Journal of Critical Care 33 (2016) 51–55

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

Ultrasound images transmitted via FaceTime are non-inferior to images on the ultrasound machine☆

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

[a] Division of Pulmonary, Allergy, and Critical Care Medicine, University of Pittsburgh School of Medicine, 3459 Fifth Avenue, 628 NW, Pittsburgh, PA, 15213, 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] Program in Trauma, University of Maryland School of Medicine, 655 W. Baltimore Street, Baltimore, MD, 21201, United States
[d] University of Maryland eCare, University of Maryland Medical System, 110 S. Paca St., Suite 5-N-162, Baltimore, MD, 21201, United States
[e] University of Maryland School of Medicine, Department of Emergency Medicine, 110 S. Paca St., 6th Floor, Baltimore, MD, 21201, United States

ARTICLE INFO

Keywords:
tele-ICU
tele-intensivist
tele-ultrasound
remote telementored ultrasound systems
RTMUS
FaceTime

ABSTRACT

Purpose: Remote telementored ultrasound (RTMUS) systems can deliver ultrasound (US) expertise to regions lacking highly trained bedside ultrasonographers and US interpreters. To date, no studies have evaluated the quality and clinical utility of US images transmitted using commercially available RTMUS systems.

Methods: This prospective pilot evaluated the quality of US images (right internal jugular vein, lung apices and bases, cardiac subxiphoid view, bladder) obtained using a commercially available iPad operating *FaceTime* software. A bedside non-physician obtained images and a tele-intensivist interpreted them. All US screen images were simultaneously saved on the US machine and captured via a *FaceTime* screen shot. The tele-intensivist and an independent US expert rated image quality and utility in guiding clinical decisions.

Results: The tele-intensivist rated *FaceTime* images as high quality (90% [69/77]) and could comfortably make clinical decisions using these images (96% [74/77]). Image quality did not differ between *FaceTime* and US images (97% (75/77). Strong inter-rater reliability existed between tele-intensivist and US expert evaluations (Spearman's rho 0.43; $P < .001$).

Conclusion: An RTMUS system using commercially available two-way audiovisual technology can transmit US images without quality degradation. For most anatomic sites assessed, US images acquired using *FaceTime* are not inferior to those obtained directly with the US machine.

1. Introduction

Approximately five million patients are admitted to the intensive care unit (ICU) per year in the United States [1]. In 2012, the national average mortality of patients admitted to the ICU was 15.6% [2]. Although 24-h board-certified critical care physician (intensivist) coverage reduces ICU mortality by up to 40%, a national shortage of intensivists has limited hospitals' ability to provide optimal intensivist staffing [3,4]. Telemedicine in the ICU (tele-ICU) has been defined as "networks of audiovisual communications and data systems to link hospital ICUs to intensivists and other critical care professionals at remote locations [5]." Tele-ICU allows remotely located intensivists to assist bedside providers by monitoring, assessing, and caring for patients in ICUs that would otherwise lack access to around-the-clock intensivist staffing.

Bedside ultrasound (US) is a valuable diagnostic tool in the ICU that allows for point-of-care image acquisition. Ultrasound is an accurate, low-cost, non-irradiating, noninvasive, and portable means of imaging that reduces the need to transport unstable, critically ill patients out of the ICU for diagnostic testing [6–13]. Furthermore, the value of US is particularly evident in developing countries where traditional imaging modalities, such as roentgenography and computerized tomography, are prohibitively expensive, or otherwise unavailable [14].

The National Aeronautics and Space Administration implemented remote telementored ultrasound (RTMUS) systems to provide expert-guided diagnostic imaging to astronauts aboard the International Space Station [15], highlighting the feasibility of having a geographically remote US expert guide a novice through real-time image acquisition and interpretation. The concept of RTMUS has recently expanded to the ICU environment where it has been demonstrated that remotely located physicians using a Philips tele-ICU system can mentor US-naive bedside providers to acquire high quality, clinically useful US images [16].

☆ Conflicts of Interest: None.

* Corresponding author at: Division of Pulmonary and Critical Care, University of Maryland School of Medicine, 110 S. Paca St., 2nd Floor, Baltimore, MD, 21201, United States. Tel.: +410 328 8141.
E-mail addresses: levinar@upmc.edu (A.R. Levine), buchneja@gmail.com (J.A. Buchner), avercele@medicine.umaryland.edu (A.C. Verceles), mzubrow@umm.edu (M.T. Zubrow), haney.mallemat@gmail.com (H.A. Mallemat), apapali@medicine.umaryland.edu (A. Papali), drmccurdy@gmail.com (M.T. McCurdy).

http://dx.doi.org/10.1016/j.jcrc.2016.02.019
0883-9441/

Tele-ICU software and hardware needed for RTMUS image acquisition and transmittal typically includes two-way audiovisual monitors and expensive, high-resolution camera technologies [17] costing up to $100,000 per monitored bed [18]. Because of the prohibitive cost of this high-fidelity equipment, developing countries have explored alternative low-cost, commercially available solutions to provide expert medical care from afar [19]. Many cheaper modalities using video-chat software, basic wireless Internet access, and laptop computers or smart phones have proven effective and more accessible in transmitting clinically useful US images [20–23].

Despite these reports, no study has yet compared the diagnostic quality of the images acquired using commercially available RTMUS systems to images obtained from the US itself. Therefore, we performed a pilot study that compared the clinical utility of the US images acquired using an Apple iPad operating *FaceTime* software (Apple, Cupertino, CA) to images acquired directly from a Sonosite S-ICU model US (SonoSite, Bothwell, WA). We hypothesized that high quality US images not only can be captured and transmitted using commercially available video-chat software, such as *FaceTime*, but also that *FaceTime* images are of comparable quality and diagnostic utility to those visualized directly on the US machine.

