Literature Review Report

Quality Use of Diagnostic Imaging

QS7(ii)

Establish technical standards for accreditation requirements for clinical teleradiology

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Executive Summary

This is the first report and discussion paper following stage 1 of QUDI project QS7.ii. Establish Technical Standards for Accreditation Requirements for Clinical Teleradiology
The project commenced with an electronic literature search. Relevant articles and documents related to teleradiology and electronic health services were catalogued and reviewed. Vendors of related products were contacted to provide relevant information for the consultants to review.

The review was performed and as each key area of teleradiology became evident it was documented and further review performed. The key areas were then developed into key components on which the discussion paper and consultation process will be undertaken.
The key areas identified include;
The DICOM standard
Image Acquisition
Image Compression
Image Data Management
The Transmission Site
Workstations and Display
Transmission Times – Bandwidth
Ubiquity
Security
Quality Control and Improvement
Communication
Protocols and Hangings
Access to Images
Documentation
The Radiologist
Applications
The Reporting Environment
Glossary of Terms
The legal environment
International Reporting

International standards and positions were examined from The American College of Radiology, The Canadian Association of Radiologists, European Association of Radiology,

The Royal College of Radiologists, London, The Royal Australian and New Zealand College of Radiologists, The College of Radiology - Academy of Medicine of Malaysia and The German Radiological Society.

In the *ACR Technical Standards for Teleradiology* it describes the reporting physician as one who has "an understanding of the basic technology of teleradiology and its strengths and limitations, and who is knowledgeable in the use of teleradiology equipment". If all reporting physicians comply with this statement then the standards developed for teleradiology should only be necessary to guide competent professionals and assist in the training of physicians in this field.

To complete this part of the project, a discussion paper has been produced to incorporate the key findings of the literature review and to enable feedback from stakeholders. This will inform the development of the final standards.

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Glossary of Terms

ACR	American College of Radiology
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 of long term (permanent) storage of images.
Baud	The number of events processed in 1 second, usually expressed in bits per second(bps) or kilobits per second (kbps).
Bit (binary digit)	The smallest piece of digital information that a computing device handles. It represents “off” or “on”.
Bit depth	The number of bits used to encode the signal intensity of each pixel of the image.
Byte	A grouping of 8 bits used to represent a character or value.
CCD (Charge-coupled device)	A photoelectric device that converts light into electronic information. 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.
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 or 2:1 would correspond to a compressed image with one half the numbers of bits of the original.
Conformance statement	A formal statement associated with a specific implementation of the DICOM standard.
Co-processor	A device in computer to which specialized processing operations are delegated, such as mathematical computation or video display. The advantage of co-processing is that it significantly increases

	processing speed.
CPU (central processing unit)	The device in a computer that performs the calculations and executes instructions.
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)	The monitor or display device in the teleradiology system.
Data carrier	The signal used to transmit the data.
Data communication	All forms of computer information exchange. Examples are LAN and WAN. (local area network and wide are network)
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 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 computer.
DICOM	Digital imaging and communication in medicine. A set of standards developed by the ACR-NEMA committee for the interconnection of medical digital imaging devices covering specifications for image format and communication protocol.
Digital signal	A form of information transmission in which the signal is made up of a series of one and zeros, when taken together represent discreet values.
Digitise	The process by which analog (continuous value) information is converted into digital (discrete value) 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 should include the full spatial resolution and the bit depth of the original.

dpi (dots per inch)	While in conventional radiography resolution is commonly expressed in line pairs per millimeter (line pairs/mm), film digitiser 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.
G giga	1 billion.
Gray scale	The number of different shades 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, 12 bits = 4,096 gray levels.
HIS	Hospital information system. A computer system to store and retrieve patient information.
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.
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. 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 fibre-optic cable.
K kilo	1 thousand
LAN	Local area network. Computers in a limited area linked by cables that allow exchange of data.

Laser film scanner	A device that uses a laser beam to convert an image on X-ray film to digital image data.
Lossless	No loss of the original digital information upon reconstruction of the digital image.
Lossy	Irreversible compression.
M mega	1 million
Matrix	An image formed by distinct points in both the horizontal and vertical directions e.g. 512 matrix is made up 512 points in one axis and 512 points in the other.
Matrix size	Small: defined as images from CT, MRI, US, NM and digital fluoroscopy. Large: defined as images from CR, DR 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.
Optical disk	A computer data storage disk used primarily for large amounts of data.
PACS	Picture archiving and communication system.
Pan and zoom	The ability to select and magnify a region in the display.
Phosphor	The coating on the inside of the 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 specific colour or intensity.
Protocols	A set of guidelines by which two different computers 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.
Resolution	Spatial resolution is the ability to distinguish small objects at high contrast. It is related to and in some cases limited by 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 cased limited to bit depth.
Reversible compression	No alteration of original image information upon reconstruction. Also known as lossless.
RIS	Radiography information system
ROM (read only memory)	A permanent memory that is an integral part of the computer.
Secondary image capture	The capture in digital format of image data that originally existed in another primary format.
SMPTE	Society of Motion Picture and Television Engineers.
Tera T	1 trillion
Throughput	A measure of the amount of data that is actually being communicated and expressed in bits per second.
Video capture	The process by which images are digitized directly from the video display console of a modality such as CT, MRI or US. The video signal is converted to a digital signal.
Voxel	Volume element. A three dimensional version of a pixel.
WAN (wide area network)	A communication system that extends over large distances (more than a metropolitan area).

