

VETERINARY TELERADIOLOGY

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Veterinary teleradiology was first commercially introduced in the early 1990s with limited success, mostly influenced by slow Internet speeds and large file sizes. Currently the practice of teleradiology in veterinary medicine is widespread due to the availability of broadband Internet connections, image compression, and economically priced PACS and DICOM software. This review article will discuss the current applications, equipment and configuration needs, the medicolegal aspects, image file formats, and methods of transmission needed for teleradiology in veterinary medicine. *Veterinary Radiology & Ultrasound, Vol. 49, No. 1, Supp. 1, 2008, pp S33–S36.*

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Introduction

THE FIRST COMMERCIALY available teleradiology system for use in veterinary medicine was sold by Professional's Software Inc. (PSI) of Effingham, IL in 1994. This system used modem to modem technology and transmitted JPEG format images from a veterinary clinic to a radiologist for interpretation. Only one case at a time could be transmitted and it often took 30 min or more to transmit a couple of radiographs and required a dedicated telephone line. The analog radiographic images were digitized using a dedicated scanner or, in some cases, they were converted to digital format using a document flat-bed scanner or a digital camera (1–3 megapixels). Over the next few years, veterinary teleradiology evolved due to computer technology advancement and the Internet. Reasonably priced broadband Internet access allowed for transmission of large files in a much more reasonable time frame. Several companies emerged and merged that helped to develop this technology and market the advantages of telemedicine to practitioners around the United States and worldwide.

This article will help familiarize the reader with the information regarding the equipment and configuration needs, the medicolegal aspects, image file formats, and methods of transmission for teleradiology. I will also attempt to share some of my own practical experiences in the practice of teleradiology over the last 15 years.

Applications of Teleradiology

The applications of veterinary teleradiology are expanding (Table 1). Many vendors market their systems not as

teleradiology systems but as telemedicine systems. In addition to transmission of radiographic images, these systems can be used to transmit photographs of animals, endoscopic, cytologic, and histologic images. Video cine clips (a series of multiple static images viewed in succession) can be sent for evaluation. Initially, most of the teleradiology systems involved middleman companies. A veterinary practitioner would digitize their images and electronically send them to one of these companies. In other cases, the practitioner would mail their hard copy radiographs directly to this middleman company, and the company would digitize the radiographs. Once the radiographs were in the digital format, the company would transmit the digitized images (with a request form) to a contracted veterinary radiologist. The veterinary radiologist would interpret the images and send a written radiology report back to the veterinarian, usually by way of the middleman company. This indirect route of primary interpretation was necessary because the software used to transmit the images and, in some cases, the file format of the images was proprietary. The contracted veterinary radiologists would be provided the software that allowed communication with the primary server. The result of this type of service is that often the practitioner had no say in determining who interpreted their images. Unfortunately, in some cases, the images were not even sent to a veterinary radiologist but to a doctor not certified in veterinary radiology. When the DICOM 3.0 standard became commonplace, veterinarians were free to send their images to anyone they chose. This more direct method of film interpretation often also allows a faster report turn around time and helps the practitioner develop a professional relationship with a veterinary radiologist of their choice. As in human medicine, one of the biggest advantages of teleradiology is that it allows remotely located (rural or small town) practitioners direct access to board-certified specialists.

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TABLE 1. Applications of Teleradiology in Veterinary Medicine

Primary interpretations
Images directly sent to radiologists
Images indirectly sent to radiologists
On-Call coverage
Second opinion consultations
Image storage and archival
Database banking

Many veterinary radiologists also have workstations outside of their office. By doing so, this allows more rapid interpretation of images compared with waiting for the radiologist to physically drive to the hospital or clinic. Also, one radiologist can cover multiple clinics allowing other radiologists time off.

Second opinion consultations commonly come from large hospitals that benefit from having all of their imaging studies reviewed by a board-certified veterinary radiologist. The advent and popularity of larger, multidiscipline referral centers accompanied and a shortage of veterinary radiologists means that many of these facilities do not have their own in-house radiologists. Teleradiology serves as an extension of their practice with direct communication to a veterinary radiologist for second opinions for all imaging modalities.

