Anesthetic Concerns of Space Flight

An Editorial View of MS#199906086, Airway Management during Spaceflight: A Comparison of Four Airway Devices in Simulated Microgravity, by Keller C, Brimacombe J, Giampalmo M, Kleinsasser A, Loeckinger A, Giampalmo G, and Puhringer F.

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tion of space progresses, space operations will evolve from brief forays planet into years-long voyages to Mars, and, eventually, permanent, lonies independent of Earth. Surgical disease and severe illnesses are i table in these operations. Anesthesiologists are acutely aware of the fact that, although a given surgical procedure may be relatively simple, the required anesthetic care is, in certain cases, extremely complex. This principle is particularly evident when one ponders the difficulties involved in providing even basic anesthetic care in microgravity. In this issue, Keller et al.[1] confront some of these difficulties through their evaluation of airway management techniques during water immersion, a simulation of the gravitoinertial conditions of space flight. As prelude for this paper, I would like to outline of some of the challenges to be overcome before surgical, anesthetic, and critical care can be delivered beyond our home planet.

## Physiologic Considerations

Anesthetic complications that arose during the recent Bion 11 mission indicate that a cautious approach should be taken to in-flight and post-flight anesthetic care. This project was conducted jointly by Russia and the United States, and it concluded in 1997. Two primates flew for 14 days in a dedicated "biosatellite". An anesthetic was delivered to the animals on the first post-flight day to perform minor surgical procedures such as muscle biopsies. Despite competent care by a team of veterinarians from both countries, one animal died during the anesthetic and the other experienced serious complications. In previous Bion flights, no animal received an anesthetic prior to the seventh post-flight day, and no anesthetic complications occurred. The causes of these incidents are not clear, but substandard anesthetic care has been excluded. Clearly, our knowledge of the risks of anesthesia during and after space flight is imperfect.

### *Likely Types of Disease and Surgical Procedures*

The goal of crew medical selection and health-maintenance programs is to fly fit people. Consequently, the type of disease seen in space is likely to arise as a reaction of a normal person to an abnormal environment. For example, microgravity induces disorders of calcium metabolism that increase the risk of nephrolithiasis[2]. Therefore, a need for the capability to perform urologic procedures should be anticipated. Trauma is also inevitable during wide-ranging space operations. Some guidance regarding likely patterns of disease can be obtained from analysis of operations in analogue environments such as Antarctic over-winter deployments and fleet ballistic missile submarine cruises[3]. Unfortunately, a wide spectrum of diseases is encountered in these operations, indicating that versatile medical capabilities will be needed during extended space missions.

### *Autonomic Dysfunction*

Cardiovascular deconditioning, disruptions of central modulation of baroreceptor reflexes, non-responsiveness of autonomic function to cardiovascular stresses, and decreases of intravascular volume have been frequently observed during and immediately after space flight[4]. The implications of these observations on the conduct of anesthetic care are profound. For example, since spinal anesthesia seems to carry a risk of cardiovascular collapse due to dysfunctional autonomic reflexes[5], an astronaut might be at increased risk for this disastrous complication.

### *Disuse Atrophy and Changes in Neuromuscular Physiology*

Succinylcholine, under certain circumstances, will produce hyperkalemic cardiovascular collapse. One type of patient at risk for this complication is the bed-ridden individual[6,7]. Extended exposure to microgravity conditions seems to carry at least a theoretical risk of producing changes in the neuromuscular junction similar to those induced by bed rest. Until more is known about the effects of spaceflight on the neuromuscular junction, depolarizing neuromuscular blockers should be avoided during and immediately after flight.

### *Gastroesophageal Reflux*

Crew frequently report mild symptoms of gastroesophageal reflux during flight. In addition, the majority of crew also experiences "space motion sickness" during the first few days of flight. Some suffer a relapse of these symptoms upon return to Earth, and an unlucky few are never really completely free of symptoms throughout their multi-week flights. In-flight investigations have discovered that marked decreases in gastric motility occur very early in the course of space motion sickness[8]. These observations suggest that crew are at increased risk for aspiration during induction of anesthesia and emergence, both in-flight and post-flight.

