

Submitted: 03/02/2024

Accepted: 26/03/2024

Published: 30/04/2024

Veterinary telemedicine: A new era for animal welfare

Ashraf M. Abu-Seida^{1,2*} , Abdulrahman Abdulkarim³  and Marwa H. Hassan⁴ 

¹Animal Research Facility, Galala University, Suez, Egypt

²Department of Surgery, Anesthesiology and Radiology, Faculty of Veterinary Medicine, Cairo University, Giza, Egypt

³Theriogenology Department, Faculty of Veterinary Medicine, Omar Al Mukhtar University, Bayda, Libya

⁴Department of Veterinary Clinical Sciences, Faculty of Veterinary Medicine, Jordan University of Science and Technology, Irbid, Jordan

Abstract

Telehealth is a rapidly developing field of veterinary medicine, particularly during and after the coronavirus 2019 (COVID-19) pandemic. The world and animal owners' expectations are changing to the point where veterinary practice will need to adapt due to information technology advancements. This narrative review describes the status, benefits, technology basics, applications, limitations, and legal aspects of veterinary telemedicine over the globe. Veterinary telemedicine is a service alongside other veterinary services that meets client needs, delivers quality medicine, and improves animal welfare. The most frequently utilized veterinary telemedicine applications include teleradiology, telesonography, teledentistry, telecardiology, telerehabilitation, anesthesia teleconsultation, telehospice and telepalliative care, telecytology, tele-endoscopy, teledermatology, tele-ophthalmology, tele-behavior therapy, and veterinary education and training. Veterinary telemedicine has a bright near future and will impact veterinary medicine and animal welfare due to its numerous advantages. These advantages include its low cost, availability, involvement in veterinary health care, online payment, and effectiveness in many clinical situations such as follow-up after an in-person examination, inspection of surgical sites, or mobility. Nevertheless, veterinary telemedicine should receive more attention from veterinary professional regulatory bodies in all countries. Moreover, it is necessary to conduct more studies to evaluate how telehealth is beginning to improve veterinary care, particularly for underserved regions.

Keywords: Telehealth, Teleradiology, Teleconsultation, Telesonography, Veterinarian-client-patient relationship.

Introduction

Technological applications for remote health information, instruction, or care are referred to as "telehealth." Telehealth is therefore divided into telemedicine, teleconsultation, and teletriage (Cushing, 2022). Although they are distinct, the terms "telehealth," "teletriage," and "telemedicine" are sometimes used synonymously.

Veterinary telemedicine (sometimes called televet) is a branch of telehealth where veterinarians and pet owners can communicate electronically for remote veterinary medical practice (consultation, diagnosis, and treatment). However, many countries require a valid veterinarian-client-patient relationship (VCPR) before veterinary telemedicine (Papageorges, 2001; Cushing, 2022). Telemedicine was a hot topic of debate before the COVID-19 pandemic but it established a new era for animal welfare in many countries during and after the pandemic (Papageorges, 2001; Chitty, 2019; Cushing 2022).

Teleconsultation is a telecommunication between a consulting veterinarian (specialists such as radiologist, dentist, or pathologist) and an attending veterinarian who is seeking advice and is in charge of all data obtained during the teleconsultation (Hess, 2017). Teletriage, on the other hand, refers to the delivery of general medical advice by a veterinarian or member of the veterinary clinic team, which is not meant to explicitly diagnose or treat an animal. This general information addresses a wide range of subjects, including suggestions for animal husbandry and nutrition, the need for yearly examinations or vaccines, and more. A teletriage service helps the pet's owner decide whether to drive late at night to an emergency animal hospital or wait until the following day (Hess, 2017; Kastelic and Ogilvie, 2021).

There have been three stages in the development of veterinary telemedicine. In stage 1, (Innovation—1990 to 1995), an ultrasound vendor had first presented veterinary telemedicine as a workable solution, but it only took up among hackers and tech-savvy veterinarians

*Corresponding Author: Ashraf M. Abu-Seida. Animal Research Facility, Galala University, Suez, Egypt. Email: ashrafseida@cu.edu.eg; ashrafseida@yahoo.com

(Papageorges, 2001). In stage 2 (Telemedicine is offered by several vendors—1996 to 2001), numerous companies provided telemedicine, but due to resistance from many veterinarians and a lack of computing competence, veterinary telemedicine remained more of an idea than a reality (Papageorges, 2001). In stage 3 (Telemedicine becomes indispensable—2002 to 2010), telemedicine would be expected to be indispensable due to the information revolution (Papageorges, 2001). Although veterinarians have used cellphones for telehealth since they were invented, veterinary telemedicine was only introduced formally in 2016 (Cushing, 2022).

In the last decade, telemedicine has been a growing area of interest for veterinarians. The COVID-19 pandemic's arrival in 2020 and the widespread lockdowns that followed have elevated veterinary telemedicine to the fore worldwide (Kastelic and Ogilvie, 2021; Smith *et al.*, 2022).

This narrative review article explored the status, technology basics, benefits, various applications, limitations, and legal aspects of veterinary telemedicine in PubMed, Scopus, and Google Scholar databases. The search terms included “veterinary telehealth,” “veterinary telemedicine,” “veterinary telerriage,” and “veterinary teleconsultation.”

Status of veterinary telemedicine use across the globe

Numerous studies on veterinary telemedicine have been carried out over the globe, particularly in small animal practices. For pet owners who are unable or unwilling to visit the veterinary hospital, several veterinarians now offer telemedicine in their offices (Mazan *et al.*, 2017; Teller, 2023).

In North America, during the COVID-19 pandemic, the use of video-based veterinary telemedicine significantly increased. Although veterinary telemedicine was more affordable and quicker than in-person examination, numerous veterinarians raised questions of probable inferiority and legal difficulties. In addition, after the pandemic is gone, many veterinarians plan to stop using telemedicine for various clinical uses (Bishop *et al.*, 2021). In Canada, college of veterinarians of ontario regulations support developments in veterinary telemedicine but insist on a VCPR (Gyles, 2019). When the COVID-19 pandemic first broke out, the rules were loosened and remote prescriptions as well as the installation of a VCPR were permitted. They reported no clinical complaints following these adjustments for 18 months, and they have no plans to return to the pre-pandemic restrictions (Gyles, 2019).