Authors Details

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He has been actively involved with the RANZCR accreditation program from its inception and successfully achieved ISO/IEC 17025 (stage 3 accreditation) for Pennant Hills Diagnostic Centre in Sydney where he is the General Manager.

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Introduction

The Royal Australian and New Zealand College of Radiologists, through the Quality Use of Diagnostic Imaging program supported by the Federal Department of Health and Aging commissioned RAS to establish technical and practice standards for accreditation requirements for clinical teleradiology (QS7.ii). This report is the first of four stages and outlines the finding of the literature review. The literature review was performed to advise a consultation and discussion paper for the second stage of the project.

Definition of Teleradiology

The ACR describes teleradiology as "...the electronic transmission of radiologic images from one location to another for the purposes of interpretation and/or consultation." (ACR standard for Teleradiology, 2003).

Teleradiology is one component of telemedicine that only deals with the transmission of Radiology images. This project will develop the standards for the teleradiology on the basis of imaging practices performing primary and interim diagnosis. Specifically excluded from this process is the review of examinations and images by referring clinicians in the electronic environment.

Methodology

A search was performed to determine the extent and availability of information relating to all aspects of teleradiology in the medical imaging environment. Search under key words included: Teleradiology, telemedicine, remote radiology, radiology reporting, international radiology reporting.

Each individual paper was reviewed and key concepts developed. As each key concept was identified, further review of literature relating to these key concepts was performed. This report was then broken into the key concepts and reference to the literature is made. At the conclusion of the document a discussion paper has been produced from the evidence for stakeholders to provide feedback and assist in the further development of the project. Throughout the development of this paper, the concepts only have been defined for the purpose of consultation. This review identifies the body of evidence and provides typical quotes identified throughout the literature. The draft standards will be developed throughout the consultation period from a combination of the literature review and feedback from stakeholders.

Results

Teleradiology has become an integral part of radiology in Australia. Teleradiology is the electronic transmission of radiologic images from one location to another for the purposes of interpretation and/or consultation (ACR standard for Teleradiology, 2003). The ongoing uptake of teleradiology and increasing reliance on the technology shows that the quality of reporting is at least as effective as plain film and provides increased efficiency in the diagnosis of patients from rural and remote areas.

A key aspect of quality teleradiology services is to maintain open channels of communication (RCR, 2004). The radiologist or the facility in which they work must ensure that the they are able to maintain relationships with the referring clinicians and practice staff equal to that which would occur in the supervised environment (European Association of Radiology).

Teleradiology requires the transmission of images from one location to another. This raises issues of file size and transmission times. The transmission times can be reduced by compression thus reducing the requirement for bandwidth, the availability of which is often reduced in regional and rural areas of Australia. It is considered that the use of compression should result in no loss of image quality (lossless compression) (Canadian Association of Radiologists). It is generally accepted that a compression ratio of no more than 3:1 will provide lossless compression. Primary diagnosis should be made on images that are displayed with lossless or near lossless compression such that image diagnosis is not compromised.

The Digital Imaging and Communication in Medicine (DICOM) standard for imaging allows for the direct interpretation of imaging data from the equipment without the loss of any image quality. It also allows for the direct transfer of images from one system to another (Tichon, 2003). The DICOM standard should be considered on any purchase and implementation of teleradiology and the equipment that may be part of the system. The standards must allow for the potential development of future standards that may provide improvements in connectivity.

Image acquisition will determine the overall quality of an image. Image acquisition is made at the time of study and how it is integrated into the teleradiology network. This may be from direct digital acquisition such as from a DICOM modality through to film scanning devices or frame grabbers. Each of these methods produces a different outcome in terms of quality. It

is important to consider this in the implementation of a teleradiology system. Images can be categorized as large or small matrix (ACR, 2005). A large matrix image would be considered to have a resolution in excess of 1,000 x 1,000 matrix with over 8 bit pixel depth. Small matrix images are below this level (ACR, 2005). Image acquisition systems will determine the matrix size. Typically, large matrix images will include Computed Radiography and film scanned images. Small matrix images will include US, CT, MRI. The matrix size of the image will affect the display characteristics and requirements (Canadian association of Radiologists). Some other key requirements at image acquisition include study demographics. Image acquisition should include Patient name, Identification number, Date and time of examination, Name of facility, Type of examination, Name of examination including right or left, Amount of data compression, Area for notes (ACR, 2005).

Teleradiology requires consideration of patient confidentiality and privacy (RCR, 2004). Australia has ten privacy principles that must be maintained in the use of teleradiology (Privacy Act 1988 Australia, June 2006). The privacy standards for teleradiology must include the protection of data in both transmission and storage. Informed consent should be considered as part of this process.

The basis for quality imaging in the team environment calls for documented protocols for the provision of examinations (RCR, 2004). This is particularly important in the use of teleradiology where the technical team is less likely to be under the direct on site supervision of a radiologist. The supervising radiologist must be available for consultation if required prior to the commencement of the study. This may be by phone or other instant communication means. Protocols must also be available for the transfer and receive of images on the teleradiology system.

Quality improvement and quality control are key aspects to maintaining a high standard teleradiology system. Quality improvement systems should commence at installation where a complete evaluation of the system should be performed by qualified personnel (RANZCR). Ongoing QC activities may include such items as monitors and image display, test images, reporting room conditions. (ACR, 2005)

The image display QC should be undertaken at regular intervals (ACR, 2003). These should include tests on SMPTE Test pattern, spatial resolution, authenticity and range of grey scale, pixel drop out/phosphor deterioration (RCR, 2004).

