# DIGITAL IMAGE STORAGE

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**Digital image archival requires less physical storage space, allows for rapid storage and retrieval and avoids loss in image quality over time or with image duplication compared with film storage. Because medical imaging data are critically important and, by law, must be stored in a safe, accessible manner, it is imperative not to have one computer error destroy all copies of the image data. Several options for image storage media are available including magnetic tape, optical media, spinning disks and solid state. Other considerations include on-site vs. off-site storage, redundancy, on-line vs. off-line storage, and removable storage media for disaster recovery. The different storage media can be used in different configurations to provide sufficient protection of digital data. Choose a storage system that will keep your data safe from unauthorized access, hardware failure, and clinic disasters.** *Veterinary Radiology & Ultrasound, Vol. 49, No. 1, Supp. 1, 2008, pp S37–S41.*

**Key words: backup archive, digital radiography, information storage and retrieval, veterinary.**

## Introduction

WHEN TRANSITIONING FROM hard copy film to digital imaging, radiology departments must switch from physical storage space to digital storage space. Fortunately digital image archival requires less physical storage space, allows for rapid storage and retrieval and avoids loss in image quality over time or with image duplication. Most digital storage systems are scaleable allowing for increased storage space based on need. Several options for image storage media are available including magnetic tape, optical media (CD, DVD, Blu-ray), spinning disks (hard drive, zip drive), and solid state (USB or flash cards). These image storage options are used within a larger hardware array creating mass storage systems such as on-site secure redundant storage, Network-Attached Storage, Storage Area Networks, and off-site image backups. Regardless of the storage system used, digital images should be stored in a nonproprietary format such as the Digital Imaging and Communications in Medicine (DICOM) standard. The American College of Veterinary Radiology supports and recommends DICOM as the digital imaging standard in veterinary medicine.[1] Storing images in a DICOM format will help guard against future problems with data transfer. For more information about DICOM, see the article in this Supplement.[2]

Because medical imaging data are critically important and, by law, must be stored in a safe, accessible manner, it is imperative not to have one computer error destroy all copies of the image data. The American Veterinary Medical Association (AVMA) states: "Veterinary medical records are an integral part of veterinary care. The records must comply with the standards established by state and federal law. And, veterinarians are obligated to provide copies or summaries of medical records when requested by the client."

Digital images are part of the medical record. To ensure that copies of these images exist even in the event of a computer failure, storage redundancy, or multiple copies of imaging data at unique locations, is utilized in medical image storage. Multiple copies of data at a single location is not adequate because a disaster or theft at that one area could result in loss of all data. An off-site backup must be present. In a redundant storage system if one storage element fails the redundant element allows the system to continue functioning and the failed element can be replaced without a loss of data or workflow. State laws usually govern the length of time medical records, and therefore, digital images must be retained.

Determining Picture Archival Communications System (PACS)[3] storage requirements can be a difficult task. Proper storage requirement must be based on optimization of cost and system performance. Choosing an easily scaleable storage system is important because it allows for expansion. Other considerations include on-site vs. off-site storage, redundancy, on-line vs. off-line storage, and removable storage media for disaster recovery. The different storage media can be used in different configurations to provide sufficient protection of digital data.

## Storage Media

Many different media are available for digital data storage. All storage media are adaptable to provide on-site or off-site, on-line or off-line, and redundant data storage

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doi: 10.1111/j.1740-8261.2007.00332.x

configurations. A veterinary hospital should set up a system with redundant storage capability that provides rapid data retrieval while minimizing risk of data loss. Media discussed are: magnetic tape, removable optical storage (CD/DVD/Blu-ray), magnetic media (zip and hard drives), and solid state media.

