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Ultrasound in Emergency Medicine

NEW HEIGHTS IN ULTRASOUND: FIRST REPORT OF SPINAL ULTRASOUND FROM THE INTERNATIONAL SPACE STATION

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☐ **Abstract—Background: Changes in the lumbar and sacral spine occur with exposure to microgravity in astronauts; monitoring these alterations without radiographic capabilities on the International Space Station (ISS) requires novel diagnostic solutions to be developed. Study Objectives: We evaluated the ability of point-of-care ultrasound, performed by nonexpert-operator astronauts, to provide accurate anatomic information about the spine in long-duration crewmembers in space. Methods: Astronauts received brief ultrasound instruction on the ground and performed in-flight cervical and lumbosacral ultrasound examinations using just-in-time training and remote expert tele-ultrasound guidance. Ultrasound examinations on the ISS used a portable ultrasound device with real-time communication/guidance with ground experts in Mission Control. Results: The crewmembers were able to obtain diagnostic-quality examinations of the cervical and lumbar spine that would provide essential information about acute or chronic changes to the spine. Conclusions: Spinal ultrasound provides essential anatomic information in the cervical and lumbosacral spine; this technique may be extensible to point-of-care situations in emergency departments or resource-challenged areas without direct access to additional radiologic capabilities.** © 2014 Elsevier Inc.

☐ **Keywords—International Space Station; ultrasound; spine; telemedicine; remote care**

INTRODUCTION

The International Space Station (ISS) medical support infrastructure has the capability to treat minor illness or injury for a crew of six members with a typical mission length of approximately 6 months. Although astronauts are screened for high-risk preexisting conditions, pathological processes may still evolve de novo during missions, and trauma is always a possibility. More common, however, are the variable and mostly transient changes associated with microgravity exposure. Among these, back pain in early days of flight and a pre- to postflight height gain of 2 inches or more is common. Spinal elongation is presumably due to an increase in intervertebral disk (IVD) volume and height, as well as straightening of the physiological curvatures of the spine. The changes to the vertebral column can conceivably increase the risk of trauma during resistive exercise and high-acceleration operations such as landing, especially if the seat configuration becomes suboptimal. Microgravity-induced changes of the spine have been described in literature based on pre- and postflight imaging and anthropometric measurements, but no in-flight spinal imaging has been attempted (1–7).

Ultrasound is increasingly relied upon for situations that benefit from instantaneous imaging results with an

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immediate effect on clinical management. The processes of radiology services are not well positioned to meet these recently recognized needs, hence, many accurate and sensitive ultrasound techniques are performed by non-radiologist clinical providers serving on prehospital, emergency department, and intensive care teams. This trend has led to the proliferation of new ultrasound applications that have not been properly evaluated or accepted by the radiology discipline. Because the ISS imaging capability is limited to ultrasound, space medicine experts not only monitor developments in this area, but play leading roles in the discovery and promotion of new ultrasound techniques and approaches (8,9). Spine ultrasound is among the least developed areas of medical imaging, yet is attractive due to the broad availability and affordability of equipment, potential benefits for space physiology and medicine, and the sizeable terrestrial patient populations that do not have access to "gold-standard" diagnostic resources.

A modern multipurpose ultrasound system is manifest on the ISS, which is heavily used for research and medical surveillance purposes. A wide variety of complex ultrasound examinations are performed in space by astronaut operators who have had limited training. These examinations are supported by onboard training software and real-time remote guidance; the effectiveness of both clinical and research tele-ultrasound are now well established within the ISS program. This report, directly submitted electronically from the ISS, describes the first ISS-based imaging experience in a new area – spinal ultrasound, based on lumbar and cervical vertebral ultrasound sessions during ISS Expedition 34. Although developed and used as part of a spaceflight investigation, the techniques of spinal ultrasound are likely to become a valuable tool for health care providers on the ISS and in other resource-constrained environments for the evaluation of trauma and other acute and chronic conditions involving the spine.

MATERIALS AND METHODS

Subjects

The experimental protocol was performed in two healthy male volunteer astronauts, 52 and 53 years old, aboard the ISS, including ultrasound imaging of the lumbar and cervical segments of the vertebral column. The investigative procedures were approved by the Human Investigation Committee and the National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center (JSC) Institutional Review Board. The crewmembers received briefings and acknowledged their informed consent prior to the mission. Experimental data included full-resolution still images and cine-loops retrieved post examination from the ISS ultrasound system, and a continuous low-fidelity video recording of the output of the ultrasound system.

Training, Equipment, and Communications

Astronauts attended a 1-h familiarization session up to a year prior to their mission that included a brief didactic presentation on the ultrasound (US) hardware and generic exposure to tele-ultrasound guidance. Approximately 3 months prior to launch, the crewmembers underwent a 1-h hands-on training at the Payload Development Laboratory (PDL) at the NASA JSC in Houston, Texas, to perform the experiment-specific procedures for spinal US. Crew training in the PDL involved focused imaging of the lumbar and cervical spine in a flight-like setting. The output of the US system from within the PDL was displayed on the remote sonographer's workstation to enable flight-like remote guidance for subject positioning, probe placement and manipulation, and equipment adjustments. Additionally, the astronauts were introduced to the 30-min multimedia refresher course – an experiment-specific computer-based program to be used within 24 h prior to the US session on the ISS (Figure 1).

Both training and in-flight US examinations were performed using identical GE Vivid q ultrasound systems (GE Medical, Milwaukee, WI). The 4C-RS and 8C-RS broadband curved array probes were selected for the lumbar and cervical regions, respectively. The images were viewed by the operator on the US system screen and were transmitted simultaneously to remote US guidance experts via local circuits (in training sessions) or satellite broadband transmission (ISS-based sessions). Due to distance, data relaying, and conversions, the latter included a delay in transmission to the Telescience Center at

Figure 1. A sample screen from the experiment-specific multimedia training software that is reviewed by the operator within 24 h of the imaging session.