The American College of Radiology, with more than 30,000 members, is the principal organization of radiologists, radiation oncologists, and clinical medical physicists in the United States. The College is a nonprofit professional society whose primary purposes are to advance the science of radiology, improve radiologic services to the patient, study the socioeconomic aspects of the practice of radiology, and encourage continuing education for radiologists, radiation oncologists, medical physicists, and persons practicing in allied professional fields.

The American College of Radiology will periodically define new standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Commission on Standards and Accreditation as well as the ACR Board of Chancellors, the ACR Council Steering Committee, and the ACR Council. The standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document.

The standards of the American College of Radiology (ACR) are not rules, but are guidelines that attempt to define principles of practice that should generally produce high-quality radiologic care. The physician and medical physicist may modify an existing standard as determined by the individual patient and available resources. Adherence to ACR standards will not assure a successful outcome in every situation. The standards should not be deemed inclusive of all proper methods of care or exclusive of other methods of care reasonably directed to obtaining the same results. The standards are not intended to establish a legal standard of care or conduct, and deviation from a standard does not, in and of itself, indicate or imply that such medical practice is below an acceptable level of care. The ultimate judgment regarding the propriety of any specific procedure or course of conduct must be made by the physician and medical physicist in light of all circumstances presented by the individual situation.

1994 (Res. 21)
Revised 1996 (Res. 26)
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ACR STANDARD FOR TELERADIOLOGY

I. INTRODUCTION AND DEFINITION

Teleradiology is the electronic transmission of radiologic images from one location to another for the purposes of interpretation and/or consultation. Teleradiology may allow more timely interpretation of radiologic images and give greater access to secondary consultations and to improved continuing education. Users in different locations may simultaneously view images. Appropriately utilized, teleradiology may improve access to radiologic interpretations and thus significantly improve patient care.

Teleradiology is not appropriate if the available teleradiology system does not provide images of sufficient quality to perform the indicated task. When a teleradiology system is used to render the official interpretation,[1] there should not be a clinically significant loss of data from image acquisition through transmission to final image display. For transmission of images for display use only, the image quality should be sufficient to satisfy the needs of the clinical circumstance.

This standard defines goals, qualifications of personnel, equipment guidelines, licensing, credentialing, liability, communication, quality control, and quality improvement for teleradiology. While not all-inclusive, the standard should serve as a model for all physicians and health care workers who utilize teleradiology. A glossary of commonly used terminology (Appendix A) and a reference list are included.

II. GOALS

Teleradiology is an evolving technology. New goals will continue to emerge.

The current goals of teleradiology include:

A. Providing consultative and interpretative radiologic services.

[1] The ACR Medical Legal Committee defines official interpretation as that written report (and any supplements or amendments thereto) that attach to the patient's permanent record. In health care facilities with a privilege delineation system, such a written report is prepared only by a qualified physician who has been granted specific delineated clinical privileges for that purpose by the facility's governing body upon the recommendation of the medical staff.

B. Making radiologic consultations available in medical facilities without on-site radiologic support.

C. Providing timely availability of radiologic images and image interpretation in emergent and nonemergent clinical care areas.

D. Facilitating radiologic interpretations in on-call situations.

E. Providing subspecialty radiologic support as needed.

F. Enhancing educational opportunities for practicing radiologists.

G. Promoting efficiency and quality improvement.

H. Providing interpreted images to referring providers.

I. Supporting telemedicine.

J. Providing supervision of off-site imaging studies.

III. QUALIFICATIONS OF PERSONNEL

The radiologic examination at the transmitting site must be performed by qualified personnel trained in the examination to be performed. In all cases this means a licensed and/or registered radiologic technologist, radiation therapist, nuclear medicine technologist, or sonographer. This technologist must be under the supervision of a qualified licensed physician.

It is desirable to have a Qualified Medical Physicist and/or image management specialist on site or as consultants.

