

PILOT PROJECT TO DEVELOP A PROCESS FOR DEFINING TELERADIOLOGY PROTOCOLS FOR DIAGNOSTIC SONOGRAPHY

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ESSENTIALS FOR TELESONOGRAPHY

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INTRODUCTION AND RATIONALE

Specialized skills required for the delivery of patient care that are unavailable at the location of the patient may be provided remotely through telemedicine. Using electronic media for the transmission of images, audio, and patient data, experts located many miles from the patient may participate in diagnosis and treatment. Such methods have been shown to improve access to quality health care in isolated settings and increase the productivity of specialists by permitting them to apply their skills efficiently over a wide geographic area.

The application of telemedicine to the transmission of diagnostic images (teleradiology) has evolved rapidly in recent years. Teleradiology is now used to transmit conventional radiographs, mammograms, computed tomographic (CT), magnetic resonance (MR) and ultrasound (US) images.¹ Teleradiology employs a variety of methods for image acquisition, compression, encryption, transmission and display, and diagnostic image quality may be significantly affected by the methods used to digitize, transmit, receive and display images using teleradiology.² Although standards such as DICOM (Digital Image Communication in Medicine) have been developed to facilitate the transfer of digital medical images, problems exist in the

uniform application of this standard to teleradiology using images produced by equipment for different vendors.³ While a comprehensive functional requirements definition is found in the American College of Radiology (ACR) Standard for Teleradiology,⁴ no single document currently addresses specific minimum requirements for acceptable quality and data integrity. With the proliferation of low cost, high bandwidth data links and increasingly powerful computer processing capability, an opportunity exists for the widespread implementation of quality teleradiology support for remote and underserved areas. In order for this to occur efficiently, standardized protocols addressing minimum requirements for teleradiology are needed. We propose, in this document, to define minimal essential requirements for teleultrasonography-the teleradiology of ultrasound images and data.

The development of these essentials is an initial step toward the development of formal standards related to teleradiology of ultrasound and other medical images. When completed, these standards will provide the basis for improved application of telemedicine for patient care in both urban and rural areas, as well in crewed space projects and in exchange of data among research centers.

GENERAL REQUIREMENTS

There are several fundamental concepts that apply to teleultrasonography. These are reflected in the following general requirements. In most cases, these principles will apply to all forms of teleradiology and, therefore, form the framework for a generic standard related to the transmission of medical images.

1. Diagnostic equivalence. The premise underlying these essentials is that the information provided to a physician reviewing studies by teleradiology should be sufficient to permit a primary final diagnosis, without reliance on later review of original images or other image data. The primary determinant of the acceptability of a teleradiology system therefore is its ability to provide the viewer with images and data of the same diagnostic content as the source images. The teleradiology system, protocols, and quality assurance must provide the reviewing physician the same diagnostically equivalent content and equivalent quality of information as would be expected if the study were performed and interpreted on site, without the use of teleradiology.

2. Dependence on practice standards. The single most important determinant of the quality of ultrasound image information and related ultrasound data received at the remote site is the quality of the study performed by the sonographer and/or physician examining the patient. Ultrasound examinations should therefore be conducted in compliance with published standards of the ACR, the American Institute of Ultrasound in Medicine (AIUM), or other recognized standard-setting bodies that relate to personnel qualifications, conduct of examinations, and communications. These include the ACR Standard for Teleradiology,⁴ the ACR Standard for Digital Image Management,⁵ the ACR Standard for Diagnostic Medical Physics Performance Monitoring of Real Time B-mode Ultrasound Equipment,⁶ the ACR Standard for Performing and Interpreting Diagnostic Ultrasound Examinations⁷ and other relevant AIUM and American Association of

Physicists in Medicine (AAPM) standards pertaining to image quality and interpretation standards.

3. Conformance levels. The requirements for teleultrasonography of ultrasound data in a given setting are influenced by the clinical setting, the urgency for interpretation, and the type of ultrasound examination performed. Requirements for examination content such as static images, multiframe images (cine loops) or real-time video, vary with the type of examination and the protocols in use. Since the transmission of multiframe images and real-time video impose special requirements for teleradiology, three conformance levels for teleultrasonography are proposed.

