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Hypothesis Article

Real-time telehealth using ultrasonography is feasible in equine practice

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Summary

Telehealth allows health care professionals to evaluate patients in remote locations using telecommunications technology. This manuscript presents a pilot experience with the goal of testing the feasibility and exploring the benefits for patients and veterinarians, technological challenges and perceived value of telehealth in ultrasound. In phase 1, experienced equine private practitioners and a sonographer performed diagnostic ultrasound examinations in collaboration using telecommunications technology. In phase 2, horses underwent two consecutive ultrasound examinations. One examination was performed by an inexperienced sonographer assisted by a remote expert, and all horses were then scanned by an expert sonographer on-site. Information about each interaction was collected, and a questionnaire was used at the end of the project to summarise practitioners' and trainees' experiences and perceptions. Thirty-six cases were evaluated using telecommunications technology. There were technological problems that were minor in 11 occasions, and in one case, the remote assistance had to be cancelled. Sonograms were longer when performed by an inexperienced sonographer aided remotely (40 $\pm$ 19, [9–73] min) than when performed by a sonographer (24 $\pm$ 12, [4–43 min], $P = 0.02$). Telehealth for ultrasound was feasible, and technological challenges could be solved. Telehealth for ultrasound was well received by private practitioners, house officers and sonography experts. The perceived benefits were the addition of clinically useful information, reassurance to practitioners and horse owners and education for practitioners. The results of this study support generating the hypothesis that telehealth could in the future increase the quality of equine medicine, and prospective studies are needed to confirm this. Rigorous care will be needed to ensure that implementation of telehealth technology prioritises equine health and the veterinary profession.

Introduction

Telehealth allows health care professionals to evaluate patients in remote locations using telecommunications technology. Telehealth is an evolving field that is radically changing human medical care (Combi *et al*. 2016; Weinstein *et al*. 2018) and will likely do so with veterinary care in the near future (Mechanic and Kimball 2018). Referrals in equine practice are often limited by the absence of specialty care near the animal location, inconvenience for owners, fear for loss of caseload or loss of the rewarding experience of managing challenging clinical cases by the referring veterinarian, poor communication between the referral centre and the referring veterinarian and the perception that referral equals admission of lack of skill. The use of telehealth could solve many, or all, of the problems stated above. In regions, in which there is limited access to veterinary expertise, the development of methods to implement this technology effectively seems particularly important.

Telehealth has training and continuing education value. It is attractive to academic institutions because it can allow students and faculty access to training and collaboration with experts located in any area of the world (Arbeille *et al*. 2016). Moreover, students in academic veterinary referral practices often receive little training in primary care cases and are frequently exposed to only the most complex or intensive cases creating bias in their learning. The development of telehealth technology could increase exposure of students to a wider spectrum of cases and open possibilities for the development of newer models of education in which students receive a combination of remote instruction by university faculty and field practitioners while working on external rotations.

Teleradiology is currently the most common use of telehealth in veterinary medicine (Poteet 2008). Ultrasonography has traditionally been the less frequent imaging modality used in teleradiology due to the importance of real-time assessment and this modality being largely operator dependent (Lanowski *et al*. 2017). Technological advances that allow duplicating screens and the use of cameras or smart glasses that allow transmission of point of view video and two-way verbal communication are rapidly solving these problems. Previous studies in humans have documented the reliability of teleultrasound (Zennaro *et al*. 2016).

The overall goal of this study was to test the feasibility of remote assistance in ultrasound to equine private practitioners and trainees in medical and surgical specialties that had experience in sonography, but no advanced training, with the hypothesis that teleultrasound would be a feasible method of providing expert assistance to general practitioners. The study also explored the benefits for patients and veterinarians, technological challenges and perceived value of telehealth in ultrasound.

Materials and methods

The study was divided into two phases. In phase 1, experienced equine private practitioners and an expert sonographer performed sonograms in collaboration using telecommunications technology. The purpose of phase 1 was to assess the feasibility of remote assistance in ultrasound to equine private practitioners. In phase 2, horses underwent two consecutive ultrasound examinations. One examination was performed by an inexperienced sonographer assisted by a remote expert sonographer (INEX-R), and all horses were then scanned by an expert sonographer on-site (EX) following the standards of care. A predefined checklist that specified the anatomical structures and ultrasound planes was used to collect data and report the ultrasound findings and diagnosis. Images from all sonograms were saved digitally and formal reports written by sonographers following clinical standards. The purpose of phase 2 was to assess the feasibility of remote assistance in ultrasound to specialty trainees and explore educational applications.

