

INTRODUCTION TO DICOM FOR THE PRACTICING VETERINARIAN

MATTHEW A. WRIGHT, DENNIS BALLANCE, IAN D. ROBERTSON, BRIAN POTEET

Digital Imaging and Communication in Medicine (DICOM) is a communication protocol that imaging devices use to communicate. The universal acceptance of the DICOM standard by the major medical vendors means that the digital transition in veterinary medicine should be relatively smooth provided DICOM is used. DICOM service objects, roles, service classes, and conformance standards are discussed. The authors strongly encourage the use of image acquisition software and image archive systems that support the DICOM standard. *Veterinary Radiology & Ultrasound, Vol. 49, No. 1, Supp. 1, 2008, pp S14–S18.*

Key words: radiology information systems, teleradiology, veterinary.

Introduction

IN THE EARLY 1980s, the use of medical digital image devices such as computed tomography (CT) and magnetic resonance imaging (MRI) increased dramatically. These new digital imaging modalities not only greatly enhanced the diagnostic capabilities of the medical profession but also necessitated the intercommunication of diverse imaging devices such as workstations, printers, and the image acquisition modalities themselves.

Interconnectivity between these devices was difficult because the vendors of medical imaging equipment at the time used proprietary communication methods. In other words, a CT from company X could not communicate with a workstation from company Y without developing expensive-customized software. This lack of a communication standard was a burden to the end user because purchasing one piece of equipment from a vendor essentially locked the user into the entire line of imaging products from that vendor.

Medical equipment users, represented by the American College of Radiology (ACR), and medical equipment vendors, represented by the National Electrical Manufacturers Association (NEMA), worked together to address this lack of interoperability. By 1993, the Digital Imaging and Communication in Medicine (DICOM) 3.0 standard was released, and since then many supplements have been released that address the new technological changes and

needs. DICOM 3.0 is now ubiquitous, respected, and acknowledged as a truly international standard by the International Organization for Standardization (ISO). In fact, there are no real alternatives.¹

The DICOM standard includes a communication protocol that allows devices manufactured by different vendors to communicate with each other, both by exchanging digital images so that they can be created, archived, viewed, or printed, and by exchanging other information such as patient demographics, exam scheduling, and exam reporting.² DICOM-conformant machines from two vendors can seamlessly communicate with each other, thus granting the user the option of purchasing a CT from one vendor, an ultrasound machine from another vendor, and a picture archiving and communication system (PACS) server from a third.

Conformance to the DICOM standard is entirely voluntary, and there is no official governing body that has the authority to enforce conformance. In fact, there is also no certification or testing authority to verify claims of conformance with the DICOM standard.¹ Rather, the DICOM standard is a cooperative standard. Connectivity works because vendors cooperate in testing via scheduled public demonstration, over the Internet, and during private test sessions.³

The DICOM Standards Committee is a standards organization administered by the NEMA Diagnostic Imaging and Therapy Systems Division. The organization is divided into a number of subgroups called working groups. These working groups have their own area of expertise such as MRI, CT, and dentistry. Currently, there are 26 different working groups. Working group—25 was recently formed to address needs specific to veterinary medicine. The primary objective of this working group is to define the necessary information fields used in veterinary medicine that will allow storage of information in DICOM files. These information fields include breed,

From the Veterinary Imaging Center of San Diego, San Diego, CA 92111 (Wright), the Veterinary Medical Teaching Hospital at the University of California, Davis, CA 95616 (Ballance), the Department of Molecular Biomedical Sciences, North Carolina State University, Raleigh, NC 27695 (Robertson), and Gulf Coast Veterinary Specialists, Houston, TX 77027 (Poteet).

Address correspondence and reprint requests to Matthew A. Wright, at the above address. Email: matt@animalinsides.com

doi: 10.1111/j.1740-8261.2007.00328.x

species, positioning, body parts, and owner (called responsible party).

Currently, many veterinarians have limited understanding of DICOM. This is because most DICOM introductory material has been written either for the engineer and is highly technical or for the hospital administrator and is rather superficial.⁴ The goal of this article is to provide veterinarians with an easy-to-understand introduction to the DICOM standard.