The quality control of the teleradiology system should also include ongoing review of policies and procedures for the acquisition, digitization, compression, transmission, archiving, and retrieval functions of the system. Within the scope of this program the technical personnel and all equipment should be reviewed (RANZCR, 2001).

Radiologist contribution to the successful use of teleradiology is paramount. Radiologists performing teleradiology must be appropriately credentialed to report in the state where the examination was performed. Official interpretation of images should be provided by a physician who has appropriate training and basic understanding of teleradiology including its strength and weaknesses (ACR, 2005).

Supervision of examinations remains a key aspect to teleradiology. The RANZCR standards provide clear guidance for the supervision requirements in radiology practice. Consideration must be given to regional and remote practice where the availability of on site radiologist supervision is limited. The MBS provides regulation on the distance for remote sites and the supervision requirements. Where a practice is more than 30km from the nearest supervised radiology location medicare benefits payable for unsupervised services that may not be available inside the 30km radius. Teleradiology is often used in these circumstances. Teleradiology does not preclude the need for supervision and all examinations should still come under the control of an appropriately credentialed radiologist who should be available for real time consultation prior to any examination being undertaken. The supervision requirements for radiology practices are the subject of an alternate project under QUDI QS1 Development of Best Practice Professional Supervision and Reporting standards for Radiologists. This document rightly treats teleradiology as a routine component of modern radiological techniques. The supervision standards for teleradiology should be maintained in accordance with the outcomes of this project.

The use of teleradiology requires security processes in image transmission and storage. Patient confidentiality is important in this area. Network and software security protocols are integral to system acceptance. There are federal and state legislative requirements in this area. Practices must ensure they comply with these regulations (ACR Technical Standards, 2003). As these regulations will differ between jurisdictions, practices must ensure they comply in the region in which they practice.

Transmission of data is an important consideration in teleradiology. There is a compromise between expense and speed. A practice should choose the highest available, affordable

transmission speeds (Tichon, 2003). It is important that transmission times take into account the need for urgent or emergency examinations. A teleradiology system should consider the transfer of images in respect to flexibility with multiple options for compression, allowing the sender to choose between speed and quality such that all situation in a remote environment can be catered.

Web based applications have become the recent movement in teleradiology systems. These provide advantages in the reporting systems do not need to have specific software installed. However, it is important that the practice is able to ensure reporting is being provided on appropriate technical equipment in compliance with the developing standards. As such control mechanisms must be in place.

A key component in any teleradiology system is the display capabilities and characteristics. The literature revealed consistent expectations of software in many areas. These include:
Brightness and contrast and/or window width and level control
Magnification
Image rotation
Linear measurement
Inversion of grey scale
Density determination
Annotation

The hardware requirements for teleradiology systems should be appropriate for the scope of work being provided. In particular the monitor configuration is important. Generally the higher the resolution on the monitor and the brighter the display the better the reporting image quality will be. There will be a cost tradeoff. 2 megapixel resolution is commonly referred to as a minimum standard. Monochrome monitors provide significantly higher intensity and should be considered for large matrix imaging in particular (Tichon, 2003).

One aspect of teleradiology that is becoming more prominent in the current environment is international teleradiology. There are many new international teleradiology companies setting up all around the world. There is very little literature on this issue. It is clear that the single most common problem is related to insurance across international jurisdictions (Elabd, 2004). The authors have sited multiple legal opinions on this that vary in their outcomes. This will be a key component of the consultation process for this study. As a minimum consideration organization should ensure that the reporting radiologist has evidence of

Australian credentialing and carry licenses and malpractice coverage in the state where the image was obtained and appropriate credentials at the source facility (Wachter,R.M).
The RANZCR is undertaking a review of the "Regulatory Framework of Teleradiology" in Australia. At the time of writing this document remains in draft form. It does however raise several key issues for consideration. The RANZCR need to adopt appropriate standards. Radiologists should undergo appropriate training in teleradiology and understand the processes involved in the clinical and medico-legal framework. Quality assurance on teleradiology systems should be considered. The outcomes of this project should reflect these recommendations and any others that arise from the legal review.

Literature Review Extracts

Communication

There should be close liaison between the clinician and the reporting radiologist.
Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

The reporting Radiologists providing the service must have sufficient understanding of the English language including idiomatic use and the specialist vocabulary necessary to provide a clear, unambiguous and sufficiently detailed report upon a medical image in a manner that will be properly understood by a medical practitioner in the receiving NHS Trust.
Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

It was shown that clinico-radiological discussions result in a change of clinical diagnosis in 50% of the cases and a change in treatment in 60% of the cases discussed.
Position on Teleradiology, European Association of Radiology

The principle that the patient is best served by a close liaison between the patient, the clinicians and the clinical radiology department should be paramount.
Position on Teleradiology, European Association of Radiology

There must be clearly defined and agreed processes of image transfer, prioritisation of reporting, reporting styles, interaction with host departments, host hospitals and primary care doctors and agreement protocols.
Position on Teleradiology, European Association of Radiology

The interpreting radiologist / medical imaging specialist must be available and able to communicate directly with the referring facility and referrer in order to discuss the clinical background, study selection or an unexpected diagnosis, which are important factors contributing to the timely management of the patient.
Clinical Teleradiology Standards Draft V.2.0. RANZCR, 2.8

