Does head-down tilt simulate zero gravity?*)

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Summary

Six anesthetized female rhesus monkeys were studied to determine the effect of head-down tilt on renal function. Head-down tilt is believed to simulate zero gravity. Some animals were tilted from 0° to -5° or -10° and others from +10° to -10°. None of these maneuvers consistently altered renal function. These results are in accord with those reported in early literature for the human but contrary to more recent reports. The interpretation of the latter are seriously hampered by experimental design. If indeed zero gravity translocates blood to the thorax with a resultant diuresis and natriuresis, head-down tilt is not an appropriate model for weightlessness.

Key words: renal function, monkey, weightlessness, head-down tilt

Introduction

There is considerable discrepancy in the literature regarding the effects of head-down tilt on renal function. This maneuver is believed to simulate zero gravity. The older literature indicates that head-down tilt does not alter renal function (1, 5, 7) while more recent work (3, 4, 6) suggests that it does, with some attributing the changes in renal function to stimulation of atrial receptors (4). Since emotional factors and their potential effect on renal function are difficult to control in the human during maneuvers such as tilting, we have studied the response of the anesthetized monkey to head-down tilt. This is a model in which the renal response to head-out water immersion is similar to that of the conscious human (2). In addition, both head-out immersion and head-down tilt are believed to be associated with an increase in thoracic blood volume. The results of our study agree with the older literature in that we find no significant effect of head-down tilt on renal function. The interpretation of more recent studies appears to be based more on what was expected to be found rather than what was actually found.

Materials and methods

Sex female rhesus monkeys weighing 4.7–9.0 kg and maintained on standard monkey chow and allowed free access to water were used. On the morning of the experiment they were sedated with ketamine (5 mg/kg, im ketaject) in their home cage, and brought to the laboratory where they were anesthetized with pentobarbital sodium (30 mg/kg, i.v.). An i.v. infusion of a .45 percent NaCl (1 ml/min), Ringer’s (4 ml/kg/hr) or glucose (40 mM) and urea (25 mM) solution was begun. The hydration was varied in order to determine if it altered the outcome of the experiments. Urine was collected from a Foley catheter inserted through the urethra into the bladder. Arterial blood pressure (BP) was recorded from a needle placed percutaneously into a femoral artery. The needle was attached to a microtip

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pressure transducer (Millar). Central venous pressure (CVP) was obtained by making a small incision over a femoral vein and inserting an second microtip transducer up to the level of the right atrium.

Three experimental protocols were employed. In seven experiments, control measurements were made with the animals lying in the horizontal position (0° tilt). Then a head-down tilt of 5° (-5±) was done in three experiments and a 10° head-down tilt (-10°) was done in the remaining four experiments. In four other experiments, the control measurements were made while the animals were in a 10° head-up tilt position (+10°) and the experimental measurements made after the animal was placed in a -10° position. The various tilt positions were done by placing an appropriate sized block under the end of an animal board.

After a steady state urine flow was achieved for three ten minute periods (about two hours after the animal had been placed in the supine position), a blood sample was obtained and the animal tilted for 90-100 minutes. A second blood sample was obtained midway through the head-down tilt period and a third sample at the end of the experiment. The blood samples (3 ml) were not replaced. Ten minute urine samples were collected throughout the experiment. At the end of the experiment, the catheters were removed, the femoral incision sutured and the animals returned to their home cages.

Urine and plasma sodium and potassium were measured by flame photometry, osmolality by freezing point depression and creatinine with an autoanalyzer. Standard clearance formulas were used and the data tabulated and analyzed on a MINC computer using a one-way analysis of variance with repeated measures.

Results

The animals that were tilted from 0° to 5° or 10° showed no difference in their response so they were pooled for data analysis. In addition, the hydration procedures did not affect the overall results. There were no significant changes in any of the measured variables in response to a 5° or 10° head-down tilt (table 1). In the control period, four animals were excreting negative and three positive free water. In response to the head-down tilt, free water decreased in the latter three animals while not changing in the remaining four. This decrease was sustained in two of the three animals. No significant changes occurred even when the animals were tilted from 10° head-up to 10° head-down, although these animals did show a trend for sodium excretion and urine volume to increase during the later periods of tilt (table 2). In nine experiments where observed, in response to tilting, CVP did not change in two, decreased in four and increased in three. The average change was +0.5 with a range of +1.5 to -1.0 mmHg. There was no relationship between the direction or extent of the changes in CVP and the degree of tilt (tables 1 and 2).

Discussion

The results of the study fail to document that head-down tilt significantly alters renal function. If this maneuver significantly translocates blood to the thorax and if the thorax contains intravascular volume sensors which modulate renal function, the control system is either very slow in responding or has a low gain. With respect to the former possibility, in the monkey, head-out water immersion, which is known to translocate blood to the thorax, produces a natriuresis within 10--20 minutes (2). With respect to the latter possibility, it has been shown previously that atrial volume receptors in the monkey have a very low gain when compared to the dog (9). Wilkins et al. (7) tilted ten subjects -30° to -75° up to 30 minutes and observed no consistent effect on renal function. In two subjects, a diuresis was observed immediately with the onset of the tilt. Viar et al. (5) tilted four subjects -20° for four hours and observed no effect on filtration rate or sodium excretion. Cathcart and Williams (1) tilted seven subjects -12° for up to 100 minutes and found no consistent increase in water, chloride or creatinine excretion. The diuresis seen in one subject was