Table 1. Glasgow Coma Scale

Eye Opening Response

- Spontaneous--open with blinking at baseline **4 points**
- To verbal stimuli, command, speech **3 points**
- To pain only (not applied to face) **2 points**
- No response **1 point**

Verbal Response

- Oriented **5 points**
- Confused conversation, but able to answer questions **4 points**
- Inappropriate words **3 points**
- Incomprehensible speech **2 points**
- No response **1 point**

Motor Response

- Obeys commands for movement **6 points**
- Purposeful movement to painful stimulus **5 points**
- Withdraws in response to pain **4 points**
- Flexion in response to pain (decorticate posturing) **3 points**
- Extension response in response to pain (decerebrate posturing) **2 points**
- No response **1 point**

In addition to GCS, factors such as age,[15, 18, 19] associated injuries,[20] intracranial hypertension,[21, 22] and the presence of a mass effect[23] are also predictors of mortality and severe disability. Preinjury productivity and education also help predict functional outcome in survivors.[24, 25] Hypoxia (defined as PaO2 less than 60 mm Hg, or apnea or cyanosis in the field) and hypotension (defined as a measure of systolic blood pressure less than 90 mm Hg at any time) are also strong predictors of death and severe disability.[22, 26-28]

Some features of the patient's course and management in the hospital are also predictors of mortality and morbidity. For example, the extent of post-traumatic amnesia (PTA) is correlated with the prognosis. The longer the amnesia occurs following the injury, the worse the prognosis for recovery. If the loss of consciousness lasts more than 4 weeks, a high prevalence of impairment, inattention, and memory loss is predicted.[29]

During the course of intensive care, episodes of hypotension, elevated intracranial pressure, decreased cerebral perfusion, and hypoxia are also predictors of a poor outcome.[30] Such episodes are very common. In a series of 184 patients receiving intensive care for acute, severe TBI,[30] all but seven patients had at least one episode of hypotension. In 157 of these patients, jugular venous oxygen saturation was monitored continuously. Ninety-seven (62 percent) of these patients experienced one or more episodes of hypoxia (jugular venous oxygen saturation <50 percent), and patients spent an average of 1.88 hours in a hypoxic state during the intensive care unit stay. These figures probably represent better-than-typical results because they were obtained in an intensive care unit that used invasive monitoring to minimize the frequency and duration of hypoxic episodes.

GCS and other prognostic factors are of little value in predicting the speed of recovery from coma. In before-after comparison studies, a presumption is often made that a patient who was discharged from the acute care hospital in a vegetative state has a very low chance of recovering consciousness spontaneously. However, several cases of recovery have been documented in

also shorter in the HBOT group but was not statistically significantly different (28.2 days vs. 32.7 days, p = NS). In one of nine subgroups, patients under 30 years old with brain stem contusion were more likely to recover consciousness by 1 month if they received HBOT. There were nine patients in each group; one died in each group, and there were six conscious in the HBOT group and one conscious in the control group at 1 month ($p < 0.03$).

Table 2. Results for Study by Artru, Chacornac, and Deleuze

	HBOT Group	Control Group
Died within 1 year	15/31	16/29
Conscious at 1 month	13/31	8/31
Independent in daily activities at 1 year among survivors	14/31	12/29

Rockswold, Ford, et al. (1994)[89-91] enrolled 168 of 272 (62 percent) potentially eligible patients with acute closed-head trauma. Of the 272 potentially eligible patients, 18 percent died within 6 hours of admission, 8 percent had contraindications to HBOT, 6 percent were not identified as potential subjects in time for randomization within 6 hours of admission, and consent could not be obtained for 6 percent (no details given on the baseline characteristics or outcome of these patients).

The 168 patients who were randomized had Glasgow Coma Scale Scores of 9 or less, 6 to 24 hours after admission with a severe head injury, or 6 to 24 hours after deterioration following admission for what appeared to be a mild or moderate injury.[89-91] This study did not describe the methods used to randomize patients. There were several differences between the HBOT and control groups at the start of the study. For example, more patients in the control group had an operative mass lesion (39 percent vs. 49 percent), while more patients in the HBOT group had intracranial pressures above 20 mm Hg (52 percent vs. 46 percent). Overall, the differences in prognostic variables did not seem to favor either the HBOT group or the control group. The authors did not report whether patients enrolled after deterioration were distributed evenly (these patients may have a worse prognosis, the results of the trial could be biased if they were not distributed equally in the two groups).

The main results of the trial are summarized in Table 3. After 1 year, patients who were assigned to HBOT treatment had lower mortality (17 percent vs. 31 percent), but there was no difference in the proportion of patients who were either dead or severely disabled. Additional analysis showed that HBOT reduced mortality in patients who had a GCS score of 4 to 6 or ICP > 20 mm Hg, but not in other subgroups of patients.