Both expert sonographers (remote and on-site) had received 2 years of specific Large Animal Ultrasound training, and each has over 10 years of specific experience in Large Animal Ultrasonography. The four equine private practitioners were clinicians with 5–15 years of experience in equine practice that perform ultrasounds on a routine basis but without specific training in sonography. Internal medicine and surgery residents of the American Colleges of Veterinary Internal Medicine and Veterinary Surgery approved programmes were the inexperienced sonographers (INEX) in the second phase. Client consent and permission from the appropriate Institutional Animal Care and Use Committee and Clinical Research Review Committee was obtained.

After each interaction, the body part examined, conclusion, duration of the sonogram and technological issues were logged. The equine practitioner answered (for each sonogram) the question: 'was the remote assistance useful?' and also provided comments about the main benefit and challenges of the consult. A phone interview at the end of the trial programme collected responses to the questions: (1) What were beneficial aspects of the programme? (2) Did sonograms change case management? (3) Would you use this service in a fee for service basis? (4) Would your clients be willing to assume the costs if the price of the assistance was similar to a sonogram performed in a referral facility? And (5) If remote assistance became a multispecialty service, which specialties are likely to use? The house officers in the second phase answered the questions: (1) What were beneficial aspects of the programme? (2) Do you consider the remote assistance of clinical value? (3) Do you consider the assistance of educational value? All participants were given the opportunity to comment on any aspect of the telehealth programme.

A telehealth system and support were provided by a telehealth platform (Aliquis Telepresence).[1] A GEMINI[1] unit was used to facilitate the communication between the private practitioner or house officer and the expert sonographer. The GEMINI unit provided on-demand communication via internet (using a wired router) between the sonographer in direct contact with the horse and the remote expert. The GEMINI solution includes a tower (containing two pair of Google Glass Enterprise Edition, a laptop (Microsoft Surface) and a speaker/microphone (**Fig 1**)). The result is a video conference with two-way verbal communication and two video feeds. The remote expert was able to see a duplicate of the ultrasound screen in the collaborating equine practice in real time and a simultaneous point of view image of the sonographer via the camera built in the glasses.

Data analysis

Categorical data are reported as the frequency of observation (of each category). Continuous data were reported as mean and (s.d.) when the data were distributed normally and otherwise as (median[range]). The results of practitioner/sonographer survey are reported as number cases (percentage). The duration of sonograms performed by INEX-R and EX was compared using a paired t-test, and significance was set at $P < 0.05$.

Results

Table 1 summarises the cases examined in Phases 1 and 2. The structures mentioned in **Table 1** were scanned using standard methods. For example, musculoskeletal regions were examined by imaging the tendinous, ligamentous, osseous and other soft tissue structures in the region of interest in the transverse and longitudinal planes. Abdomen and thoracic scans were performed by placing the probe in the intercostal spaces and imaging from dorsal to ventral. In the case of the abdomen, the paralumbar fossa was also imaged in this plane and the ventral abdomen in a longitudinal and transverse planes.

Phase 1: In all 25 cases (100%), the interaction was considered useful by the clinician performing the sonogram on site. The main value to the private practitioner was reported as follows: (1) Remote assistance added information that was used to manage the case (10 cases [40%]); (2) Remote assistance provided reassurance to the practitioner and/or owner about the clinical plan (10 cases [40%]); (3) Remote assistance helped improve ultrasound skills (5 cases [20%]).

Practitioners' response to the telephone survey at project completion indicated that the primary perceived benefits to the practitioner were increased reassurance for clients (n = 3), educational value (n = 2), information gained that impacted case management (n = 1) and same day specialist opinion without the need for travel (n = 1). Two practitioners felt that remote assistance impacted case management, one felt it did not and one was unsure. Three practitioners would use the remote assistance on a fee-for-service basis and one answered that would depend on the price. Three practitioners considered that their clients would willingly assume the costs of remote assistance (if priced similarly to a referral sonogram), and one was unsure/thought it would be owner dependent. When asked in which specialties they felt remote assistance would be beneficial, the response was internal medicine (n = 3), ultrasound (n = 2), cardiology (n = 2), neurology (n = 1), ophthalmology (n = 1) and reproduction (n = 1).

