THE CLINICAL APPLICATION OF HYPERBARIC MEDICINE

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ABSTRACT/SUMMARY

An attempt has been made to determine the clinical usage of hyperbaric medicine (OHP) in some 55 North American OHP hospital units during the years 1971 to 1976 (included). Questions were asked in terms of conditions (diseases) treated and the actual yearly number in each category, the location of active functional chambers, types of chambers used, running costs and the medical and chamber personnel requirements.

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INTRODUCTION:

Following an initial surge of interest in hyperbaric medicine (OHP) and research in the mid 1960's. (1,2) interest declined as the novelty wore off. Today we are in another resurgent period, but enthusiasm is being balanced by a very strong desire to prove the efficacy of OHP by conducting well controlled trials. Perhaps this will result in OHP becoming a fully respected form of therapy in the ever increasing therapeutic armamentarium.

A survey of the clinical usage of hyperbaric medicine (OHP) in some 55 North American OHP hospital units during the years 1971 to 1976 was conducted. Questions included the conditions treated, the yearly number in each category, the location of active functional chambers, types of chambers used, operating costs, and the medical and chamber personnel requirements.

METHOD:

Using the "Directory of the World Wide, Shore-based Hyperbaric Chambers" (3), 51 OHP chamber sites were selected because of their stated objectives of use for medical treatments and research. A further 5 were added from other sources of information. (4)

A short questionnaire was sent to these 55 units. To increase the chances of completion and return, the questions were to the point and few in number (see Illustration 1). After six weeks, a second letter with a copy of the questionnaire was sent to the non-responders. Two months later, a telephone call was made to those still failing to complete and return the questionnaires.

No attempt was made to evaluate protocols, outcome and success of treatments, complications rate and types of complications, or problems of running a program of this nature.

RESULTS:

Table I shows the response to the questionnaire.

A breakdown of the nonfunctional units is seen in Table II. The Armed Forces Units in this group were engaged in research and were not open to civilian use.

The conditions treated over the six year period (1971 - 1976) are shown in Table III.

Miscellaneous conditions treated with OHP

A bewildering array of conditions have been treated in chambers and because of sparcity of numbers and lack of controls, the effectiveness of treatment can be doubted. (see Table IV)

Types of chambers used

As can be seen from Table V, the numbers of monoplace and multiplace chambers are about equal. However, it would appear that the multiplace chambers were more active, but one multiplace unit has treated 2268 of the total 5582 multiplace chamber cases.

Six of the monoplace and two multiplace chambers are now no longer functional.

Costs

The returns on this part of the questionnaire were poor - 18 out of 41 units.

There was a wide range of costs from no charge to $200 per dive. One vascular unit received a $100,000 per year grant and was operating on between 75 to 100 carotid artery, aortic aneurysms yearly in addition to a yearly average of 37 cases with other conditions. (Table VI)

Types of hospitals

The types of hospitals maintaining chambers are indicated in Table VII.

Staffing

An attempt was made to assess the staff requirements for each dive. These varied greatly with the type of unit, gravity of illness and condition being treated. In 35 out of 41 units a doctor was present at some time, particularly for the critically ill cases or first dives of new patients. At all other times a registered nurse and at least one other person were present with the operator of the chamber. The other person was a respiratory therapist, technician, military corpsman, researcher, medical assistant or another diver.

Discussion

The Ad Hoc Committee on Hyperbaric Oxygen Therapy of the Underseas Medical Society has compiled a report indicating treatment conditions covered by Medicare. Included are acute gas embolism, acute carbon monoxide &acute cyanide poisoning, decompression sickness, gas gangrene, Meleney ulcer, exceptional blood loss anemia (religious grounds), compromised skin grafts, smoke inhalation with presumption of CO poisoning, acute thermal burns, traumatic head and spinal cord injury, refractory osteomyelitis, osteoradionecrosis, soft tissue radionecrosis, acute peripheral traumatic ischemia, · resuturing severed limb, and as an adjunct to surgical therapy involving cervical arteries, abdominal aorta, open heart surgery in infants. Treatment of the covered conditions constitutes 71.06% (5499) of the total case load (7738). Therefore, some 28% of the treatments are not accepted by Medicare. Controlled trials are needed to gain the knowledge to refute or validate the claims of OHP therapists who advocate the therapies not recognized by Medicare.

