Title: ANESTHETIC CONSIDERATIONS FOR A MICROGRAVITY SPACECRAFT ENVIRONMENT

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INTRODUCTION: The continuous presence of man in space is a reality. The U.S. space station will be constructed over the next 10 years, and plans for long duration space-flight for exploration of Mars are also under study. It is probable that surgical procedures will need to be performed in space within the next few decades because of trauma or medical emergencies. Emergency evacuation to Earth is not a realistic possibility. We must thus consider how anesthesia can be administered in the unique environments of microgravity and the semi-closed life-support system of spacecraft. Little research has been done on the practical problems of surgery in this environment, and there are no published data concerning anesthesia. We outline relevant anesthetic considerations and indicate where further data are needed.
PHYSIOLOGIC EFFECTS OF MICROGRAVITY: Cardiovascular: There is an early cephalad shift of extracellular fluid (1.5 -2 liters)[1] leading to a transient (24 hours) increase in central venous volume and pressure. This then leads to a diuresis, and decreased fluid intake. At equilibration there is a decreased total plasma volume, a slight increase in heart rate, a slight decrease in blood pressure, and no significant change in cardiac output.[1] Pulmonary: A small (10%) decrease in vital capacity has been described,[1] and West, et al.[2] have demonstrated that normal topographic distributions in lung expansion and blood flow are eliminated during short periods of microgravity in aircraft. There are ambitious plans for detailed studies of pulmonary function during the Spacelab 4 mission.[2] Head and Neck : Motion sickness in space (Space Adaptation Syndrome or SAS) affects roughly 50% of astronauts.[1] Symptoms include nausea and vomiting as well as vertigo, diaphoresis and nystagmus. However, this syndrome appears early in flight, is usually induced by head movement, and subsides in 2 - 7 days.[1] The effects of anesthetics on this etiology of nausea and vomiting are unknown, and will need to be determined. While gastric contents in anesthetized patients would not "fall" into the tracheobronchial tree in microgravity, they would not drain without active regurgitation or suction, making their aspiration more likely.[3] The airway might be more likely to remain patent during anesthesia in microgravity because the tongue would not "fall" into the airway when muscle tone is relaxed. Other: There is a 5-15% decrease in red cell mass.[1] Over long duration flights there is a significant loss of calcium from bone, causing decreased bone density, which can only be partially attenuated through active excercise.[1] It is unknown if astronauts will be more susceptible to trauma for this reason. Muscle atrophy occurs because of reduced muscular requirements for support of the body or locomotion.
TECHNICAL CONSIDERATIONS: There are many unique technical aspects of anesthesia administration in this envirnoment. Equipment must be compact, lightweight, and the miminum necessary for safety. Much standard equipment depends on a vertically directed gravitational force for proper operation (flowmeters, vaporizers, intravenous sets, etc.) and would need modification for use in space. Patient/anesthetist positioning: In the absence of gravity there is no Trendeleburg, prone, lateral, or sitting position. A higher likelihood of venous air embolus might exist for operative sites where this is not a problem on earth. The patient would have to be restrained in a fixed position -- A system has been tested for this purpose.[4] Methods of restraining instruments for ready access have also been tested[4,5] The anesthetist would also need restraints fixed to the patient's positioning frame. An unusual technique for laryngoscopy has been suggested.[3] Anesthetic techniques: Regional anesthesia offers benefits of requiring little equipment and allowing maintenance of normal mental status. In microgravity all subarachnoid blocks would be isobaric, although spinal fluid dynamics in microgravity are not currently known. The technical aspects of most regional procedures could be easily taught to physician astronauts. General anesthesia might be required for certain procedures. Mask ventilation might be easier in space because of better airway patency, but the risk of aspiration might be increased.[3] Spontaneous ventilation would be preferrable to avoid the weight of a mechanical ventilator, but a lightweight means of positive pressure ventilation by hand would be essential. Inhalation anesthesia would be a problem because of the necessity for non-gravity-dependent vaporizers, and because contamination of the cabin atmosphere with anesthetic gases should be avoided. N_2O would not be used because of its weight and space requirements. Thus, a total intravenous technique might be optimal if general anesthesia is required. Computer-controlled infusion pumps would work in microgravity and would offer precise control of anesthetic depth.[6] Monitoring: Most of the usual monitors will already be available in the space station for use in life science research. Pulse oximetry would be desirable, especially in view of possible changes in pulmonary physiology.[2] Surgical considerations: The largest problem may be the control of shed blood which might scatter in small droplets. Solutions have been designed which control shed blood using laminar airflow,[4] or a plastic chamber surrounding the operative site, with glove ports for the surgeon and assistants.[5]
DISCUSSION: The physiologic changes seen in microgravity are probably of minor significance for the healthy adults who will occupy spacecraft. Except for the possibility of an increased risk of aspiration (which should be investigated) there should be few changes in anesthetic protocols dictated by physiology. Size, weight, and ease of use would appear to be the main determinants of optimal anesthetic techniques and equipment. As man takes up permanent occupancy in space, detailed plans for anesthesia administration in this unique environment should be developed.

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