Phase 2: Response to the survey at project completion with the 3 INEX indicated that the primary perceived benefits were that it created new opportunities for scanning (n = 3). Surgical and medical residents felt the remote assistance was of clinical and educational value. The only negative comment regarding the process was that the technical issues were frustrating.

Discussion

Thirty-six cases were evaluated using telecommunications technology, demonstrating the feasibility of this technology in horses. There were technological issues in 12 instances (33%). These problems were mainly with internet connectivity and in

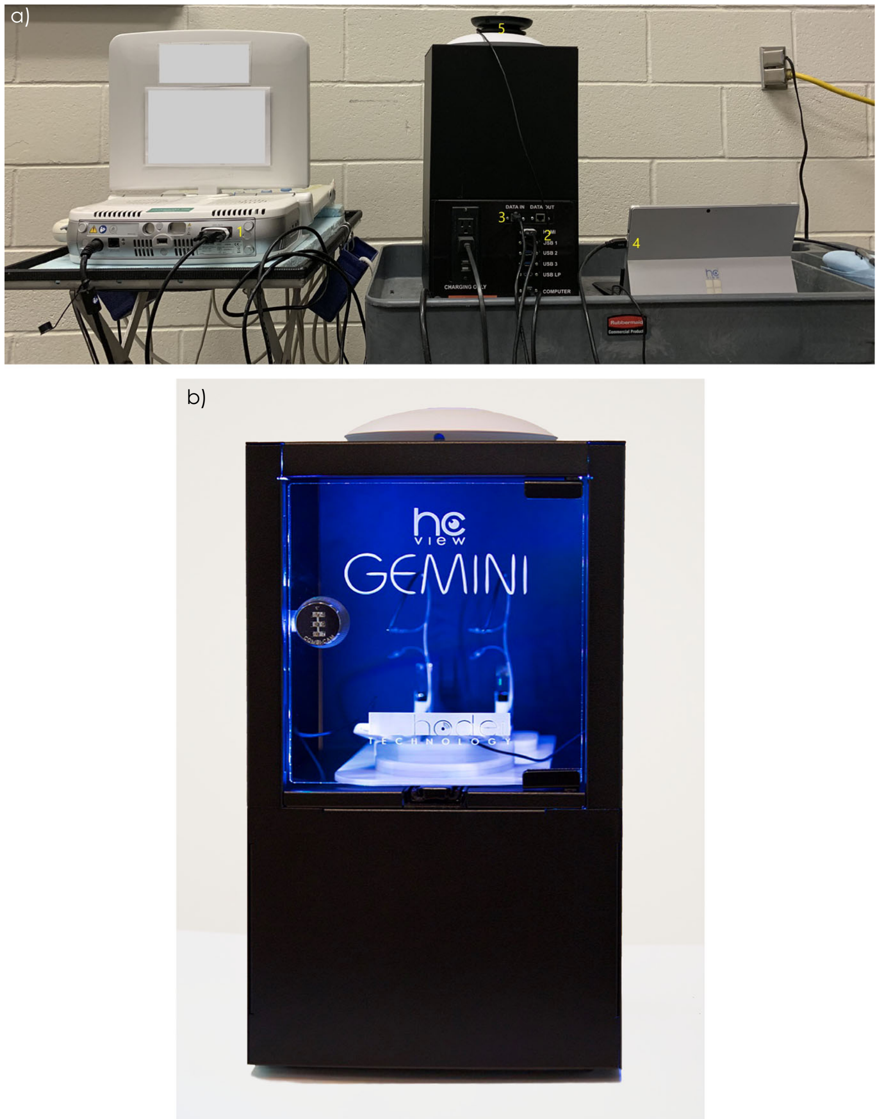

Fig 1: a) The video output (1) of the ultrasound equipment (left) is connected to the tower's HDMI port (2). The tower is connected to an Ethernet port (3) and a tablet that displays the videoconference software. An external microphone (4) is used to support audio. b) The tower stores and charges Google Glasses that provide a point of view video input.