## Technical Considerations for In-flight Care

### *Fluid Handling*

In microgravity, fluids and gases do not separate as a result of their differing densities. Consequently, a multi-dose vial of a drug or a conventional bag of normal saline contains something akin to a foam (Figure 1). This seemingly trivial methodologic detail is one of the most troublesome obstacles to the delivery of health care in microgravity. Each fluid transfer involves a detailed procedure that, if not performed properly, produces a useless mix of gas and fluid. Furthermore, many medical devices which depend upon gravity-induced separation of gases and fluids such as anesthetic vaporizers and patient suction equipment do not function properly in microgravity.

### *Closed Cabin Atmospheres*

Spacecraft are tightly sealed environments. Although some substances can be "scrubbed" from the cabin atmosphere, strict precautions must be taken to minimize the venting of exotic substances into the atmosphere. The safe use of volatile an[illegible] in such an environment is hard to imagine. Spacecraft operations also can no[illegible]anton dumping of oxygen from respiratory support equipment into the c[illegible]phere since oxygen enrichment of the atmosphere increases fire hazards. The [illegible]cuit systems that have been developed to utilize xenon as an anesthetic gas[9] ma[illegible] applicability to space operations.

*Consumables, Logistics, and Shelf-Lives*

The bill associated with placing one kilogram of material (e.g., one liter of crystalloid solution) into low Earth orbit is currently about $22,000 USD. Furthermore, stowage space aboard spacecraft for medical supplies is extremely limited. Clearly, the inventory of medical supplies that is flown will have to be carefully chosen to minimize mass and volume. Also, pharmaceuticals with a long shelf-life that do not require refrigeration will be highly desirable.

*Crew Skills*

In current space flight operations, the crew complement of each mission includes a Crew Medical Officer (CMO). The CMO may have no biomedical background whatsoever prior to entering the Astronaut Corps, and the formal training a CMO receives totals about eighty hours. CMO background requirements and training will need to be modified before advanced medical care in space is a realistic possibility.

*Telemedicine and Information Technology*

As telemedicine technology matures, the goal of establishing the presence of a "virtual expert" in remote locations comes closer. This technology has obvious applicability to space flight operations. However, during a journey to Mars, the speed of propagation of electromagnetic transmissions is such that as much as 40 minutes may be required to receive an answer to a question. Given the fast pace of events during anesthetic procedures, telemedicine technology will need to be supplemented with advanced on-board information systems.

## Approaches to In-flight Care

*Local and Regional Anesthesia*

Expertly performed local and regional anesthesia may avoid many of the problems associated with conducting a general anesthetic in space operations. However, the on-board anesthetist is unlikely to be an expert, regional blocks sometimes fail, and anesthetic complications do occur. Consequently, although local and regional anesthesia may be preferred approaches, they can not be the only options.

*Total Intravenous Anesthesia (TIVA)*

Many drug combinations and techniques are now avail[illegible] to perform TIVA, and more will come. Adaptation of these methods to microgravit[illegible] [illegible]nditions seems entirely feasible. TIVA would seem to be a promising means o[illegible] providing a general anesthetic in space.

Post-flight Care

Given the large number of landing sites throughout the world that might be utilized in current and planned operations, the medical infrastructure necessary to support these missions is vast and dispersed. Surgical procedures may need to be performed immediately after landing. Advances in our understanding of the anesthetic considerations of these conditions will need to be thoroughly communicated to any practitioner who might play a role in such a drama.

Significant difficulties must be overcome before anesthetic care can be delivered safely in-flight and post-flight. The same can be said of virtually any other aspect of medical care. Meeting these challenges is the task of the nascent field of space medicine. Anesthesiologists have much to contribute to these efforts.

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Legends:

Figure 1. A one-liter bag of normal saline in orbital flight. Gas and liquid do not separate in microgravity, a factor that greatly complicates routine fluid handling tasks.

