featured in this section are constantly evolving and are written by the students themselves, with each profile sharing with the reader the individual's story of where they came from, what they are currently doing and where they see themselves headed in the future. This section also provides a great opportunity for space industry representatives to identify some of the country's brightest students who may be at the forefront of leading the next wave of Canadian innovation.

For more information on any of these programs, as well as many other learning opportunities, please visit the student section of the CSA website at: http://www.asc-csa.gc.ca/eng/youth-students/17/

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CROSSROADS

Medical Education for Exploration Class Missions

NASA Aerospace Medicine Elective at the Kennedy Space Centre

Gregory E. Stewart*, Laura Drudi

BACKGROUND OF AEROSPACE MEDICINE ELECTIVE

For over a decade, the Canadian Space Agency (CSA) has selected Canadian medical students & residents to attend NASA's prestigious Aerospace Medicine Elective at either the Kennedy Space Center (KSC) on the Space Coast in Florida or the Johnson Space Center (JSC) in Houston, Texas (1). Selected students have the privilege to learn from pioneers and leading experts in space life sciences about the physiologic adaptations that occur during space-flight as well as the preparations and medical support required for a Space Shuttle launch to the International Space Station (ISS).

INTRODUCTION

The spaceflight environment poses many challenges to astronauts. Understanding the effects of long duration space travel and how a crew medical officer (CMO) operates in this extreme environment was the focus of the research project. The knowledge and skills set for future CMOs as the endeavours to space exploration continue, and Canada's involvement in this initiative was further assessed in this project.

Physicians are often chosen to be astronauts; however, non-physicians are often the CMO on the ISS. Forty hours of CMO training occurs during the two-year period leading up to the actual mission and there is no protocol for maintaining medical skills during a long duration mission (2,3). Therefore, procedural skill decay will be an important issue worth considering for long duration space missions, and effective countermeasures should be developed for CMOs to manage arising medical events. Also, extensive equipment and supplies for the medical interventions cannot be provided due to the severe weight and volume constraints of spaceflight (4,5,6). Thus, risk management strategies dictate that only those situations that are the most severe, or the most easily diagnosed and treated will be anticipated and supplied.

The greatest medical concerns to a crew on an exploration class mission include (i) radiation exposure (ii) human behaviour and performance and (iii) physiologic alterations in the reduced gravitational environment (2,4,5). With the cancellation of the Constellation program, the current plan for NASA is to support the extension of the ISS through 2020. Thus, the ISS will serve as a platform for space life sciences research as well as preparation for future exploration class missions by increasing our understanding of space physiology (6,7).

The standard of care on the ISS is to support the crew 24/7 from Mission Control and to stabilize & transport an astronaut to Earth for definitive medical care (2). For future exploration class missions, however, the medical care system will need to be very autonomous and self-sufficient due to the communication delay and extremely long separation from definitive medical care. Furthermore, procedural skill decay will become a mission-threatening medical consideration, as the expected rate of a significant medical event extrapolated to a 2.5 year Mars mission involving 6 crew members is approximately 1 event/mission (8).

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Current countermeasures for procedural skill decay include efficient and structured medical training design (9). Specifically, the educational experience can be enhanced by designing realistic simulations, also known as High-fidelity Environment Analog Training (HEAT) (10,11). Similar to flight simulators, medical simulation allows effective training and maintenance of skills, and has been successful in improving the training of physicians in safety critical environments including the Emergency Department, the Operating Room and the Intensive Care Unit (12,13). NASA has also developed a flight-ready human patient simulator that can operate in simulated microgravity (i.e. KC-135) and potentially spaceflight (14,15,16).

The importance of simulation based learning is highlighted by the Dual process model which describes efficient reasoning and judgment as distinguishing crew characteristics in safety critical environments (17). Essentially, the model describes two cognitive systems for problem solving:

System 1: characterized by intuitive, rapid reasoning.

System 2: characterized by deliberate, careful reasoning.

Thus, simulation based learning allows the student to develop essential reasoning and judgment skills (i.e. develop System 2) while continued practice allows unfamiliar situations to become more automated and efficient (i.e. develop System 1). This allows advancement to more complex tasks once competence in basic skills has been shown.

Ideally, efficient training design mitigates human error and the risk of an adverse event to a safe and acceptable level. In aviation, it is accepted that errors and mistakes by crewmembers will occur in any flight and a non-blame approach to error is emphasized (18). By shifting the focus from blame to safety, the error is dealt with as any other threat to safety, and the best course of action is discussed in an open atmosphere to determine the most appropriate response to the new situation (19). This philosophy of error management has been formalized into simulation based training entitled Crew Resource Management. It was developed in the late 1970s when it was found that up to 70% of aviation accidents were due to crew issues including failure in communication, lack of situational awareness and poor error management (20). Similarly in medicine, communication issues have been implicated in 70% of perinatal deaths and injuries (21). Also, it was found that 30% of neonatal resuscitation steps are not performed or performed incorrectly. Certainly, check-lists can be a helpful memory aid in these safety critical environments, especially when all relevant human factors are not addressed (22).

Human factors engineering is the study of the interaction between humans and their working environment (20,23). More specifically, its goal is to understand how human limitations, capabilities, characteristics, behaviours and responses will affect performance in a given environment. Furthermore, the application of our understanding of human factors to the design of an intuitive system will minimize risk and optimize performance (24,25).

