism, hyperbaric oxygen therapy, stroke recovery, stroke rehabilitation

Reporte sobre la Oxigenoterapia Hiperbárica: Una Opción Terapéutica Ignorada en la Recuperación del Accidente Cerebrovascular y una Fuente Potencial de Ingresos en el Sector de la Salud y el Turismo de Salud

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RESUMEN

Se trata de un reporte de caso sobre el primer uso en Jamaica de la terapia con oxigenación hiperbárica (TOHB) en la recuperación del accidente cerebrovascular, presentado en la 56ta Conferencia Anual de la Asociación de Cirujanos de Jamaica, Kingston, Jamaica. Se exploran la literatura y la historia detrás de la prueba experimental − que abarca los antecentes del caso, el diagnóstico y la discusión de los resultados−, así como los problemas técnicos, costos, seguro, las posibilidades de obtener ingresos, y el turismo de salud.

Palabras claves: Recuperación tras un accidente cerebrovascular, turismo de salud, terapia de oxígenación hiperbárica, recuperación tras el ictus cerebral, rehabilitación tras del ictusractice

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INTRODUCTION

We present a special case report on Jamaica's first use of hyperbaric oxygen therapy (HBOT) in stroke recovery. There was absolute cooperation from the Principal of The University of the West Indies (UWI) through the Faculty of Science and Technology to the management and staff of The UWI, Centre for Marine Sciences, Discovery Bay Marine Laboratory (DBML) Hyperbaric Unit.

Hyperbaric oxygen therapy is 100% pure oxygen administered at greater than atmospheric pressure in a mono- or

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multi-place chamber housing one or more supine patients. It is safe and associated with few adverse effects (1). There are rare central nervous system (CNS) and pulmonary toxic effects including seizures, visual changes, sweating, muscle twitching, cough, pulmonary fibrosis and shortness of breath. The most common and easily managed complication is barotitis, which can lead to episodes of barotrauma such as rupture of the tympanic membrane or middle ear and sinus injury (1). As well as administration for decompression sickness, the Undersea and Hyperbaric Medical Society has approved use of HBO for conditions including burns, gas gangrene, soft tissue infection, skin graft, bone infection, intracranial abscess, anaemia and blood loss, crush injury, carbon monoxide poisoning, radiation complications and air and gas embolism (1). Hyperbaric oxygen therapy was also found to be effective in the experimental treatment of complications related to heroin overdose, arthritis, multiple sclerosis, cyanide poisoning, autism, stroke, chronic fatigue, allergy, senility, cirrhosis and gastrointestinal ulcer (1). The effects and suggested mechanisms of action are presented in the Table.

Table: Proposed mechanisms of action of hyperbaric oxygen in the treatment of patients with stroke

– Brain infarction is decreased
– Blood-brain barrier maintained
– Outcome improved and survival rate increased
– Motor deficits attenuated
– Complications of pneumonia, pulmonary and cerebral oedema and raised intracranial pressure, thromboembolism and recurrent cerebral circulatory disorders prevented
– Ischaemia-reperfusion injury is reduced
– Tissue/wound healing is accelerated
As hyperbaric oxygen therapy:
– Inhibits leukocyte activation and infiltration
– Inhibits cyclooxygenase-2 expression
– Reduces lipid peroxidation
– Increases oxygen level at neuronal tissues and maintains tissue oxygenation in the absence of haemoglobin
– Decreases immuno-reactivity of substance P
– Increases level of glutathione and induces expression of antioxidant enzymes
– Suppresses proliferation of macrophages and foam cells in atherosclerotic lesions
– Stimulates angiogenesis and neovascularization
– Increases the flexibility of red cells
– Preserves intracellular adenosine triphosphate

CASE REPORT

The 68-year old client experienced a stroke in 2013, presumably of embolic aetiology in the setting of atrial flutter (heart rate of 140–144 beats per minute), which had developed at least one month prior to stroke onset. Significantly, he had undergone an adenosine stress test outside of protocol approximately six months before the onset of atrial flutter. A middle cerebral artery, acute non-haemorrhagic stroke was diagnosed, affecting the left corona radiate, and caused a mild right upper motor neuron facial palsy, right-sided upper and lower limb weakness and paraesthesia, moderate gait ataxia, right homonymous hemianopia and moderate impairment of short-term memory and executive functions.

Over the following six months, all the above conditions improved or resolved except paraesthesia and the client regained complete autonomy. The client underwent HBOT during this period. The above events also overlay pre-existing diabetes mellitus, gout, mild hypertension, chronic alcohol abuse without addiction and a history of cardiac arrest six years previous to the stroke, associated with *Streptococcal* pneumonia.