Any veterinarian using digital imaging modalities such as ultrasound, digital radiography, MRI, or CT needs to understand DICOM. Most veterinarians are familiar with analog (film) images, and analog images can be viewed anywhere there is a light source. It is the transition from analog images to digital images and the need to communicate, display, and store these images that has made DICOM necessary. It is easy to bundle printed CT and ultrasound images with traditional radiographs into an envelope and store the folder on a shelf or mail it to a colleague. However, to store the images of differing modalities electronically in a system that enables easy retrieval, viewing, and transmission of images to a remote destination requires a much higher level of technical infrastructure.

A cursory understanding of how a DICOM communication works is necessary to understand vendor marketing materials and DICOM conformance statements. An imaging device is described with three elements of DICOM information. These three elements are as follows:

- the DICOM service object(s) a particular device supports,
- the role the imaging device plays in the DICOM communication, and
- the service classes the device supports.

DICOM Service Objects

DICOM specifies the types of data that can be sent and the format of those data. In DICOM, the different types of imaging data such as computed radiography (CR), digital radiography, or ultrasound images are called DICOM objects. DICOM objects are also known as DICOM image object definitions.² Common DICOM objects in veterinary medicine include CR images, CT, and secondary capture (SC) images, such as those produced by a radiograph scanner.

DICOM Roles

A DICOM communication is based on an interplay between the participants in the communication. These participants are called DICOM service class users (SCU) and DICOM service class providers (SCP), and each



FIG. 1. Example of a digital radiography service class user and a picture archiving and communication system service class provider for the DX image storage service object pair. Images reprinted with permission from Eklin Medical Systems.

of these participants plays a specific role in a DICOM communication.

As an analogy, consider dialing to an internet service provider (ISP) for an internet access. The caller initiates the call from his computer, requesting the use of internet service from the ISP. The caller is the service user and the ISP is the service provider.²

As another example, a digital radiography unit sends an image to a PACS for archival. In this situation, the digital radiography machine is the SCU of the storage service provided by the SCP (PACS) device (Fig. 1).

It is important to understand that the role of user or provider can change and is based on the relationship for a specific transaction. For instance, when a viewing workstation queries the server for a list of studies, the workstation is the user—SCU and the server is the provider—SCP of that information. It should be noted that when transferring images, the images are sent from SCU to SCP. Therefore, if the workstation subsequently requests an image from the PACS server, the server will act as the service user—SCU and send the image to the workstation that is acting as the provider—SCP. This process is important to understand, as a firewall that sits between the PACS server and the workstation will have to allow connections to be initiated from one device to the another. For more details on firewalls, refer to the article in this supplement related to networking.⁵

DICOM Service Classes

DICOM specifies types of communications called DICOM service classes. Each service class performs a different function. Examples of DICOM service classes include store, print, and query/retrieve.

The concepts of DICOM services and objects are used within DICOM in terms of a service object pair (SOP). An SOP is a combination of a DICOM service (store images) and an object (e.g., an image). The SOP instance is a unique occurrence of a specific SOP class (Fig. 2).⁶

An SOP tells the user what service class the modality supports and what types of images (DICOM objects) it handles.² For example, the CT storage SOP represents the store command as it is used to exchange a CT image object.

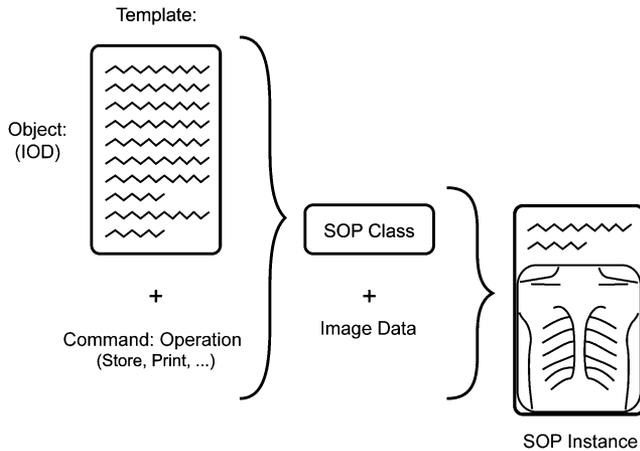


FIG. 2. Relationship between a Digital Imaging and Communication in Medicine image object and a service object pair. Reprinted with permission from OTECH Inc. www.otechimg.com.

