venes in dogs after ligation of a major coronary branch.

Comparison of cardiac output data obtained by the Fick method and the aortic pulse contour method showed sufficient disagreement to indicate that the latter method is not sufficiently accurate for quantitative evaluation of cardiac output, even when pressure pulses of normal contour and normal aortic pressures prevail.

Received November 27, 1950. P.S.E.B.M., 1951, v76.

Effect of Adding Carbon Dioxide to Inspired Air on Consciousness Time of Man at Altitude.* (18415)

F. G. HALL AND K. D. HALL.

From the Department of Physiology and Pharmacology, Duke University School of Medicine, Durham, N. C.

Accurate appraisal of the factors which influence useful consciousness states in flyers under hypoxic stress is of fundamental importance in aviation. The duration of consciousness of subjects breathing ambient air of normal composition at various altitudes has been reported by several investigators (1-3). A method which gives a critical end point for loss of useful consciousness has also been described(4). The following reports extend the range of studies to include the addition of carbon dioxide to the normal composition of inspired air. Such a situation may at times exist in aircraft flying at high altitudes.

It is apparent from the paper by Fenn *et al.* (5) that the additions of carbon dioxide to inspired air containing nitrogen will have a beneficial effect on subjects at altitude. Otis *et al.*(6) have shown, however, that carbon dioxide added to inspired oxygen does not increase the tolerance of mice and men at altitude. Because of the complexity of the physiological processes involved one cannot safely predict as to the quantitative effect of carbon dioxide on consciousness time. Consequently, an experiment was designed to determine the effect of certain concentration of carbon dioxide on the duration of consciousness at 30,000 (226 mm Hg) and 35,000 feet (179 mm Hg) simulated altitudes.

Procedure. The time of useful consciousness was determined under conditions where the ambient pressure in a decompression chamber was maintained constant and the subjects changed from breathing pure oxygen to breathing gas mixtures from Douglas bags. Gas mixtures were made in a large spirometer and transferred to Douglas bags just previous to ascent. It should be noted that the partial pressure of oxygen in the inspired air was kept constant and that the addition of carbon dioxide was not made at the expense of oxygen. In other words a calculated quantity of oxygen was added with the carbon dioxide to correct for the dilution effect. Analyses during experiments confirmed the accuracy of the gas mixing procedure. Thus uniform partial pressure of oxygen existed in the inspired air of both control and experimental tests. Gas analyses were made in 2 ways. Samples of air delivered to the mask were analyzed by means of a Haldane gas analyser. A Pauling oxygen meter was also employed to determine the partial pressure of oxygen which was kept constant within ± 1 mm Hg. Carbon dioxide

* Work done under contract with the Physiology Branch, Aero-Medical Laboratory Materiel Command, U.S.A.F.

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analyses showed that the CO_2 concentration in the experimental tests ranged from 13.8% to 14.3% at 30,000 feet and 18.8% to 19.2% at 35,000 feet. Standard Air Force oxygen masks were used and a three way valve was arranged to connect the oxygen supply, or the Douglas bags, to the mask. Mask leakage was inappreciable. Breathing resistance was kept at a low value. Gas samples were drawn from the oxygen mask inlet and analyzed for composition of the inspired air. The effective external dead air space of the oxygen mask was approximately 90 cc. Nine healthy young men, aged 20-24, were selected as subjects. Each was given preliminary training and experience in high altitude ascends in the decompression chamber. No subject showed any untoward symptoms resulting from these experiments. Resuscitation following loss of consciousness was prompt and without any detectable after effects, either from hypoxia or carbon dioxide breathing.

Each subject served as his own control. This is necessary since a marked individual variation occurs in consciousness time at altitude. Two tests were made on each subject with a 40-50 minutes interval of rest between runs. On one day the control run was made first and on the next day the experimental run was made first. Subjects were not informed as to which were control runs and which were experimental runs and in only a few cases were they able to detect the one to which they were being subjected. Three control and 3 experimental tests were performed for each subject. The method for measuring the duration of useful consciousness at altitude has been described by Hall(4). Photokymographic records were used to determine pulmonary ventilation from which ventilation ratios were calculated.

Results. Summaries of results are presented in Tables I and II. It will be noted that a marked difference in useful consciousness time at simulated altitudes of 30,000 (225 mm Hg) and 35,000 feet (179 mm Hg) occurs when certain amounts of carbon dioxide are added to the inspired air. This effect is more marked at 30,000 feet. It is probably that the effect of addition of carbon dioxide to inspired air will have a less pronounced effect at higher altitudes.

TABLE I.

	Consciousness time at 30,000 ft. breathing	
Subjects	Ambient air (normal composition) sec.	Gas mixture containing 14% CO_2, 21% O_2, 65% N_2, sec.
H	96	181
T	87	198
TK	91	126
P	90	110
D	78	177
J	79	137
B	73	181
JW	95	172
K	108	184
Avg	88	163

TABLE II.