Holistic rehabilitation included traditional medical treatment and nutritional and environmental supplementation (2–5). He was given pentoxyfilline, but compliance and dose might have compromised efficacy (6, 7). He refused to eschew alcohol completely. Rehabilitation helped to reduce depression.

Hyperbaric oxygen therapy was chosen based on the coordinating author's familiarity with SCUBA diving and observational experience of longstanding use of HBO and ozone central nervous system (CNS) therapies in Cuba *via* the HelpAge programme of the Department of Community Health and Psychiatry, The UWI from 1990–1992. The client's other attending physicians and DBML chamber staff were trained in HBOT for decompression illness and other approved indications, as was the client himself. Additionally, indication for HBOT CNS rehabilitation was found (8) and there was the serendipitous acquisition by the DBML of a new custom-built chamber with assistance from the Tourism Enhancement Fund (TEF).

Treatment

The prescribed HBOT schedule was based on a synthesis of protocols learned *via* the Cuban Ibero-American Centre for Research on Ageing, Longevity and Health (CITED), Havana; the Diving Diseases Research Centre, Plymouth, United Kingdom; International ATMO, Inc. Training Centre, San Antonio, United States of America (USA); the Divers Alert Network (DAN); the Undersea Hyperbaric Medical Society, North Carolina, USA; the US Navy Diver's Handbook, Revision 6, Table 5 (9), traditionally used to treat Type 1 decompression sickness (usually just painful to the patient) and empirical observation of the case as treatment progressed.

Hyperbaric oxygen therapy began approximately three months after the stroke and continued for approximately three months for a total of 27 sessions. The sessions were scheduled as two weeks of alternate days and then two weeks with one session per week, repeating this cycle for three months, skipping weekends and some holidays. Vitals were recorded before and after each session. As outlined below, resources permitting, the CNS lesion and vision were monitored as best possible.

First and second sessions were used to acclimatize the client at 20 minutes of O_2 exposure at 2 and then 3 ATA (multiples of surface atmospheric pressure); the latter of which was the target 'depth' for full protocol. He did well at both pres-

sures and full protocol was undertaken. Figure 1 represents the final protocol. General progress is represented in Fig. 2. Note the apparent difference in O_2 effect on retina/other optic tissues (toxicity if over exposed) and eye muscles (rejuvenation after fatigue if dosing appropriate).

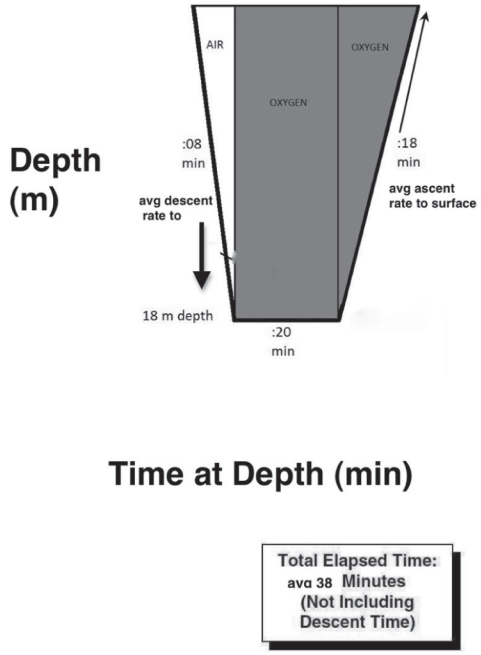


Fig. 1: Depth/time profile – final hyperbaric oxygen therapy protocol. Source: (9)

Start HBOT month 3 after CVA			month 4 after CVA					month 5 after CVA	END HBOT- month 6 after CVA
1st exposure 20min at 2 ATA descent very slow	2nd exposure 20min at 3 ATA descent very slow.	3rd exposure 70min at 3 ATA descent time cut resulting in diaphoresis.	7th exposure 70min at 3 ATA	8th exposure cut to 20min at 3 ATA	9th exposure 20min at 3 ATA	10th exposure 20min at 3 ATA	11th exposure titrated back up to 35 min at 3 ATA	14th exposure 35 min at 3 ATA	Continued 35 min exposures.
Acute infarcts had been seen on small vessel ischemia 3 mons previously. Partial recovery of vision already noted at this time and	Acid Reflux treated with OTC	Slept very well this night	Cloudy vision for 45 mins after session 3rd field of vision measurement & overall improvement continued. Fig 4c	No cloudy vision. No resolution of distal limb numbness up to this point	No cloudy vision. Easier reading of computer.	No cloudy vision.	Marked ^ in cog skills noted this week, attention span, reading emails, management discussions	Tired eyes fuzzy before, cleared after HBOT. Over last 2 weeks feeling better, reflexes sharper (subj), occupation pattern resumed. Distal limbs still numb. 1 episode disorient. obs.	Steady progress, no further major events or marked recovery gains, distal limb numbness remained, executive mental functions steadily improved
			Ataxia			resolving ->			

Fig. 2: Milestones – general progress of client during hyperbaric therapy (HBOT) over 27 sessions following cerebrovascular accident (CVA/stroke).

