larger number of subjects might have resulted in a difference of statistical significance. Erythropoietin decreased in flight in all crew members. The method used should have been able to measure as significant a 50 percent decrease if it had occurred consistently (coefficient of variation, 25 percent).

The lack of significant change in erythropoietin with a significant decrease in reticulocyte number and a decrease of about 1 percent per day in mean RCM suggests that inhibition of erythropoiesis is not the primary or only cause of the inflight RCM reduction. The decrease in RCM seems not to be a result of the increased hematocrit and hemoglobin, since it was not found in the bed rest subjects, who showed a statistically significant mean decrease in plasma volume.

The findings reported are preliminary. Many factors remain to be analyzed, including the effects of salt and water ingestion before landing, the influence of antimotion sickness drugs, and circadian shift effects; additional data will be forthcoming.

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27 March 1984; accepted 23 May 1984

Venous Pressure in Man During Weightlessness

Abstract. *To determine whether the body fluid shift from the lower limbs toward the head that occurs during spaceflight leads to lasting increases of venous pressure in the upper body, venous pressure and hematocrit measurements were made on four astronauts before flight and 1 and 12 hours after recovery and compared with measurements in space. During the mission the hematocrit was elevated and the venous pressure lowered by 1 to 8 centimeters of water as compared with the preflight data. One hour after landing the hematocrit decreased, indicating a hemodilution, venous pressures were unexpectedly high, and a body weight loss of 4 to 5 percent was observed. Twelve hours later the venous pressures were the lowest recorded during the study. The fluid shift apparently takes place during the first several hours of spaceflight. Thereafter, the pressure in the peripheral veins and the central circulation is lower than that measured before flight.*

Reports from American and Russian astronauts indicated that during spaceflight appreciable amounts of body fluids are translocated from the lower to the upper parts of the body (*1*). An increase in central venous pressure should accompany this and should have a similar effect on the pressure in an arm vein. As a consequence a negative water balance should ensue, as proposed by Gauer and Henry (*2*).

Before Spacelab, no direct venous pressure measurements were available to test this hypothesis. We conducted experiments (1ES026 and 1ES032) on Spacelab 1 to clarify this point by measuring the pressure in an antecubital vein and comparing the results with data obtained on the ground.

Methods. The equipment consisted of a small conventional strain gauge connected with a 19-gauge needle, a preamplifer, a small oscilloscope, and a tape recorder to store the signals. Pulse-cod-

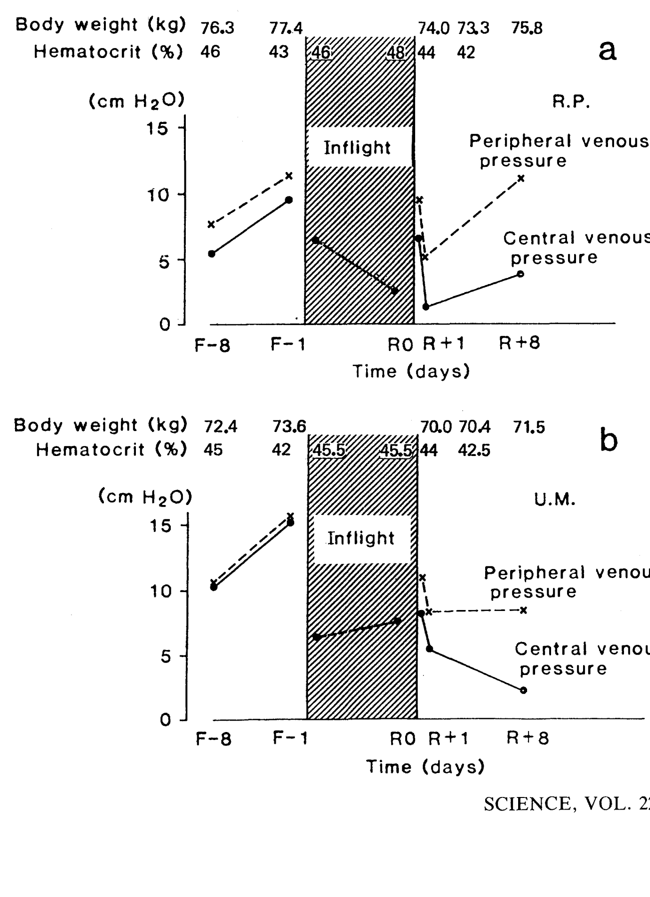

Fig. 1. Time course of body weight, hematocrit, and peripheral, and central venous pressure in two astronauts before, during, and after the Spacelab 1 mission. The data are characteristic for all four subjects. Times were: F − 8, 8 days before flight; F − 1, 1 day before flight; R + 0, 1 to 2 hours after recovery; and R + 1, 12 hours after recovery.

ed modulation was used for data acquisition. The flight unit was battery-driven. An identical unit was used to collect the ground-based data.

