



Pioneering Remotely Piloted Aerial Systems (Drone) Delivery of a Remotely Telementored Ultrasound Capability for Self Diagnosis and Assessment of Vulnerable Populations—the Sky Is the Limit

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Abstract

Remotely Piloted Aerial Systems (RPAS) are poised to revolutionize healthcare in out-of-hospital settings, either from necessity or practicality, especially for remote locations. RPAS have been successfully used for surveillance, search and rescue, delivery, and equipping drones with telemedical capabilities being considered. However, we know of no previous consideration of RPAS-delivered tele-ultrasound capabilities. Of all imaging technologies, ultrasound is the most portable and capable of providing real-time point-of-care information regarding anatomy, physiology, and procedural guidance. Moreover, remotely guided ultrasound including self-performed has been a backbone of medical care on the International Space Station since construction. The TeleMentored Ultrasound Supported Medical Interventions Group of the University of Calgary partnered with the Southern Alberta Institute of Technology to demonstrate RPAS delivery of a smartphone-supported tele-ultrasound system by the SwissDrones SDO50 RPAS. Upon receipt of the sanitized probe, a completely ultrasound-naïve volunteer was guided by a remote expert located 100 km away using online video conferencing (Zoom), to conduct a self-performed lung ultrasound examination. It proved feasible for the volunteer to examine their anterior chest, sides, and lower back bilaterally, correlating with standard recommended examinations in trauma/critical care, including the critical locations of a detailed COVID-19 lung diagnosis/surveillance examination. We contend that drone-delivered telemedicine including a tele-ultrasound capability could be leveraged to enhance point-of-care diagnostic accuracy in catastrophic emergencies, and allow diagnostic capabilities to be delivered to vulnerable populations in remote locations for whom transport is impractical or undesirable, speeding response times, or obviating the risk of disease transmission depending on the circumstances.

Keywords Telemedicine · Unmanned aerial vehicles · Remote mentoring · Tele-ultrasound · Prehospital care · Vulnerable populations

Introduction

Worldwide, there remains a “tyranny of distance” in health care. “Distance” may be physical, socioeconomic, cultural, or political, however. Nonetheless, distance equates to unnecessary death and disability, where for example the majority of potentially preventable post-traumatic death occur before combatants can access formal medical care [1], or where challenges and poor outcomes in northern Canada have been described as “fourth-world” [2]. Remotely Piloted

Aerial Systems (RPAS) or “Drones” are poised to revolutionize health care, especially prehospital care, and in the care of otherwise inaccessible patients [3, 4]. RPASs have been shown capable of delivering blood products and medical supplies including autonomously functioning defibrillators [3]. Demonstrations have also advanced the potential capability of RPAS-delivered care through telemedical assistance to first-responders administering tourniquets and chest seals, whose application was guided remotely [4]. However, we are unaware of any reported instances of point-of-care ultrasound (POCUS) capabilities being RPAS-delivered. POCUS is powerful tool when integrated into the resuscitation and it is practically the only diagnostic imaging modality portable enough to go to a critical patient’s location [5, 6]. The TeleMedical Ultrasound Supported Research Group

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(TMUSMI) of the University of Calgary has long sought to advance medical care in far-forward locations through refining the science of telementored remote medicine. Remotely telementored self-performed ultrasound examinations were developed to support medical care on the International Space Station [7], and is a technique we have found very applicable to self-lung examination [8]. We herein describe the RPAS delivery of a POCUS ultrasound system with subsequent remote mentoring of an ultrasound naïve subject to conduct a remotely mentored self-performed lung ultrasound examination as a proof of concept.