general delayed the completion of the sonograms, and only in one case, the remote assistance could not be provided. Overall the problems were considered minor and reflect the status of a developing communications technology. The connectivity issues were likely due to variable or low upload speed of internet connections. The two videos feeds and audio require a high bandwidth with upload speeds in the Gigabits per second range. The speed of internet connections in some locations does not allow this type of communication. Interestingly, the practice located in the most rural area had the fastest internet connection and never experienced technological issues and the university setting with a more sophisticated IT support had problems more frequently. Methods to 'boost' internet speed are currently available and it is expected that 5G networks will be soon available widely. In the future, this technology will need to be tested with more varied types of internet connections, including mobile networks, for its use to be widely available to equine clinicians. The authors felt that the anticipated upload speed based on the maximal speed of the connection and online tools to assess speed did not predict the quality of the connection but this was not formally analysed.

The mean duration of the sonograms was longer when performed using remote assistance than when performed by an expert sonographer on-site. This was to be expected. The longer sonogram often reflected time used in explaining how to perform or interpret specific images or communicating, discussing and agreeing in the interpretation of findings. It was our subjective impression that there was a period of adjustment in how to communicate guidance and findings. The number and heterogeneity of the cases do not allow testing the hypothesis that sonograms aided remotely become faster with time but the authors believe this is a plausible hypothesis. The on-site sonographers were

TABLE 1: Summary of sonograms performed using real-time telehealth

	No of cases	No of sonographers	Duration (min)	Area examined	Image quality	Technological problems
Phase 1	25	4	40 ± 16, [20–70]	10 abdomen, 1 thoraxes, 14 musculoskeletal†	Good in 24 cases and poor in one case§	Poor internet connectivity in 3 cases.‡ Problems with pairing of Google Glasses in 3 cases.
Phase 2 INEX-R	11	3 on-site, 1 remote	40 ± 19, [9–73]*	4 abdomen, 2 thoraxes, 2 digital sheaths, 1 echocardiogram, 1 high-risk pregnancy and 1 fetlock	Good in 10 cases poor in one case§	Poor internet connectivity in 5 cases.‡ Problems with server that supports communications precluded completion. Poor audio signal in 4 cases.¶
Phase 2 EX	11	1	24 ± 12, [4–43]*	4 abdomen, 2 thoraxes, 2 digital sheaths, 1 echocardiogram, 1 high-risk pregnancy and 1 fetlock	Good in 10 cases poor in one case¶	NA

EX, expert sonographer on-site; INEX-R, inexperienced sonographer assisted by a remote expert sonographer.
*Denotes statistically significant difference between groups, P = 0.02.
†Musculoskeletal examinations included five sonograms of the metacarpal/metatarsal area, 5 of the digital sheath and one sonogram each of the carpal sheath, stifle, pastern and pelvis.
‡In all instances the problems were solved by remote IT assistance and did not preclude completion of the sonogram. Eliminating the Google Glass input was necessary in all 5 cases of internet connectivity issues in order to have adequate internet speed.
§The poor-quality image was attributed to the hair coat and fat deposits in these cases.
¶Audio performed via telephone in these cases.

experienced equine practitioners with solid basic ultrasound skills. For many sonograms, the on-site veterinarians were able to obtain images without instruction. Some of the sonograms, or parts of the sonograms, were, however, of structures that would not have been imaged without guidance. In these cases, the sonogram becomes a continuing education exercise in addition to a clinical procedure. On-site veterinarians highlighted this aspect in questionnaires, and in 20% of the interactions, educational value was considered the most important aspect of the interaction. Interestingly house officers that receive ultrasound training on-site by expert sonographers also highlighted the educational value of the programme. Perhaps this programme made the training more structured in these cases or perhaps this just reflects excitement and a positive attitude towards new technologies. The potential of telecommunication technology for teaching in unconventional ways deserves attention (Becker *et al*. 2019).

In 40% of the interactions, the sonogram was perceived as useful for clinical management. In 40%, reassurance to veterinarians or owners was the reported main value. With 100% positive interactions, the trial was considered a success. There is a likely bias in this perception as costs of the trial were covered by the remote expert institution, and the on-site veterinarians and remote expert had a previous good working relationship. The mentioned biases could make the results of questionnaires more positive than in a situation in which this modality is used commercially or with a random population of on-site veterinarians. Controlled trials are necessary to prove many of these preliminary perceptions.