Study, Series, and Image

Each patient can have one or more studies, each of which may consist of one or more series of images. A series may be a single image, such as a thoracic radiograph, or several images, as in a set of CT slices. Because each image, series, and study is unique, each is assigned a unique identifying number (UID) to identify it unambiguously. In fact, no two images anywhere in the world should have the same number. Each study is identified by a Study Instance UID, each series by a Series Instance UID, and each image by an SOP Instance UID. Technically, a UID will appear as a long string of numbers such as 1.2.840.1008.5.1...1.4321. The first several sets of digits, or the root of the number, are assigned to an organization or a vendor and can be used to determine whose equipment generated the image.

Important DICOM Service Classes for Veterinary Medicine

The DICOM standard addresses many aspects of image communication. As stated previously, the standard is composed of many different DICOM services, each performing a unique function. Most veterinary practices and veterinary imaging devices will neither need nor use all of the DICOM services. Therefore, the DICOM requirements will vary with the needs of individual practice and the type of imaging device. Additionally, many DICOM services are not yet supported by the vendors of veterinary digital imaging devices and PACS.

Determining what DICOM functionality is needed is an essential part of purchasing imaging equipment. The following is an introduction to the major DICOM service classes as they apply to veterinary medicine.

DICOM Storage Service Class

This is an essential service for all image-acquiring devices. The DICOM storage service class allows the imaging device to send images to a DICOM server for storage.

DICOM Query/Retrieve Service Class

One must be able to search (query) an image server and retrieve images for review or have them sent elsewhere. DICOM does not specify how the database is structured, but it does specify how to ask the database for a list of patients and studies and how to initiate the transfer of these images to a remote device. Servers that do not support the DICOM query/retrieve service class can only be accessed by proprietary software that can complicate communication with the server by other software products made by other vendors.

DICOM Modality Worklist

The DICOM modality worklist service class is designed to maximize the efficiency of a digital radiography installation. It allows a DICOM device to communicate with the hospital information system (HIS) or radiology information system and automates the entry of patient demographic information into an image acquisition device. Users of an acquisition device that supports a DICOM modality worklist are presented with a list (worklist) of studies that need to be performed that day, instead of being required to manually enter the demographic data, which is a laborious and error-prone task. Indeed, repeated manual entry of this type of data is reported to have an error rate of 15–20%.^{*} Failure to accurately enter patient demographic data results in lost studies and requires a PACS administrator to continuously monitor the database to identify and correct errors.

As of this writing, few veterinary hospital information systems have the ability to generate the order data necessary to populate a modality worklist, so the DICOM modality worklist is rarely used. Nonetheless, it is expected that user demand for integration between the modalities and the HIS will soon elevate the importance of the DICOM modality worklist in veterinary medicine. In fact, a veterinary healthcare integration committee (or Integrating the Veterinary Healthcare Enterprise, IVHE) was recently launched,⁷ with the goal of standardizing methods of communication between the HIS and digital imaging modalities.

^{*}Wright, MA. Error rate of data entry in a digital radiography installation. Unpublished data. 2005.

DICOM Print

Many veterinary hospitals use laser printers to print film copies of their images. The DICOM print service class enables the use of printers from different vendors and provides a method of accurately printing images so that they appear similar to how they appear on the monitor.

DICOM Grayscale Display Function (GSDF)

With analog radiography, the appearance of the image on film is static and cannot be altered once the film is developed. The only factors that affect the appearance of the image or perception of a film image after processing are the luminance of the view box and the ambient light used to view the image. With digital radiography, there are many variables that affect the appearance of an image, primarily monitor luminance, monitor size, and display resolution. Importantly, image manipulation (contrast, brightness, magnification, and postprocessing filters) can dramatically change the appearance of an image. Furthermore, image quality on an electronic display degrades over time. Monitors that are miscalibrated or aging can potentially result in misdiagnosis.

The key to establishing and maintaining optimal soft copy quality (displayed image on a monitor) is to calibrate the monitor at regular intervals.⁶ Medical display device vendors should provide the tools necessary to calibrate a monitor according to specific DICOM standards (DICOM—GSDF curve). Part 14 of the DICOM standard describes a GSDF curve that is used to calibrate display monitors.

The quality of monitors with respect to viewing medical images is a subject of controversy, particularly among hospital administrators, as the optimal medical-grade monochrome monitors are expensive. A common preference among radiologists is to use a properly calibrated medical-grade monochrome monitor (3 MP or higher). For additional information about monitors, see the article in this supplement.⁸

Because support for the different parts of DICOM will vary between vendors and imaging devices, the terms DICOM compliant or DICOM 3.0 (which frequently appear in vendor marketing materials) are essentially meaningless. It is more accurate to identify what service classes are supported by a given imaging modality.¹ This critical information can be found in the DICOM conformance statement.