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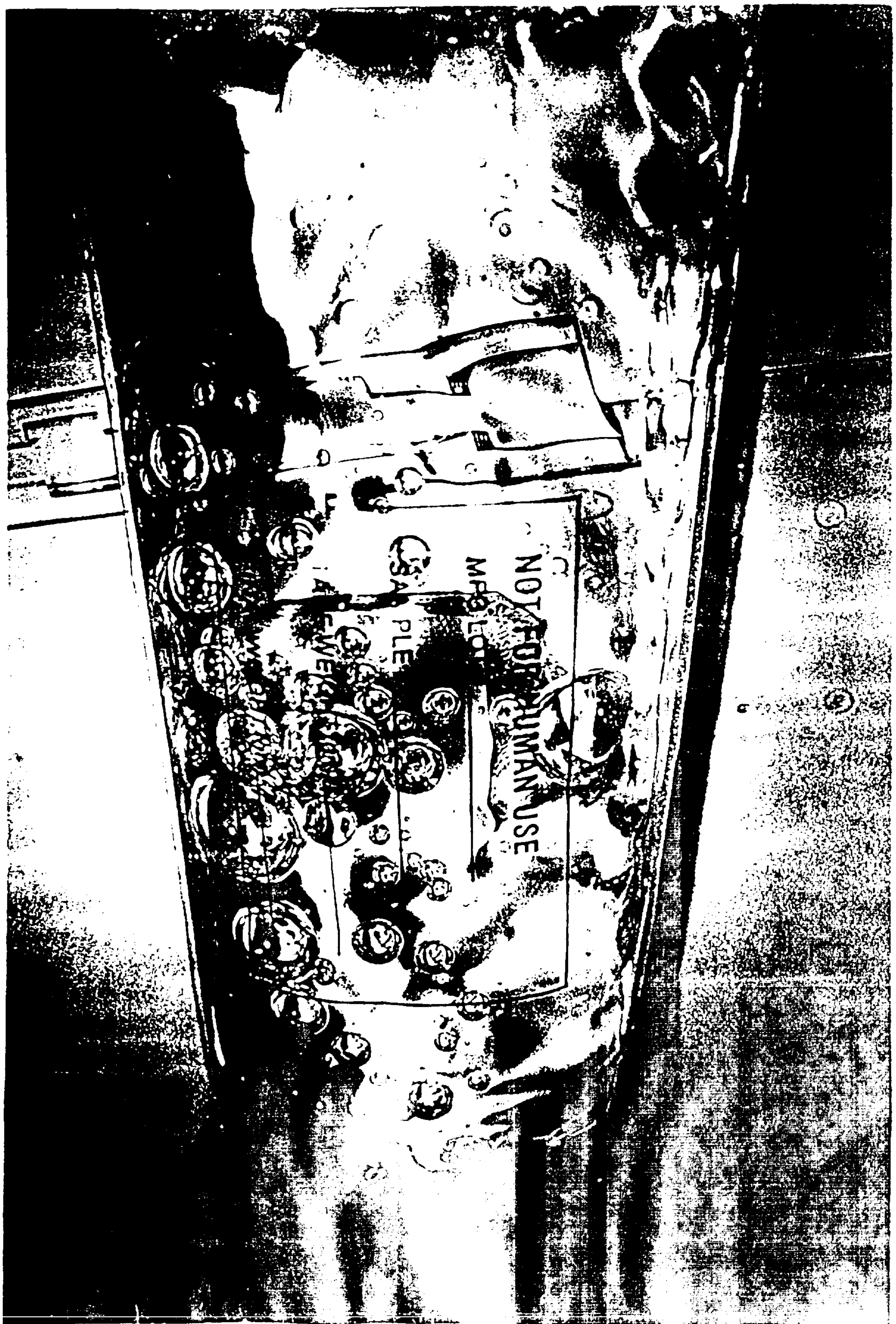
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