The interpreting radiologist / medical imaging specialist must have sufficient command of the language used in the interpreting facility including idiomatic use of the language and the professional vocabulary necessary to provide a clear, unambiguous and sufficiently detailed report in a manner that will be properly understood by the medical practitioner in the referring jurisdiction.
Clinical Teleradiology Standards Draft V.2.0. RANZCR, 2.8

Compression

"The types and ratios of compression used for different imaging studies transmitted and stored should be selected and periodically reviewed by the responsible physician to ensure appropriate clinical image quality."
American College of Radiology Technical Standards for Teleradiology, available www.acr.org

"The DICOM committee has deemed lossless JPEG and lossy JPEG to be acceptable image compression techniques for use on medical images"
Amit Mehta, Keith J. Dreyer, James H. Thrall, PACS, A Guide to the Digital Revolution. *2002 Springer and Verlag*

"Part 12 of JPEG 2000, ISO/IEC 15444-12, has a common text with Part 12 of the MPEG-4 standard, ISO/IEC 14496-12. It is a joint JPEG and MPEG initiative to create a base file format for future applications." www.jpeg.org

A major advantage of wavelet compression over JPEG compression is that it permits substantially higher compression ratios while maintaining image quality.
Amit Mehta, Keith J. Dreyer, James H. Thrall, PACS, A Guide to the Digital Revolution. *2002 Springer and Verlag*

JPEG 2000 will use wavelets to improve quality and reduce the size of the compressed image.
Amit Mehta, Keith J. Dreyer, James H. Thrall, PACS, A Guide to the Digital Revolution. *2002 Springer and Verlag*

There should be provision for the selection of appropriate compression for improved transmission rates and reduced archiving/storage requirements. There must be no reduction in clinically diagnostic image quality.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

For primary reads we recommend low or lossless compression algorithms.
http://www.brit.com/html/educational_material.html

Compression algorithms below about 3:1 are usually considered lossless. Compression ratios above this are considered lossy (destructive) and can result in image degradation.
http://radiology.uiowa.edu/MoreRAD/Teleradiology/equipmen.htm

DICOM

"DICOM 3 is important to teleradiology because a direct digital connection can be made from the image source to the teleradiology server and then from the teleradiology-receiving computer to a diagnostic workstation. Furthermore, DICOM 3 offers no loss of the full 12 bit data set (2056 grayscales) generated from digitally acquired images, no image degradation, and has a full capability to adjust image window levels and settings". *Amit Mehta, Keith J. Dreyer, James H. Thrall, PACS, A Guide to the Digital Revolution*. *2002 Springer and Verlag*

"Compliance with Digital Imaging and Communication in Medicine (DICOM) standard is strongly recommended for all new equipment acquisitions as this provides a uniform, well understood set of rules for communication of digital images, allowing interdepartmental and

interagency transfers." *J. Tichon, Minimum technical requirements and evaluating effectiveness of Teleradiology. Technology and Health Care 11 (2003) IOS Press*

"It is recommended that the DICOM standard be used" *American College of Radiology Technical Standards for Teleradiology, available www.acr.org*

"If you use a direct digital interface, such as DICOM 3, you could have all 12 bits of data (i.e 4096 shades of gray)." *http:/www.brit.com/html/education_material.html*

"Communications protocols, file formats and compression shall conform to the current DICOM 3.0 network standard."
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

The practice shall conform to the current DICOM network standard for communication protocols, file formats and compression.
Clinical Teleradiology Standards Draft V.2.0. RANZCR, T.1.4.1

Image Acquisition

Small matrix – 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.
American College of Radiology Technical Standards for Teleradiology, available www.acr.org

The images must be able to be displayed in their full native matrix size and bit depth or have display software that allows the user to "pan" over the entire image when displayed in its full matrix size.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

Large matrix – 2.5lp/mm spatial resolution at a minimum 10 bit pixel depth
Conventional radiographs - 2000 x 2000 pixels x 12 bits for image acquisition and display.
American College of Radiology Technical Standards for Teleradiology, available www.acr.org
Direct Image Capture. "The entire image data set produced by the digital modality in terms of both image matrix size and pixel depth should be transferred to the teleradiology system".
American College of Radiology Technical Standards for Teleradiology, available www.acr.org

General requirements
Patient name
Identification number
Date and time of examination
Name of facility
Type of examination
Name of examination including right or left
Amount of data compression
Area for notes
American College of Radiology Technical Standards for Teleradiology, available www.acr.org

Annotation capabilities for use at the transmitting station must identify the patient accurately and unambiguously. This may include patient name, identification number, date and time of examination, film markers, institution of origin, type of examination, degree of compression (if used) and a brief patient history. This information should be bundled with the image file but may also be transmitted by other secure means e.g. fax.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

Film Scanning Devices

Acquisition or digitization system: These systems should enable spatial resolution of a minimum of 2.5 line pairs/mm and acquisition of 10 bit gray scale.
Display system: These systems should enable spatial resolution of a minimum of 2.5 line pairs/mm and display 8 bit gray scale.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

Frame Grabbers

Images captured from displayed versions of the originals shall only be permitted to be used when there is no other means of displaying the original images themselves. When this is the case, the matrix size of the captured images shall not be less than the matrix size of the original images, and the bit depth shall be 8 bits or equal to that of the original images.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

Image Quality

When a clinical teleradiology system is used to render the official interpretation, there shall not be a clinically significant loss of data from the image acquisition through transmission to

final image display. For transmission of images for display use only, the image quality shall be sufficient to satisfy the needs of the clinical circumstance.
Clinical Teleradiology Standards Draft V.2.0. RANZCR, T.1.2.1