Table 3. Results of Study by Rockswold, Ford, et al.

	HBOT Group	Control Group
Died within 1 year	14/84	26/84
Dead or severely disabled at 1 year	40/84	40/84

Differences between these two studies might explain the discrepant mortality results. First, Artru was a much smaller study and could have missed an important difference in mortality. Second, the HBOT protocols differed among these studies. The Rockswold trial used 1.5 atm, while the Artru study used 2.5 atm.[88] In the Rockswold trial, patients were treated for 60 minutes every 8 hours for 2 weeks or until the patient regained consciousness or died. In the

Table 4. Controlled trials of HBOT in brain injury

Study, population, n	HBOT Protocol;Control	Results	Quality Rating
Traumatic brain injury			
Artru, 1976[88] France; Patients with head injuries and in a coma; 31 HBOT, 29 control	2.5 atm x 60 minutes x 10 days of treatment alternating with 4 days off until patient regained consciousness or died. Control: Standard treatment	No significant difference on any comparison (persistent coma at 1 month, consciousness recovery rate at 1 month, death rate at 1 month, death rate at 1 year, mean duration of coma, except in 1 of 9 subgropus: patients less than age 30, not reacting in an adapted manner to painful stimuli, and not operated on) n=9 HBOT, 9 control. Persistent coma at 1 month: 22% (HBOT); 78% (control); p<0.03 Independent in daily activities at 1 year among survivors: 45% (HBOT); 41% (control)	Fair
Rockswold, 1992,[90] 1994[91] Minnesota; severe head injury at one institution, admitted 1983-1989. Total GCS score of 9 or less for at least 6 hours; 84 HBOT, 84 control	1.5 atm x 60 minutes every 8 hours x 2 weeks or until the pt was brain dead or could consistently follow simple commands. Average 21 treatments per patient. Control: standard intensive neurosurgical care, all patients received phenytoin.	Mortality at 12 months: 14/84 (17%) (HBOT); 26/82 (32%) (control) $p = 0.04$ Favorable outcome at 12 months (GCS score of 1 or 2) 44/84 (52%) (HBOT); 44/82 54%) (control) $p = 0.99$	Fair
Other brain injury			
Jianhua, 1995[106] China; children (aged 1 to 11 years) with viral cerebritis; 47 HBOT, 45 control	1.8-2.0 atm x 90 minutes once daily x 10 days. Control: supportive therapy, including drugs naofukang, naofuxin.	HBOT group: 18/47 (38%) curative, 25/47 (53%) effective, 3/47 (6%) ineffective (1 missing?). Control group: 8/45 (18%) curative, 20/45 (44%) effective, 17/45 (38%) ineffective. HBOT vs control: % curative $p < 0.05$, % effective $p > 0.05$, % ineffective $p < 0.001$.	Poor

GCS=Glasgow Coma Scale; GOS=Glasgow Outcomes Scale; atm=atmospheres ; NS=non-significant; ICP=intracranial pressure; CT=comuterized tomography

Table 5. Controlled trials of HBOT in cerebral palsy

Study, population, n	HBO Protocol (Type of chamber) Control	Results	Quality rating
Collet, 2001[119] Canada Children with cerebral palsy with history of hypoxia in perinatal period, age 3-12 years, motor development age of 6 months to 4 years, and psychological development age 24 months or more.	100% oxygen at 1.75 atm x 60 minutes x 40 sessions. Sessions 5 days/week x 8 weeks. (Chamber type not given) Control: Room air at 1.3 atm x 60 minutes x 40 sessions. Sessions 5 days/week x 8 weeks.	Change in Global Gross Motor Function Measure Post-intervention (after 40 treatments): HBOT: 2.9 (1.9, 3.9) Control: 3.0 (2.1, 3.9) p = 0.54 At 3 months: HBOT: 3.4 (2.2, 4.5) Control: 3.1 (2.2, 4.1) p = 0.97 Secondary outcome measures: NS between groups (including other measures of functional status and neuropsychiatric assessments)	Fair
Packard, 2000[118] New York Children age 15 months to 5 years, with CP secondary to prenatal insults, premature birth, birth asphyxia, and post-natal hemorrhage. Criteria for enrollment were age between 1 and 5 years, moderate to severe CP, no evidence of brain malformation, developmental delay of at least 33% in one area, and no active seizures for the previous 6 months.	1.5 atm x 60 minutes twice daily x 40. Five days per week for 4 weeks. (Chamber type not given) Control: Delayed HBOT treatment 6 months after first group. T1= baseline, T2=1month after baseline (Group 1 treated, Group 2 not treated), T3=5 months after baseline, T4=6months after baseline (Group 1 5 months post-treatment, Group 2= just treated).	Blinded Assessments: No statistical difference in change scores on any blinded assessments (change in Peabody scores for T2 minus T1 and T4 minus T3; change in Bayley II and PLS scores for T3 minus T1), p values not given. *PEDI Results:* Improved scores on mobility sub-domains of PEDI for time period T2 minus T1 in favor of immediately treated group (p<0.05), trend favoring recently treated delay group for time period T4 minus T3 (p<0.058). ***Parental diaries:*** 83% of parents noted a marked improvement in mobility, however no comparison between groups given. Improved vision: 4/9 (44%) children with cortical visual impairment had improvement in vision noted by families, vision therapists and ophthalmologists.	Poor

