Brain "Implications for HBO_2."

M. MITANI

Director, Department of Neurosurgery, Yagi Hospital, Fukuoka, Japan

I am a neurosurgeon and will discuss the clinical use of hyperbaric oxygen therapy (HBO_2) on the central nervous system, especially the brain. Is there a role for HBO_2 in brain injury? This is not an easy question to answer. I shall focus on traumatic brain injury. To date, "Brain Injury" is not among the approved indications of the UHMS.

I have been working in Fukuoka, Japan. Fukuoka is located in the north of Kyushu Island and is the site of pioneering work in HBO_2. My colleague, Dr. H. Yagi, is one such pioneer, as is Dr. M. Kawashima. We have a sub-society in the Kyushu district under the Japanese Society of Hyperbaric Medicine (JSHM). In Kyushu, we have now 168 monoplace and 17 multiplace chambers. We treat various kinds of diseases using these chambers. Last year, we treated 182 patients in the hospital using HBO_2. About half of vascular disease cases, both in the central nervous system and peripheral regions, were indications for HBO_2. Others had many kinds of diseases, including head injury. Last year, only two patients were given HBO_2 to treat head injuries. Because it is such a small number, my talk will be about a pilot study. We are estimating the effect of HBO_2 on brain injury and going to the next step. The treatment pressure commonly used in Japan is 2 to 2.8 ATA, depending on the severity of the disease. The treatment time is sixty minutes. The patients breathe 100 percent oxygen once each day.

Table 1

Classification of Head Injury (Gennarelli)

1. Skull injuries
   1) Vault fracture
   2) Basilar fracture
2. Focal injuries
   1) Epidural hematoma
   2) Subdural hematoma
   3) Contusion
   4) Intracerebral hematoma
3. Diffuse brain injuries
   1) Mild concussion
   2) Classical cerebral concussion
   3) Prolonged coma (Diffuse axonal injury: DAI)
      a. Mild DAI
      b. Moderate DAI
      c. Severe DAI

Skull fracture itself is not an indication for HBO_2, because the brain injury itself is crucial. It is important to determine whether or not the brain injury is focal or diffuse. Focal injuries include several types of hematomas and contusions.

A head injury classification is shown in **Table I** (1).

Hematomas include epidural, subdural and intracerebral. Diffuse brain injury can occur due to concussion or diffuse axonal injury (DAI), which typically causes coma. DAI is divided into three categories: mild, moderate and severe. The candidates for HBO_2 are focal injury and DAI. Evacuation of acute epidural hematoma (AEH) should be done promptly, but in pure acute epidural hematoma, HBO_2 is not indicated.

The prognostic outcome of severe head injuries is still poor, especially in traumatic acute subdural hematoma (ASH). In comatose patients with ASH, severe cerebral contusion or edema accompanying hemorrhage which is initially undetectable by CT may be progressive.

Fig. 1. Representative case of ASH with a poor outcome**.**

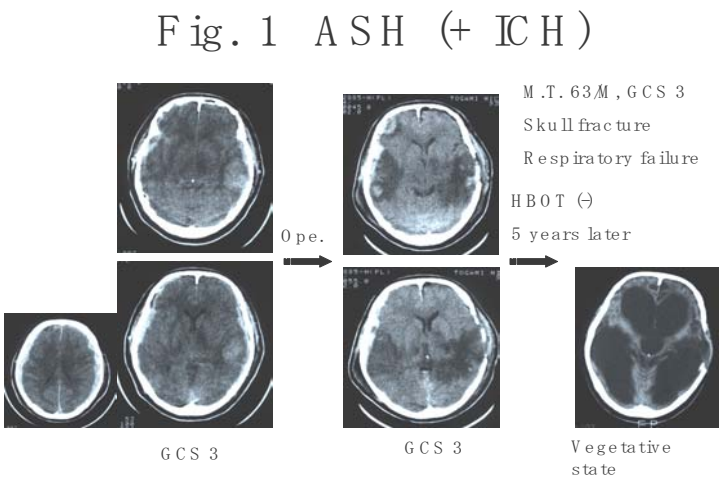
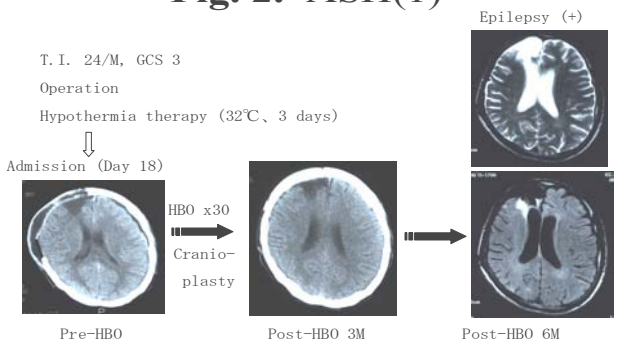


