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Tele-intensivists can instruct non-physicians to acquire high-quality ultrasound images☆

Andrea R. Levine, MD [a,*], Michael T. McCurdy, MD [b,c], Marc T. Zubrow, MD [d,e], Alfred Papali, MD [b], Haney A. Mallemat, MD [c], Avelino C. Verceles, MD [b]

[a] Department of Medicine, University of Maryland School of Medicine, 22 S. Greene St., Baltimore, MD, 21201, United States
[b] Division of Pulmonary and Critical Care, University of Maryland School of Medicine, 110 S. Paca St., 2nd Floor, Baltimore, MD, 21201, United States
[c] Department of Emergency Medicine, University of Maryland School of Medicine, 110 S. Paca St., 6th Floor, Baltimore, MD, 21201, United States
[d] Program in Trauma, University of Maryland School of Medicine, 655 W. Baltimore Street, Baltimore, MD, 21201, United States
[e] University of Maryland eCare, University of Maryland Medical System, 110 S. Paca St., Suite 5-N-162, Baltimore, MD, 21201, United States

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ABSTRACT

Purpose: Intensive care unit telemedicine (tele-ICU) uses audiovisual systems to remotely monitor and manage patients. Intensive care unit ultrasound can augment an otherwise limited bedside evaluation. To date, no studies have utilized tele-ICU technology to assess the quality and clinical use of real-time ultrasound images. We assessed whether tele-intensivists can instruct nonphysicians to obtain high-quality, clinically useful ultrasound images.
Methods: This prospective pilot evaluated the effectiveness of a brief educational session of nonphysician "ultrasonographers" on their ability to obtain ultrasound images (right internal jugular vein, bilateral lung apices and bases, cardiac subxiphoid view, bladder) with real-time tele-intensivist guidance. All ultrasound screen images were simultaneously photographed with a 2-way camera and saved on the ultrasound machine. The tele-intensivist assessed image quality, and an independent ultrasound expert rated their use in guiding clinical decisions.
Results: The intensivist rated the tele-ICU camera images as high quality (70/77, 91%) and suitable for guiding clinical decisions (74/77, 96%). Only bilateral lung apices demonstrated differences in quality and clinical use. All other images were rated noninferior and clinically useful.
Conclusion: Tele-intensivists can guide minimally trained nonphysicians to obtain high-quality, clinically useful ultrasound images. For most anatomic sites, tele-ICU images are of similar quality to those acquired directly by ultrasound.

1. Introduction

Although only about 30% of intensive care unit (ICU) patients receive bedside care from trained intensivists, intensivist management has consistently demonstrated improved ICU clinical outcomes [1–4]. The Leapfrog Group recommends ICU Staffing Safety Standards, which include either 24/7 in-house intensivist staffing of ICUs or off-hour rapid and reliable access to a bedside or telemedicine intensivist [5]. ICU telemedicine (tele-ICU) leverages technology to overcome geographic separation to simultaneously provide intensivist coverage for multiple remote locations, providing a potential solution to the growing shortfall of intensivists. Tele-ICU coverage may use a variety of delivery models (i.e., continuous, episodic, on-demand) to provide ICU support. As of 2013, tele-ICU monitoring and care delivery supported nearly 13% of all ICU beds in the United States [3,6] and demonstrated a significant reduction in mortality (adjusted hazard ratio of death, 0.84; 95% confidence interval [CI], 0.78-0.89; $P < .001$) and ICU length of stay (20% shorter; 95% CI, 19%-22%; $P < .001$) [6].