A. Physician

The official interpretation of images must be done by a physician who has:

1. An understanding of the basic technology of teleradiology, its strengths and weaknesses (as well as limitations), and who is knowledgeable in the use of the teleradiology equipment.
2. Demonstrated qualifications as delineated in the appropriate American College of Radiology (ACR) standard for the particular diagnostic modality being transmitted through teleradiology.

B. Radiologic Technologist, Radiation Therapist, Nuclear Medicine Technologist, or Sonographer

The technologist, therapist, or sonographer should be:

1. Certified by the appropriate registry and/or possess unrestricted state licensure.
2. Trained to properly operate and supervise the teleradiology system.

C. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently in one or more of the subfields in medical physics. The ACR considers that certification and continuing education in the appropriate subfield(s) demonstrate that an individual is competent to practice one or more of the subfields in medical physics and to be a Qualified Medical Physicist. The ACR recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR).

The appropriate subfields of medical physics are: Therapeutic Radiological Physics, Diagnostic Radiological Physics, Medical Nuclear Physics, and Radiological Physics.

The continuing education of a Qualified Medical Physicist should be in accordance with the ACR Standard for Continuing Medical Education (Res. 17, 1996).

D. Image Management Specialist

1. The image management specialist is an individual who is qualified to assess and provide problem-solving input, initiate repair, and coordinate system-wide maintenance programs to assure sustainable high-image quality and system function. This individual would also be directly involved with any system expansion programs.
2. This specialist should be available in a timely manner in case of malfunction to facilitate return to optimal system functionality.

IV. EQUIPMENT SPECIFICATIONS

Specifications for equipment used in teleradiology will vary depending on the individual facility's needs but in all cases should provide image quality and availability appropriate to the clinical need.

Compliance with the ACR/NEMA (National Electrical Manufacturers Association) Digital Imaging and Communication in Medicine (DICOM) Standard is strongly recommended for all new equipment acquisitions, and consideration of periodic upgrades incorporating the expanding features of that standard should be part of the continuing quality-improvement program.

Equipment guidelines cover two basic categories of teleradiology when used for rendering the official interpretation: small matrix size (e.g., computed tomography [CT], magnetic resonance imaging [MRI], ultrasound, nuclear medicine, digital fluorography, and digital angiography) and large matrix size (e.g., digital radiography and digitized radiographic films).

Small matrix: The data set should provide a minimum of 512 x 512 matrix size at a minimum 8-bit pixel depth for processing or manipulation with no loss of matrix size or bit depth at display.

Large matrix: The data set should allow a minimum of 2.5 lp/mm spatial resolution at a minimum 10-bit pixel depth.

A. Acquisition or Digitization

Initial image acquisition should be performed in accordance with the appropriate ACR modality or examination standard.

1. Direct image capture

   The entire image data set produced by the digital modality both in terms of image matrix size and pixel bit depth should be transferred to the teleradiology system. It is recommended that the DICOM standard be used.

2. Secondary image capture

   a. Small matrix images. Each individual image should be digitized to a matrix size as large or larger than that of the original image by the imaging modality. The images should be digitized to a minimum of 8 bits pixel depth. Film digitization or video frame grab systems conforming to the above specifications are acceptable.
   b. Large matrix images. These images should be digitized to a matrix size corresponding to 2.5 lp/mm or greater, measured in the original detector plane. These images should be digitized to a minimum of 10 bits pixel depth.

3. General requirements

   At the time of acquisition (small or large matrix), the system must include:

   Annotation capabilities including patient name, identification number, date and time of examination, name of facility or institution of acquisition, type of examination, patient or anatomic part orientation (e.g., right, left, superior, inferior), and amount and method of data compression. The capability to record a brief patient history is desirable.

B. Compression

Data compression may be used to increase transmission speed and reduce storage requirements. Several methods, including both reversible and irreversible techniques, may be used, under the direction of a qualified physician, with no reduction in clinically significant diagnostic image quality. The types and ratios of compression used for different imaging studies transmitted and stored by the system should be selected and periodically reviewed by the responsible physician to ensure appropriate clinical image quality.