Figure 1 shows the head CT of a 63-year-old man who sustained his injury in a traffic accident. He suffered coma (Glasgow coma scale: GCS 3) and acute respiratory failure. Intratracheal intubation was done and CT was checked. The head CT showed a skull fracture and bilateral high-density subdural spaces due to subdural hematoma and contusional intracerebral hematoma in the left temporal lobe. An emergency operation was done. The hematomas of the left side, both subdural and intracerebral, were evacuated and external decompression (removal of the bone flap) was performed. Four days later, he was still comatose and the CT was checked again. The middle portion of Figure 1 shows low-density areas consistent with bilateral brain edema. A new hemorrhage also appeared.

Fig. 2. ASH(1)



Neither hypothermia nor HBO_2 was performed in this case because his injuries were very severe. Although the patient survived, he has never recovered consciousness and has remained in a vegetative state. An MRI taken five years later (Figure 1) showed marked ventricular dilatation due to severe brain atrophy. This suggests the existence of the late type of cell death. When the brain is injured, primary and secondary injuries occur. The primary injury is inevitable but preventing or minimizing secondary injuries is the key point of treatment. Hypothermia therapy has been attempted, but satisfactory results have not been obtained. Therefore, a combination of hypothermia and HBO_2 has been considered in severe ASH patients. A second case of ASH is shown in Figure 2. This patient underwent surgery and hypothermia therapy at the university hospital for three days. He was then transferred to us, 18 days after his accident. His CT shows a low-density area in the right frontal lobe and a defective skull (Figure 2, left image). After thirty sessions of HBO_2 and cranioplasty, he recovered well and with no neurological deficits. An MRI taken six months later showed a minimal lesion in the right frontal lobe.

The third case had a similar injury, though slightly more severe. The patient underwent cranial surgery and hypothermia therapy for four days and was transferred to us 23 days after head injury. At the time, head CT showed low density areas in bifrontal and left temporal lobes. HBO_2 was started and he underwent cranioplasty. After thirty sessions of HBO_2, he recovered. The head MRI (FLAIR image) showed minimal lesions in both bifrontal and left temporal lobes. The patient returned to work.

Table 2. Case Summary of Post-operative HBOT in Focal Injuries

No.	Age/Sex	Dx	Duration of Hypothermia	HBOT		GOS
				Started on	Total	
1	24/M	ASH	3d	18d	30	GR
2	38/M	ASH	4d	23d	30	GR
3	21/M	ASH	9d	28d	50	MD
4	42/M	ASH	8d	51d	30	VS
5	19/M	ASH	-	47d	69	SD
6	60/F	ASH	-	13d	30	SD
7	73/F	ASH, ICH	-	1d	50	VS
8	49/M	AEH, ICH	-	5d	15	D
9	57/M	ICH	-	17d	20	SD
10	63/M	ICH	-	30d	30	GR

(32-33℃)

Table 2. A list of ten patients who underwent operations for focal brain injuries and had HBO_2.