On the ground the central venous pressure was measured by the arm-down method. Peripheral venous pressure was measured with the astronaut lying on his back, keeping his arm almost perpendicular to his trunk. After the venous pressure measurements blood was drawn to determine the hematocrit and other values (*3*). Body weight was determined before the measurements.

Procedure. Measurements were made and blood drawn in the morning before breakfast. After entering the laboratory the subjects rested for 15 minutes. The last data points on the ground were obtained 8 days and 1 day before flight (days F − 8 and F − 1). During flight, data were taken 22 hours after launch on mission day 0 (MD0) and on MD2 and MD7. Postflight data were obtained 1 hour after recovery (R + 0) and 12 hours later (R + 1). Four astronauts took part in the experiments.

Results. During the prelaunch phase at least four measurements could be made on each subject. The central venous pressure levels were characteristic for each subject. One subject always had rather low levels while another showed high ones. During the mission ten measurements were scheduled and successfully completed for the four subjects. Figure 1 shows body weight, hematocrit, and peripheral and central venous pressure as a function of time from 8 days before flight to 8 days after recovery. The results are for two astronauts but are representative for all four subjects. From day F − 8 to F − 1 all subjects experienced a weight gain, a drop in hematocrit, and an increase in central and peripheral venous pressure. They all showed the highest pressure levels on day F − 1. For instance, in subject R.P. (Fig. 1a), central venous pressure was 9.5 cm H_2O and in subject U.M. (Fig. 1b) it was 15.2 cm H_2O. On MD0 and MD7, the respective numbers were 6.5 and 2.6 cm H_2O for R.P. and 6.5 and 7.7 for U.M. Under microgravity conditions, it can be assumed that the pressure in an arm vein is close to the intrathoracic venous pressure, since in all likelihood an open connection between intra- and extrathoracic veins existed. In space the hematocrits were markedly increased.

On recovery day all subjects had lost 4 to 5 percent of their body weight as measured on day F − 1. To our surprise, at that time the hematocrit was always lower than during flight, despite their negative water balance. The venous pressures were comparatively high. Twelve hours later the hematocrit had almost reached preflight levels, while the venous pressures showed a decrease and reflected the hydration level of the body better than they had 12 hours before. Later in the recovery period, until day R + 8, the subjects gained weight; however, the central and peripheral venous pressure patterns were different.

Conclusions. The fluid shift from the lower to the upper parts of the body that occurs during spaceflight and its reversal immediately after recovery seem to be highly dynamic processes which take place within 3 to 6 hours. This conclusion is based on our findings in the early recovery period. One hour after landing the retranslocation of fluids stored somewhere extravascularly in the upper parts of the body is fully under way, diluting the blood as indicated by a decreasing hematocrit and keeping the venous pressures unexpectedly high. At this time there is apparently a discrepancy between the central venous pressure and the hydration status of the body. Twelve hours later this discrepancy has been overcome since the central venous pressure has dropped to low levels.

If the same pattern applies to the headward movement of body fluids in microgravity, then our findings 22 hours after launch are understandable. Fluid migration had already taken place. In the time between launch and 22 hours after launch there might have been a phase where the central and peripheral venous pressures were elevated. However, this pressure peak disappeared as soon as the fluid had left the intravascular space, and a negative water balance followed, explaining the high hematocrit. This has been predicted by ground-based studies (*4*) and is in agreement with findings published by Pourcelot *et al.* (*5*).

Important questions in cardiovascular physiology in space still remain open. For instance, where is the fluid located during spaceflight and what forces drive the fluid toward the upper parts of the body?

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6. The willingness and patience of the astronauts who participated in this study are gratefully acknowledged. This study was supported by the Bundesministerium für Forschung und Technologie of the Federal Republic of Germany.

27 March 1984; accepted 17 May 1984

Mass Discrimination During Prolonged Weightlessness

Abstract. *Thresholds for mass discrimination under zero gravity in flight were found to be higher by a factor of about 1.8 than those for weight discrimination before flight. This suggests that humans are not as sensitive to inertial mass as they are to weight, and that adaptation can only partially compensate for loss of gravity. Weight discrimination thresholds were raised for 2 or 3 days after flight, suggesting an aftereffect of adaptation to weightlessness.*

When comparing the weights of objects, it is normal to pick them up and jiggle them. This method yields lower discrimination thresholds that does static pressure (*1*). The improvement is partly due to the involvement of the kinesthetic senses in addition to the pressure receptors (*2*). It may also be due to the availability of inertial cues to mass, sensed through the force required to accelerate the objects. In a 1-*g* environment it is difficult to distinguish between the contributions of weight and mass to what is usually called "weight discrimination." In a 0-*g* environment weight cues are effectively absent, and the discrimination can be made only by accelerating the objects and using inertial cues. An experiment was therefore conducted to compare thresholds for the same test, when performed on the ground and under weightless conditions in Spacelab 1.