Three neurosurgeons found that for satisfactory remote consultation a minimum size of 640 x 480 pixels was required for CT and MR images and 1025 x 768 pixels for angiography images.
Dong-Keun, Sun K Yoo, Sun H Kim / Instant Wireless Transmission of Radiological Images Using a Personal Digital Assistant Phone for Emergency Teleconsultation. Journal of Telemedicine and Telecare 2005; 11 (suppl. 2)

Patient Confidentiality

The teleradiology service must ensure patient confidentiality. The technical specification must be sufficiently robust to ensure compliance with data protection legislation.
Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

The teleradiology service must ensure patient confidentiality and be of adequate technical specification. It must comply with data protection legislation in the transmitting and receiving country.
Position on Teleradiology, European Association of Radiology

Image storage at either the transmitting or receiving site as well as transmission must be arranged such that patient confidentiality is maintained and the system secure.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

4. The facility must comply with all data protection standards as laid down by the local jurisdiction. It is essential that the privacy and the integrity of the patients' information must be preserved at all times.
Clinical Teleradiology Standards Draft V.2.0. RANZCR

Protocols and Hangings

If the service is to include complex imaging (CT, MRI etc) detailed protocols with respect to the technical requirements for each examination must be agreed.
Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

When creating teleradiology contracts, it must be clear who has responsibility for defining the protocol of an individual CT study.
Position on Teleradiology, European Association of Radiology

Capability for the selection of the image sequence for transmission and display at all the receiving sites.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

Quality Improvement and Quality Control

Important parameters must be accompanying the transmitted study when used for the official authenticated written interpretation. These will include, at a minimum, the matrix size, bit depth, compression (if used) and what kind of image processing, if any, was used (edge enhancement etc)
A test image such as the SMPTE phantom or its equivalent must be captured and transmitted at least weekly to test the overall operation of the system. As a dynamic range test, both the 0/5% and the 95/100% areas must be seen as distinct from the respective adjacent 0% and 100% areas.
An imaging physician must be involved in the selection of imaging systems at both the receiving and transmitting sites.
Monitoring shall include the evaluation of the accuracy of the interpretations as well as the appropriateness of the examination.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

A luminescence meter corresponding to at least application category B
(DIN 5032-7) shall be used.
German Standard DIN V 6868-57 : 2000

A set of test images and clinical reference images shall be produced. Please refer to *German Standard DIN V 6868-57 : 2000 page 14 –16*

Quality Assurance of Monitors and Image Display
The teleradiology service issuing a definitive diagnostic report must do so on images viewed losslessly compressed, at their full acquisition resolution. Agreements needs to be reached as to whom will perform quality assurance on the monitors and workstations of the teleradiology site, the frequency at which this will be performed, and what parameters will be assessed. Examples of the latter include:
Authenticity and range of grey scale (colour and display) if appropriate
Test pattern assessment
Pixel drop out (for flat liquid display screens)/phosphor deterioration of cathode ray tubes monitors
Ambient lighting conditions at which images are viewed for diagnosis
The spatial and contrast resolution of the monitors and images viewed.
Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

Prerequisite for the performance of the acceptance test.
German Standard DIN V 6868-57 : 2000 page 21 – 27

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.
ACR Technical Standards for Teleradiology. Effective 1/1/03.

As a spatial resolution test, at least 512 x 512 resolution should be confirmed for small-matrix official interpretation, and 2.5lp/mm resolutions for large-matrix official interpretation.
ACR Technical Standards for Teleradiology. Effective 1/1/03.

A complete evaluation of the system performance must be conducted by a qualified clinical teleradiology equipment support specialist / service personnel after completion of the installation prior to regular clinical use.
Clinical Teleradiology Standards Draft V.2.0. RANZCR

The radiologist / medical imaging specialist must regularly participate in the on site quality assurance process and be involved in maintaining records of the process.
Clinical Teleradiology Standards Draft V.2.0. RANZCR

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, digitisation, compression, transmission, archiving, and retrieval functions of the system. The quality control program should be designed to maximise the quality and accessibility of diagnostic information.
http://www.radiologymalasia.org/Content/MedPro/CircsNGuides/telerad.htm

Quality standards and procedures should encompass technical personnel and all equipment used in the teleradiology process.
RANZCR Position on Teleradiology, November 2001.

A clearly documented service agreement must be established between the purchaser or referring facility and the provider or interpreting facility.
Clinical Teleradiology Standards Draft V.2.0. RANZCR. Page 10.

Radiologist

Under no circumstances should teleradiology reports be made by unsupervised reporting Radiologists in training……
Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

Under no circumstances should teleradiology reports be made by Radiologists in training and the implementation of teleradiology should not be to the detriment of the training in the originating centre.
Position on Teleradiology, European Association of Radiology

A trainee may provide a preliminary teleradiology interpretation but a qualified radiologist / medical imaging specialist shall be available to provide on site supervision of trainees at all times in hours and be available to provide advice and backup at all times out of hours.
Clinical Teleradiology Standards Draft V.2.0. RANZCR

The official interpretation of images must be done by a physician who has an understanding of the basic technology of teleradiology and its strengths and limitations, and who is knowledgeable in the use of teleradiology equipment.
ACR Standard for Teleradiology. Effective 1 October 2005.

