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Remote just-in-time telementored trauma ultrasound: a double-factorial randomized controlled trial examining fluid detection and remote knobology control through an ultrasound graphic user interface display

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Abstract

BACKGROUND: Remote-telementored ultrasound involves novice examiners being remotely guided by experts using informatic-technologies. However, requiring a novice to perform ultrasound is a cognitively demanding task exacerbated by unfamiliarity with ultrasound-machine controls. We incorporated a randomized evaluation of using remote control of the ultrasound functionality (knobology) within a study in which the images generated by distant naive examiners were viewed on an ultrasound graphic user interface (GUI) display viewed on laptop computers by mentors in different cities.

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Trial Registration: ISRCTN registry 30345.

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METHODS: Fire-fighters in Edmonton (101) were remotely mentored from Calgary (n = 65), Nanaimo (n = 19), and Memphis (n = 17) to examine an ultrasound phantom randomized to contain free fluid or not. Remote mentors (2 surgeons, 1 internist, and 1 ED physician) were randomly assigned to use GUI knobology control during mentoring (GUIK+/GUIK−).

RESULTS: Remote-telementored ultrasound was feasible in all cases. Overall accuracy for fluid detection was 97% (confidence interval = 91 to 99%) with 3 false negatives (FNs). Positive/negative likelihood ratios were infinity/0.0625. One FN occurred with the GUIK+ and 2 without (GUIK−). There were no statistical test performance differences in either group (GUIK+ and GUIK−).

CONCLUSIONS: Ultrasound-naive 1st responders can be remotely mentored with high accuracy, although providing basic remote control of the knobology did not affect outcomes.

Traumatic injury continues to be the leading cause of potentially preventable years of life lost in our society.[1–3] The early management of catastrophic trauma is critical to salvaging the most critically injured and avoiding unnecessary morbidity.[4] Thus, ultrasound, which offers almost unlimited scope of enhancing bedside care in the critically ill/injured is an indispensable tool that, ideally, would always be immediately available.[5,6] As ultrasound technology becomes smaller and less expensive there is often a disconnect between the availability of trained ultrasonographers and ultrasound machines. This is the situation in space medicine. An ultrasound machine is the only medical-imaging capability onboard the International Space Station,[7–9] yet nonphysicians may be required to make critical diagnoses and provide invasive therapies to fellow crew members.[10,11] This led investigators with the National Aerospace and Aeronautics Administration to pioneer remote guidance techniques, wherein a novice care-provider onboard the International Space Station is mentored to obtain meaningful ultrasound images interpreted by terrestrial experts to guide diagnosis and therapy.[10–13] Although this paradigm to providing medical imaging in remote and austere environments has now become the standard of care in space medicine, the potential of this disruptive technology is only being cautiously explored terrestrially.[14]

There has been little study of the human-machine interactions required to facilitate remote-telementored ultrasound (RTMUS). Most smart computing/communicating devices now use graphic user interfaces (GUIs), which reduce user learning curves to control powerful electronics. Newer ultrasound machines are essentially specialized computers in which the physical knobs and switches have been digitally replaced. "Knobology" in reference to the performance of ultrasound is defined as "operating the ultrasound-machine controls".[15] Previous study in our institution has demonstrated that knobology requirements maybe quite detrimental to the learning task and disproportionately burden the cognitive load of novices.[15] GUI control and display capabilities are an innovation that frees the ultrasound image generating hardware from its control software. This technology thus offers the option to shift the responsibility for knobology control from the novice performing ultrasound to the remote mentor directing the examination. We thus sought to prospectively study whether; (A) RTMUS diagnoses of a simulated massive hemoperitoneum could be conducted by novices while experts viewed the examination on a remote ultrasound GUI interface, and (B) whether remotely controlling the knobology on behalf of the inexperienced examiners improved accuracy and efficiency.

Methods

A prospective double-factorial–randomized control design was used. City of Edmonton fire-fighters performed the examinations within fire halls throughout the city. All participants volunteered and were free to withdraw at any time. Remote mentors guiding these examinations were a trauma surgeon/intensivist and an internist in Calgary, Alberta; an emergentologist in Nanaimo, British Columbia, and a trauma surgeon/intensivist in Memphis, Tennessee (Table 1). Ethics approval was provided by the University of Calgary (E-20949). The study used an ultrasound phantom examined by completely inexperienced and remotely mentored fire-fighters. The ultrasound Phantom (FAST Exam Real-Time Ultrasound Training Model, CAE Healthcare, Sarasota, FL) provided a capacity to introduce/withdraw fluid.

The primary outcome was diagnostic accuracy for free-fluid detection determined by the remote mentor related to: (A) true presence/absence of significant fluid within the right upper quadrant of the phantom and (B) ability to use remote control of the ultrasound knobology by the mentor during the examination. Secondary outcomes addressed qualitative issues related to user perceptions and satisfaction with the RTMUS concept and the specific use of the GUI.

The SonicTelemed system (SonixTelemed, Ultrasonix Corporation, Richmond, British Columbia, Canada) is a software package enabling remote control of an Ultrasonix scanner over an IP network and real-time streaming of ultrasound images from the scanner to connected clients. It includes a GUI providing real-time video display of the remote examination and visual controls for the user to interact with the ultrasound scanner and change its configuration remotely, as if they were using the buttons located on the ultrasound machine itself (Fig. 1). The specific technological parameters adjustable by the remote mentor are described in Table 2.