Providing adequate medical care for spaceflight crews requires that appropriate diagnostic tools and treatment modalities be available to them throughout their mission. The challenge for mission planners is deciding what medical capability to provide and then packaging it in a way that meets the many unique constraints of space flight. Crews also must receive adequate training that will help them to make correct diagnoses and administer the appropriate level of care to an ill or injured crewmember.

As discussed in Chap. 7, identification of appropriate levels of medical care is driven by the risks that have been identified in space flight. One practical way of identifying such risks is by studying risks among analogous populations, such as military pilots, submarine crews, and Antarctic winter-over research teams. From these groups, which undergo medical screening processes similar to those of spaceflight crews, the probabilities and risks of illness occurring during a mission can be estimated. Review of reported illnesses in U.S. and Russian spaceflight crews also can be useful, although such data were not available to medical mission planners in the earliest days of space flight. The duration of a space mission and the number of high-risk activities associated with it (e.g., extravehicular activities) will also influence decisions concerning the content of onboard medical systems. Mission planners must also consider environmental factors that are unique to the space environment—factors that include microgravity, radiation, toxicology, microbiology, and purity of reclaimed water. Finally, the unique physiological responses to space flight must also be examined—space adaptation syndrome, cardiovascular deconditioning, and bone demineralization, among others. Only by accounting for all of these factors can the best possible care and facilities be provided to spaceflight crews.

Space Medical Practitioners

Two groups are charged with providing real-time care for spaceflight crews: the onboard crew medical officers (CMOs) and the ground medical support personnel. Although communications resources may enable a ground-based flight surgeon to guide a CMO through a technical procedure, the extent of the CMO’s training will correlate strongly with medical success. The CMO’s skill level must therefore be taken into account in the selection of medical hardware.

Medical hardware flown should be appropriate to the skill level and training of the crew. There is no sense in selecting medical hardware that a CMO has not been trained to use. Although including a physician in every spaceflight crew would greatly enhance mission safety [1], there are too few NASA astronaut-physicians for this to be possible. Flight rules now designate that each Space Shuttle crew of five to seven individuals must include two CMOs who, whether they are physicians or not, must complete a training syllabus designed to provide them with the basic knowledge and skills necessary to provide first-line care on orbit. Similarly, two CMOs are designated from the crew complement of three to six long-duration crewmembers on the International Space Station (ISS). These individuals are trained by flight surgeons and other operational personnel.

The medical kits provided on various spacecraft (including the ISS, the Space Shuttle, and the Russian space station Mir) were and are designed to meet identified mission-specific risks and to account for any limitations in the medical background of the crew. CMOs are trained to a basic degree of competence through a series of structured classes and field exercises. Onboard refresher training for medical emergency procedures is included for long duration flights.

Medical Hardware Considerations

The desired medical capability must be weighed against the limited resources available on board a spacecraft. Electrical power, potable water, and other consumables are valuable and limited commodities and are not always available for routine medical purposes. The most expensive and scarce commodity is crew time. Vehicle operations and maintenance tasks, payload operations, and other important activities compete
with medical requirements for time in the crew schedule. To ensure that medical tasks are completed, the procedures must be simple and intuitive and must involve a minimal number of personnel. A medical evaluation procedure that is either awkward to perform or requires an inordinate amount of time to complete may not be completed. Also, an injured or ill crewmember will reduce the workforce for onboard activity significantly.

Providing terrestrial standards of care to space crews requires careful planning and forethought. Mass, volume and power are extremely valuable on a spacecraft, and the medical systems flown must minimize their consumption of these assets. Priority must also be given to items with a long shelf life, stability at ambient temperature and humidity, and minimal maintenance requirements. Simple and intuitive designs for equipment will aid in its effective use, particularly by the non-medical user who may handle the items very infrequently. This is especially important for resuscitation hardware.

Microgravity itself presents many design challenges. For example, any process that includes gas-fluid separation will require centrifugal force or gas-fluid filter systems to act in place of gravity. Procedures that generate particulate or fluid contamination of the spacecraft, such as dental drilling, specimen handling, or surgical procedures, must be performed in specialized enclosures. Finally, restraint of operator, subject, and support items is a fundamental requirement in microgravity.

In microgravity, most examination techniques are unchanged, and most of the standard diagnostic and therapeutic instruments need not be modified. Stethoscopes, otoscopes, venipuncture kits, and many other familiar items have been used successfully for years in space flight, once crews have become accustomed to moving and managing these items in weightlessness and adjusting for other factors such as high ambient noise and low light levels.

The following subsections provide a discussion of selected medical equipment and capabilities and some of these unique considerations. Astronauts with spaceflight experience must be included in the design of new medical systems, as they have insight not available to ground engineers. Each new generation of hardware must reflect the hard won lessons of space medical operations.

Medical Restraint Systems

Experience has shown that medical examinations, intravenous (IV) techniques, and other procedures can be accomplished in the microgravity environment without specialized restraint systems. However, more complicated medical procedures cannot be performed without the use of proper restraint systems to bring CMO, patient, and medical support items into close proximity. To support contingency events in which acute care would be required, the best solution is a dedicated medical restraint table that either can be deployed quickly or is always deployed and at the ready. Prototypes of such systems have been tested during parabolic flight [2] and space flight [3]. The ideal medical restraint would accommodate the neutral body posture assumed in microgravity (by both patient and CMO) and would support basic procedures, such as simple wound repair, as well as more complex operations. This restraint also would incorporate interfaces for medical equipment and medical waste management, such as body-fluid-saturated pads and discarded sterile packaging.

For the near future, dedicated constantly deployed medical restraints are unlikely to be included in spacecraft because of volume constraints. Other available surfaces have been and will be used, however, such as cabin walls and galley tables. However, a smaller hybrid system consisting of a rapidly deployable surface attached to dedicated structural mounts offers a viable alternative. In an acute, life-threatening situation, the time to deploy a restraint is a critical factor that could well affect patient survival. These considerations contributed to the development of the current ISS crew medical restraint system. That system consists of a rapidly deployable rigid platform that quickly restraints both patient and operator in close proximity to the onboard medical system. This restraint system also affords electrical isolation from the station systems and rescuers should defibrillation be required.

Automated Ventilation

Advanced airway handling methods have been developed for use in the weightless environment and have been taught to CMOs. Equipment for endotracheal intubation has been on hand on Skylab, Space Shuttle, Mir space station, and ISS missions. Some type of manual respirator has always been available during these programs, and a small automated ventilator also is now part of the ISS medical inventory.

Because of electrical power constraints in spacecraft, the best option for automated ventilation is a compact pressure-driven ventilator that uses the storage pressure of respirable gas. On Earth, such ventilators are typically used for short-term acute care. For a patient who is incapable of adequate spontaneous respiration, the compact pressure-driven ventilator is a potentially lifesaving device that replaces a crewmember who would otherwise be required to give manual respirations with a bag device. As noted above, ample assistance may not be available should a medical crisis occur in flight. In the ground-based transport and acute roles, pressure-driven ventilators are generally powered by 100% oxygen. This immediately creates a problem in the enclosed environment of a spacecraft in that the patient-ventilator exhaust is nearly 90% oxygen, with the remaining 10% being expired CO2 and water vapor. In an enclosed cabin, ambient concentrations of oxygen can rise quickly and exceed flammability limits. A short-term option in such a contingency would be to add a diluent gas such as nitrogen to the cabin atmosphere to maintain safe concentrations. However, this option comes at a cost in consumables as overall atmospheric pressure bleeds off to maintain cabin pressure limits.