Reporting Environment

Quality Assurance of Monitors and Image Display

The teleradiology service issuing a definitive diagnostic report must do so on images viewed losslessly compressed, at their full acquisition resolution. Agreements needs to be reached as to whom will perform quality assurance on the monitors and workstations of the teleradiology site, the frequency at which this will be performed, and what parameters will be assessed. Examples of the latter include:
Authenticity and range of grey scale (colour and display) if appropriate
Test pattern assessment
Pixel drop out (for flat liquid display screens)/phosphor deterioration of cathode ray tubes monitors
Ambient lighting conditions at which images are viewed for diagnosis
The spatial and contrast resolution of the monitors and images viewed.
Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

Prior to testing, the proper placement of a display device should be verified and adjustments made as appropriate. In the placement of a display device, the following should be considered:
1. Display devices should always be positioned to minimize specular reflection from direct light sources such as ceiling lights, film illuminators, or surgical lamps. The reflection of such light sources should not be observed on the faceplate of the display in the commonly used viewing orientations.
2. Many display devices, such as CRTs, are affected by magnetic fields; they should not be placed in an area with strong magnetic fields (i.e., in vicinity of MRI scanners), unless properly shielded.
3. Displays should be placed ergonomically to avoid neck and back strain at reading level,

with the center of the display slightly below eye level.
Assessment of Display Performace for Medical Imaging Systems, online report no.03, American Association of Physicists in Medicine Task Group 18, 2005

Security

Image storage at either the transmitting or receiving site as well as transmission must be arranged such that patient confidentiality is maintained and the system secure.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

Teleradiology systems should provide network and software security protocols to protect the confidentiality of patient's identification and imaging data consistent with federal and state legal requirements.
ACR Technical Standards for Teleradiology. Effective 1.1.03

There must be measures to safeguard the clinical teleradiology data and to ensure data integrity against intentional or unintentional corruption of the data. This should include internal redundancy systems, backup telecommunications links and a disaster plan.
Clinical Teleradiology Standards Draft V.2.0. RANZCR, A.3.4.1

Transmission of Data

Bandwidth

"The choice of bandwidth for teleradiology is a compromise between expense and speed"
"It would be prudent to choose the highest available and affordable bandwidth transmission lines."
J. Tichon, Minimum technical requirements and evaluating effectiveness of Teleradiology. Technology and Health Care 11 (2003) IOS Press

"You will need to select the facility (bandwidth) based on the speed you require, considering both the capacity or the line and the time to transmit a given image."
http:/www.brit.com/html/education_material.html

Latency, the time required to transmit data across the network, is determined by a combination of hardware and physical distance, and is perceived as the delay between sending and receiving a message. In teleradiology, latency requirements will vary depending upon the role of the service provided and the timeliness with which the records must be accessed, for example in routine versus emergency consultations.
J. Tichon, Minimum technical requirements and evaluating effectiveness of Teleradiology. Technology and Health Care 11 (2003) IOS Press

The ideal teleradiology sending station would have very high resolution, little or no compression, and very high transmission speeds.
http://radiology.uiowa.edu/MoreRAD/Teleradiology/equipmen.htm

If economically feasible, one selects a sending station that has a reasonably fast modem (about 19,200 bps), operator-selectable resolution of 512 to 2048 bits and several selectable compression levels. A station with this flexibility will allow the sender and receiver to decide on a case by case basis which is more important; quality of the received image or the speed at which it arrives. If selectable resolution and compression are not an option, the sending station should have a reasonably high fixed resolution (1024 X 1024 X 12) and lossless compression (3:1).
http://radiology.uiowa.edu/MoreRAD/Teleradiology/equipmen.htm

For successful teleradiology to be implemented, it was necessary to have a means of image transfer that:
Automated the manual steps of image transfer, to reduce the time required of the PACS Administrator
Reduce human error in image transfer, so images were automatically routed to the intended clinical recipient
Allowed transfer of images outside normal office hours.
Liam Caffery and Ken Manthey / Implementation of a Web Based Teleradiology Management System. Journal of Telemedicine and Telecare 2004; 10 (Suppl.1)

The main advantage of web-based teleradiology is that dedicated image display software does not need to be on the reviewer's computer; instead images are displayed inside a standard web browser e.g Microsoft's Internet Explorer.

Smith AC, Bensink M, Armfield N, Stillman J, Caffrey L. Telemedicine and Rural Health Care Applications. J Postgrad Med 2005;51:286-293

Workstations and Display

Display workstations employed for teleradiology systems must provide the following characteristics
Luminance of the gray scale monitors shall be at least comparable to the workstations used for acquisition.
Display stations for digistised radiographic films, computed radiography and digital radiography must include
Brightness and contrast and/or interactive window and level functions.
Magnification function
The capability of rotating and flipping displayed images
The capability of accurate linear measurements
The capability of inverting the gray scale values of the displayed image
Display stations for CT, MRI, Ultrasound and Nuclear Medicine must accurately reproduce the original study and be equipped with similar functional capabilities as the workstation used for acquisition.
Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01

This application category (CT, MRI, DR, Digital Fluoroscopy, DSA, US, NM, PACS) shall represent images in the diagnostically required format and with the diagnostically required number of image elements, but with at least 1000 X 1000 image elements.
German Standard DIN V 6868-57 : 2000

Display Capabilities

Display workstations used for official interpretations and employed for small matrix and large matrix systems should provide the following characteristics:
Luminance of the gray scale monitors should be at least 50 foot-lamberts
Lighting in the reading room that can be controlled to eliminate reflections in the monitor and to lower the ambient light as much as is feasible.
Capability for selecting image sequence.