C. Transmission

The type and specifications of the transmission devices used will be dictated by the environment of the studies to be transmitted. In all cases, for official interpretation, the digital data received at the receiving end of any transmission must have no loss of clinically significant information. The transmission system shall have adequate error-checking capability.

D. Display Capabilities

Display workstations used for official interpretation and employed for small matrix and large matrix systems should provide the following characteristics:

1. Luminance of the gray-scale monitors should be at least 50 foot-lamberts.
2. Lighting in the reading room should be controlled to eliminate reflections in the monitor and to lower the ambient lighting level as much as is feasible.
3. Capability for selecting image sequence.
4. Capability of accurately associating the patient and study demographic characterizations with the study images.
5. Capability of window and level adjustment, if those data are available.
6. Capability of pan and zoom functions.
7. Capability of rotating or flipping the images provided correct labeling of patient orientation is preserved.
8. Capability of calculating and displaying accurate linear measurements and pixel value determinations in appropriate values for the modality (e.g., Hounsfield units for CT images), if those data are available.
9. Capability of displaying prior image compression ratio, processing, or cropping.
10. Should have the following elements of display available:
    a. Matrix size.
    b. Bit depth.
    c. Total number of images acquired in the study.
    d. Clinically relevant technical parameters.

When the display systems are not used for the official interpretation, they need not meet all the characteristics listed above.

E. Archiving and Retrieval

If electronic archiving is to be employed, the guidelines listed below should be followed:

1. Teleradiology systems should provide storage capacity sufficient to comply with all facility, state, and federal regulations regarding medical record retention. Images stored at either site should meet the jurisdictional requirements of the transmitting site. Images interpreted off-site need not be stored at the receiving facility, provided they are stored at the transmitting site.

However, if the images are retained at the receiving site, the retention period of that jurisdiction must be met as well. The policy on record retention must be in writing.

2. Each examination data file must have an accurate corresponding patient and examination database record, which includes patient name, identification number, examination date, type of examination, and facility at which examination was performed. It is desirable that space be available for a brief clinical history.
3. Prior examinations should be retrievable from archives in a time frame appropriate to the clinical needs of the facility and medical staff.
4. Each facility should have policies and procedures for archiving and storage of digital image data equivalent to the policies for protection of hard-copy storage media to preserve imaging records.

F. Security

Teleradiology systems should provide network and software security protocols to protect the confidentiality of patients' identification and imaging data consistent with federal and state legal requirements. There should be measures to safeguard the data and to ensure data integrity against intentional or unintentional corruption of the data.

G. Reliability and Redundancy

Quality patient care may depend on timely availability of the image interpretation. Written policies and procedures should be in place to ensure continuity of teleradiology services at a level consistent with those for hard-copy imaging studies and medical records within a facility or institution. This should include internal redundancy systems, backup telecommunication links, and a disaster plan.

V. LICENSING, CREDENTIALING, AND LIABILITY

Physicians who provide the official interpretation of images transmitted by teleradiology should maintain licensure as may be required for provision of radiologic service at both the transmitting and receiving sites. When providing the official interpretation of images from a hospital, the physician should be credentialed and obtain appropriate privileges at that institution. These physicians should consult with their professional liability carrier to ensure coverage in both the sending and receiving sites (state or jurisdiction).

The physician performing the official interpretations is responsible for the quality of the images being reviewed.[2]

[2] The ACR Rules of Ethics state: "it is proper for a diagnostic radiologist to provide a consultative opinion on radiographs and other images regardless of their origin. A diagnostic radiologist should regularly interpret radiographs and other images only when the radiologist reasonably participates in the quality of medical imaging, utilization review, and matters of policy which affect the quality of patient care."

Images stored at either site should meet the jurisdictional requirements of the transmitting site. Images interpreted off-site need not be stored at the receiving facility, provided they are stored at the transmitting site. However, if images are retained at the receiving site, the retention period of that jurisdiction must be met as well. The policy on record retention should be in writing.