DICOM Conformance Statements

The DICOM standard is extensive and no single device or server implements the entire standard. Therefore, a document is required to accompany each DICOM implementation that specifies what parts of the standard are supported.⁴

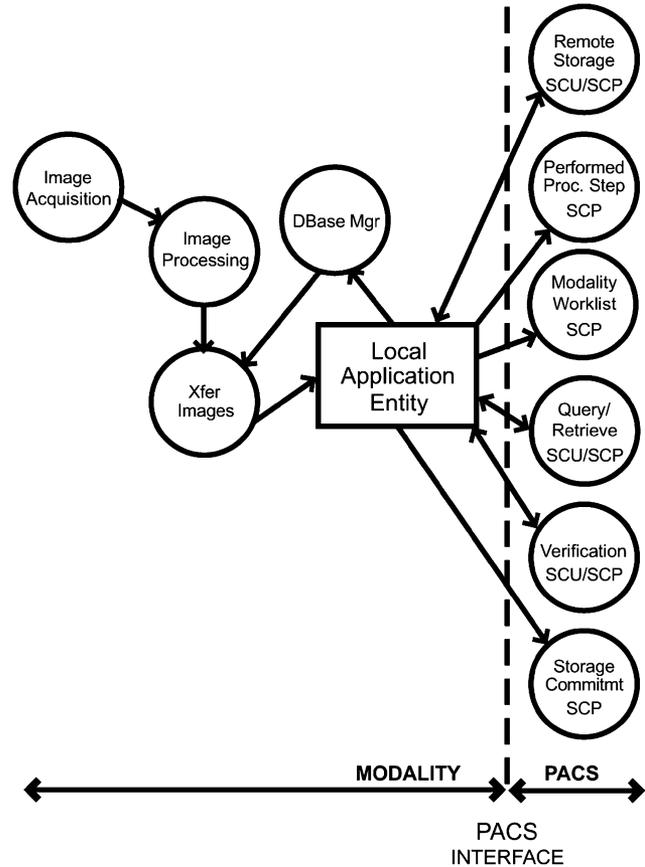


FIG. 3. Bubble diagram from a Digital Imaging and Communication in Medicine (DICOM) conformance statement. Reprinted with permission from OTECH Inc. www.otechimg.com. All DICOM conformance statements have a bubble diagram that describes the functional relationship between the imaging device and the various DICOM services.

To facilitate comparisons, DICOM conformance statements have a standard structure that is described in Part 2 of the DICOM standard. Conformance statements can be obtained directly from the vendor and are often made available on the vendor’s website.¹ In the author’s opinion, any vendor claiming DICOM conformance must provide a DICOM conformance statement to users. Without such a document, claims of DICOM conformance cannot be verified if a problem with connectivity arises (Fig. 3).

A full discussion of DICOM conformance statements and how to evaluate one to assess interoperability between devices is outside the scope of this paper. Nonetheless, the reader should be aware of the existence of such documentation and, if necessary, should consider engaging a professional consultant to help assess vendor claims of DICOM conformance before purchasing imaging devices that will be used in a networked environment.

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

REFERENCES

1. Dreyer KJ, Mehta A, Thrall JH (eds). PACS: A guide to the digital revolution. New York: Springer-Verlag, 2002.
2. A practical guide to DICOM. Toshiba Medical Systems. 2001. <http://www.auntminnie.com/index.asp?Sec=ref&sub=wh&pag=dis&ItemId=51662> (accessed October 16, 2007).
3. DICOM strategic document, version 7.2. DICOM NEMA. 2007. <http://medical.nema.org/dicom/geninfo/Strategy.pdf> (accessed October 16, 2007).
4. Horii SC. A nontechnical introduction to DICOM, Radiological Society of North America Inc. 1997. <http://medical.nema.org/dicom/geninfo/Strategy.pdf> (accessed October 16, 2007).
5. Ballance D. The network and its role in DICOM imaging. *Vet Radiol Ultrasound* 2008;49: S29-S32.
6. Oosterwijk H. DICOM basics, 2nd ed. OTech Inc., 2002.
7. Wright MA. Integrating the veterinary health care enterprise. 2005. http://www.animalinsides.com/ivhe_site/introduction.htm (accessed October 16, 2007).
8. Puchalski SM. Image display. *Vet Radiol Ultrasound* 2008;49: S9-S13.