	Consciousness time at 35,000 ft. breathing	
Subjects	Ambient air (normal composition) sec.	Gas mixture containing 19% CO_2, 21% O_2, 60% N_2, sec.
H	60	82
R	60	67
T	58	83
TK	50	66
D	54	67
J	45	66
B	54	66
JW	56	64
K	59	69
Avg	55	70

In Fig. 1 and 2, pulmonary ventilation ratios are shown. These were calculated from photokymographic records of the breathing patterns (Rheopneumograms) made during the simulated flights. A ventilation ratio of 1 indicates the level of the pulmonary ventilation of subjects breathing pure oxygen for a period of two minutes just previous to breathing ambient air. Records were made on all subjects for all tests and the values indicate the mean values for all tests. Thus on each graph is shown the effect of the "anoxia drive" on pulmonary ventilation when subjects are breathing ambient air at low barometric pressures and the effect of supplementing this air with carbon dioxide. It should be pointed out that the quantity of carbon dioxide added does not raise its partial pressure in the inspired air above the normal value of 40 mm Hg for alveolar air. Consequently, the respiratory center maintains a quantitative regulation of pulmonary ventilation

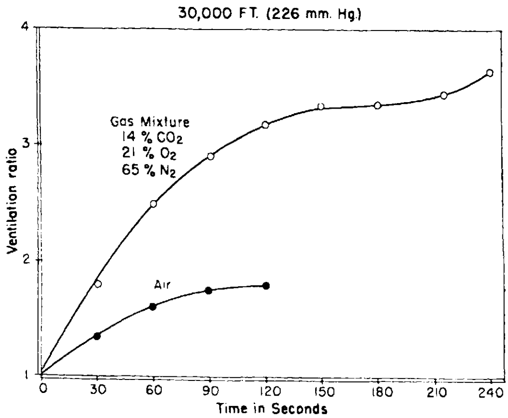

FIG. 1.
Ventilation ratios of subjects breathing air of normal composition and a gas mixture containing 14% carbon dioxide, 21% oxygen, 65% nitrogen, at a simulated altitude of 30,000 feet.

throughout the duration of consciousness in these experiments.

Doubtless there are many interacting factors involved in the explanation of these results. Carbon dioxide through its influence on cerebral blood vessels may influence the supply of oxygen to the brain. It seems plausible from theoretical consideration presented by Fenn *et al.*(5), that the more important factor is the high ventilation rate caused by the increased carbon dioxide and resulting in an increased partial pressure of oxygen in alveolar air, when nitrogen is a component of the inspired air. Consequently, carbon dioxide increases tolerance to altitude when breathed with normal air and does not do so when breathed with pure oxygen. Further experiments are necessary to place these factors in their proper relationship.

Summary. The addition of certain amounts of carbon dioxide to ambient air at low barometric pressures of 225 mm Hg. and 179 mm Hg increases the duration of useful consciousness in human subjects. This effect is more pronounced at lower simulated altitudes than at higher altitudes.

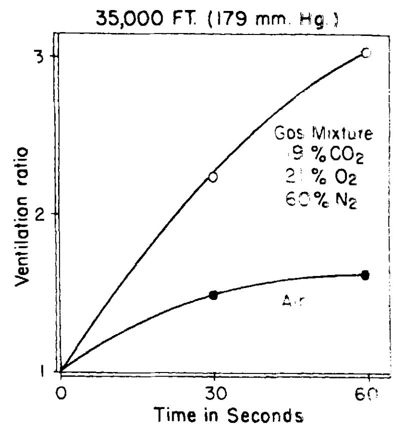

FIG. 2.
Ventilation ratios of subjects breathing air of normal composition and a gas mixture containing 19% carbon dioxide, 21% oxygen, and 60% nitrogen, at a simulated altitude of 35,000 feet.

Received December 4, 1950. P.S.E.B.M., 1951, v76.

Nutritional Hydrocephalus in Infant Rats.* (18416)

L. R. RICHARDSON.

From the Department of Biochemistry and Nutrition, Texas Agric. Exp. Station, Texas Agric. and Mechanical College System, College Station, Texas.

Hydrocephalus in infant rats as a result of inadequate nutrition of the mother has been reported by Richardson and Hogan(1) and by Richardson and DeMottier(2). Recently Hogan *et al.*(3) reported that folic acid decreased the incidence of the abnormality and

* The author is indebted to Merck and Co. for vitamins and APF No. 3, to Lederle Laboratories for folic acid and APF concentrate, to Wilson Laboratories for supplying liver "L," and to Nancy Muller and Christine Lovelace for technical assistance.

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