The physicians who are involved in practicing teleradiology will conduct their practice in a manner consistent with the bylaws, rules, and regulations for patient care at the transmitting site.

VI. DOCUMENTATION

Communication is a critical component of teleradiology. Physicians interpreting teleradiology examinations should render reports in accordance with the ACR Standard for Communication: Diagnostic Radiology.

VII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education Concerns appearing elsewhere in the ACR Standards Book.

Any facility using a teleradiology system must have documented policies and procedures for monitoring and evaluating the effective management, safety, and proper performance of acquisition, digitization, compression, transmission, archiving, and retrieval functions of the system. The quality-control program should be designed to maximize the quality and accessibility of diagnostic information.

A test image, such as the SMPTE test pattern,[3] should be captured, transmitted, archived, retrieved, and displayed at appropriate intervals, but at least monthly, to test the overall operation of the system under conditions that simulate the normal operation of the system. As a spatial resolution test, at least 512 x 512 resolution should be confirmed for small-matrix official interpretation, and 2.5 lp/mm resolutions for large-matrix official interpretation.

As a test of the display, SMPTE pattern data files sized to occupy the full area used to display images on the monitor should be displayed. The overall SMPTE image appearance should be inspected to assure the absence of gross artifacts (e.g., blurring or bleeding of bright display areas into dark areas or aliasing of spatial resolution patterns). Display monitors used for primary interpretation should be tested at least monthly. As a dynamic range test, both the 5% and the 95% areas should be seen as distinct from the respective adjacent 0% and 100% areas.

[3] SMPTE test pattern RP 133-1991. Grey JF, Lisk KG, Haddick DH, et al. Test pattern for video displays and hard copy cameras. Radiology 1985; 154:519-527.

The use of teleradiology does not reduce the responsibilities for the management and supervision of radiologic medicine.

