Portable Radiography: A Reality and Necessity for ISS and Explorer-Class Missions

David J. Lerner; Allen J. Parmet

ABSTRACT: On ISS missions and explorer class missions, unexpected medical and surgical emergencies could be disastrous. Lack of ability to rapidly assess and make critical decisions affects mission capability. Current imaging modalities on ISS consist only of ultrasound. There are many acute diagnoses which ultrasound alone cannot diagnose. Portable X-Ray imaging (radiography) technology has advanced far enough to where it is now small enough, cheap enough, and accurate enough to give diagnostic quality images sent wirelessly to the onboard computer and on Earth for interpretation while fitting in something the size of a briefcase. Although further research is warranted, Portable Radiography is an important addition to have on ISS and future Explorer Class Missions while maintaining a very small footprint.

KEYWORDS: space medicine, space diagnostics, radiology, imaging.

Lerner DJ, Parmet AJ. *Portable radiography: a reality and necessity for ISS and explorer-class missions*. Aerosp Med Hum Perform. 2015; 86(2):140–142.

On ISS and explorer class missions (ECMs), unexpected medical/surgical emergencies could be disastrous. Lack of ability to rapidly assess and make critical decisions affects mission capability.[3] Imaging plays a major role in this on Earth; however, it is limited on the ISS to ultrasound. This could be due to many reasons: technical limitations, volume and mass penalties, and overall cost of prior radiography systems.[2] While ultrasound is a great method of detection for pathology,[7] there are important diagnoses which cannot be made by ultrasound alone, such as: imaging for lung parenchyma, including pneumonitis from inhalation of fuels/oxidizer vapors (as potentially happened on the Apollo-Soyuz mission);[2] pulmonary embolism; traumatic thoracic aortic injury; penetrating injury; radio-opaque foreign bodies (deep, as ultrasound is excellent for superficial foreign bodies); insufficiency fractures; osteomyelitis; bone infarct; evaluation for post-reduction fractures after extremity dislocations (finger dislocations have been documented in space);[8] fractures of the axial skeleton; extremity fractures (ultrasound can do this but to a much lesser degree for characterization and for fractures smaller than the lateral spatial resolution of ultrasound that is overcome by radiography); and evaluation of teeth and jaw for processes like dental caries. Ultrasound is a wonderful tool that has been used for years and greatly adds to imaging capability, especially in soft tissue, orbital, cardiothoracic, and abdominal imaging. However, difficulties can include operator error, technical limiting factors, and misinterpretation.[7] Radiography is checklist-based and simple to use. For example, portable radiography is employed in rural Africa where villagers have been taught to take radiographs and send them via email to radiologists for evaluation (Andronikou S. Imaging of infectious diseases: Visiting Lecturer Series from the University of Missouri Kansas City School of Medicine, Department of Radiology, Kansas City, MO; December 2013). Additionally, image-guided treatment can be obtained with percutaneous ultrasound guidance;[5] however, additional imaging modalities can improve technical success rates and open up additional interventional radiological procedures that can be performed to treat medical and surgical emergencies in microgravity.[6]

Over the past two decades, there has been an incredible jump in technological advancements in healthcare on Earth thanks to the development of microprocessors, power supplies, and other technologies. Diagnostic radiological imaging has benefited greatly from these advancements. Newer technologies in the field of diagnostic radiography have become

From the University of Missouri Kansas City School of Medicine and Saint Luke's Hospital, Kansas City, MO.

This manuscript was received for review in July 2014. It was accepted for publication in November 2014.

Address correspondence to: David J. Lerner, M.D., 8953 Linden Lane, Prairie Village, KS 66207; dlerner111@gmail.com.

DOI: 10.3357/AMHP.4110.2015

efficient and portable enough to greatly improve the diagnostic and interventional/surgical capability on the ISS and future ECMs.