Description

The RPAS Delivered Remotely TeleMentored Self-Diagnostic Ultrasound (RPAS-RTSDUS) capability consisted of commercially available components based on a light-weight hand-held ultrasound (Philips Lumify, Philips, Andover, MA) powered and connected to a cellular network through a cellphone. The study was performed in Olds, Alberta, Canada, on the Rogers network. There is some 5G availability listed by Rogers; however, this coverage is not consistent. In the Olds area the network availability is mostly 4G LTE. Examination of the coverage map (<https://www.rogers.com/consumer/wireless/network-coverage-map>) reveals that 5G is not consistent in the area where the study was performed or the province of Alberta as a whole. Using TeamViewer remote connectivity software (TeamViewer, GmbH, Goppingen, Germany) a remote clinical ultrasound expert was able to access and control the cellular phone supporting the ultrasound, and thereafter, both view the images, as well as remotely control the “knobology” of the Philips L12-4 broadband linear array transducer. As both mentors and mentees were using ZOOM and screen sharing videos, the bandwidth requirements for 1 to 1 sharing would range from 1.25Mbps up to 1.95Mbps to share a minimum 720p video (the download and upload speed are the same). As the investigators were cognizant of bandwidth issues the mentor never shared his screen and note that such similar investigations by ourselves have often separated the audio from the video in situations where bandwidth was a concern.

The entire system was sanitized (Supplemental File 1) and packaged for transport aboard the SwissDrones SDO50 V2 VTOL multi-purpose single-engine unmanned Helicopter system (Swissdrones, Buchs, Switzerland) with a payload capacity of 43 kg and endurance in excess of 3 h flight-time (Figs. 1 and 2). A flight occurred near Olds, Alberta and landed near the completely ultrasound-naïve volunteer (Supplemental File 2). The volunteer recovered and unpacked the contents of the RPAS-RTSDUS (Fig. 3 and Supplemental File 3) under the direction of the remote mentor located in Foothills Hospital, Calgary, who viewed



Fig. 1 SDO-50V2 multi-purpose single-engine unmanned Helicopter system equipped with the RPAS Delivered Remotely TeleMentored Self-Diagnostic Ultrasound System being prepped for take-off

and communicating over ZOOM (Zoom Video, San Jose, CA). Following informed consent (University of Calgary REB14-0634), the mentor guided the subject to conduct a remotely mentored lung examination on himself (Fig. 4 and Supplemental File 4), successfully examining all the anatomic areas of the Extended FAST [9] and Bedside Lung Ultrasound in Emergency protocols [10], and in addition all the anterior, lateral, and inferior posterior lung bases, recommended for use with patients suspected or diagnosed of Coronavirus Disease 2019 (COVID-19) [11]. It is emphasized that the examination was fully guided by the mentor, who was responsible for any and all interpretation of the images.



Fig. 2 SDO-50V2 multi-purpose single-engine unmanned Helicopter system equipped with the RPAS Delivered Remotely TeleMentored Self-Diagnostic Ultrasound System in flight



Fig. 3 Location of the RPAS Delivered Remotely TeleMentored Self-Diagnostic Ultrasound System under the SDO-50V2 multi-purpose single-engine unmanned helicopter

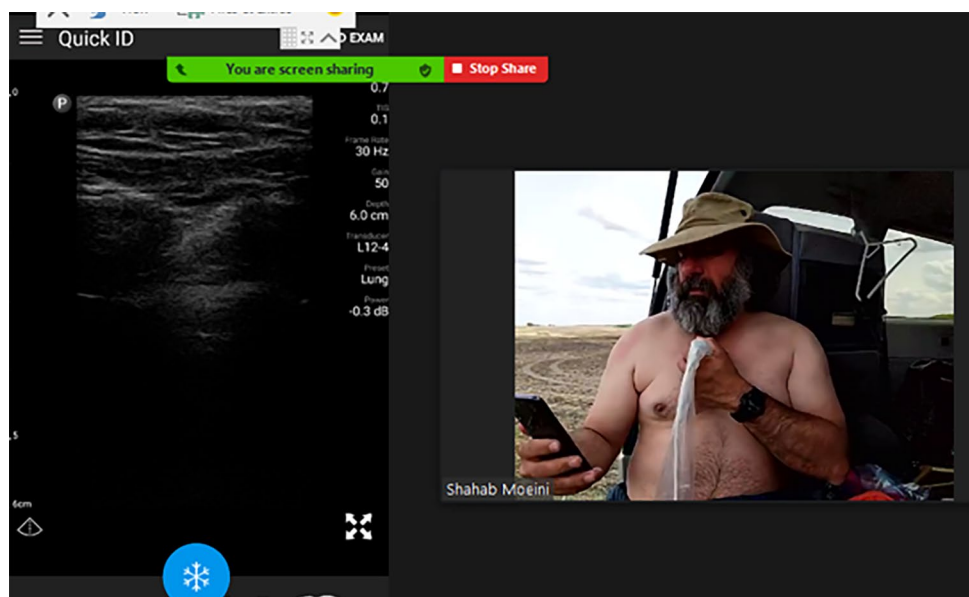
The specific focus of this evaluation was on lung ultrasound, whose application has exploded in the last decade in trauma resuscitation, managing critical cardiopulmonary diseases [12]. In particular in recent months, lung ultrasound has utility for diagnosing, stratifying, and following the course of pulmonary therapies in COVID-19 [11, 13, 14], including potentially diagnosing asymptomatic patients, or those with false negative or delayed PCR testing [15]. However, with POCUS being a non-invasive means of assessing anatomy, physiology, it enables just-in-time first responders to better recognize the need for and deliver directed life-saving interventions leading to increasing inclusion across the entire field of medicine [16], especially those challenged