Cancer Therapy

Two of the chambers involved primarily in cancer therapy stopped using OHP as an adjunct to radiotherapy. Radiation under hyperbaric conditions has not been demonstrated to be unequivocally superior to well fractionated, well conceived, conventional radiotherapy (5). Any resulting gains in survival from the addition of hyperbaric oxygen were limited, especially with more advanced stages of disease. Tumors of the head and neck offered the most promising site of further study and continued trials with OHP.

Accumulated basic radiobiologic data confirms the importance of the "oxygen effect" in the treatment of malignant disease. The problem lies in deciding what the optimal dose fractionation of radiation in OHP should be. Large, well controlled randomized studies with statistically significant results should help resolve this problem.

Osteo and Soft Tissue Radionecrosis

Radionecrosis is a late complication of radiation therapy and due to ischemia from progressive obliterative endarteritis. Hart and Mainous (14) described the results of their work showing that pain which is usually crippling is relieved and that wounds either heal or accept a skin graft readily. The patient must stop smoking, debridement and irrigation are done repeatedly, and tetracycline or systemic antibiotics based on culture and sensitivity are given. OHP up to a total of 80 exposures, once a day, with a one to three month break after half the treatments have produced dramatic results. Other researchers including Dr. R. Tobey, Bethesda Naval Hospital, Maryland and Dr. J. Farmer, Duke University Durham, North Carolina are confirming these results. Strict protocols of patient selection, documentation and follow up are required and multicenter trials will help achieve a statistically significant result.

Chronic Osteomyelitis

There is increasing evidence favoring the use of OHP in the treatment of chronic osteomyelitis. (7,8,10,13). The continued yearly increase in number of cases treated (in 1971, 89 cases and in 1976, 247 cases) supports this evidence. OHP appears to have a definite role in the treatment of this condition and well controlled clinical trials are in progress (4). Centers are reporting a 60 to 90 percent complete healing rate of previously refractory osteomyelitis. It is essential to couple hyperbaric oxygen with sequestrectomies and appropriate antibiotics. Hunt et al. (9) believe that a state of chronic tissue hypoxia exists and that OHP permits diffusion of oxygen to provide tissue tension adequate to activate fibroblasts and osteoblasts with consequent increased collagen production and neovascularization.

Burn Therapy

Burn therapy is also being reviewed with experimental and clinical work (4). OHP appears to allow earlier reversal of capillary stasis, which results in less wound dessication and destruction. There is increased oxygenation to the otherwise hypoxic, thermally damaged cell that might not otherwise survive, thus preserving a larger surviving epithelial mass. OHP optimizes the conditions for normal healing (12,11). Response to the present questionnaire indicates the increased interest in this field of OHP.

Exclude

Acute Coronary Thrombosis - Myocardial Infarction

At the present time interest in this field is minimal. Thurston's initial work (6) showed great promise but only in a particular subset of patients" older patients, females, those in cardiovascular shock or with arrythmias or heart block, a previous history of infarction and a high Peel index.

Saltzman (4) discussed these subsets: a) Cardiogenic shock group for whom OHP is most dramatic, but which has a mortality of 80% at the end of the one year. The OHP may save the patient in the immediate situation but does not alter the outcome - a new heart is needed. b) No cardiovascular collapse and low mortality where there is no justification of OHP. c) Angina, cardiac failure group with a mortality of 25% where longevity is good and OHP may be of value.

Thus the field is open for research and controlled trials.

Carbon Monoxide

An increasing interest in treating CO poisoning is seen. The need for a more efficient system for transferring smoke inhalation and carbon monoxide poisoning patients to the OHP chamber is evident.