The American Veterinary Medical Association (AVMA) states that a valid VCPR is required, but that each state is in charge of establishing the rules for veterinary telemedicine. Many states in the United States permit setting up the VCPR remotely (Larkin, 2015). In the USA, the results of a survey concluded that there is a need for interventions in veterinary schools and continuing education programs to increase

veterinarians' knowledge of and use of veterinary telehealth and telemedicine (Watson *et al.*, 2019).

Veterinary professional regulatory agencies in Europe have only given veterinary telemedicine sporadic consideration. The Portuguese Veterinary Order, the country's regulatory body, now considers veterinary telemedicine to be outside of permissible veterinary practice. Responses to a poll show the value of veterinary telemedicine in enhancing animal treatment as well as its drawbacks. Approximately 80% of participants (Portuguese veterinarians) thought that there should be restrictions on the use of veterinary telemedicine, and 66% thought that a remote consultation should always be followed by a face-to-face consultation. Despite the fact that the majority of participants believed that vet-to-vet teleconsulting should be permitted and governed by ethical norms (Magalhães-Sant'Ana *et al.*, 2020).

A conference titled “ICT, Telemedicine and Knowledge Networks in Veterinary Medicine” was hosted in 2008 by the Italian Society of veterinary science, which first identified the prospects presented by information and communications technologies in the veterinary industry in 2007. The seminar raised awareness of new initiatives and concepts in Italian veterinary telemedicine (Forlani *et al.*, 2010).

In Germany, the COVID-19 pandemic promoted the use of digital techniques by many veterinarians despite the absence of a clear legal framework (Becker *et al.*, 2023). In a companion animal intensive care center in the Netherlands, a virtual pet visit system was used. The majority of pet owners felt better using the utilized virtual pet visit system while their animals were being treated in hospitals because it was a pretty straightforward application (Robben *et al.*, 2016).

In a survey, veterinarians in the United Kingdom noted that although many of their clients use the internet to read about animal health, they frequently do not comprehend what they read. The health of pets is negatively impacted by the internet, according to 40% of veterinarians (Kogan *et al.*, 2017). It was recognized that the field of telemedicine was poorly defined in the UK, fast expanding, and it would be years before technology reached the veterinary market when the Royal College of Veterinary Surgeon (RCVS) began its telemedicine consultation in early 2017 (Nelson-Pratt, 2018). Current RCVSs and British Veterinary Association guidance indicates that any advice given to animals that are not under the veterinarian's care should be general in nature and not case-specific (Barrand and Jarvis 2021). To permit remote prescribing during the COVID-19 pandemic, the RCVS and the British Small Animal Veterinary Association loosened their rules; however, this provision has since expired (Littlehales *et al.*, 2020; Loeb, 2022).

Telephone consultations are employed for veterinary telemedicine in rural areas of Africa, with all the drawbacks and benefits it entails. In recent years, Internet use has improved veterinary telemedicine in

Africa and enabled long-distance exchange of images and movies. Today, telemedicine is practical and easy to use, and its use is growing in Africa, where access to and utilization of knowledge is frequently problematic (Bath, 2006). Although there are several restrictions, such as the unavailability of smartphones and reliable internet in many remote locations, many veterinarians in Uganda have expressed a strong interest in veterinary telemedicine (Takuwa *et al.*, 2023). The recent rise in mobile phone use and increased signal coverage has created opportunities for the growth of the mobile health sector in many low-resource settings. A smartphone-based application, VetAfrica-Ethiopia, helps in the diagnosis of cattle diseases through the estimation of the related disease probabilities based on various clinical signs being present in Ethiopian cattle (Beyene *et al.*, 2017). This application can be a valuable means of assisting less experienced animal health professionals in disease diagnosis and consequently helping in treatment (Beyene *et al.*, 2017).

Even though India lacks adequate healthcare infrastructure and disease epidemiological data, particularly in rural regions, the concept of veterinary public telemedicine is far from being developed there (Pathak and Kumar, 2017). Recently, cellphones, applications, digital cameras, and other conveniently accessible technology have provided new instruments for communication among veterinary professionals. However, the use of social networks for veterinary telemedicine services happens haphazardly and randomly (Pathak and Kumar, 2017). Infectious disease surveillance and analysis system (IDSAS), a mobile phone-based animal health monitoring system, has been created and is utilized in Sri Lanka for the timely collection of animal health data, tracking disease patterns, and early detection of developing diseases (Robertson *et al.*, 2010).

Most veterinarians all over the world have likely already sent emails to clients and received information (text, videos, and pictures) about their patients. This is considered telemedicine and should be documented in the medical record of the animal (Papageorges, 2001; Cushing, 2022).

In farm animal practice, there are some differences in veterinary telemedicine. Many farm animal owners use facetime and skype to obtain and exchange patient information to gain a head start on decision making and to assist less experienced coworkers in activities (Gyles, 2019). Therefore, systems for remotely monitoring the health of farm animals are being researched. Several obstacles exist in the care of farm animals; including those related to cost-effectiveness, the reliability and accuracy of the equipment, the ability to accurately predict health conditions, and information security (Gyles, 2019).

Benefits of veterinary telemedicine

Veterinary telemedicine is able to enhance the way veterinary medicine is practiced and brings more

animals into the health care system. With the use of veterinary telemedicine, pet owners now have a way to communicate with a veterinarian from the comfort of their own home (Papageorges, 2001; Cushing, 2022). Therefore, the geographical reach of clinical veterinary practice is increased via veterinary telemedicine. Veterinary telemedicine, as an adjunct to traditional veterinary medicine, has many benefits for animals, clients, and veterinarians (Papageorges, 2001; Hess, 2017; Kastelic and Ogilvie, 2021; Cushing, 2022).