From the perspective of the remote experts that work in referral academic practice, the ability to communicate and collaborate with practitioners was a highlight of the study. The mission of many academic institutions includes to communicate and create new knowledge. Telecommunications technology opens novel and exciting opportunities to improve equine health, foster a team approach to medicine and create new learning opportunities for equine veterinarians worldwide.

Telehealth is likely to replace part of the veterinary medical care, and we currently provide and expand the spectrum of veterinary work. The goal of a telehealth programme from the specialists involved in this pilot would not to be to substitute referrals, but to expand the spectrum of what both practitioners and specialists can offer. Reassurance to animal owners was highlighted by on-site veterinarians as a benefit of the remote consultations and perhaps telecommunications technology can help bridge gaps in communication between horse owners, practitioners and referral intuitions. The implementation of telehealth is likely to be fast and may disregard adequate testing of its shortcomings, due to the potential for large economic gains of this modality (Jackson and McClean 2012). We believe this initial pilot trial should be followed by controlled trials that can help design best practice guidelines and establish that the health and welfare of patients is not compromised by this medical modality. The experience gained with this pilot study makes us hypothesise that there will be good agreement between sonographic studies performed by inexperienced sonographers aided remotely by an expert and studies performed by an expert sonographer on-site. We also hypothesise that this will improve agreement between studies performed by inexperienced sonographers without assistance and studies performed by an expert sonographer.

These hypotheses can be expanded to many other fields of equine practice, and we believe that many specialties could be good candidates for telehealth programmes. Each specialty would need different tools but the principles may be shared and the real-time component of the current pilot is considered by the authors to be a big improvement when compared to interpretation of still images. Technology can be used in different ways to send live screen feeds to senior clinicians and specialists. However, it should be stressed that security is of importance. The impression makes us hypothesise that real-time telehealth in which a remote expert and on-site veterinarian can communicative and exchange clinical information in real time provides higher quality medicine than remote consults that use a store-and-forward or asynchronous approach. This has been proven in some human medical fields in which the easier and often less expensive store-and-forward approach was less effective when compared to real-time telehealth (Loane *et al*. 2000). We also believe the best scenario remains to have the horse in the same room, and at the same time as the expert veterinarian and that telehealth should be considered an additional tool but not a substitution of traditional referrals. Prospective controlled studies will also be needed to prove these perceptions. The data presented here are heterogenous in regards to the type of sonograms, equipment used, internet connectivity or sonographers' level of skill. This severely limits generalisations that can be made by this study. Extrapolation of information between specialties and between human and veterinary medicine needs to be viewed cautiously. It is likely that simple decisions could be made using less complex systems of communications that provide less information while complex cases may need more advanced telecommunications technology and/or on-site interactions.

In summary, telehealth for ultrasound was feasible, well received by horse owners, private practitioners, specialty trainees and sonography experts. There were technological challenges that could be solved. The perceived benefits of the telehealth programme were the addition of clinically useful information, reassurance to practitioners and horse owners and education for practitioners. We hypothesise that telehealth could increase the quality of equine medicine in the future by improving access to expert advice, and this hypothesis will need to be tested prospectively. It is very likely that telehealth will replace and expand the types of veterinary medical care we currently provide. The veterinary profession will need to determine how to implement changes while maintaining the priorities of animal health and evidence-based principles. If implemented wisely, changes could improve animal health, client satisfaction, the quality of veterinary care and the veterinary profession and provide new opportunities for learning and collaboration worldwide.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

The study was approved by the Texas A&M Animal Care and Use Committee and the client owned animal research committee. Authors adhered to the Principles of Veterinary Medical Ethics of the AVMA.

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Authorship

C. Navas and C. Underwood contributed to the study design, study execution, data analysis and interpretation and preparation of the manuscript. D. O'Gan, K. Bevevino and A. Doering contributed to the study execution, data interpretation and preparation of the manuscript. L. Teller contributed to the data analysis and interpretation and preparation of the manuscript. All authors gave their final approval of the manuscript.

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