Today, some companies and even some referral institutions are providing image archival and back-up services for clients with digital systems. In most cases, these off-site back-up facilities store these images in a searchable, query and retrieve database, typically using the DICOM 3.0 standard.^{1,2} This serves as data protection if the on-site hard drive fails or if they do not have a large hard drive that can store images accumulated over years. A nominal fee is typically charged for this service, but it is generally considered cheap insurance for data protection. For more on digital image storage, see the article in this Supplement.³

Methods of Image Acquisition and Digitization

Any kind of medical image can be transmitted using teleradiology, although it must be in a digital format before transmission can occur. Most imaging modalities produce digital images directly—ultrasound, computed tomography, magnetic resonance, and nuclear medicine. Making digital radiographic images, using computed radiography (CR), and direct digital radiography (DR) is becoming more common in veterinary medicine. These radiographic images also can be sent electronically. Many practitioners will continue to make analog radiographs. These analog radiographs can be digitized for transmission to veterinary radiologists, but this topic is not included in this article. It is strongly recommended that if these images are to be transmitted to a PACS system, they must first be converted into a DICOM format. The DICOM 3 standard is important to teleradiology because

it offers a direct communication between the referring veterinarian and the radiologists reading station. Briefly, digital medical images can be converted to other file formats other than DICOM. Using non-DICOM file formats is not recommended for medicolegal reasons. For more information about DICOM, see the article in this Supplement.⁴

Once these images are converted to a digital format, they can then be sent electronically using a PACS, emailed, or downloaded from an ftp site. A more compressed (smaller file size) image will transmit faster but the image quality will be lower than the uncompressed image. A typical uncompressed 14×17 thoracic radiograph is approximately 12 megabytes, making standard email an impractical method for sending images. Compressing this image may make email transmission possible, but at the expense of image quality.⁵ It is best left to the referring veterinary clinician and the veterinary radiologist interpreting these images to determine what is diagnostically acceptable.

Historically, many manufacturers output images in proprietary file formats that only a workstation of the same brand could open. Fortunately, today, nearly all such modalities output images in the DICOM format, allowing these images to be sent to any radiologist (or other veterinarian, referral center, etc.) no matter what brand of imaging system is used to acquire the images. DICOM allows the veterinarian to choose the radiologist to whom they send their images, not the vendor that sold them the equipment. Images that are sent directly from DICOM ready systems can be fully manipulated (windowing, leveling, etc.) while these capabilities are very limited on digitized images acquired with a laser, CCD, or digital camera.

Image Compression and Film Quality

Because of the large file size of most medical images, some form of compression is typically required, even with broadband Internet connections. Without compression on a standard dial-up Internet connection it could take up to 60 min to transmit two radiographic images. Even with a broadband connection, it could take 5–10 min. A broadband Internet connection is highly recommended. If the images are compressed, however, the same set of films could be transmitted in seconds. Compression ratios of up to 10:1 are needed to experience a significant reduction in transmission time. There are several studies that have shown that compression ratios of up to 20:1 or even higher can be achieved without sacrificing image quality. At high compression ratios, image quality deteriorates and the subsequent image appears pixilated. Unfortunately, many vendors that market film scanners, CR, and DR systems recommend JPEG compression as this is a common format sent via the World Wide Web in email attachments. Typical JPEG compression works well with email because

there is a high degree of compression and subsequently irreversible loss of image data, which in turn may lead to a misdiagnosis. Once an image has been converted into a JPEG image, the radiologist loses nearly all ability to digitally alter the brightness, contrast, or windowing of the image. For this reason, JPEG compression and email images are NOT recommended.⁶ Wavelet compression allows significantly higher compression ratios without noticeable deterioration in image quality. Once the images are received by the radiologist's local area network they can be manually or automatically routed to a particular radiologist's workstation for interpretations. DICOM provides for vendor-independent compression of medical images. The type of image compression is a part of the DICOM tag information that is embedded within each image.

DICOM Image Transmission (DICOM Send)

A direct link or direct teleradiology allows the veterinarian to send their images directly to a veterinary radiologist of their choice without the aid of any middleman software (and the middleman fee to use the software). With this method, the veterinarian can develop a working relationship with a veterinary radiologist in whom they have confidence and at the same time save costs. The indirect teleradiology model, where the images are sent using software owned and managed by a middleman company and subsequently distributed to a radiologist they employ, is also common. The DICOM Send function allows for direct teleradiology, thus avoiding the middleman.

In order to use the DICOM image transmission, one's system must be able to support the DICOM Send function. Unfortunately, it is common for many vendors that claim to be DICOM compliant not to be DICOM Send compliant. The system must be able to allow you to edit and change the AE Title information, the port number, and the IP address to send your images to the veterinary radiologist's image server. The veterinary radiologist should be able to provide these three pieces of information (AE Title, port number, and IP address) that can then be entered into the sending computers software and the DICOM Send function should work. Conflicts can arise if firewalls are active (a specific port may need to be opened).