These benefits include the ability for veterinarians to quickly and effectively chat support around the clock, the ability for fewer veterinarians to monitor more ill animals, and the ease with which primary veterinarians can access specialists that will lower clinical errors and enhance treatment outcomes. In addition, veterinary telemedicine gives vets a chance to connect with customers who might be physically unable to transport their patients to a hospital for every assessment or follow-up visit (Cushing, 2022). Telemedicine offers veterinary nurses job options without the hassle of moving (Donahue, 2022; Smiley, 2022a).

In addition, veterinary telemedicine aids in the treatment of animals in remote locations. However, traveling and the stress it causes can occasionally put a case in danger (Chitty, 2019). There are places where getting veterinary care is difficult, called veterinary deserts. Telemedicine enables pet owners in these regions to receive professional guidance regarding the appropriate length of time for care (Donahue, 2022; Smiley, 2022 a,b).

Moreover, telemedicine provides an opportunity for the initial encounter between the patient and the veterinarian to highlight the genuine need for traditional veterinary care. Customers' convenience would grow with subsequent telemedicine consultations following an in-person examination (Cushing, 2022). Compared to in-person examination, veterinary telemedicine is quicker and less expensive (Forlani *et al.*, 2010).

Those who are less inclined to attend veterinary hospitals due to factors including distance, transportation, nervous animals, or owner disease may be able to receive veterinary care through telemedicine (Chitty, 2019; Donahue, 2022).

Several studies concluded that pet owners had excellent experiences while using telemedicine as a supplement to conventional in-person veterinarian care (Bishop *et al.*, 2018; Roca and McCarthy, 2019). A study on pet owners' willingness to pay for veterinary telemedicine found that they are more willing to pay a statistically higher sum for a consultation with their own veterinarian via telemedicine than with one connected to a large call center or large-scale veterinary telemedicine operation (Widmar *et al.*, 2020). Furthermore, by improving scheduling efficiencies, telemedicine offers traditional veterinary clinics financial advantages as well.

Veterinary telemedicine is a useful tool in a variety of circumstances, including some recheck examinations,

ongoing chronic disease management in animals with pre-existing conditions, and preventative care examinations (such as renewing tick/flea medicine). Depending on the laws of the country and/or the province, the diseased animal may be examined virtually or by being dropped off at the veterinary clinic (Cushing, 2022; Becker *et al.*, 2023). Remote consultation is a legitimate technique for behavioral specialists to give owners advice on how to deal with their dog's separation anxiety (Cottam *et al.*, 2008). Cats are stressed out at the veterinary hospital; therefore, their blood and urine analyses can be incorrect. At-home diagnostics will be transformational for cats (Caney *et al.*, 2022). Several veterinary specialists felt that cats responded better to remote consultations than other animals due to a reduction in stress levels in both the cats and their owners. In addition, they mentioned how helpful it was to observe the cat in its natural habitat, particularly when assessing behavioral issues (Caney *et al.*, 2022; Smiley, 2022a).

Technology basics for veterinary telemedicine

An Internet connection is required for all veterinary telemedicine technology. The internet is used by about 4.9 billion individuals worldwide. As a result, veterinarians have an excellent chance to offer veterinary services wherever. However, certain veterinary practitioners are frequently hesitant to change due to anxiety and mistrust of technology. The cure for this phobia is education (Mitek, 2022a; Smiley, 2022b). Veterinarians should focus on the future rather than preserve the past.

With the proper equipment, software, and personnel, a physical examination can be performed remotely. A remote veterinarian can analyze the situation using cameras, electronic stethoscopes, robots, and support workers or a human facilitator during a supported virtual visit (Smiley, 2022b). Therefore, technical and support professionals are crucial for successful veterinary telemedicine to offer assistance when technical issues develop. In addition, effective veterinary telemedicine depends on connection with the electronic medical record (Mitek, 2022a; Smiley, 2022b).

Both open and closed systems are offered by telemedicine providers. The open system allows for the integration of numerous pieces of hardware and software from numerous distinct outside sources. In contrast, every component in a closed system is created, developed, and supplied by a single company (Smiley, 2022b).

Since the early 1980s, specific veterinary telemedicine applications have been in use, but there has not been much study done in this area (Mars and Auer, 2006). Now, there are several veterinary telemedicine easy-to-use applications such as PetDesk, Airvet, GuardianVets, AskVet, Anippanion, and others. These applications get clients really involved in their animal's health through performing mini examinations such as counting respirations per minute, letting the pet trot, showing the

animal's gums, and many others during telemedicine with a remote vet. But any disorders that would require blood or other laboratory tests, or physically feeling something such as a tumor, cannot be diagnosed by this service. Therefore, most companies of veterinary telemedicine recommend that the animal's owner still see a regular in-person veterinarian (Mitek, 2022a; Smiley, 2022b).

Asynchronous and synchronous communications are the two modes of communication. Information is exchanged at various times in asynchronous communication methods such as emails, Slack chats, Asana, and Trello boards. While synchronous communication, such as phone or video calls, occurs in real time with little to no delay in the flow of information. Even though both forms of communication can be used simultaneously, most pet owners favor asynchronous communication. As a result, asynchronous communication is a useful tool for veterinarians who want to provide excellent telemedicine (Bishop *et al.*, 2021).