DISCUSSION

Figure 3 represents return of fields of vision, pre-treatment to immediately post treatment. Figure 4 represents a brain imaging composite of reports – pre-treatment (three results) to approximately two months through HBOT protocol (one result). The brain lesion exhibited resolution. Acute haemorrhagic features seen in the 3rd of the impressions listed in Fig. 4 are most commonly consistent with cardio-embolic, ischaemic infarcts – the client's diagnosis. The haemorrhagic change is hypothesized as due to any of three possible causes of reperfusion: recanalization of an occluded vessel, collateral blood supply to the ischaemic territory or disruption of the blood-brain barrier and usually occurs approximately within two weeks after stroke (10).

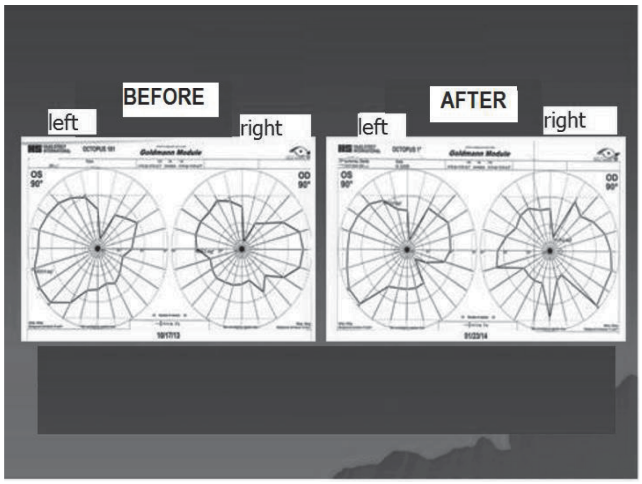
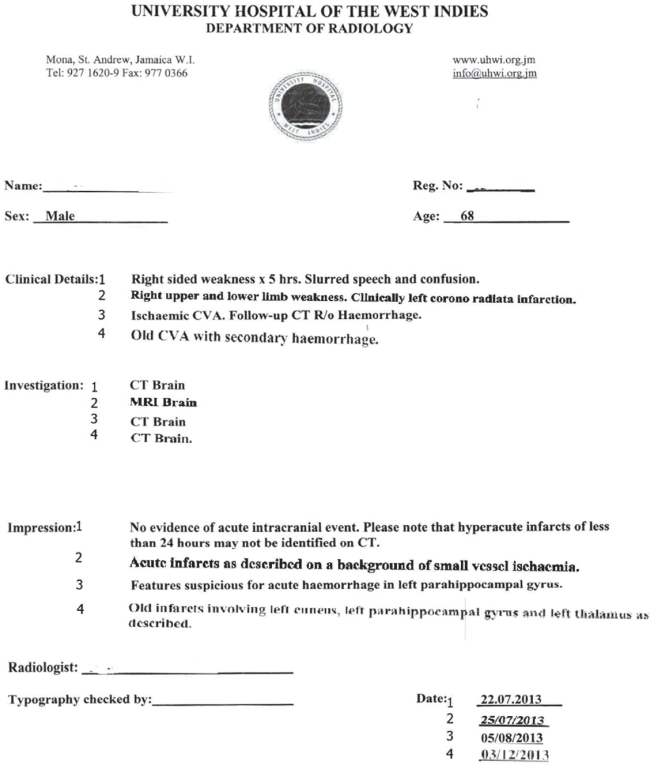


Fig. 3: Progress return of field of vision over three-month course of treatment, pre-treatment to immediately post treatment (October 2013 to January 2014).



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Name:_____ Reg. No: _____

Sex: Male Age: 68

Clinical Details:
1 Right sided weakness x 5 hrs. Slurred speech and confusion.
2 Right upper and lower limb weakness. Clinically left corono radiata infarction.
3 Ischaemic CVA. Follow-up CT R/o Haemorrhage.
4 Old CVA with secondary haemorrhage.

Investigation:
1 CT Brain
2 MRI Brain
3 CT Brain
4 CT Brain.