The overall outcome is bad. However, in cases one through four, all of whom received hypothermia therapy (cases one through three are presented here), three of four recovered well; 50% is good recovery (GR) and 25% is moderate disability (MD). The combination of hypothermia and HBO_2 is expected to be an effective method to treat comatose, post-operative patients suffering from ASH.

Next, I will discuss diffuse-type injury, or the so-called diffuse axonal injury (DAI). DAI is caused by a shearing mechanism where there is usually no indication for surgery.

Fig. 3 Mild DAI (1)

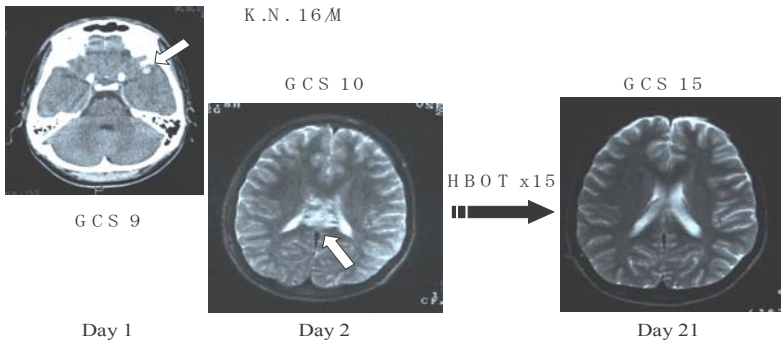


Figure 3 illustrates the case of a 16 year-old boy that had a traffic accident and was transported to us immediately. Head CT shows a small, high-density area at the tip of the left temporal lobe (arrow). In spite of only a small lesion, his consciousness was disturbed (GCS9). The MRI was checked the next day and revealed a white hyperintensity lesion on T-2 weighted images between the bodies of lateral ventricles, that is, corpus callosum (Day 2, arrow shown). This is a characteristic of DAI. The patient underwent 15 sessions

of HBO_2. The lesion disappeared and he was completely recovered.

A summary of DAI patients treated with HBO_2 is shown in Table 3. Mild to moderate DAI patients recovered well, but for those classified as severe, the outcomes were poor. Case number five had an additional fifty sessions of HBO_2 at another hospital after discharge. She was getting better and is now in MD.

According to an interesting paper published last year in *Journal of Neurosurgery* (2), the increased cerebral metabolic rate of oxygen ($CMRO_2$) and decreased CSF lactate levels after HBO_2 indicate that treatment may have improved aerobic metabolism in severely brain injured patients. It was also reported that HBO_2 reduced mortality by fifty percent in a prospective, randomized trial of severely brain-injured patients. Their functional recovery, however, was not improved [3]. Our cases showed functional recovery. We speculate that HBO_2 may have a promoting effect on some kinds of nerve growth factor (NGF). To conclude, it is time to answer the question: "Is there a role for HBO_2 in brain injury?" At this time, my answer is yes. We believe the indications for HBO_2 in brain injury are as follows:

Table 3. Case Summary of HBO-treated DAI

No.	Age/Sex	DAI	HBOT		GOS
			Started on	Total	
1	16/M	Mild	3d	15	GR
2	38/M	Mod.	12d	20	GR
3	24/M	Mod.	6d	20	GR
4	32/M	Severe	20d	60	SD
5	19/F	Severe	33d	50	SD→MD
6	30/F	Severe	73d	30	SD→MD

(1) Focal injuries, including acute subdural hematoma, contusion and intracerebral hematoma. These frequently coexist. The combination of hypothermia and HBO_2 is expected to be an effective method to treat comatose patients with severe focal injuries, especially those with acute subdural hematomas, after surgery.

(2) DAI; mild, moderate and severe. HBO_2 is effective in DAI when the disturbance of consciousness is severe, in spite of mild or lack of abnormal CT/MRI findings. The HBO_2 indications are not definite. Randomized control studies should be done to prove the efficacy of HBO_2 on severely brain-injured patients.

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