A telemedicine system is a tool that will not advance veterinary practice unless the veterinarians take action to do so; therefore, veterinary professionals should be prepared to grow along with technology and do not be afraid (Papageorges *et al.*, 2001a; Richards, 2019). The differences between systems are the price and services offered by the system (Papageorges and Hebert, 2001a). A telemedicine system is made up of a computer, imaging software, text software, communication software, a modem or Ethernet card, and one or more X-ray image capture equipment to digitize images (Papageorges and Hebert, 2001b). When specialist treatment is not immediately available and the transmission of visual information would be advantageous, facetime video calling was also employed successfully (Donham and Wickett, 2018). For the majority of the active clientele, telemedicine services can be implemented. This opens up a new way to deliver veterinary care during social isolation restrictions and beyond (Naimark *et al.*, 2022). Moreover, multitheory model (MTM) should be taken into consideration by academics, teachers, and veterinary professionals when developing interventions to improve the usage of telehealth (Wells *et al.*, 2023). Medical technology powered by artificial intelligence (AI) is currently developing quickly into a number of treatments for clinical problems, and it will undoubtedly continue to grow in the near future. Although AI will not replace veterinarians, it will supplement the current system of veterinary care, and veterinarians will be helped by advanced medical technologies (Mitek, 2022a). Imagine a program that might analyze a difficult case's notes, compare laboratory results to known test sensitivities and specificities, and generate a differential list to supplement the clinicians (Richards, 2019).

Recently, wearable devices have moved the field away from a reactive healthcare system toward a proactive culture that can spot diseases early and enable

veterinarians to remotely monitor a patient's vital signs in addition to other factors. The way veterinarians acquire and use patient data to perform medicine may be significantly altered by advancements in this technology (Mitek *et al.*, 2022). In the near future, it is expected that every pet will have a health chip that communicates the animal's complete medical history in addition to its identity and ownership (Taylor, 2020).

Applications of veterinary telemedicine

Veterinary telemedicine has a legitimate position in contemporary veterinary care since it can enhance animal welfare and reduce the load on physical veterinarian clinics (Williams, 2023).

Teleradiology, telesonography, teledentistry, telecardiology, telerehabilitation, anesthesia teleconsultation, telehospice and telepalliative care, telecytology, tele-endoscopy, teledermatology, teleophthalmology, telebehavior therapy, and veterinary education and training are the most frequently utilized veterinary telemedicine applications (Papageorges and Hebert, 2001c; Pang *et al.*, 2020; Cox, 2022; Mitek, 2022b; Ross-Estrada and Snyder, 2022; Wong and Alvarez, 2023).

Veterinary teleradiology

In teleradiology, a radiographic image is produced and then electronically communicated. The commercialization of veterinary teleradiology started in the early 1990s but met with little success, mostly because of the slow internet and large file sizes. Teleradiology is currently a standard procedure in veterinary medicine with the accessibility of broadband Internet connections, image reduction, and reasonably cost PACS and DICOM software (Papageorges *et al.*, 2001b; Poteet, 2008). Primary veterinarians can benefit from the veterinary teleradiology service via the creation of a radiographic image that is then transmitted electronically to an expert veterinarian for consultation (Cushing, 2022). On the other hand, low-cost teleradiology may only provide moderate accuracy when applied to grading schemes like elbow-grading schemes, which may limit its application to breed score algorithms (Hammond *et al.*, 2008). This is due to the effect of digitization on the quality of original radiographs. Therefore, future study of teleradiology using a different scoring model such as hip dysplasia may be recommended.

Veterinary telesonography

In contrast to teleradiology, veterinary teleultrasound is gradually gaining popularity. Telesonography can be used in two major ways: synchronous real-time interpretations and asynchronous "store-and-forward" techniques. In small animal medicine, there are not many teleultrasound protocols that are standardized. The interaction between the veterinarian asking for remote assistance and the expert giving support is crucial to the success of a telesonography (Seiler *et al.*, 2022). Telesonography is more widely accepted among veterinarians than teleradiology due to its cost-

effectiveness because images can be captured directly from ultrasound machines using an inexpensive image-capture device. Moreover, telesonography is a speedy and affordable method of sending ultrasound images to experts (Papageorges *et al.*, 1998; Papageorges *et al.*, 2001c).

Veterinary teledentistry

Veterinary dentists, their clients, and their colleagues across the profession can all benefit from improved communication. When a veterinarian refers a patient to a specialist, they see it as an expansion of the care they already offer. Consequently, establishing a rapport with the specialist is a crucial component of patient treatment (Mulherin and Bannon, 2022).

Telecardiology

Numerous telemedicine applications fall under the category of telecardiology, including teleradiology (thoracic radiographs), telesonography (echocardiograms), and tele-electrocardiography. Although telecardiology takes more time, the outcomes are more effective because the cardiologist has access to all the data required to make a precise diagnosis (Papageorges and Hebert, 2001c).

Telerehabilitation

For the evaluation, progression, and monitoring of canine patients, telerehabilitation is a practical solution that rehabilitation practitioners can quickly apply. In a recent survey, high client satisfaction was on par with in-person consultations while using telemedicine for canine rehabilitation (Wong and Alvarez, 2023). More research is recommended to determine how effective telerehabilitation is.

Anesthesia teleconsulting

It is possible to execute anesthesia teleconsulting successfully, including the management of anesthetic problems. Although there are many technological factors to take into account, it is possible to harness the effectiveness of current technology and communications networks to create a positive experience for all parties and enable high-quality patient care (Pang *et al.*, 2020). Client consent for anesthetic teleconsulting should be obtained by the attending veterinarian in accordance with the established VCPR who retains ultimate case responsibility and decision-making authority (Pang *et al.*, 2020). A video camera (such as a smartphone), monitor (such as a laptop or tablet), and videoconferencing platform are sufficient for the majority of veterinary demands (Pang *et al.*, 2020). Anesthesiologists can be included in the care team for every patient, wherever in the globe, with the use of electronic anesthetic records and video, phone, and chat consultations (Mitek, 2022b).

Telehospice and telepalliative care

Hospice and palliative care can be provided to patients remotely through videoconferencing, telephone communication, or remote symptom monitoring (Cox, 2022). Therefore, telehospice and telepalliative care can serve the needs of both patients and clients. Hospice

and palliative care providers may be able to assess and address patient care needs through telehealth-based interventions, such as the provision of efficient pain and symptom management, quicker assessments and medical interventions, increased compliance, and more opportunities for client education (Cox, 2022).