Table 6. Controlled trials of HBOT in stroke.

Study, population, n	HBO Protocol; Control	Results	Quality Rating
Anderson, 1991[127] Minnesota; patients with ischemic cerebral infarction; 20 HBOT, 19 control.	100% oxygen at 1.5 atm x 1 hour every 8 hours x 15 treatments. Vitamin E 400 units given with each HBOT. Control: Room air at 1.5 atm x 1 hour every 8 hours x 15 treatments. Both groups received standard ICU plus physical and occupational therapy.	Average graded neurological exam scores Baseline 44.6 (control), 45.5 (HBOT): Day 5: 38.5 (control), 43.8 (HBOT) $p = 0.54$ Week 6: 28.3 (control), 38.5 (HBOT) $p = 0.25$ Month 4: 25.6 (control), 34.5 (HBOT) $p = 0.33$ Year 1: 25.8 (control), 31.4 (HBOT) $p = 0.53$	Fair
Sarno JE, 1972,[128] and Sarno MT, 1972[130] New York; patients with vascular stroke at least 3 months post-stroke. 32 (all received both HBOT and control; order randomized)	100% oxygen at 2.0 atm x 1.5 hours x 1 session. Control: 10.5% oxygen at 2.0 atm x 1.5 hours x 1 session.	Communication baseline done 24 hours prior to exposure, and immediately after HBOT treatment. No significant effect on any measure.	Fair
Rusyniak, 2003[131] Indiana; patients presenting within 24 hours of ischemic stroke; 17 HBOT, 16 control	100% oxygen at 2.5 atm x 1 hour Control: 100% oxygen at 1.14 atm x 2 hour	No difference in proportion with good outcome on NIHSS at 24 hours (HBOT 18%, control 31%, p=0.44) 90 days: No difference based on intention to treat using Barthel Index, Modified Rankin score, GOS, or NIHSS. Control group significantly higher proportion with "good" outcome on Modified Randkin score, GOS and NIHSS by per protocol analysis.	Fair

Table 6. Controlled trials of HBOT in stroke.

Study, population, n	HBO Protocol; Control	Results	Quality Rating
Nighoghossian, 1995[126] France Patients with ischemic stroke in middle cerebral artery confirmed by CT and seen within 24 hours of onset; 17 HBOT, 17 control	100% oxygen at 1.5 atm x 40 minutes daily x 10 treatments. Control: Room air at 1.5 atm x 40 minutes daily x 10 treatments.	Pretherapeutic and posttherapeutic differences (HBOT-Control) No significant differences on Orgogozo scale, Trouillas scale, or Rankin scale at 6 months or 1 year	Poor
Marroni, 1987[129], 1988[132] Italy Stabilized stroke patients no longer undergoing any form of therapy or rehabilitation who had a stroke from 2 to 172 months earlier (average 29.2 months). 80 total	Group C1: 2.0 atm x 60 minutes x 30 sessions; Group C2: Same as C1 at 1.5 atm; Group D1: in-water rehab + HBOT 2.0 atm x 60 minutes; Group D2: Same as D1 at 1.5 atm; Group E1: 30 simultaneous, 60-minute HBOT + 40-minute in-water rehab sessions at 2.0 atm; Group E2: Same as E1 at 1.5 atm. Control*:* Group A: No treatment, Group B: 30 in-water physical therapy sessions x 40 minutes.	All dry HBOT groups showed greater improvement in their motor ability, but no clear-cut difference could be observed among the 4 groups that scored improvements of from 3.1 to 3.8 degrees. HBOT 1.5 atm rehab group reached 8.1 degrees 1 month after treatment, leveling off to 7.7 at 3 months, and the 2.0 atm HBOT rehab group showed an 11.6 degree improvement still present 3 months after treatment.	Poor