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REFERENCES

1. Ackerman LV, Gitlin JN. ACR-NEMA digital imaging communication standard: demonstration at RSNA 1992 InfoRAD. Radiology 1992; 185:394.
2. Ackerman SJ, Gitlin JN, Gayler RW, et al. Receiver operating characteristic analysis of fracture and pneumonia detection: comparison of laser-digitized workstation images and conventional analog radiographs. Radiology 1993; 186:263-268.
3. Averch TD, O'Sullivan D, Breitenbach C, et al. Digital radiographic imaging transfer: comparison with plain radiographs. J Endouro 1997; 11:99-101.
4. Barnes GT, Morin RL, Staab EV. InfoRAD: computers for clinical practice and education in radiology. Teleradiology: fundamental considerations and clinical applications. RadioGraphics 1993; 13:673-681.
5. Batnitzky S, Rosenthal SJ, Siegel EL, et al. Teleradiology: an assessment. Radiology 1990; 177:11-17.
6. Baur HJ, Engelmann U, Saurbier F, et al. How to deal with security issues in teleradiology. Comput Methods Programs Biomed 1997; 53:1-8.
7. Berger SB, Cepelewicz BB. Medical-legal issues in teleradiology. Am J Roentgenol 1996; 166:505-510.
8. Bidgood WD, Horii SC. Introduction to the ACR-NEMA DICOM standard. RadioGraphics 1992; 12:345-355.
9. Bidgood WD, Horii SC. Modular extension of the ACR-NEMA DICOM standard to support new diagnostic imaging modalities and services. J Digital Imaging 1996; 9:67-77.
10. Blaine GJ, Cox JR, Jost RG. Networks for electronic radiology. Radiol Clin North Am 1996; 34:505-524.
11. Bolle SR, Sund T, Stormer J. Receiver operating characteristic study of image preprocessing for teleradiology and digital workstations. J Digit Imaging 1997; 10:152-157.
12. Braunschweig R, Klose HJ, Neugebauer E, et al. Digital radiography. Results of a survey (part A) and a consensus conference (part B). Eur Radiol 1997; 3:S94-S101.
13. Brenner RJ, Westenberg L. Film management and custody: current and future medicolegal issues. AM J Roentgenol 1996; 167:1371-1375.
14. Brody WR, Johnston GS. Computer applications to assist radiology, SCAR 1992. 11th Symposium for Computer Applications in Radiology.
15. Busch HP. Digital radiography for clinical applications. Eur Radiol 1997; 7:66-72.
16. Cawthon MA, Goeringer F, Telepak RJ, et al. Preliminary assessment of computed tomography and satellite teleradiology from Operation Desert Storm. Invest Radiol 1991; 26:854-857.
17. Deibel SR, Greenes RA. Radiology systems architecture. Radiol Clin North Am 1996; 34:681-696.
18. De Simone DN, Kundel HL, Arenson RL, et al. Effect of a digital imaging network on physician behavior in an intensive care unit. Radiology 1988; 169:41-44.
19. Dwyer SJ III. Imaging system architectures for picture archiving and communication systems. Radiol Clin North Am 1996; 34:495-503.
20. Dwyer SJ III, Templeton AW, Batnitzky S. Teleradiology: costs of hardware and communications. Am J Roentgenol 1991; 156:1279-1282.
21. Franken EA Jr, Berbaum KS. Subspecialty radiology consultation by interactive telemedicine. J Telemed Telecare 1996; 2:35-41.
22. Franken EA Jr, Berbaum KS, Smith WL, et al. Teleradiology for rural hospitals: analysis of a field study. J Telemed Telecare 1995; 1:202-208.
23. Franken EA Jr, Harkens KL, Berbaum KS. Teleradiology consultation for a rural hospital: patterns of use. Acad Radiol 1997; 4:492-496.
24. Gitlin JN. Teleradiology. Radiol Clin North Am 1986; 24:55-68.
25. Goldberg MA, Rosenthal DI, Chew FS, et al. New high-resolution teleradiology system: prospective study of diagnostic accuracy in 685 transmitted clinical cases. Radiology 1993; 186:429-434.
26. Goldberg MA. Teleradiology and telemedicine. Radiol Clin North Am 1996; 34:647-665.
27. Gray JE. Use of the SMPTE test pattern in picture archiving and communication systems. J Digital Imaging 1992; 5:54-58.
28. Hassol A, Gaumer G, Irvin C, et al. Rural telemedicine data/image transfer methods and purposes of interactive video sessions. J Am Med Inform Assoc 1997; 4:36-37.
29. Horii SC. Image acquisition: sites, technologies, and approaches. Radiol Clin North Am 1996; 34:469-494.
30. Kamp GH. Medical-legal issues in teleradiology: a commentary. Am J Roentgenol 1996; 166:511-512.
31. Kehler M, Bengtsson PO, Freitag M, et al. Teleradiology by two different concepts. Technical note. Acta Radiol 1997; 38:338-339.
32. Kelsey CA. A guide to teleradiology systems. Reston, Va: American College of Radiology, 1993.
33. Langlotz CP, Seshadri S. Technology assessment methods for radiology systems. Radiol Clin North Am 1996; 34:667-679.
34. Lou SL, Huang HK, Arenson RL. Workstation design. Image manipulation, image set handling, and display issues. Radiol Clin North Am 1996; 34:525-544.
35. Maldjian JA, Liu WC, Hirschorn D, et al. Wavelet transform-based image compression for transmission of MR data. Am J Roentgenol 1997; 169:23-26.
36. Martel J, Jimenez MD, Martin-Santos FJ, et al. Accuracy of teleradiology in skeletal disorders: solitary bone lesions and fractures. J Telemed Telecare 1995; 1:13-18.