### *Magnetic Tape*

Magnetic tape can be used as a writable media device; however, rewritable magnetic tape can present a legal problem. Several types of tape backups are available with cost based on storage capacity. These systems can be integrated into a server or can be rack mounted for large installations. Magnetic tape has a large storage capacity, is easy to use, and typically has a lower cost than hard drives. However, magnetic tape storage has slow data recovery migration, at 15–30-s access per MB or 0.067 MB per second (MB/s) compared with CD or DVD technology, which usually starts at 36 MB/s.[4] Tape drives have seek time delay, or the time for the tape to load and spool to the desired location. Every data retrieval query will have an added 15 + s delay making a tape drive a poor choice for on-line data archive. Most magnetic tape systems allow data to be altered after the fact meaning the information can be discredited in court. The exception to this is the LTO Generation 3 Write Once Read Many (WORM) tape cartridges that can only be written to once. Because the tapes are magnetic, magnetic fields can damage the tape. In addition, heat can warp the tape and tape will degrade over time making periodic tape replacement essential. Tape storage is a more viable option for systems that can tolerate recovery downtimes of several hours and for companies that can afford a tape robot. A tape robot selects the appropriate tape, copies old tapes, and periodically replaces tapes. Free, open-source, and home built tape backup systems do not address many of these disadvantages.

### *CD/DVD*

Data backup on a writable media such as CDs or DVDs is an acceptable image storage method that is used primarily for disaster recovery purposes. DVDs are the logical choice because they hold about seven times more data than CDs. The benefits of a removable storage media backup (CD or DVD) are their mobility, low cost, and easy replication. Because CDs and DVDs are easy to replicate, a copy can be kept at the hospital and off-site in case of a disaster. In addition, CDs and DVDs are write-once media, so they cannot be altered and thereby stand up to scrutiny in court. When using a CD or DVD backup, someone must be responsible for maintaining and organizing the backup system. In many instances the responsibility for CD/DVD backup is neglected and only becomes an issue after a disaster has occurred.

### *Zip Drives and External Hard Drives*

Zip* drives can be used as recordable and removable storage methods. Zip drives come in 250, 500, and 750 GB sizes. They work like removable floppy disk drives but are sturdier than the older magnetic media. These drives are easy-to-use and inexpensive and have a large storage capacity. However, these disks may be more suitable for temporary storage than for permanent storage because of past problems with drive failures.[5] Compatibility issues may be present and currently Iomega provides limited support for Windows Vista† users.

External hard drives are a cost effective way to store data. A 500 GB external drive with a USB connection can be purchased for less than $150. Because most uncompressed digital radiographs are 10–20 MB this allows room for approximately 25,000–50,000 images. For most clinics this is more than adequate. External hard drives have several advantages including cost, ease of setup, use, and portability. An external hard drive can easily be moved from one clinic to another where the data can be transferred and then returned to the first clinic for future use. External hard drives do have disadvantages too. The PACS or viewing software may need to be reconfigured to save data to the external hard drive. This setup usually takes information technology (IT) assistance for those unfamiliar with mapping a drive. Second, and probably the most important concern, is ensuring that routine off-site backup of the hard drive occurs. This requires someone being in charge of taking the drive out of the clinic regularly and transferring the information to a safe off-site data source. Lastly, external hard drives have no redundancy so if the drive fails the data is lost. This last point brings us back to the importance of backing up the data, preferably at an off-site location.

### *Blu-Ray Disc*

One recordable storage system to consider in the near future is the Blu-ray Disc.‡ Currently, single-layer Blu-ray Discs holds about 25 GB of data. A dual-layer disk will hold 50 GB of data, and eight-layer disks are in development that will hold 200 GB of data. Compared with traditional DVDs, Blu-ray Discs will hold five–10 times more data than the current DVD technology.[6] Blu-ray systems cost between $500 and $1200; a recordable disk costs about 70 cents/GB, and a rewritable disk about $1/GB.[7]

*Iomega, San Diego, CA, http://www.iomega.com/na/landing.jsp

†Microsoft Corporation, Redmond, WA, http://www.microsoft.com/windows/products/windowsvista/default.mspx

‡Blu-ray Disc Association.