Conformance Level 1 - Sonographic studies consisting of one or more single still static grayscale or color images.

Conformance Level 2 – Level 1 studies plus multiframe image sequences (e.g., cine loops).

Conformance Level 3 – Level 2 plus real-time streaming video.

4. Relationship to Technical Standards. Where applicable, conformance with DICOM standards⁸ is strongly recommended. Minimal DICOM requirements for teleultrasonography are provided in Appendix I. Streaming video and other image formats currently not addressed by DICOM should use open standards for hardware and software to implement such features as videoconferencing, and Web-based access.

5. Security and Confidentiality. Teleradiology requires that medical images and text be transmitted over common carriers. Therefore, it is essential that patient confidentiality be maintained. Institutional policies and procedures related to security and confidentiality of patient data and compliance with the Health Insurance Portability and Accountability Act of 1996 (HIPAA)⁹ should apply to all teleultrasonography transactions.

6. Data Integrity and Preservation of Diagnostic Quality. Diagnostic image quality must be preserved in image transmission. The ultimate determinant of image quality is the physician. Thus, while certain physical parameters, such as the image size, the number of bits, and the frame rate, etc. must be preserved; the use of lossy image compression is allowable, provided that the diagnostic quality is not degraded.

SPECIFIC REQUIREMENTS

A teleultrasonography session may be viewed as a series of image handling and processing steps involving the acquisition of image data in a digital form, the transmission of these data and the viewing of the digital image information at a remote location. Each of these steps influences the overall performance of the system and has the potential to degrade image quality. Specific requirements intended to ensure reasonable system performance and preservation of diagnostic image quality are outlined in the following paragraphs.

1. Networking and Bandwidth. A key factor influencing system performance is the time necessary to transmit a diagnostic study from its source to the interpreting physician. Transmission time is largely a function of the bandwidth of the network used in transmission and the amount of data to be transferred. In addition to bandwidth, other considerations can affect system performance. In general, network connections used for telemedicine should meet the following criteria:

- Network bandwidth must be adequate to ensure timely transmission of the image data. Appendix II outlines bandwidth requirements for telemedicine for each level of compliance and provides examples of transmission times for images at several levels of lossless and lossy compression.
- Network uptime must be commensurate with the urgency of the studies being read.
- Network security should comply with the security requirements of the institution providing the data.
- Image transmission methods must be fault-tolerant.
- Where applicable, a negotiated quality of service is encouraged.

2. Display. The remote display device must permit replication of the original image quality. Display requirements are identical for all conformance levels defined on page 3. The remote display system must replicate the original image in terms of size and pixel matrix and provide 8 bit-gray scale or 24-bit color display. It shall have spatial, contrast, color, and temporal resolutions so as to render images at no less than the resolutions obtained at the originating site. The display monitor should meet minimum standards with respect to screen size, pixels, contrast ratio, dot pitch, number of images per monitor screen, and text display such that images may be displayed at their native resolution in a size comparable to that available in the primary location. In addition, the display monitor must be capable of displaying patient demographics and all other information displayed at the primary location including image labels, information presented in look-up tables (e.g., for fetal age, etc.), anatomic orientation, and scanning parameters. Information regarding image transmission parameters such as compression mode, and bandwidth, etc. should also be displayed on the monitor.

3. Verification of Image Quality. The goal of verification methods is to provide a rapid means for an observer to assess and establish that the image received is diagnostically equivalent to the original. This should be accomplished by evaluation of a side-by-side display of a locally stored version of a test image and the transmitted version of the same test image. This evaluation should be performed by the physician interpreting the remote image at the initiation of every reading session. The criterion for verification of image quality is the assessment of the interpreting physician that the

diagnostic quality of the transmitted image is equivalent to that of the test image.

The verification process should include an automatic display of the test images at the initiation of a teleonography session and require acknowledgement by receiver of satisfactory image quality. Ideally this should be accomplished by an automatic display of the reference and transmitted test images at the time of session initiation as a part of the log-on validation process with acknowledgement by the receiving physician of satisfactory image quality.