by distance. Alternatively, in the new COVID-19 reality, distance may however constitute an attribute, in terms of preventing infection and conserving personal protective equipment resources, when a highly accurate ultrasound-based assessment can be performed completely remotely [17].

Limitations and Cautions

The examination was conducted as a proof of concept to illustrate what we consider to be the nearly unlimited capabilities of POCUS ultrasound to vulnerable and remote populations needing improved healthcare. Despite its many attributes, ultrasound is the most user-dependant modality. However, misinterpretation of imaging results may mislead rather than guide care. Thus it is critical for image interpretation to remain the responsibility of the remote expert, who is also responsible for recognizing when ultrasound is not technically feasible, and not inordinately delaying care through the persistence in trying to obtain interpretable images in time critical situations (sonoparalysis) when a clinical diagnosis may already be apparent and other actions are in the patients best interest [12]. A technical feature noted during these studies concerned the orientation position-marker on the ultrasound transducer which when enclosed within a sterile probe cover was difficult for both mentor and mentee to see. Future ultrasound systems designed for remote teleultrasound use might therefore be equipped with fluorescent or LED indicators which are easily noted by remote mentors. It finally be cautioned that many questions related to drone operation relate to air-space, regulations, capacity of the internet connections, and even vulnerability to cyberattack that still need to resolved before such care is ready for “prime-time” [3] (Supplemental File 5–10).

Fig. 4 Mentors image of subject performing guided self-examination and shared ultrasound images from the subject’s cellular phone



Future Expectations

It is expected that the development of drone and informatic technologies with ever more powerful and accessible internet connectivity that support drone delivered telemedicine will only continue to be rapidly developed and increasingly more powerful, more economical, and smaller. This supports the opinion that fleets of prepositioned and medically equipped drones might prove invaluable for disaster assistance and for enhancement of care in Canada's many remote locations [4]. We further envision that the delivery of a comprehensive package of communications/diagnostics including remotely mentored ultrasound and interventional equipment plus accompanying therapeutics (e.g., chest tubes, medical supplies, critical drugs) may prove life-saving in catastrophic situations where patients are too unstable to be transported to a fixed facility [18]. This demonstration represents a first "proof-of-concept demonstration" recognizing that future logistical questions/challenges that will require future design and evaluation include (but are not limited to) processes required for requesting and delivering the equipment, tracking information, operator requirements (training), patient data entry, real-time transmission (speed vs. quality) of relevant data, mentoring/guiding and consultation result, regulatory requirements, record keeping, and returning of the equipment. We believe such challenges are worth addressing, as even in less catastrophic situations, RPAS-delivery might prove cost-effective in bringing tele-mentored medicine to the isolated patient not easily accessible and thus precluding unnecessary transport or enabling better informed transport. Thus, RPAS-based telemedicine has the potential to transform disaster, rural, and remote medical responses [4], but also in our opinion to reduce health-care disparities related to distance. This pioneering advance described in proof-of-principle thus has limitless possibilities, and we believe "the sky is the limit."

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10278-021-00475-w>.

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