Telecytology

Telecytology can be quick, affordable, safe, and accurate. Close cooperation between practitioners and consultants is necessary for telecytology. They each offer information that is often unavailable to the other (Hebert *et al.*, 2001). Telecytology needs at least 12–18 photographs per lesion or organ. In general, more is better, and blurry photographs should be deleted. Images with low (100X), middle (400X), and high (1,000X) magnification are crucial for diagnosis. Images at intermediate and high magnification should, whenever possible, include one or more neutrophils and/or erythrocytes for scale. A thorough history, description of the lesion, radiography and ultrasound results, and a description of the submission are as crucial as the telecytology images themselves.

Low cellularity bone marrow samples, buffy coat smears, smears from normal-size/small kidneys without focal abnormalities, cavitory splenic lesions, and any hemodiluted sample with low cellularity are among the tissues/lesions with a reduced telecytology diagnostic yield. Repeating the biopsies in these circumstances is advised to obtain a larger cellular sample (Hebert *et al.*, 2001).

Although video cameras have been utilized for telecytology in the past, digital still cameras are highly advised because the digitization and transmission of images are essential (Campbell, 1996). Moreover, a high-quality microscope with a third eyepiece and a C-mount adapter should be available for frequent telecytology use. A microscope adapter is also necessary. The microscope can be converted into a video microscope by permanently mounting a camera on the third eyepiece and connecting it to a monitor (Campbell, 1996). Glass slides and body fluids must be physically transported to a diagnostic laboratory, which might delay patient care. Recently, digital cytology has made it possible to process samples in the clinic and send them right away to pathologists. Digital cytology is transforming clinical pathology and patient care as technology becomes more accessible (Piccione and Baker, 2023).

Veterinary education and training

Many clinical instructors had to adjust to teaching online as a result of the COVID-19 pandemic. In a recent survey, the majority of students believed that the online clinical experience met or exceeded expectations and provided a worthwhile learning experience (Ross-Estrada and, Snyder, 2022). The inclusion of such learning environments in the curriculum for veterinary medical education is crucial to preparing students

for the modern veterinary workplace as the field of telemedicine develops.

Veterinary students in Ghana are well-versed in telemedicine. This understanding grows as more years are spent studying (Emikpe *et al.*, 2021). The majority of students (>95%) who responded to a recent study on the benefits of telehealth sessions felt that taking part in them had increased their clinical competence and confidence. The learning environment for potential telehealth users is improved by telehealth (Lubbers *et al.*, 2022).

In other recent surveys of an underserved population, the authors discussed how telehealth might help remove obstacles to receiving veterinary service, as well as their opinions on telehealth consultations, and improvements in veterinary students' empathy. About 25% of clients said they would not have had the money for transportation, and 58% said they could not have afforded a visit to a local veterinarian facility. Telehealth provided this population with an alternative modality to address transportation challenges as a barrier to accessing veterinary care. The experiences of both clients and students were overwhelmingly favorable, supporting expanded service-learning programs for veterinary student education (Lundahl *et al.*, 2022). Virtual microscopy (VM) is changing telemedicine, online diagnostics, and the teaching of microscopic structures (Mills *et al.*, 2007). The accessibility, effectiveness, and integration of VM with computer-assisted interactive learning are advantages of VM over traditional microscopy. Moreover, utilizing VM has other several benefits over utilizing digital photomicrographs, including better image clarity, less infrastructure need, high flexibility, and the opportunity to examine the slide and conduct independent research (Mills *et al.*, 2007; Lundahl *et al.*, 2022). Although VM is utilized in a case-based style to teach students about histopathology, it can also be successfully incorporated into other models of medical student teaching, such as integrated and problem-based learning curricula and the traditional pathology laboratory (Dee and Meyerholz, 2007). Because VM provides sharper images, the opportunity for collaborative learning, more efficient time management, and the flexibility of online learning, the students evaluated VM much higher than traditional microscopy as a tool for studying histology (Mills *et al.*, 2007).

In addition, telemedicine can help in veterinary continuing professional development by providing ongoing education (Papageorges and Tilley, 2001). Videoconferencing enables veterinarians to virtually include specialists in their daily or weekly rounds and offers one-on-one training sessions on the topic and time they want as well as providing continuous education through regular interaction with specialists via teleconsults (Papageorges *et al.*, 2001a). The previously mentioned VetAfrica-Ethiopia application

can be a valuable means of assisting less experienced animal health professionals in disease diagnosis and consequently helping in treatment (Beyene *et al.*, 2017).

Tele-endoscopy

A video endoscope is prepared for telemedicine. A computer with a video card or a still digital camera is required. In tele-endoscopy, taking representative photographs and saving them to disk should be performed. Then, importing the photographs into imaging software or sending them via email is carried out for analysis (Papageorges *et al.*, 2001a).

Teledermatology

Teledermatology is the simplest and clearest telemedicine application. A video camera or a still digital camera with macro settings for close-up views of skin lesions is the only tool needed for teledermatology. Taking representative photographs of the lesion(s), adding the clinical details, and sending the case to a dermatologist are the steps required (Papageorges *et al.*, 2001a).

Teleophthalmology

For tele-ophthalmology, a digital still camera with macro capabilities can take external pictures of the eyes. However, a video ophthalmoscope is required for the internal inspection. The processes for teledermatology and external examination of the eyes are identical while internal examination is comparable to tele-endoscopy (Papageorges *et al.*, 2001a).

Telebehavior therapy

Animal behaviorists can study the patient and interact with the owner(s) as if the evaluations were taking place in person. Videoconferencing is required for this application (Papageorges *et al.*, 2001a; Cottam *et al.*, 2008).

Legal aspects of veterinary telemedicine

The veterinary community should be aware of the increased legal concerns that come with the use of modern technology. There is no doubt that the laws governing telemedicine for animals are in a state of upheaval. A standard protocol could be used in a clinical setting to help prevent some unfavorable legal repercussions (Papageorges and Tilley, 2001). This will help to reduce some of the uncertainty surrounding these problems.