Impression:
1 No evidence of acute intracranial event. Please note that hyperacute infarcts of less than 24 hours may not be identified on CT.
2 Acute infarcts as described on a background of small vessel ischaemia.
3 Features suspicious for acute haemorrhage in left parahippocampal gyrus.
4 Old infarcts involving left cuneus, left parahippocampal gyrus and left thalamus as described.

Radiologist: _____

Typography checked by:_____

Date:
1 22.07.2013
2 25/07/2013
3 05/08/2013
4 03/12/2013

Fig. 4: Brain image composite: three results pre-treatment and one result two months into treatment (October 2013 to January 2014).

The UWI insurance liability was waived as its mandate covers treatment of decompression illness only and the client was charged for disposables and contracted services due to Jamaica's financial constraints. Ethico-legally, experimental treatment is never charged and HBOT for stroke rehabilitation remains experimental in Jamaica.

Logistics were solved by a car rental company, as was the safety concern of travelling over mountains in under 12 hours post treatment in regards to possible side effects and fatigue.

The final protocol was determined based on the client's age, medical condition and therapist familiarity with HBOT. Known principles of replacement/supplementation (with O_2 in this case) resulting in cure/restoration of function were also considered, as were naturopathic principles of more slow-acting use of therapy (also O_2 in this case) to treat the underlying cause of disease in chronic conditions compared to allopathic traditions, which are largely based on treatment according to symptoms with speed of resolution a primary aim (11). Slow recovery of nerve tissue and a neuroplasticity period of at least six months post stroke with neurological sequelae were also considered (12). With the right therapies, data now challenge this period as being longer (8). It was thought that although 27 sessions were fewer than best practice, 20 minutes of breathing 100% O_2 (one of the fastest CNS modulators) for this number of sessions should provide worthwhile support in overcoming a stroke that evolved over 12 hours, occurring in mixed air at low altitude. Final protocol entailed a 35-minute oxygen breathing period (Fig. 1). Logistics and finances precluded the six-month protocol observed in Cuba, as was the experimental nature of HBOT for stroke rehabilitation in Jamaica. The authors agreed on an acclimatization period to observe the client for tolerance of HBOT. They also agreed that daily monitoring and adjustment of protocol, as necessary, were required both during sessions and on non-session days. The latter was achieved *via* face to face, computer and telephone contact and guided by HBOT indications (13).

The final treatment protocol at 18 m depth and 35-minute exposure treatments gave due consideration to the need for adjusting the recompression schedules usually used by DBML, *ie* increased pressure and long exposure sessions used over days and possibly weeks to a final less aggressive, multiple depth/exposure combination, administered over months to facilitate elevated O_2 saturation levels in injured/ischaemic tissues. Figure 1 demonstrates 20 minutes of 100% oxygen exposure at 18 m which normally necessitates a five-minute air break to prevent O_2 toxicity. In this case, O_2 was safely continued by administering it on ascent (compare Figs. 1 and 5).

After treatment number seven, following the more aggressive recompression-type protocol, the client had 'fuzzy' vision for 45 minutes after therapy, the presumed first signs of O_2 toxicity to optic tissues and this event was the only adverse one during the course of treatment. According to HBOT indications, this occurrence is more likely in diabetics with increasing age. The reference also implied that even so, in our

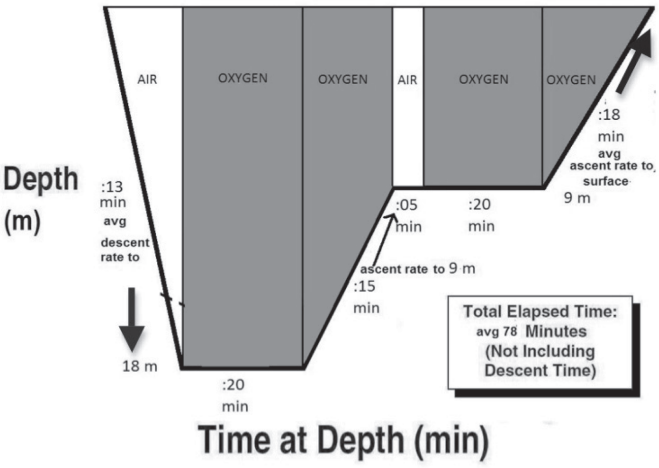

Fig. 5: Depth/time profile – interim hyperbaric oxygen therapy protocol. Source: (9)

client, this adverse reaction had occurred earlier than the literature might lead one to expect it would. Immediate steps were taken to ensure safety and correct the situation. The third field of vision check was done and although it showed overall gain, no chances were taken and the following three sessions entailed only 20-minute O_2 exposures at 3 ATA and no further adverse events occurred. After the third uneventful 20-minute session, the client was titrated to the final protocol (Fig. 1). Vitals exhibited an unremarkable pattern throughout.