37. Pierce JR. An introduction to information theory; symbols, signals, and noise. New York, NY: Dover Publications, 1980.
38. Prokop M, Schaefer-Prokop CM. Digital image processing. Eur Radiol 1997; 7:73-82.
39. Rose A. Vision, human and electronic. New York, NY: Plenum Press, 1973.
40. Sargent TA, Kay MG, Sargent RG. A methodology for optimally designing console panels for use by a single operator. Hum Factors 1997; 39:389-409.
41. Stewart. Clinical utilization of grayscale workstations. IEEE Eng Med Biol 1993:86-102.
42. Stormer J, Bolle SR, Sund T, et al. ROC-study of a teleradiology workstation versus film readings. Acta Radiol 1997; 38:176-180.
43. Templeton AW, Dwyer SJ, Rosenthal SJ, et al. A dial-up digital teleradiology system: technical considerations and clinical experience. Am J Roentgenol 1991; 157:1331-1336.
44. Wang J, Langer S. A brief review of human perception factors in digital displays for picture archiving and communications systems. J Digital Imaging 1997; 10:158-168.
45. Whelan LJ. Teleradiology legal issues. J Digital Imaging 1997; 10 (Suppl 1):17-18.
46. Yamamoto LG, Ash KM, Boychuk RB, et al. Personal computer teleradiology interhospital image transmission of neonatal radiographs to facilitate tertiary neonatology telephone consultation and patient transfer. J Perinatol 1996; 16:292-298.
47. Yoo SK, Kim SH, Kim NH, et al. Design of an emergency teleradiology system based on progressive transmission. Yonsei Med J 1995; 36:426-437.

APPENDIX A

Glossary

Analog signal - a form of information transmission in which the signal varies in a continuous manner and is not limited to discrete steps.

Archive - a repository for digital medical images in a picture archiving and communications system (PACS), typically with a specific purpose of providing either short-term or long-term (permanent) storage of images. Erasable or nonerasable media may be utilized in an archive.

Baud - the number of events processed in 1 second, usually expressed in bits per second (bps) or kilobits per second (kbps). Typical rates are 14.4 kbps, 28.8 kbps, and 56 kbps.

Bit (binary digit) - the smallest unit of digital information.

Bit depth - the number of bits used to encode the signal intensity of each pixel of the image.

Bits per second - see throughput, baud.

Byte - a grouping of 8 bits used to represent a character or value.

Carrier - see data carrier

CCD (charge-coupled device) - a photoelectric device that converts light into electronic information. CCDs are commonly used in television cameras and image scanners and consist of an array of sensors that collect and store light as a buildup of electrical charge. The resulting electrical signal can be converted into digital values and processed digitally in a computer to form an image.

CCD scanner - a device that uses a CCD sensor to convert film images into electronic data.

Clock - a component in a computer's processor that supplies an oscillating signal used for timing command execution and information handling.

Clock speed - the rate at which the clock oscillates or cycles. Clock speed is expressed in MHz, equal to 1 million clock ticks per second.

Compression ratio - the ratio of the number of bits in an original image to that in a compressed version of that image. For example, a compression ratio of 2:1 would correspond to a compressed image with one-half the number of bits of the original.

Consultation system - a teleradiology system used to determine the completeness of examinations, to discuss findings with other physicians, or for other applications, with the knowledge that the original images will serve as the basis for the final official interpretation rendered at some later time by the physician responsible for that report.

Co-processor - a device in a computer to which specialized processing operations are delegated such as mathematical computation or video display. The advantage of a co-processor is that it significantly increases processing speed.

CPU (central processing unit) - the device in a computer that performs the calculations. It executes instructions (the program) and performs operations on data.

CR (computed radiography) - a system that uses a storage phosphor plate contained in a cassette instead of a film-screen cassette. A laser beam scans the exposed plate to produce the digital data that is then converted into an image.

CRT (cathode ray tube) - refers to the monitor or display device in the teleradiology system.

Data carrier - the signal that is used to transmit the data. If this signal is not present, there can be no data communication between modems.

Data communication - all forms of computer information exchange. Data communication may take place between two computers in the same building via a local area network (LAN) or elsewhere by wide-area network (WAN).

Data compression - methods to reduce the data volume by encoding it in a more efficient manner, thus reducing the image processing and transmission times and storage space required. These methods may be reversible or irreversible.