Another advantage of DICOM Send is that this functionality helps to avoid vendor lock-in. Vendor lock-in is a common marketing practice used to ensure that your business (and money) will stay with the company that sold the equipment. If you purchase a system that uses only proprietary software to acquire, store, or send images and the company only allows you to send those images to their radiologists for interpretation, you have been locked-in.⁷ DICOM standards allow for a universally accepted system of image storage and transmission that all radiologists and all vendors could read, import, or export. Both the Amer-

ican College of Radiology and the American College of Veterinary Radiology have taken steps to try and prevent vendor lock-in.⁸

Accuracy and Acceptance of Teleradiology

Initially, there were legitimate concerns that veterinary radiologists would not accept interpreting soft-copy images, such as those viewed on a monitor. It has become apparent that this concern was false and now most practicing veterinary radiologists are comfortable and often prefer reading images displayed electronically. The advantages of postprocessing image manipulation, speed, image storage, and management are apparent. The interpretation accuracy of hard copy vs. soft copy images has been questioned. With cross-sectional imaging (CT and MR), the ability to stack images and pan through a series of images has obvious advantages compared with searching individual images adjacent to each other on multiple hard-copy films arranged on view boxes. For this reason and the relatively low-resolution images that come from these modalities, the accuracy of viewing soft-copy images from these modalities has not been questioned.

The diagnostic accuracy of radiographic images is different. As stated earlier, radiographic images are large files with high-resolution demands. There are numerous studies that have been conducted that compare the accuracy of soft-vs. hard-copy radiographic images. When original hard-copy radiographs are digitized and represented in the soft-copy format, there is inevitably a loss of spatial resolution. However, in several studies, this loss of resolution did not significantly alter the diagnostic yield for detecting small pulmonary nodules, pneumothoraces, and fractures. It is interesting to note that in the same study, it was pointed out that the accuracy for detecting these subtle lesions was approximately 70% for both.² Apparently, it is not the method of viewing that affects the diagnostic accuracy, many lesions are missed on both soft-and hard-copy images.

Legal Issues of Teleradiology

Veterinary teleradiology faces some legal issues (Table 2). Even more so than in human medicine, many of these questions are unresolved. Many veterinary radiologists interpret digital images made in States other than the one in which they live. Many States' Veterinary Medical Practice Acts, but not all, address this subject. At present, only a handful of States specifically prohibit a nonlicensed consultant rendering advice to veterinarians in their state. Some States are mum on the issue.

A veterinarian radiologist that provides teleradiology services to out-of-state clients must ensure that their liability insurance extends coverage to all States in which they are doing business. If a lawsuit is filed, typically the State in

TABLE 2. Legal Issues of Teleradiology

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1. State veterinary licensure
 2. Liability insurance coverage
 3. Jurisdiction over malpractice suits
 4. Client–patient–veterinary relationship
 5. Turf issues among radiologists
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which the animal patient resides will have jurisdiction, and thus the veterinary radiologist may need out-of-state counsel.

In most States, the establishment of the client–patient–veterinarian relationship is a requirement for practicing veterinary medicine. With veterinary teleradiologists, establishing this relationship can be confusing. The radiologist in this case is working for the referring veterinarian, providing an opinion and interpretation. The teleradiologist is paid by the referring veterinarian for these services. In most if not all cases, this is no different from a veterinary radiologist interpreting films for a local veterinarian. A specific client–patient–veterinarian relationship is not obtained in this case either. Unfortunately, many of the medicolegal issues are not clear-cut and advice from an attorney is recommended.

Meeting the Goals of the Future

In general, the goal of any teleradiology practice is to provide high-quality patient care in an expeditious

manner. High-speed Internet and cautious file compression offer a means of transmitting large images quickly from place to place. Fast computer hardware with substantial random access memory is just as essential as broadband service. In some systems, the images are initially seen in a low-resolution setting and as time passes the remaining data packets are added to the images, resulting in high-resolution crisp images. In these systems, the veterinary radiologist can get a head start on their report instead of staring at a blank screen waiting for the images to arrive. As an added convenience, some interpretation software packages allow for web-based access whereby a radiologist can access and report on one of their cases from any computer, anywhere (assuming it has Internet access). Most, if not all, teleradiology software packages allow more than one image to be transmitted at one time. Perhaps the most critical stumbling block that may face the veterinary radiology practice is the lack of manpower. Never before has there been such a demand for qualified, experienced board-certified veterinary radiologists and the demand is growing.

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