An informal review of diagnostic radiography and possible medical/surgical diagnostic and interventional dilemmas that could occur on ISS/ECMs was performed. This included reading/reviewing multiple diagnostic/interventional radiology textbooks, reviewing radiation imaging physics and technological advancements in this field, and discussions with board certified radiologists, interventional radiologists, and aerospace medicine fellowship trained physicians regarding medical/surgical concerns. Diagnostic radiography was compared with ultrasound in the ability to evaluate medical/surgical emergencies. The American College of Radiology (ACR) Appropriateness Criteria and Guidelines were reviewed, which dictate the most appropriate study to obtain in various clinical situations.[1] Technical specifications of new portable radiography devices were compared with standard of care radiography in hospital use.

Possible medical/surgical emergencies by clinical presentation and history determine what study is indicated. This has been described in excruciating detail in the ACR Appropriateness Criteria (**Table I**). While for some things ultrasound ranks ahead of X-ray, for example gastrointestinal/genitourinary imaging, X-ray is more highly recommended for thoracic, musculoskeletal, and some neurological symptomatology. It also serves as a great complement in cardiac imaging with echocardiography. These recommendations are standard of care on Earth and should be as close to the standard of care as reasonably possible on the ISS and ECMs since the technology is finally available.[1] No one can argue that ultrasound imaging alone is better than ultrasound imaging combined with radiographic imaging. The only question is whether or not the weight and volume penalty is worth it.

The benefit of portable radiography over nonportable radiography is due to weight and volume. Current technology allows for small volume/mass of X-ray capability. It is highly mobile and can be taken to an unstable patient without risking moving them. The possible quality of a portable radiographic unit in terms of kilovoltage peak (KvP), milliamps (ma), spatial resolution, and contrast resolution are similar if not equal to a nonportable counterpart (depending upon portable platform). An additional benefit of portable radiography not allowed by a fixed unit is the ability to do nondestructive testing on infrastructure. This allows one to look inside of walls and hull for mechanical problems such as heat shield cracks, wiring that has come unplugged, etc. An additional benefit includes a portable energy pack that charges from a simple adapter.

Technical specifications compared to previous portable units have immensely improved in the past few years. With portability and low volume/weight yielding high resolution diagnostic images, many medical diagnostic issues could be resolved from something that is stored in a small protective briefcase (**Fig. 1**). Various companies make these for use in many different fields and they have been field tested and in use every day across the world. These units are chargeable from various sources, including electrical outlets. Some can function unplugged, run on battery, and be fully charged in 15 min. Everything functions wirelessly, facilitating ease of placement of energy source and image receptor, with the image quickly and easily wirelessly downloading onto the onboard computer or a tablet for immediate imaging in an emergency, and could then be confirmed by sending the image to the world's foremost radiologists in that field on Earth. These are relatively inexpensive compared to other forms of imaging systems, i.e., ultrasound, MRI, or CT.

Portable digital radiography could also help in situations where interventional techniques are needed,[4,6] i.e., drain placement in pyonephrosis or percutaneous cholecystostomy in acute cholecystitis. This would improve needle localization and help with confirmation of placement as this can be difficult with ultrasound alone. Multiple images could be obtained with relatively quick frequency, making this a "poor man's fluoroscopy" unit. Having a portable radiography unit available would also significantly increase the ability to study bone demineralization in microgravity over time as this could provide a noninvasive way to measure bone using dual X-ray

Table I. ACR Appropriateness Criteria.