Goldbaum et. al. (14) have shown a toxic action of carbon monoxide on cellular respiration in the mitochondria with CO COMPETING completing with 0_2 for cytochrome a_3. Hyperbaric oxygen reduces the half-life of CO to 23 minutes and thus reduces the toxic effect on the central nervous system.

A three year follow-up on acute CO poisonings by Smith and Brandon (15) showed that of the survivors, 33% showed a deterioration of personality and 43% a memory impairment. The level of consciousness on hospital admission correlated significantly with the development of gross neuropsychiatric sequelae. This emphasizes the importance of prompt and efficient OHP treatment in the acute case.

Acute Head Injury and Cerebral Edema

Hayakawa (16) has reviewed the literature on OHP treatment in neurology and neurosurgery. The exact mechanism remains obscure, but OHP does protect against cerebral anoxia and ischemia and edema. OHP increases cerebral tissue oxygenation or available oxygen to the brain despite the presence of reactive cerebral vasoconstriction. Miller (17) showed 2 atmospheres absolute caused a maximal reduction of cerebral edema and that there was no advantage to go above this level. Artru (18) et.al. felt that the influence of OHP on each subject varies according to the extent of the brain lesion and that it was difficult to compare patients. A concept of differential effects would explain how in some situations an initially low cerebral blood flow (CBF) is increased and a higher CBF is decreased by OHP.

Controlled clinical trials are needed to find the place of OHP in acute head and spinal cord trauma.

Chronic Brain Ischemia

In a series of patients with chronic organic brain syndrome, Jacobs (19) observed a marked and significant improvement in cognitive function and behavior, which persisted for a longer period than could be accounted for by elevated brain tissue oxygen tension. The patients in Goldfarb's et.al. series (20) showed no improvement. These differences may be due to different patient population or disparity in administration and interpretation of psychological tests. Again, one sees the need for controlled trials to clear the confusion. Interest in this field is increasing, and there is a larger potential application of OHP treatment in this group than in any other.

Acute Blood Loss Anemias

(In patients who will not accept transfusions on religious grounds)

Acutely shocked patients with anemias (ranging between 3-6 gram hemoglobin per 100 ml blood) have been successfully treated by OHP. A regime of alternate hours of OHP for 36 hours at 2 ATA and then every four to six hours as the situation demands has been used with very good results and no fatalities. (4,21) It has also been successfully used in the treatment of the acute hemolytic crisis. (22)

Gas Gangrene

The hyperbaric oxygen literature abounds with praise and acceptance of OHP combined with surgery and antibiotics as being the prime mode of therapy for gas gangrene. (23,24,25, 28,30,31) General surgeons however do not necessarily accept this and advocate basic surgical principles of debridement and ablation. (26,27,29)

The results of groups treated by surgery or OHP show mortality rates ranging widely from under 14% (30,31) to 33% (23) on OHP and 11% (29) - 35% without OHP.

It would appear that trauma patients developing gas gangrene do better than those developing it after abdominal surgery. (24,25, 26,28)

The situation is further complicated by the type of center handling the case. The cases referred to centers with chambers invariably arrive long after the diagnosis has been suspected. General surgeons who treat gas gangrene patients usually diagnose the cases and commence therapy more quickly.

Differences in sampling and deciding what constitutes clostridial "gas gangrene" have necessitated classifications of clinical manifestations of gas gangrene. (25,27,29,30)

As shown, comparing results is difficult. Because few centers receive sufficient numbers of cases to statistically validate a mode of therapy, one sees the need for pooling results and controlled trials.