Many veterinary services require that an animal be checked by a veterinarian in person before diagnosis and treatment of this animal via a televet service. Therefore, using this tool requires some necessary regulations like a valid VCPR and informed consent that allows a veterinarian to diagnose and treat a patient through telemedicine. A valid VCPR indicates that a veterinarian has adequate information about an animal to pursue diagnosis and treatments of various disorders and implies timely care and follow-up of the animal. However, it is less certain whether such a connection may be made via other unconventional techniques, like an emergency hotline (Papageorges and Tilley,

2001). In some countries and states, a VCPR can be established virtually using telemedicine (Larkin, 2015). Veterinarians should be aware that practicing remotely or consulting with clients involves adherence to the same professional norms as in-person clinical veterinary practice, such as licensing, confidentiality, and malpractice insurance (Jack, 1999).

Like other medical practices, telemedicine includes the possibility of confidentiality violations. Therefore, it would be preferable to create a special “telemedical” consent form that, among other things, addresses the concerns about disclosing information to telemedical consultants via electronic means. In addition, sensitive and secret information must be transmitted with some type of data protection (Jack, 1999).

Limitations of veterinary telemedicine

Veterinary telemedicine is a supplement to present veterinary medical practice; it does not replace it. TeleVet should take legal and ethical considerations into account. Each country and/or province has its own telemedicine regulations (Papageorges *et al.*, 2001a). Lack of a valid VCPR, technological constraints (especially those relating to data security), and legitimate complaints of malpractice/misdiagnosis are possible limitations of veterinary telemedicine (Hammond *et al.*, 2008; Cushing, 2022).

Sometimes in rural areas, several phone calls are necessary to perform telemedicine. Other limitations related to phone calls include misunderstandings and misquotations, wastage of time, and missed calls can delay a satisfactory outcome (Kogan *et al.*, 2017).

Telemedicine can also include live video chat between the veterinarian and client/owner via Skype, Facetime, Microsoft Teams, Zoom, and others. The choice of platform is based upon several factors such as ease of use, security, payment methods, documentation, video availability, number of users, and others (Kogan *et al.*, 2017; Cushing, 2022).

There is significant professional concern about medium to high risks, according to the published RCVS analysis of the profession’s perspective on telemedicine (Brown, 2019; Paterson 2019). Another limitation is remote prescribing; a change to the code of conduct, that would permit prescribing outside of the normal VCPR (Mitek, 2022a).

Potential drawbacks mentioned include the possibility of inaccuracy, the absence of a physical examination, the harm to the reputation of the veterinary profession, and less effective client-veterinarian dialogue (Magalhães-Sant’Ana *et al.*, 2020; Teller, 2022). Moreover, technological difficulties may lead to missed diagnoses or delayed treatment (Roca and McCarthy, 2019; Dubin *et al.*, 2021; Teller, 2022).

In addition, wearable monitors, animal-side diagnostic devices, and animal diagnostics all have substantial margins of error due to the variations between animal species and breeds (Mitek, 2022a).

Conclusion

Veterinary telemedicine has a bright future and will impact veterinary medicine and animal welfare due to its low cost, availability, online payment, and effectiveness in many clinical scenarios. Nevertheless, veterinary telemedicine should receive more attention from veterinary professional regulatory bodies in all countries. Moreover, it is necessary to conduct more studies to evaluate the real value of veterinary telemedicine.

Acknowledgements

Not applicable.

Conflict of interest

The authors declare no competing interests.

Funding

This study was self-funded and did not receive any funding from any agency.

Authors' contributions

AMA set the conception as well as the design of the study. All authors collected and analyzed the data. MHH and AA wrote the original manuscript. AMA wrote the final version of the manuscript. All authors have approved the final manuscript.

Data availability

All data analyzed in this review are included in the published article.