CRITERIA	X-RAY RADIOGRAPHY	ULTRASOUND
Acute chest pain: suspected aortic dissection	9	4 (Transthoracic)
Blunt chest trauma	9	5
Acute respiratory illness: immunocompetent	9	Not appropriate
Hemoptysis	9	Not appropriate
Rib fractures	8	1
Chronic dyspnea of suspected pulmonary origin	9	Not appropriate
Acute onset flank pain: suspected stone	1	6
Acute pyelonephritis: uncomplicated	1	1
Suspected lower urinary tract trauma	5	2
Renal trauma	4	2
Acute trauma: hand and wrist	9	1
Acute trauma: ankle	9	1
Acute trauma: foot	9	1
Acute trauma: knee (with tenderness, effusion, or inability to bear weight)	9	1
Acute pain: shoulder	9	1
Soft tissue mass: nonspecific	9	1
Stress fracture	9	Not appropriate
Acute (nonlocalized) abdominal pain and fever or suspected abdominal abscess	6 (To evaluate for perforation)	6
Acute pancreatitis	Not appropriate	9
Blunt abdominal trauma: unstable patient	8	8 (FAST scan)
Left lower quadrant pain: suspected diverticulitis	4	4
Right lower quadrant pain: suspected appendicitis	4	6
Right upper quadrant pain	Not appropriate	9
Suspected small-bowel obstruction	5	2

Scoring is 1-9, with 1 being least appropriate and 9 most appropriate.

Fig. 1. Portable radiography setup: high definition tablet display (left), direct digital TFT X-ray receptor (middle), and portable generator (right).

absorpitometry (DEXA) protocols, which is a common practice and proven way to measure on Earth.

Many medical and surgical dilemmas may arise on the ISS or during ECMs. The ability to diagnose/treat such problems is of utmost importance. Diagnostic radiology plays a large role in this on Earth. Ultrasound is currently the only imaging modality available on the ISS. Although great for abdominal imaging and limited evaluations of other body parts, radiography is the workhorse of radiology and indicated as the initial study of choice in most musculoskeletal/thoracic types of symptomatology as published by the ACR.[1] Given technology is now widely available to make this modality highly portable and efficient, and that it has been researched, tried, and proven on Earth, it could be highly useful on the ISS and during future explorer class missions.

ACKNOWLEDGMENTS

Special thanks to Brandt C. Wible, M.D., Kenneth Cho, M.D., John J. Borsa, M.D., Lawrence R. Ricci, D.O., Douglas C. Rivard, D.O., Nathan Saucier, M.D., Kelli Andresen, M.D., Melissa L. Rosado de Christenson, M.D, Nima Kasraie, Ph.D., Michael Roys, M.D., and Lisa H. Lowe, M.D., for being willing to answer my questions at all hours of the day.

Special thanks go to Craig Forrester at Interstate Imaging for portable radiography images.

Authors and affiliation: David J. Lerner, M.D., and Allen J. Parmet, M.D., M.P.H., Saint Lukes Hospital, Kansas City, MO.

REFERENCES

1. American College of Radiology. ACR Appropriateness Criteria®. [Accessed 2014 Jan. and May]. Available at www.acr.org/ac.
2. Barrat M, Pool S. Principles of clinical medicine in space flight, chapter 9. New York (NY):Springer Publishing; 2008.
3. Campbell MR, Billica RD. Surgical care in spaceflight. In: Barratt MR, Pool SL, editors. Principles of clinical medicine for space flight. New York (NY): Springer; 2008.
4. Kaufman JA, Lee MJ. Vascular and interventional radiology: the requisites. Philadelphia (PA): Saunders; 2003.
5. Lerner DJ, Parmet AJ. Interventional radiology: the future of surgery in microgravity. Aviat Space Environ Med. 2013; 84(12):1304–1306.
6. Mauro MA, Kieran Murphy K, Thomson K, Venbrux AC, Zollikofer CL. Image-guided interventions: expert radiology series, 1st ed. Philadelphia (PA): Saunders; 2008.
7. Middleton WD, Kurtz AB, Hertzberg BS. Ultrasound: the requisites, 2nd ed. Philadelphia (PA):Elsevier Health Sciences; 2004.
8. NASA Human Research Wiki. [Accessed 2014 Sept. 16]. Available from https://humanresearchwiki.jsc.nasa.gov/index.php?title=ExMC.