Data transfer rate - the speed at which information is transferred between devices, such as a scanner and a computer; between components within a device, such as between storage and memory in a computer; or between teleradiology stations.

Dedicated lines - a telephone line that is reserved for the exclusive use of one customer. It can be used 24 hours a day and usually offers better quality than a standard dial-up telephone line but may not significantly increase the performance of data communication.

DICOM (digital imaging and communication in medicine) - a standard for interconnection of medical digital imaging devices, developed by the ACR-NEMA committee sponsored by the American College of Radiology and the National Electrical Manufacturers Association, consisting of a standard image format and a standard communication protocol.

Digital signal - a form of information transmission in which the signal is made up of a series of ones and zeros, which taken together represent discrete values.

Digitize - the process by which analog (continuous value) information is converted into digital (discrete value) information. This process is a necessary function for computer imaging applications because visual information is inherently in analog format and most computers use only digital information.

Direct image capture - the capture or acquisition of digital image data that have been acquired in digital format by an imaging modality. The image produced from the data, regardless of the modality that produced it (CT, MRI, CR, ultrasound), should include the full spatial resolution and bit depth of the original.

Diskette drive - the device on a computer that can read and write to diskettes. It is used to import and export data.

dpi (dots per inch) - while in conventional radiography, resolution is commonly expressed in line pairs per millimeter (lp/mm), film digitizer resolution is commonly expressed as dots (pixels) per inch.

Dynamic range - the difference in signal intensity, or frequency, between the largest and smallest signals a system can process or display. The optical density is the difference between the lightest and darkest useful regions of the image. Increasing the number of bits per pixel in a digital image increases the dynamic range of the image.

File - a set of digital data that have a common purpose, such as an image, a program, or a database.

Floppy diskette - a data storage device made of metal-coated plastic that can store computer information and can be physically transported from one place to another.

G (giga) - stands for the number 1 billion. It is used primarily when referring to computer storage capacities; for example, 1 GB = about 1 billion bytes or 1,024 megabytes.

Gray scale - the number of different shades of levels of gray that can be stored and displayed by a computer system. The number of gray levels is directly related to the number of bits used in each pixel: 6 bits = 64 gray levels, 7 bits = 128 gray levels, 8 bits = 256 gray levels, 10 bits = 1,024 gray levels, and 12 bits = 4,096 gray levels.

Gray-scale monitor - a black-and-white display with varying shades of gray, ranging from several shades to thousands, thus being suitable for use in imaging. This type of monitor also may be referred to as a monochrome display (see also monochrome monitors).

Hard disk drive - an internal computer device that is used for storage of data.

Hardware - a collective term used to describe the physical components that form a computer.

HIS (hospital information system) - an integrated computer-based system used to store and retrieve patient information, including laboratory and radiology reports.

IDE (integrated device electronics) - a type of interface used for hard disk drives that integrates the control electronics for the interface on the drive itself. Its purpose is to increase the speed at which information can be transferred between the hard disk and the rest of the computer.

IMACS - image management and communication system.

Image compression - reduction of the amount of data required to represent an image. This is accomplished by encoding the spatial and contrast information more efficiently, somehow discarding some information.

Interface - the connection between two computers or parts of computers.

Irreversible compression - some permanent alteration of digital image data. This is sometimes referred to as lossy.

ISDN (integrated services digital network) - a switched network with end-to-end digital connection enabling copper wiring to perform functions such as high-speed transmission which frequently require higher capacity fiberoptic cable.

k (kilo) - stands for the number one thousand. It is used primarily when referring to computer storage and memory capacities: for example, 1 kbps = 1024 bytes.

LAN (local area network) - computers in a limited area linked by cables that allow the exchange of data.

Laser film scanner - a device that uses a laser beam to convert an image on X-ray film into digital image data.

Leased line - same as a dedicated line.

Lossless - see reversible compression.

Lossy - see irreversible compression.