References

- Barrand, K.R. and Jarvis, S. 2021. Online consultations. *Vet. Rec.* 188(9), 359.
- Bath, G.F. 2006. Telemedicine in Africa. *J. S. Afr. Vet. Assoc.* 77(3), 107.
- Becker, B., Tipold, A., Ehlers, J. and Kleinsorgen, C. 2023. Veterinarians' perspective on telemedicine in Germany. *Front. Vet. Sci.* 10, 1062046.
- Bishop, G.T., Evans, B.A., Kyle, K.L. and Kogan, L.R. 2018. Owner satisfaction with use of video conferencing for recheck examinations following routine surgical sterilization in dogs. *J. Am. Vet. Med. Assoc.* 253(9), 1151–1157.
- Bishop, G.T., Rishniw, M. and Kogan, L.R. 2021. Small animal general practice veterinarians' use and perceptions of synchronous video-based telemedicine in North America during the COVID-19 pandemic. *J. Am. Vet. Med. Assoc.* 258(12), 1372–1377.
- Beyene, T.J., Eshetu, A., Abdu, A., Wondimu, E., Beyi, A.F., Tufa, T.B., Ibrahim, S. and Revie, C.W. 2017. Assisting differential clinical diagnosis of cattle diseases using smartphone-based technology in low resource settings: a pilot study. *BMC Vet. Res.* 13(1), 323.
- Brown, G. 2019. Telemedicine and conflicts of interest. *Vet. Rec.* 185(7), 209.
- Campbell, W.E. 1996. Collecting, archiving, and sharing of digitized medical information. *Semin. Vet. Med. Surg. Small Anim.* 11(2), 93–95.
- Caney, S.M.A., Robinson, N.J., Gunn-Moore, D.A. and Dean, R.S. 2022. Veterinary surgeons', veterinary nurses' and owners' experiences of feline telemedicine consultations during the 2020 COVID-19 pandemic. *Vet. Rec.* 191(5), e1738.
- Chitty, J. 2019. Telemedicine—the opportunity in the threat. *Vet. Rec.* 184(10), 322.
- Cottam, N., Dodman, N.H., Moon-Fanelli, A.A. and Patronek, G.J. 2008. Comparison of remote versus in-person behavioral consultation for treatment of canine separation anxiety. *J. Appl. Anim. Welf. Sci.* 11(1), 28–41.
- Cox, S. 2022. Telehealth in hospice and palliative care. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), 1123–1133.
- Cushing, M. 2022. What is telemedicine, telehealth, and telerriage. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), 1069–1080.
- Dee, F.R. and Meyerholz, D.K. 2007. Teaching medical pathology in the twenty-first century: virtual microscopy applications. *J. Vet. Med. Educ.* 34(4), 431–436.
- Donahue, K. 2022. Telerriage-how remote advice provides better care. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), 1081–1086.
- Donham, B. and Wickett, M.L. 2018. Novel use of facetime video calling in a deployed setting to assist with the care of a military working dog. *Can. J. Surg.* 61(6), S232–234.
- Dubin, R.J., Angliss, G., Eng, C., Cisneros, T. and Griffon, D. 2021. Veterinarians' perceptions of COVID-19 pandemic-related influences on veterinary telehealth and on pet owners' attitudes toward cats and dogs. *J. Am. Vet. Med. Assoc.* 259(10), 1140–1147.
- Emikpe, B.O., Asare, D.A., Emikpe, A.O., Folitse, R.D. and Botchway L.N. 2021. Knowledge and perception of veterinary students in Ghana on telemedicine. *Niger. J. Physiol. Sci.* 36(1), 115–121.
- Forlani, E., De Lazzari, C., Maiolino, P., Poli, A., Pugliese, A., Rabbito, C. and Sicurello, F. 2010. The first veterinary telemedicine study group. *J. Telem. Telecare.* 16(3), 162–163.
- Gyles, C. 2019. Veterinary telemedicine. *Can. Vet. J.* 60(2), 119–122.
- Hammond, G., Gemmill, T., Mellor, D. and Sullivan, M. 2008. Assessment of low-cost teleradiology for grading elbow dysplasia. *Vet. Radiol. Ultrasound.* 49(1), 20–25.
- Hebert, P., Latouche, J.S., Menard, M. and Papageorges, M. 2001. Teleradiology. *Clin. Tech. Small Anim. Pract.* 16(2), 122–124.
- Hess, L. 2017. Telemedicine: the future of veterinary practice. *J. Avian Med. Surg.* 31(2), 165–171.
- Jack, D.C. 1999. The legal implications of veterinary telemedicine and telecare. *J. Telem. Telecare.* 5 Suppl 1, S80–84.

- Kastelic, J. and Ogilvie, T. 2021. Veterinary telemedicine is not only here to stay, it's poised to grow and likely exponentially. *Can. Vet. J.* 62(12), 1277–1279.
- Kogan, L.R., Oxley, J.A., Hellyer, P. and Schoenfeld-Tacher, R. 2017. United Kingdom veterinarians' perceptions of clients' internet use and the perceived impact on the client-vet relationship. *Front. Vet. Sci.* 4, 180.
- Larkin, M. 2015. AVMA panel to scrutinize telemedicine. *J. Am. Vet. Med. Assoc.* 247(9), 987–988.
- Littlehales, R., Noble, P.M., Singleton, D.A., Pinchbeck, G.L. and Radford, A.D. 2020. Impact of Covid-19 on veterinary care. *Vet. Rec.* 186(19), 650–651.
- Loeb, J. 2022. Telemedicine is here to stay after Covid-19. *Vet. Rec.* 191(1), 6.
- Lubbers, B.V., Fajt, V.R., Teller, L.M., Apley, M.D. and Stillisano, J. 2022. Using telehealth clinical case vignettes to enhance clinical confidence and competence in veterinary students. *Front. Vet. Sci.* 9, 1075752.
- Lundahl, L., Powell, L., Reinhard, C.L., Healey, E. and Watson, B. 2022. A pilot study examining the experience of veterinary telehealth in an underserved population through a university program integrating veterinary students. *Front. Vet. Sci.* 9, 871928.
- Magalhães-Sant'Ana, M., Peleteiro, M.C. and Stilwell, G. 2020. Opinions of portuguese veterinarians on telemedicine-a policy delphi study. *Front. Vet. Sci.* 7, 549.
- Mars, M. and Auer, R.E. 2006. Telemedicine in veterinary practice. *J. S. Afr. Vet. Assoc.* 77(2), 75–78.
- Mazan, M.R., Kay, G., Souhail, M.L., Bubeck, K., Jenei, T. and Merriam, J. 2017. Patients without borders: using telehealth to provide an international experience in veterinary global health for veterinary students. *J. Vet. Med. Educ.* 44(4), 632–639.
- Mills, P.C., Bradley, A.P., Woodall, P.F. and Wilderboth, M. 2007. Teaching histology to first-year veterinary science students using virtual microscopy and traditional microscopy: a comparison of student responses. *J. Vet. Med. Educ.* 34(2), 177–182.
- Mitek, A. 2022a. Technology basics for telemedicine: what practitioners need to know. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), 1109–1122.
- Mitek, A. 2022b. Anesthesiologists in the ether: technology and telemedicine in anesthesiology. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), 1099–1107.
- Mitek, A., Jones, D., Newell, A. and Vitale, S. 2022. Wearable devices in veterinary health care. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), 1087–1098.
- Mulherin, B.L. and Bannon, K.M. 2022. Communication, veterinary-client-patient relationship, and teledentistry. *Vet. Clin. North Am. Small Anim. Pract.* 52(1), 25–47.
- Naimark, A.M., Elwood, S.E., Emily, M., Kragen, B., King, E.K. and Wolfus, G. 2022. Barriers to accessing video-based telehealth appointments at a community veterinary clinic during the COVID-19 pandemic. *Front. Vet. Sci.* 9, 878220.
- Nelson-Pratt, A. 2018. Telemedicine debate is taking far too long. *Vet. Rec.* 183(21), 663.
- Pang, D.S.J., Pang, J.M., Payne, O.J., Clement, F.M. and Faber, T. 2020. Teleconsulting in the time of a global pandemic: application to anesthesia and technological considerations. *Can. Vet. J.* 61(10), 1092–1100.
- Papageorges, M. 2001. Veterinary telemedicine. Introduction. *Clin. Tech. Small Anim. Pract.* 16(2), 87–89.
- Papageorges, M. and Hebert, P. 2001a. Choosing your telemedicine system. *Clin. Tech. Small Anim. Pract.* 16(2), 107–110.
- Papageorges, M. and Hebert, P. 2001b. Telemedicine using standard internet technologies (telemedicine for less than \$1,000). *Clin. Tech. Small Anim. Pract.* 16(2), 102–106.
- Papageorges, M. and Hebert, P. 2001c. Other telemedicine applications. *Clin. Tech. Small Anim. Pract.* 16(2), 125–126.
- Papageorges, M. and Tilley, L. 2001. Why telemedicine? *Clin. Tech. Small Anim. Pract.* 16(2), 90–94.
- Papageorges, M., Hanson, J. and Girard, E. 1998. Telesonography may solve ultrasonography dilemma. *J. Am. Vet. Med. Assoc.* 212(7), 948.
- Papageorges, M., Hanson, J., Girard, E., Leveille, R., Hebert, P., Latouche, J.S and Menard, M. 2001a. How to make telemedicine work. *Clin. Tech. Small Anim. Pract.* 16(2), 111–114.
- Papageorges, M., Hanson, J., Girard, E. and Leveille, R. 2001b. Teleradiology. *Clin. Tech. Small Anim. Pract.* 16(2), 115–116.
- Papageorges, M., Hebert, P., Hanson, J., Girard, E., Leveille, R. and Feleciano, J. 2001c. Telesonography. *Clin. Tech. Small Anim. Pract.* 16(2), 117–121.
- Paterson, D. 2019. Telemedicine and conflicts of interest. *Vet. Rec.* 85(7), 209.
- Pathak, A. and Kumar, D. 2017. Telehealth in India: helping to achieve health for all. *Vet. Rec.* 180(23), 572–573.
- Piccione, J. and Baker, K. 2023. Digital cytology. *Vet. Clin. North Am. Small Anim. Pract.* 53(1), 73–87.
- Poteet, B.A. 2008. Veterinary teleradiology. *Vet. Radiol. Ultrasound.* 49 (1 Suppl 1), S33–36.
- Richards, I. 2019. Telemedicine—the threat in the opportunity. *Vet. Rec.* 185(1), 25.
- Robben, J.H., Melsen, D.N., Almalik, O., Roomer, W. and Endenburg, N. 2016. Evaluation of a virtual pet visit system with live video streaming of patient images over the internet in a companion animal