Capability of accurately associating the patient and study demographic characterisations with the study images.
Capability of window and level adjustments, if those data are available.
Capability of pan and zoom functions
Capability of rotating or flipping the images provided correct labeling of patient orientation is preserved.
Capability of calculating and displaying accurate linear measurements and pixel value determinations in appropriate values for the modality (eg Hounsfield units for CT images), if those data are available.
Capability of displaying prior image compression ratio, processing, or cropping.
The following elements of display:
Matrix size
Bit depth
Total number of images acquired in the study.
Clinically relevant technical parameters.
When the display systems are not used for the official interpretation, they need not meet all the characteristics listed above.
ACR Technical Standards for Teleradiology. Effective 1/1/03.

Display monitors used for primary interpretation should be tested at least monthly. As a dynamic range test, both the 5% and 95% areas should be seen as distinct from the respective adjacent 0% and 100% areas.
ACR Technical Standards for Teleradiology. Effective 1/1/03.

Workstation Display Capabilities.
Workstations employed for clinical teleradiology interpretation shall include capabilities for
Selecting image sequence for transmission or display
Displaying patient name and identification
Associating the patient with the images
Displaying the study details: site, date, time, matrix size, bit depth, total images, compression ratio and other clinically relevant parameters
Contrast and brightness adjustment when viewing 8-bit images or full window and level adjustment when viewing 12-bit images, luminescence of the gray-scale monitors should be at least 50 foot-lamberts.

Image viewing / analysis functions covering: magnification, gray-scale inversion, linear, angle and pixel measurements, annotation; and rotating or flipping the images with preservation of the correct labeling of patient orientation.
Display stations for CT, MRI, Ultrasound and Nuclear Imaging must accurately reproduce the original study and be equipped with similar functional capabilities as the acquisition workstation. The capability to record brief patient history is desirable.
Clinical Teleradiology Standards Draft V.2.0. RANZCR

The screens for viewing the images should be large, flat, high resolution and bright. For diagnostic work and reporting the requirement is for larger brighter monochrome screens with image sequencing and manipulation, pan and zooming capabilities.
J. Tichon, Minimum technical requirements and evaluating effectiveness of Teleradiology. Technology and Health Care 11 (2003) IOS Press

It is generally recommended that for teleradiology applications monitors have a pixel resolution of 1000 by 1000 or above.
http://radiology.uiowa.edu/MoreRAD/Teleradiology/station.htm

Indeed, many people recommend that primary reading be done with a 2-megapixel (MP) monitor for modalities such as CT and MRI, while a 3MP works best for computed radiography, digital radiography, and mammography.
Dan Harvey, Remote Reading — PACS and Teleradiology Let Radiologists Work Almost Anywhere Radiology Today Vol. 7 No. 7 P. 14

International Reporting

Medicare billing and liability issues have posed a considerable barrier for teleradiology providers who operate overseas. Many companies have U.S. board-certified radiologists reading images in other countries, such as Australia, China, Brazil, and India. In many cases, the physicians were trained and working in the United States before relocating overseas for different reasons.
Sonia Elabd, 2004, Long-Distance Diagnosis — A Closer Look at Teleradiology, Radiology Today

The ACR recommends that radiologists who are performing distant readings be board-certified and carry licenses and malpractice coverage in the state where the image was obtained and appropriate credentials at the source facility.
Wachter,R.M, International Teleradiology, New England Journal of Medicine Vol 354:662-663 No 7.

The technical and logistic hurdles of remote teleradiology have been overcome, and the practice of having radiologists who were trained and credentialed in the United States read films overseas is now largely accepted. If the ACR guidelines hold, the growth of overseas teleradiology will be markedly constrained by the limited supply of U.S.-trained radiologists who are willing to work abroad. It seems likely that battles over licensure, credentialing, and reimbursement will determine whether providers who were trained and credentialed overseas will be allowed to compete openly with U.S. radiologists. The outcome of these battles will strongly influence the diffusion of international outsourcing to other areas of U.S. medicine.
Wachter,R.M, International Teleradiology, New England Journal of Medicine Vol 354:662-663 No 7.

The Legal Environment

Specifically, in regard to the RANZCR it is recommended that:
The urgent adoption of the American Radiology Council Code of Teleradiology as a minimum standard for the practise of teleradiology in Australia;
A regulatory awareness program for all practising radiologists using teleradiology in regard to the legal structure and responsibilities of teleradiology;
A specific post-accreditation training and quality assurance programs for practising radiologists using teleradiology in teleradiology;
Development of a teleradiology curriculum and a teleradiology accreditation standard.
RANZCR, THE REGULATORY FRAMEWORK OF TELERADIOLOGY Draft 7, 2006

Summary Results/Conclusions

As we studied the list of articles it became apparent that the vast majority concentrated on the benefits to organisations who undertake this activity and the articles themselves however provided very limited, currently relevant, technical detail. Therefore, we decided to concentrate our research to articles that may provide “evidence” to support the standards adopted by these international professional bodies.

Within the guise of this limitation we were surprised to learn how little evidence-based, technical information was available in the published literature. There are some notable exceptions including German Standard DIN V 6868-57 Image Quality Assurance in X-ray Diagnosis Part 57: Acceptance Testing for Image Display Devices. It was prepared by the Radiology Standardisation Committee of the German Standards Institute in cooperation with the German Radiological Society.

We found that the literature available barely kept up to date with the advances in teleradiology technology. Therefore, to prepare a draft set of standards for teleradiology one must be prepared for a continuation of rapid advancement in this area and the standards must be flexible to allow for the medical imaging professionals to make determinations based upon relevant technology and patient care.