Our team has no local case for comparative purposes but offers the following observations. Hyperbaric oxygen therapy for decompression illness and all other indications have similar objectives, namely the re-establishment of adequate blood supply to hypoxic/anoxic tissues. Though the protocols may differ regarding the various indications for HBOT, the safety guidelines remain the same. The earlier acute and rehabilitation intervention is undertaken, the better it is for stroke clients. Furthermore, unlike current advanced cardiac life support (ACLS) practice, had the client been in a Cuban HBOT setting, emergency protocol for O_2 administration would not have been based only on blood-gas measurement. It would have been routine and variable with close monitoring and consideration of individual tolerance despite normal, measured blood oxygen levels because non-haemorrhagic stroke is essentially an ischaemic event.

Return of vision may not be attributable to HBOT but one expert felt the vision field scans were remarkable enough to warrant further investigation (personal e-mail communication from Mr B Moriarty [Private practice at Prospect Eye Clinic, UK], December 1, 2013).

During treatment, the client refused to eschew alcohol completely; this fact synchronistically corresponded to findings that two jiggers of hard alcohol, two glasses of wine or two beers daily may be beneficial in CVA recovery concerning regeneration of the brain's microvasculature; circulatory benefits are already generally known (14). Small amounts of alcohol intake may assist revascularization around a lesion.

Rehabilitation of strokes should be holistic including: diet, mental status, physical and social activity. Each HBOT case is individual and must be tailored and strictly monitored with protocols designed and adjusted as required (14).

There is great potential for this therapy in Jamaica for an expanding range of medical conditions (15) and it has a place in rehabilitation here despite current financial, insurance and logistical challenges. There is no hyperbaric centre in Jamaica's two cities. It only exists in a relatively remote rural research site with some housing available.

The full cost of the above course remains to be itemized and totalled, excluding transport and housing at this time. Comparative financial data from centres in the USA show great potential for income generation should HBOT become a health tourism entity, even adding transport, airfare and room and board. Examples ranged from approximately US$1200–4600 per session, depending on case-type, session length and market forces. In cases where Medicare was accepted, Medicare paid anywhere from US$300–500 per two-hour treatment (treatment only; physician/facility fees not included) with up to another US$400 to the facility and US$100 to the hyperbaric doctor. In contrast, private insurance paid up to US$4000 per session (treatment only; physician/facility fees not included) and also employed a system of separation of payment.

In one Mexican facility, locals are charged US$150 per hour and foreigners US$1000 per hour, including all fees (personal communication from a Mexican colleague, May 2014).

There have been two other HBOT, wound healing trials at the DBML Unit, and HBOT in Jamaica could join the growing world recognition of this useful treatment and research tool which remains expectant here under the influence of Western medical associations (16). It has high prospects for earning and reproducible research data but would currently depend on one commissioned chamber at The UWI DBML, Jamaica. Established with TEF aid in 2012, it is an eight-man, double medical lock chamber allowing 6' 6" walk-in entry, insured only as a decompression illness rehabilitation unit. It is available to The UWI staff or students engaged in underwater research island-wide as well as the local fishing and tourism industries.

There are two other potentially usable HBO chambers at the DBML but both are decommissioned. One is a recently decommissioned (2012) 60-inch diameter 1976 model. It is a medium sized, two-man, double lock chamber and is available for re-commissioning at this facility. Re-commissioning would provide a second unit, allowing uninterrupted HBOT sessions, since dive accidents are unpredictable. Hyperbaric oxygen therapy training of University Hospital of the West Indies (UHWI) staff could then proceed while long-term plans are fulfilled for installation of HBOT at that hospital, which is located in Kingston. The UHWI is hoping to marshal currently unused chamber resources in the service of the Sickle Cell Unit, Mona (personal communication with Mr T McCartney, then Chief Medical Officer, UHWI, 16 March 2014).

Cuba uses this form of therapy for a range of medical conditions, from CNS to wound healing and cancer therapy, and the authors understand that the Cayman Islands uses it for wound healing, with one protocol reported as 1.5 ATA for two hours per session every day (personal communication with Mr C Smith, HBOT client in Cayman Islands, March 2014).

We reiterate the potential for the expansion of HBOT in Jamaica to benefit both local and overseas patients and clients in providing essential and elective services with great income earning potential and in facilitating pioneering research in this field of medicine in the Caribbean.

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