*Solid State*

Solid state media is storage media without moving internal parts. The most common form of solid state media is a USB jump drive. Although these drives are durable and useful for backing up small amounts of data, they are currently limited by data storage size and cost. Solid state storage media is currently cost prohibitive for the veterinary market. However, as the price decreases and the storage capacity increases, solid state storage media will likely become a dominant player in storage needs.

*Removable Storage Media for Disaster Recovery*

For hospitals that choose not to purchase a redundant storage system their staff must be vigilant about keeping a removable backup off-site for disaster recovery. Removable storage media options include CD/DVD, zip drives and external hard drive, Blu-ray discs, and solid state media such as USB drives.

## Data Storage Location and Accessibility

*On-Site vs. Off-Site Storage*

On-site data storage is located at the facility and allows for rapid data transfer because an intranet is faster than the internet. Off-site storage is located somewhere other than at the facility and helps protect against data loss. On-site and off-site storage utilize the same types of storage media and the decision on which medium to use is commonly based on cost, IT personnel preferences and facility needs. It is prudent to have simultaneous on-site and off-site storage.

The disadvantages of off-site storage are the ongoing costs, a requirement for internet access on at least one computer, and distribution of images cannot be instantaneously throughout the hospital. Some off-site storage companies offer online access to images allowing hospital wide image viewing.

*On-Line vs. Off-Line Storage*

On-line vs. off-line storage determines how rapidly data are accessed for viewing or retrieval. This differs from on-site and off-site storage (location of the data storage). Current technology limits the amount of data storage space making it necessary to transfer or remove some data from the system making space for new data. However, one never knows when the transferred data will be needed making long-term data storage a must.

Long-term data storage can be subdivided into on-line and off-line. On-line storage is rapidly accessible to the radiologist or requesting clinician. In contrast, off-line data storage refers to images that are stored in a less accessible archive and need to be restored to on-line status before being accessible.

## Storage Systems

*RAID Server*

By storing data on more than one disk, Redundant Array of Independent Disks (RAID) servers ensure that no data are lost if one disk in the array fails. If one disk fails, it can usually be exchanged without interrupting normal system operation or losing data. Well-built RAID servers typically have an audible alarm that alerts personnel if a disk fails. RAID servers have different configurations, and a RAID 5 server or higher is recommended because of high reliability and high performance. On-site image storage allows immediate image access and hospital wide image distribution, especially when partnered with a PACS. RAID systems cost $5000–20,000 and have ongoing maintenance costs, which include hiring IT personnel. On-site RAID servers do not protect images from disasters such as floods, fires, server theft, or building destruction.

Originally there were five RAID levels but more variations have evolved. The RAID 5, a good compromise between cost, capacity, and redundancy, is commonly used but may not be appropriate for all archive applications. A RAID 5 server has a minimum of three disks, with data split across more than one disk (striping) and distributed parity of the information over other disks thereby allowing one disk to fail without loss of data. However, if two disks fail information will likely be lost.

A RAID 6 configuration has a minimum of four disks with striping and dual-distributed parity providing fault tolerance from two disks without permanent data loss.

Nested RAID configurations refer to one RAID system using another RAID system as a storage element. In this case an entire RAID system replaces one of the discs. In a RAID 10, or RAID $1+0$, configuration mirrored set in a striped set that requires a minimum of four disks, or any even number configuration greater than two disks. Data loss occurs when a single pair of mirrored drives is lost.

In a RAID 50, or $5+0$, configuration the data is striped across distributed parity RAID systems. Instead of a standard RAID 5 configuration using individual disks the RAID 50 configuration uses multiple RAID 5 configurations to store data putting the data that has been striped with parity on multiple servers each with multiple disks.