Illustration I

HYPERBARIC THERAPY QUESTIONNAIRE

1) Date of answers
2) Name of unit
3) Condition Treated

Condition Treated	Year and Number of Cases Treated					
	1971	1972	1973	1974	1975	1976
Gas Gangrene						
Air Embolism						
Decompression sickness (bends)						
Carbon Monoxide Poisoning						
Skin Grafts						
Burns						
Osteomyelitis						
Head Injuries						
Cancer Therapy						
Chronic Brain Ischemia/Senility						
Acute Myocardial Infarction						
Other - Specify						

4) One man chamber ______ Air lock chamber ______
5) Staff present with each dive. Numbers

Doctor	Yes	No
Nurse	Yes	No
Operator	Yes	No
Other - Specify	Yes	No

6) Rough cost estimate per dive in $

7) Are you a: (circle or check appropriate catagories) i.e. 1 8 University Hosp. and Researcher

1) University Hospital ______
2) Teaching Hosp. - Major Univ. Affiliation ______
3) Teaching Hosp. - Minor Univ. Affiliation ______
4) Military Teaching Hosp. ______
5) Military non teaching Hospital ______
6) Public Institution ______
7) Private Institution ______
8) Researcher ______

8) Other Comments - Please enter on reverse side of questionnaire.

TABLE I

QUESTIONNAIRE

Total number of chambers questioned	=	55
Response to first questionnaire	=	29
Response to second questionnaire	=	11
Response to telephone	=	5
Non responders	=	10

TABLE II

NON FUNCTIONAL UNITS

2	Misreported in Directory - No chamber
4	Armed Forces Units - Research. No civilians
*3	No medical staff, very low patient load, damaged chambers
*3	Oncology Radiotherapy Departments - OHP not indicated
*1	Acute coronary care unit
*1	Open Heart Pediatric Surgery Unit
14	

*7 of these last 8 chambers were monoplace.

TABLE IV

Conditions/Diseases Treated

	Cases	Units/ Chambers
Peripheral Vascular Disease	54	7
"Gangrene"	20	1
Post Cardiac Surgery	19	2
Retinal Artery Thrombosis	22	4
Wound Healing	19	4
Pulmonary Insufficiency	23	9
Soft Tissue Infection	14	1
*Reversible Ischemia; Skin Lesions	10	1
Infected Pacemakers	9	1
Pulmonary Embolism	6	2
Hurlers Syndrome	5	1
Drowning	5	1
Frost Bite	4	4
Post Cardiac Arrest; Multiple Sclerosis (2)	4	I
Vertigo, Tetanus (2)	3	2
Fractures; wound infection; *acute spinal cord injury, hanging, *crushed limbs (6)	3	1
Moyo Moyo; deafness; scleroderma; surgical emphysema; mycobacterium TB; pharyngeal fistula, stenotic valvular disease, *cyanide poisoning, *post surgical reinplantation of fingers, overdose, asthma, pneumomediastinum, abscess, chronic granuloma (14)	2	1
Intestinal obstruction; cortical blindness; thrombophlebitis; necrotizing fascitis; viral encephalitis; aspergillosis; pneumotosis coli; post op confusion; acute hemorrhage; diabetic neuropathy; closed heart surgery; post epileptic headaches, brain cyst, radiation pneumonitis, bite, gas posioning, balloon aspiration. (18)	1	1

In addition a further 12 non specified cases were reported. It can be seen that 50 miscellaneous conditions involving some 214 cases were submitted for OHP.

KEY: Treatment Accepted by Medicine (*)

TABLE V

TYPES OF CHAMBERS USED

CHAMBER TYPE	NUMBER OF CHAMBERS	NO. CASES TREATED
Monoplace	19	1317
Multiplace	17	5582
Both	4	713
Unspecified	1	126
TOTAL	41	7738

TABLE VI

ECONOMIC CONSIDERATION

Type of chamber	no cost	50	60	75	90	100	150	200
Mono	0	1	0	1	3	2	0	1
Multi	1	1	1	2	0	0	2	3

10% 17 multiplace and 8 of 19 monoplace chambers responded

TABLE VII

TYPE OF HOSPITAL

Type of Hospital	Number of Hospitals
1) University	7
2) University, Research	1
3) Teaching major University affiliations	8
4) Teaching major University affiliation Research	2
5) Teaching major University affiliation Private	2
6) Teaching minor University affiliations	6
7) Teaching minor University affiliations Private	4
8) Military teaching, Research	3
9) Military non teaching, Research	2
10) Private	3
11) Teaching major University affiliation, Public, Research	2
12) Unknown	1
	41

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