2. Methods

This feasibility pilot study was approved by the University of Maryland School of Medicine IRB and was performed in partnership with the University of Maryland eCare, the tele-ICU program of the University of Maryland Medical System.

An internal medicine (IM) resident and two board-certified intensivists affiliated with the University of Maryland eCare program designed and implemented a training module consisting of a 20-min didactic session for eleven non-physician healthcare providers with minimal prior point-of-care US experience (Table 1). The didactic session focused on elementary US principles, including appropriate US probe handling, "knobology," and techniques for evaluating the bladder, the internal jugular vein, the lung for pneumothorax and pleural effusion, and pericardial effusion (via four-chamber subxiphoid cardiac view). Each module participant completed an anonymous demographic form and a five-point Likert scale regarding the training at the session's completion [24].

We developed a model RTMUS system using a simulated patient room. The simulated patient room contained a mounted tele-ICU camera controlled using Philips VISICU technology. Remote telementoring and US visualization was performed using a Sony camera (Tokyo, Japan) with 340 degrees Pan, 120 degrees Tilt, 18x optical, 12x digital, and 380 k pixel and transmitted to an intensivist monitoring the patient room from a remote site using Philips VISICU monitoring software. With this set-up, a remotely located tele-intensivist provided real-time guidance to the module participant while visualizing both the US machine and the participant. A pilot team member located at the bedside simultaneously interfaced with the tele-intensivist using Apple iPads and transmitted the images acquired using the US via *FaceTime* software. The Apple iPads were second-generation devices featuring a 9.7-in., 1024x768-pixel LED display. The iPad uses a high-definition, 720-pixel camera with 5x digital zoom. Wireless connectivity was established using a *Linksys* wireless router. Ultrasound images were acquired with a SonoSite S Series Model US (SonoSite Inc., Bothell, Washington, USA).

Module participants acquired images on a volunteer "patient" that was a 30-year-old healthy male with a body mass index of 25. The tele-intensivist provided verbal instructions over the Philips tele-ICU software to the ultrasonographer to obtain the following images: 1) right internal jugular vein; 2) bilateral lung apices to assess for lung sliding; 3) bilateral axillae to assess for pleural effusion; 4) heart to visualize the sub-xiphoid four-chamber cardiac view; and 5) bladder. When the module participant obtained a high-quality image, as determined by the tele-intensivist, two images were simultaneously captured: 1) the image on the US machine and 2) an iPad screenshot of the image transmitted via *FaceTime* to the tele-intensivist. The US image and the *FaceTime* screenshot were labeled with a common numeric code for future image comparison. The tele-intensivist indicated whether each of the imaged anatomical sites was adequately visualized and rated the quality of each obtained image using a five-point Likert scale. The tele-intensivist compared the quality of images acquired directly from the US to those acquired using *Face Time* software.

To avoid introducing bias in image comparison, a physician board-certified in emergency medicine, internal medicine, and critical care medicine with ten years of experience performing and interpreting US compared the images from the US to those from the iPad (Fig. 1). This physician, who was not involved in image acquisition or remote monitoring but was cognizant of the probe location, rated his level of confidence with the following statements for the images captured on the US and iPad: 1) the carotid artery and the internal jugular vein can be differentiated; 2) a pneumothorax can be excluded (bilaterally); 3) a clinically significant pleural effusion can be excluded (bilaterally); 4) a clinically significant pericardial effusion can be excluded; and 5) the urinary bladder can be identified. The physician was blinded to whether the images were acquired directly from the US or from the iPad. Evaluation of the images was performed using a five-point Likert scale.

3. Results

Eleven non-physician medical providers from our hospital's Medical ICU and Cardiac ICU volunteered for the pilot. Each volunteer attended a training session prior to image acquisition, during which time they provided demographics information (Table 1). Seventy-seven images were acquired according to the standardized checklist and time to image acquisition was recorded (Table 2). The tele-intensivist agreed (further defined as "agree" or "strongly agree" on the five-point Likert scale) that he could visualize all images acquired at each anatomical location using *FaceTime*. The tele-intensivist agreed that 90% (69/77) of the images captured via *FaceTime* were high quality. High quality images were defined as those rated 4 or 5 and lower quality images were defined as those rated 3 or below. All images of the internal jugular vein, bilateral lung apices, and bladder were considered high quality. Image quality was compared between the groups of ultrasonographers with and without prior ultrasound experience. No difference in image quality existed between the two groups when comparing means using a Student's t-test. For 97% of images (75/77), the tele-intensivist indicated no difference in image quality between the *FaceTime*-acquired and direct US-acquired images. The tele-intensivist felt comfortable making clinical decisions based on the real-time US images obtained using *FaceTime* technology 96% (74/77) of the time. Image quality and clinical utility discriminated by anatomic site is provided in Table 2. All data are

Table 1
Demographic Characteristics of Non-physician Ultrasonographers

Ultrasonographer	N (%) = 11
Female	10 (91)
Training level	
Registered nurse	2 (18)
Bachelors of Science in nursing	5 (45)
Nurse practitioner	1 (9)
Nursing student	2 (18)
Respiratory therapist	1 (9)
Employment Location	
Medical Intensive Care Unit	9 (82)
Step Down Unit	1 (9)
Trauma Intensive Care Unit	1 (9)
CCRN Certification	5 (45)
Previous Experience with US	3 (27)
Years of Prior US experience	0.6 ± 1.5
Years of Prior Nursing Experience	6.7 ± 7.7