*Direct-Attached Storage*

Direct-attached storage consists of separate cabinets that contain a RAID 5 or higher configuration. Only the number of slots available limits the storage capacity and the configuration used. The cabinet in the direct-attached storage configuration is the most expensive component. Theoretically, it is possible to create unlimited storage options in RAID 5, 6, 10, or 50 configurations for various degrees of backup. Data on a direct attached storage sys-

tem are always accessible, and backup can be continuous. In addition, these systems can be partnered with a storage software program. The cost of a direct attached storage and a network-attached storage are relatively the same. The big difference is that a direct attached storage system is attached to the on-site computer while the network-attached storage can be off-site, protecting your data in case of a clinic catastrophe. Therefore, direct attached storage systems can experience catastrophic failure with complete loss of stored data.

### *Network-Attached Storage*

Network-attached storage is dedicated data storage technology that connects directly to a computer network, providing centralized data access and storage potentially from an off-site location. Network-attached storage systems typically combine redundant storage features such as RAID 5 configurations with file sharing ability across the network while not limiting file transfer protocols. The type of file-sharing protocols used is one difference between network-attached storage and the storage area network, which typically uses proprietary protocols. However, unlike storage area networks, network-attached storage collocation is limited by a clinics Internet bandwidth constraints. In a storage area network system, these storage servers are mirrors of each other and contain the same data; if one server goes down, another server can take over. Network-attached storage has less flexibility with mirroring multiple storage servers. For a company that needs only one backup that everyone can use, a network-attached storage system is appropriate. However, for a company that requires multiple storage facilities to make sure data are available at all times, a storage area network system would be more appropriate. Network-attached storage is becoming popular in small businesses because of its low cost ($650–2000 for approximately 1–4 Terabytes of storage) and small space requirement and because it typically fits the data storage needs of these businesses.

## Storage Area Network

Storage area network systems work a lot like network-attached storage systems; however, they require their own network infrastructure. Storage area network configurations are expensive, designed for large data warehousing applications, and are not practical for a veterinary clinic. Multiple storage area network units can be added to a network and can be located off-site to ensure data safety in case of fires, floods, or other disasters in which only one part of the storage area network is affected. Also, these units can be set to back up each other without any human interaction, and these units provide minimal downtime if one site fails, provided the software is also collocated. Storage area networks allow you to manage all your storage centrally and to back up continuously. However, the setup and maintenance of these systems is expensive (tens of thousands of dollars), and storage area network capabilities may be excessive for most veterinary hospitals.

### *Off-Site Third-Party Backup*

Off-site backup involves contracting a third party to maintain a secure copy of your images. To transmit images offsite a fast internet connection or image compression is required. The necessary internet connection speed depends on how much data your business needs to move a day multiplied by 2, but the minimum requirement is 36 kB/s (kilobytes per second) excluding dial-up service as an option. The goal is to have all of your hospital's data backed up by the next business morning. The initial cost is less than on-site backups because you will not need to purchase an on-site server, hire IT personnel, or schedule regular CD or DVD backup. However, there will be a recurring service fee. Over several consecutive years of service, the service fee may add up to more than the cost of on-site storage. The advantages of off-site storage are ease-of-use, less initial cost and peace of mind knowing that somewhere your images are being stored securely. Also, off-site storage is relatively disaster proof, and some companies store data in a nonproprietary format for future image migration. Storing data in a nonproprietary format is important because many digital image companies use proprietary imaging formats within their hospital data system. So even though images may be acquired using a DICOM standard, they may be changed and stored by the hospital software into a proprietary format. This can lock a hospital into using one vendor's software. Thus, if hospitals send copies of the original DICOM images off-site for storage, this enables them to import those DICOM images into any veterinary hospital management software in the future.[8]

## Conclusion

Ideally, a hospital switching to digital imaging would have on-site and off-site storage. This solution would make data accessible across the entire network, allowing staff members access where and when they needed it and providing a secure off-site copy of the images. However, most hospitals must choose between the two. The most important point is that you choose a storage system that will keep your data safe from unauthorized access, hardware failure, and clinic disasters. For image backup and recovery in most veterinary hospitals, a high-quality RAID 5 server joined with an off-site backup service will more than suffice, but one should consult an IT professional before purchase.

Disclosure of Conflicts of Interest: The authors have declared no conflicts of interest.

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