For example, telemedicine has been used in the design of a model for safe technology transfer to community surgeons in Southwestern Ontario, Canada (26). The study used a preceptor guided training schedule to meet minimum case requirements. The preceptor allowed progression from direct “scrubbed-in” supervision to “verbal-only” supervision and finally to telementoring only when competent skill and judgment was observed. The study demonstrated the feasibility of a training program for laparoscopic colon surgery that shortens hospital stays and ultimately improves patient outcomes.

Telemedicine can also be applied to space travel. A case in point is Just-In-Time telemedicine for ultrasound exam, as it provides a means to investigate a wide variety of conditions in remote & austere environments (27). For the ISS, the training design uses a pre-mission familiarization with the equipment followed by on-board CD-ROM based skill enhancement, as well as remote expert guidance for patient exam. This telemedicine training algorithm developed for spaceflight has also been used to rapidly train medical and non-medical personnel to perform complex procedures (28). Furthermore, it has been used to confirm the diagnosis of High Altitude Pulmonary Edema (HAPE) in mountain climbers on Mount Everest (29).

CANADA’S INVOLVEMENT IN THE FUTURE OF SPACE EXPLORATION

A unique contribution Canada can make to future exploration class missions is to develop a remote medical training program for crew medical officers. This could be a niche sector for the Great White North as it offers a vast and largely uninhabited geographic area, harsh climate and established medical infrastructure necessary to support the training of future astronaut-physicians.

Thus, as the International Space Station nears completion, it demonstrates how teamwork and collaboration foster the motivation and determination to overcome even the greatest of obstacles. Ultimately, efforts to better our world will undoubtedly inspire the next generation of scientists and explorers to improve their world as well. No matter how large or small the contribution, all those involved with the international space exploration effort can be proud of their motives.

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Gregory E Stewart (BMSc MD CCFP(c)) completed medical school at The University of Ottawa and is now a resident at The University of Western Ontario in the Rural Family Medicine Program in Goderich. As a pilot and traveler as well as a physician in training, he investigated "Medical Education for Exploration Class Missions" because he was interested in learning about the medical concerns of long duration space travel and how a CMO operates in this extreme environment.

Laura Drudi (M.D., C.M. candidate 2013) is a third year medical student at McGill University. Her interest in combining her two passions of space and medicine has led her to conduct aerospace medicine research. She will be taking a one year's leave of absence from the Faculty of Medicine and will be pursuing a Diploma of Space Studies and an MSc in Experimental Surgery prior to completing her MD. She hopes to work for the manned space program as a flight surgeon and to further continue her research in space life sciences.

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CROSSROADS

Ultrasound: From Earth to Space

Jennifer Law*, Paul. B. Macbeth

ABSTRACT: Ultrasonography is a versatile imaging modality that offers many advantages over radiography, computed tomography, and magnetic resonance imaging. On Earth, the use of ultrasound has become standard in many areas of medicine including diagnosis of medical and surgical diseases, management of obstetric and gynecologic conditions, assessment of critically ill patients, and procedural guidance. Advances in telecommunications have enabled remotely-guided ultrasonography for both geographically isolated populations and astronauts aboard the International Space Station. While ultrasound has traditionally been used in spaceflight to study anatomical and physiological adaptations to microgravity and evaluate countermeasures, recent years have seen a growth of applications adapted from terrestrial techniques. Terrestrial, remote, and space applications for ultrasound are reviewed in this paper.

Keywords: Ultrasound, Spaceflight, Telemedicine, Telesonography, Remote consultation

INTRODUCTION

The use of ultrasound to diagnose and facilitate therapeutic interventions has become routine in many areas of medicine and surgery (1). With advances in computing power and probe design, ultrasound systems have become a widely available imaging modality. Traditionally, ultrasound is best known for its assessment of pregnancy and fetal growth. A growing number of applications have developed to include detailed assessments of almost every organ system. Clinicians have also identified benefits in trauma, critical care, and remote diagnostics. Ultrasound is an ideal diagnostic tool as it is noninvasive, low-cost, and highly portable. Image generation and interpretation, however, is highly user-dependent. As a result, ultrasound has traditionally been limited to expert users. With new advances in ultrasound technology and personnel training, the use of ultrasound has expanded beyond these traditional boundaries and has become an extension of the physical examination to many. Bedside ultrasound assessments have enhanced physicians' capabilities to accurately diagnose and understand patient physiology with the benefit of real-time feedback (2).

In this review we discuss the development of ultrasound technology and its expanded assessment of patients. A detailed description of its applications will be highlighted with discussion of its remote capabilities and utility for human space exploration.

BACKGROUND

History of ultrasound. The origins of ultrasonography can be traced back as far as the early 1800s, when Swiss physicist Jean-Daniel Colladon accurately determined the speed of sound through water. In the late 1800s, Pierre Curie and Jacques Curie demonstrated the connection between voltage and pressure in crystalline materials now known as the piezoelectric effect. This breakthrough led to the creation of the modern ultrasound transducer. It was not until the late 1930s when Austrian psychiatrist Dr. Karl Dussik demonstrated the clinical utility of ultrasound by generating images of brain tumors. A decade later, Dr. George Luwig characterized the differences of sound waves in different tissues. Early clinical applications primarily focused on clinical assessment of pregnancy and fetal development. As the technology matured, more clinical applications

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