- intensive care unit in the Netherlands. *J. Vet. Emerg. Crit. Care (San Antonio)*. 26(3), 384–392.
- Robertson, C., Sawford K, Daniel SLA, Nelson TA, Stephen C. 2010. Mobile phone-based infectious disease surveillance system, Sri Lanka. *Emerg Infect Dis*. 16(10), 1524–1531.
- Roca, R.Y. and McCarthy, R.J. 2019. Impact of telemedicine on the traditional veterinarian-client-patient relationship. *Top. Companion Anim. Med*. 37, 100359.
- Ross-Estrada, M.D. and Snyder, A.M. 2022. Creating an authentic small animal primary care experience using online simulated appointments. *J. Vet. Med. Educ*. 49(2), 187–198.
- Seiler, G.S., Cohen, E.B., d’Anjou, M.A., French, J., Gaschen, L., Knapp, S., Manzi, T. and Navas de Solis, C. 2022. Small animal teleultrasound. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), 1141–1151.
- Smiley, A.J. 2022a. Veterinary remote care. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), ix.
- Smiley, A. 2022b. Asynchronous veterinary telemedicine. *Vet. Clin. North Am. Small Anim. Pract.* 52(5), 1135–1140.
- Smith, S.M., George, Z., Duncan, C.G. and Frey, D.M. 2022. Opportunities for expanding access to veterinary care: lessons from COVID-19. *Front. Vet. Sci.* 9, 804794.
- Takuwa, M., Mbabazi, S.E., Tusabe, M., Mulindwa, B., Makobore, P.N., Mulerwa, M., Kansiime, E.C., Birungi, D.M., Reboud, J., Cooper, J.M. and Ssekitoleko, R.T. 2023. Mobile health access and utilisation in Uganda: knowledge, attitudes and perceptions of health and veterinary workers. *Telemed. J. E. Health*. 29(6), 912–920.
- Taylor, N. 2020. A glimpse into a post-covid vet future. *Vet. Rec.* 186(15), 500.
- Teller, L.M. 2022. Exploring the challenges and opportunities presented by veterinary telemedicine. *Vet. Rec.* 191(5), 210–212.
- Teller, L. 2023. Advancing telehealth to enhance and expand patient care. *J. Am. Vet. Med. Assoc.* 261(2), 148.
- Watson, K., Wells, J., Sharma, M., Robertson, S., Dascanio, J., Johnson, J.W., Davis, R.E. and Nahar, V.K. 2019. A survey of knowledge and use of telehealth among veterinarians. *BMC Vet. Res.* 15(1), 474.
- Wells, J., Watson, K., Sharma, M., Davis, R.E., Gruszynski, K., Robertson, S.R. and Nahar, V.K. 2023. Application of the multi-theory model to explain veterinarians’ intentions to use telehealth/telemedicine. *Vet. Rec.* 192(4), e2385.
- Widmar, N.O., Bir, C., Slipchenko, N., Wolf, C., Hansen, C. and Ouedraogo, F. 2020. Online procurement of pet supplies and willingness to pay for veterinary telemedicine. *Prev. Vet. Med.* 181, 105073.
- Williams, A. 2023. Telemedicine has a valid place in a modern veterinary profession. *Vet. Rec.* 192(2), 87.
- Wong, S.Y. and Alvarez, L.X. 2023. Veterinary telerehabilitation was as satisfactory as in-person consultations. *Can. Vet. J.* 64(7), 654–658.