Key Areas

The literature review undertaken has identified 12 key areas in which the consultation with stakeholders should focus. These 14 key areas include:

Communication
Compression
DICOM
Image Acquisition
Patient Confidentiality
Protocols and Hangings
Quality Improvement and Quality Control
Radiologist
Reporting Environment
Security
Transmission of Data

Workstations and Display
The Legal environment
International Reporting

Key Elements

Each of these 14 key areas was further reviewed down to key elements for consultation and discussion. The following summary defines the key elements.

Communication
Clinical Liaison Between referrer and Radiologist.
Clinical Liaison between the radiographer and radiologist.

Compression
The types and use of compression must be selected appropriately for the type of imaging performed.
The types and use of compression must be periodically reviewed to ensure image quality.
Compression ratio's of 3:1 provide no loss of image data.

Types of compression include; JPEG lossless, JPEG lossy, Wavelet.
DICOM
Standard for digital medical images. Equipment on imaging network must consider DICOM compliance.

Image Acquisition
Methods include; direct connection from DICOM modality, film scanning devices, derived images, frame grabbers.

Consideration must be given to variation in matrix of images at the point of acquisition.

Images must have appropriate accompanying information. This may include name, unique identifier, date and time of examination, facility, type of examination, name of examination including side markers, compression type and level, patient notes, annotations.

Patient Confidentiality
Patient confidentiality must be maintained in all aspects of teleradiology in accordance with local regulations. This may include but not be limited to;

Data Transfer including images and reports
Image Storage
Compliance with the Australian federal privacy principles

Protocols and Hangings

Examination protocols availability to radiographer in remote locations
Where reporting is contracted details must clearly state who is responsible for protocol of examinations.
Protocols for the transmission and display of images.

Quality Improvement and Quality Control

Test image SMPTE test pattern.
Luminescence testing.
Test images and clinical reference image availability.
Service and maintenance agreements/protocols.
Monitors and image display characteristics.
Environmental conditions.
System evaluation by qualified support specialist.
QC Program inclusions.

Radiologist

Supervision and reporting.
Trainee Radiologists.
Preliminary and final interpretations.
International Reporting.

Reporting Environment

Monitors and Image Display.
Room conditions.

Security

Image storage and transmission.
Network Security.
Redundancy and Back up.
Confidentiality.

Transmission of Data

Bandwidth selection and trade offs

Latency time and reporting effects

Flexibility of acquisition and compression

Workstations and Display

Workstation characteristics relative to reporting stations

Minimum specification of function on reporting stations

International reporting

Medico-Legal issues

Medicare Australia acceptance

The Legal Environment

The RANZCR adopt a standard for teleradiology

Training for Radiologist in key aspects of teleradiology

Quality Assurance programs in teleradiology

References

Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

Position on Teleradiology, European Association of Radiology

Clinical Teleradiology Standards Draft V.2.0. RANZCR

American College of Radiology Technical Standards for Teleradiology, available www.acr.org

Amit Mehta, Keith J. Dreyer, James H. Thrall, PACS, A Guide to the Digital Revolution. 2002 Springer and Verlag

www.jpeg.org

Teleradiology Standard - Canadian Association of Radiologists, Resolution no AGM03-01 http://radiology.uiowa.edu/MoreRAD/Teleradiology/equipmen.htm

J. Tichon, Minimum technical requirements and evaluating effectiveness of Teleradiology. Technology and Health Care 11 (2003) IOS Press

http:/www.brit.com/html/education_material.html

Dong-Keun, Sun K Yoo, Sun H Kim / Instant Wireless Transmission of Radiological Images Using a Personal Digital Assistant Phone for Emergency Teleconsultation. Journal of Telemedicine and Telecare 2005; 11 (suppl. 2)

German Standard DIN V 6868-57 : 2000

ACR Technical Standards for Teleradiology. Effective 1/1/03.

http://www.radiologymalasia.org/Content/MedPro/CircsNGuides/telerad.htm

RANZCR Position on Teleradiolgoy, November 2001.

Teleradiology – A Guidance Document for Clinical Radiologists, Royal College of Radiologists, London. 30 April 2004.

ACR Standard for Teleradiology. Effective 1 October 2005.

http:/www.brit.com/html/education_material.html

http://radiology.uiowa.edu/MoreRAD/Teleradiology/equipmen.htm

Smith AC, Bensink M, Armfield N, Stillman J, Caffrey L. Telemedicine and Rural Health Care Applications. J Postgrad Med 2005;51:286-293

http://radiology.uiowa.edu/MoreRAD/Teleradiology/station.htm

Medicare Benefits Schedule, November 2005

Privacy Act 1988 Australia, June 2006

Sonia Elabd,2004, *Long-Distance Diagnosis — A Closer Look at Teleradiology*, Radiology Today

Dan Harvey, *Remote Reading — PACS and Teleradiology Let Radiologists Work Almost Anywhere* Radiology Today Vol. 7 No. 7 P. 14

Wachter,R.M, International Teleradiology, New England Journal of Medicine Vol 354:662-663 No 7.

RANZCR, THE REGULATORY FRAMEWORK OF TELERADIOLOGY Draft 7, 2006

American Association of Physicists in Medicine Task Group 18, *Assessment of Display Performace for Medical Imaging Systems*, online report no.03, 2005

Attachment 1: Stage 2

Stage two of this project involves consultation and development of draft standards for teleradiology. The documents in this attachment have been produced from the information in the literature review.