Tele-ICUs use sophisticated hardware and software to continuously monitor vital signs, laboratory values, radiographic studies, visualize patients and their surroundings, view ventilator parameters, and initiate therapeutic or prophylactic care [7]. Despite having access to such advanced patient data, remote monitoring precludes the physician from performing a bedside physical examination. As compared with the physical examination, however, ultrasound is arguably a more effective means of diagnosing thoracic and abdominal pathophysiology in critically ill patients. Thoracic ultrasound has been shown to more accurately diagnose pleural effusion, consolidation, alveolar interstitial syndrome, pneumothorax, and lung contusion than either auscultation or chest radiography [8,9]. In acute respiratory failure, ultrasound can facilitate real-time identification of lung pathology, with 90% accuracy when compared with either computerized tomography or plain radiography [10]. Bedside cardiac ultrasound was superior to physical examination, laboratory findings, and electrocardiograph findings for diagnosing acute decompensated heart failure [11,12]. Surgeons rely

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* Corresponding author at: Department of Medicine, University of Maryland School of Medicine, 22 S. Greene St., Baltimore, MD, 21201, United States. Tel.: +1 818 359 5031.
E-mail addresses: Alevine1@umm.edu (A.R. Levine), drmccurdy@gmail.com (M.T. McCurdy), mzubrow@umm.edu (M.T. Zubrow), apapali@umm.edu (A. Papali), hmallemat@umm.edu (H.A. Mallemat), avercele@medicine.umaryland.edu (A.C. Verceles).

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on ultrasound to enhance the physical examination when diagnosing patients with abdominal pain [13].

Outside of the hospital setting, the National Aeronautics and Space Administration originally designed remote telementored ultrasound (RTMUS) to help diagnose and care for astronauts aboard the space station [14,15]. Remote telementored ultrasound consists of a geographically separated expert providing real-time guidance and interpreting ultrasound images that are captured and electronically transmitted by an inexperienced ultrasonographer. With minimal training, physician and nonphysician ultrasonographers at the bedside can obtain high-quality images, which are oftentimes superior to other more costly and more invasive diagnostic tests [16–18]. Further studies demonstrated that nonphysician, ultrasound-naive examiners can competently obtain clinically relevant focused assessment with sonography for trauma and extended FAST ultrasound images when guided by a tele-mentor [19–21].

To date, no studies have evaluated either the use of point-of-care bedside ultrasound performed by nonphysicians in the tele-ICU environment or the role of a tele-ICU infrastructure in constructing RTMUS systems. Furthermore, no studies have assessed the use of these images in guiding clinical diagnostic decisions. We conducted an educational feasibility pilot aimed to determine the frequency with which (1) a tele-intensivist using RTMUS principles and tele-ICU technology can instruct nonphysicians to obtain high-quality ultrasound images; (2) a tele-intensivist can interpret ultrasound images by visualizing the ultrasound screen; and (3) remotely visualized images are noninferior to images acquired directly from the ultrasound machine with regard to the ability to guide the clinical decision-making process.

2. Methods

We performed an educational feasibility pilot to determine (1) the ability of nonphysicians to obtain quality images after receiving minimal ultrasound training using tele-intensivist mentored bedside ultrasound; (2) the ability of tele-intensivists to interpret the ultrasound images by visualizing the ultrasound screen; and (3) if the images captured using the tele-ICU infrastructure are comparable to those obtained from the ultrasound machine in their ability to guide point-of-care diagnosis and clinical decisions. This pilot was institutional review board–exempt and used the facilities and equipment of the University of Maryland eCare, the University of Maryland Medical System's tele-ICU.

An internal medicine (IM) resident and two board-certified critical care tele-intensivists designed a standardized training module consisting of a 20-minute didactic session delivered by the IM resident to eleven nonphysician healthcare providers. Teaching used PowerPoint slides to convey elementary ultrasound principles, including appropriate ultrasound probe handling, “knobology,” and techniques for evaluating pneumothorax, pleural effusion, pericardial effusion (via four-chamber subxiphoid cardiac view), bladder, and internal jugular vein. Publicly available SonoSite eLearning videos supplemented the PowerPoint presentation to demonstrate proper ultrasonography technique. Each nonphysician learner completed an anonymous demographic form and 5-point, Likert scale [22] regarding his training (1, strongly disagree; 2, disagree; 3, neutral;, 4, agree; 5, strongly agree). We used the 5-point Likert scale because it allows a more descriptive and quantifiable means of measurement by creating an objective grading system based on one's subjective assessment.

