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Critical Care Medicine Limited by Speed of Light

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Remote delivery of critical care is a feasible option with the advancement of remote guidance and telementoring techniques.

The development of solutions for medical care in the resource-scarce environment of space flight is an ongoing demand for the International Space Station (ISS), where the care providers are not medical professionals; further efforts in this direction are essential for exploration-class space missions. The science and practice of space medicine have progressed significantly in recent years, and many of these advances may enhance medical care delivery on Earth.

No significant mission-impacting or mission-terminating medical events have yet occurred on the ISS, and the probability of such events occurring in the future is low. The current plan for medical care on National Aeronautics and Space Administration (NASA) shuttles and the ISS relies on a non-physician Crew Medical Officer (CMO), who is trained for approximately 70 hours to serve as a medical technician for a variety of medical conditions. It is impossible to predict the exact nature of critical care and life support procedures which the CMO, with limited medical training, may be asked to perform aboard the ISS. Many of these procedures, however, may be challenging even for a trained physician.

In terrestrial settings, critical care is generally provided in intensive care units (ICU) by intensivists, critical care nurses, respiratory therapists and others. The use of telecommunications partially compensates for the absence of such expertise onboard the spacecraft. Experiments onboard the ISS and ground-based experiments with “CMO analogs” (non-medical professionals given training equivalent to that of the astronauts) have examined the feasibility of performing state-of-the-art diagnostic and treatment procedures using expert remote guidance. The procedures were designed to be compatible with current equipment and training constraints aboard the ISS.

The Advanced Diagnostic Ultrasound in Microgravity (ADUM) project, developed by NASA-selected researchers, has effectively trained and remotely guided non-physicians to perform diagnostic and therapeutic image-guided ultrasound procedures. Remote clinicians were able to effectively guide the CMO in a number of diagnostic and therapeutic procedures. Musculoskeletal injury, pneumothorax, hemothorax and ocular trauma, among others, can be readily visualized by non-physician crew members and communicated to the medical expert for diagnosis. In addition, remotely guided micro-laparoscopy with a 3-mm endoscope has been successfully completed in the microgravity conditions of parabolic aerial flight. Such exploration of the abdomen could be used to evaluate and treat abdominal pathology, including appendicitis, biliary disease, abdominal trauma, or gynecologic disease. Percutaneous cholecystostomy and suprapubic cystostomy were also successfully performed in these experiments, providing potential alternative treatment modalities for crewmembers with surgical conditions such as cholecystitis, urinary retention or urolithiasis, in lieu of acute evacuation from the ISS.

In addition to the validation of new microgravity sonographic imaging and therapeutic techniques, our group also evaluated new critical care life support and monitoring equipment. An advanced ventilator was evaluated in aerial microgravity trials to address scenarios in which crewmembers require intensive care, including physiologic monitoring, over a period of time. A compact, 12-pound, closed-loop mechanical

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ventilator was developed that allows remote clinicians to monitor and control all ventilator parameters while the data are stored in the integrated electronic medical record. The closed-loop control can also manage oxygen delivery from a digitally controlled compact concentrator or a 100% oxygen source.

A large body of unpublished data demonstrates the ability to perform cardiopulmonary resuscitation (CPR), intravenous access with infusion of fluids and medications, intravenous anesthetic techniques and central arterial, central venous and intracerebral pressure monitoring in microgravity conditions. In a consortium with NASA, a partner in industry is currently developing lightweight modules that provide a universal medical data station to accept a wide variety of data types, from sensor readings to video streams, and to control devices such as a ventilator, an oxygen source or an IV pump.

Established critical care approaches and innovative, minimally invasive diagnostic and treatment techniques, coupled with advanced training methodologies and remote expert guidance, significantly expand the potential critical medicine capabilities for use in future space flight programs. The application for elements of the above investigations in terrestrial medicine seems to be promising. In the case of planetary exploration, the latency of medical telemetry signals between the experts and the patient’s site will increase, thus making the speed of light the only remaining limitation to critical care delivery in space.

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