M (mega) - stands for the number 1 million. It is used primarily when referring to computer storage and memory capacities; for example, 1 MB = 1 million bytes. 1 MB = 1,024 thousand bytes or 1,000 kbytes.

Matrix size:
Small - defined as images from CT, MRI, ultrasound, nuclear medicine, and digital fluorography.

Large - defined as images from computed radiography, digital radiography, and digitized radiographic films.

Memory - electronic circuitry within a computer that stores information.

Modem - a device that converts digital signals from a computer to pulse tone signals for transmission over telephone lines.

Monochrome monitor - a computer display in which an image is presented as different shades of gray from black to white. (See also gray-scale monitor.)

Mouse - an input device that allows the computer user to point to objects on the screen and execute commands.

Operating system - software that allocates and manages the resources available within a computer system. UNIX, MS-DOS, Macintosh, and Windows are examples of operating systems.

Optical disk - a computer data storage disk used primarily for large amounts (GB) of data.

PACS - picture archiving and communication system.

Pan and zoom - the ability to select and magnify a region in the display.

Peripheral - a device that is connected to a computer and performs a function. Scanners, mouse pointers, printers, keyboards, and monitors are examples of peripherals.

Phosphor - the coating on the inside of a CRT or monitor that produces light when it is struck by an electron beam.

Pixel (picture element) - the smallest piece of information that can be displayed on a CRT. It is represented by a numerical code within the computer and displayed on the monitor as a dot of a specific color or intensity. An image is composed of a large array of pixels of differing intensities or colors.

Protocol - a set of guidelines by which two different computer devices communicate with each other.

RAM (random access memory) - a type of temporary memory in a computer in which programs are run, images are processed, and information is stored. The amount of RAM that a computer requires varies widely depending on the specific application. Information stored in RAM is lost when the power is shut off.

Resolution - spatial resolution is the ability to distinguish small objects at high contrast. It is related to and in some cases limited by the pixel size. Contrast (gray scale) resolution is the ability of a system to distinguish between objects of the same size having different signal intensity. It is related to and in some cases limited by the bit depth.

Reversible compression - no alteration of original image information upon reconstruction. This is sometimes referred to as lossless.

RIS - radiology information system.

ROM (read only memory) - a permanent memory that is an integral part of the computer. Programs and information stored in ROM are not lost when the power is removed.

SCSI (small computer systems interface) - SCSI is an interface protocol that is used to link dissimilar computer devices so that they can exchange data. SCSI interfaces are most common in image scanners and mass storage devices. This type of interface is well suited for imaging applications.

Secondary image capture - the capture in digital format of image data that originally existed in another primary format (e.g., a digital image data file on a CT scanner, or a screen-film radiographic film) through the process of video capture or film digitization.

SMPTE - the Society of Motion Picture and Television Engineers.

Software - a name given to the programs or sets of programs that are executed on a computer.

Tera (T) - stands for approximately 1 trillion (10^{12}). It is used primarily when referring to archive storage capabilities; for example, 1 TB = one trillion bytes or 1 million MB or 1,000 GB.

Throughput - a measure of the amount of data that is actually being communicated, expressed in bits per second. It is related to the baud rate but is usually somewhat less in value due to nonideal circumstances. Typically, modems with higher baud rates can attain a higher throughput.

Video capture - the process by which images are digitized directly from the video display console of a modality, such as CT, MRI, or ultrasound. The video signal is converted to a digital signal. This process is more efficient and produces better quality images than scanning films that are produced by the same equipment.

Voxel (volume element, derived from pixel) - a voxel is, as the name would imply, a three-dimensional version of a pixel. Voxels are generated by computer-based imaging systems, such as CT and MRI. Using voxels, three-dimensional simulations of objects can be reconstructed by imaging systems.

WAN (wide-area network) - a communication system that extends over large distances (covering more than a metropolitan area), often employing multiple communication link technologies such as copper wire, coaxial cable, and fiberoptic links. The cost of these wide-area networks is presently dominated by transmission costs.

WORM (write once read many times) - a peripheral memory device that stores information permanently.