We constructed an RTMUS system using a simulated patient room with a mounted tele-ICU camera to visualize both the ultrasound machine and the ultrasonographer. Images were captured using a Sony camera with a 340° pan, 120° tilt, 18× optical, 12× digital, and 380k pixel and transmitted to an intensivist monitoring the patient room from a remote site using Philips VISICU monitoring software. We acquired ultrasound images with a SonoSite SICU model ultrasound (SonoSite Inc, Bothell, Washington).

Various nonphysician medical providers volunteered as “ultrasonographers” and acquired images on a volunteer “patient.” The patient was a 30-year-old healthy male with a body mass index of 25. A single tele-intensivist with ultrasound training and experience in the ICU and who routinely works at the University of Maryland eCare was tele-consulted. The tele-intensivist logged into the tele-ICU system and confirmed visualization of the patient, the ultrasonographer's hand, and the ultrasound screen by the tele-ICU camera. The tele-intensivist verbally instructed the ultrasonographer to obtain the following images: (1) right internal jugular vein; (2) bilateral lung apices to assess lung sliding; (3) bilateral axillary lower lung fields to assess pleural effusion; (4) heart (four-chamber subxiphoid view); and (5) bladder. When the tele-intensivist felt the ultrasound image sufficed, he focused the camera on the ultrasound machine to capture an ultrasound screenshot; the time to image acquisition was recorded, and the screenshot was labeled with a unique numeric code. The same image was simultaneously saved directly from the ultrasound machine and labeled with the above-mentioned code. The tele-intensivist completed an ultrasound checklist at the time of image acquisition to indicate whether each anatomical site was adequately visualized. Furthermore, the tele-intensivist mentor completed an anonymous demographic form regarding his ultrasound experience and two additional 5-point Likert scales [22] (1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree) to evaluate the images' quality and clinical use (ie, whether a clinical decision could be made on the basis of the images). The tele-intensivist mentors also compared the images acquired directly from the ultrasound to those acquired using the RTMUS.

A physician board-certified in emergency medicine, IM, and critical care medicine, who was not involved in image acquisition or mentorship, later compared the images acquired directly from the ultrasound machine to those acquired using the Phillips VISICU tele-ICU technology (Fig. 1). Images captured using the tele-ICU technology were compared side by side to the images captured directly on the ultrasound machine. The independent physician was asked to focus specifically on the clinical use of the images. The physician was informed of the probe location and asked to determine his level of confidence with which the following statements could be made for both the images captured on the ultrasound and the images captured with the tele-ICU camera software: (1) the carotid artery and the internal jugular vein could be differentiated, (2) a pneumothorax could be excluded (bilaterally), (3) a clinically significant pleural effusion could be excluded (bilaterally), (4) a clinically significant pericardial effusion could be excluded, and (5) the urinary bladder could be identified. Evaluation of the images was performed using a 5-point Likert scale [22] (1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree).

3. Results

Eleven nonphysician medical providers volunteered for the educational pilot based on word-of-mouth advertising in our hospital's medical ICU (MICU) and cardiac ICU. Each of the volunteers attended a mandatory training session, during which time they provided their demographic information (Table 1) and completed a Likert scale–based evaluation regarding the training experience. We reported data from the “nonphysician training experience” Likert scale as mean ± SD (Table 2). All data are reported as mean ± SD for continuous variables or counts and percentages for proportions.

One physician with nine years of experience obtaining ultrasound images in the ICU and emergency department, interpreting self-acquired images and overreading ultrasound images acquired by residents and fellows, and five years of tele-ICU experience, acted as the tele-mentor. He completed a checklist indicating whether images were adequately visualized at each anatomic site, a Likert scale regarding the ease of his experience collecting images using the RTMUS system, and a Likert scale regarding the quality and clinical use of the images collected. Seventy-seven images were acquired according to the standardized checklist. The time to adequate image acquisition was measured in seconds and reported as a mean ± SD (Table 3). The