The key for assuring that image quality is maintained is the availability and regular use of standard methods and procedures to evaluate image acquisition, transmission, and display performance. Testing should check overall system performance sufficiently to ensure that the capture, transmission, and display processes do not significantly degrade the image or information being transmitted. In addition, it is important that the test procedures be done quickly (no more than 2 to 3 minutes) and be used at the initiation of every teleonography session. Finally, the test tools and procedures should be based on the assessment of the image quality by comparison with a reference image or image set by the physician responsible for interpretation of the transmitted study.

Test apparatus and methods should be easy to implement, reside on or be integral to the system being evaluated whenever possible, and utilize visual inspection as much as possible. Image test patterns are the preferred means of assessing system performance. Depending on the particular aspect of system performance being evaluated, the test patterns would be resident on the system under evaluation (e.g. acquisition, transmission or PACS, display) for comparison with another part of the system following acquisition or transmission.

Test procedures to verify preservation of diagnostic information during data acquisition, transmission and display are outlined below. Although some of the tests and methods relate to specific steps of the teleonography process, the objective of these measures is not to evaluate each step separately and independently, but rather to evaluate the overall performance of the system. Recommended procedures and troubleshooting strategies are further detailed in Appendix III.

Data Acquisition: During the acquisition phase, the primary goal is to confirm that the original image quality has been preserved. Images used in teleonography may be acquired by direct digital capture of image data, by video digitizer to capture a frame from the video display signal and by scanning a printed film using a scanner of sufficient quality.

Direct digital capture (usually into a PACS system) should be tested and verified as part of the initial PACS system setup,

precluding the need for further verification as a source for teleonography purposes.

Video digitizer performance will vary with the quality of the product used. Therefore, each digitizer should be independently evaluated in accord with procedures in Appendix IV(A). Special requirements for acquisition of multiframe images (cine loops) and streaming video are also addressed in Appendix IV (B, C). Verification should be performed at the initiation of each teleonography session.

Printed film scanner performance will vary with the quality of the product and thus each scanner should be independently evaluated in accord with procedures in Appendix IV(D). Verification should be performed at the initiation of each teleonography session.

Image Transmission: The primary goal of performance evaluation during the transmission phase is to ensure that transmission does not degrade the image and that error-correcting algorithms are a part of the process. In order to reduce transmission time, image compression may be used. Compression is allowed insofar as it meets the following requirements:

- Lossy and lossless compression are allowed for all compliance levels provided there is no compromise of diagnostic information.
- Compression must be explicitly described and allowed by the site policy and procedures manual.
- Images subjected to lossy compression must be so marked.

Verification of quality of transmission is accomplished by evaluation of a side-by-side display of a locally stored version of the test image and the transmitted version of the same test image. This evaluation should be performed by the physician interpreting the remote image at the initiation of every reading session. The criterion for verification of image quality is the assessment of the interpreting physician that the diagnostic quality of the transmitted image is equivalent to that of the test image.

Display: The primary goal of display evaluation is to confirm that the original image quality is replicated on the remote display device. Deviations in the quality of the image displayed at the remote site from the source image may reflect problems with the display itself, or with image acquisition or transmission.

Verification of display quality is accomplished by evaluation of a side-by-side display of a locally stored version of the test image with the transmitted version of the same test image. This evaluation should be performed by the physician interpreting the remote image at the initiation of every reading session. The

criterion for verification of image quality is the determination by the interpreting physician that the diagnostic quality of the image test patterns being compared is equivalent. In addition, procedures to evaluate proper operation of the remote display should include the ability to assess contrast, brightness, resolution, noise, uniformity, focus, dynamic range, color display, color fidelity and aspect ratio using a reference image. In addition to the verification procedures are outlined in Appendix IV, more specific display evaluation tools are discussed in Appendices V and VI.

SECURITY AND PATIENT CONFIDENTIALITY

In communicating between a remote site and a central site using a common carrier for the purpose of transmitting sonographic data, security mechanisms are essential. Compliance with HIPAA or equivalent standards is required. Security methods should ensure that the data may not be read by anyone other than the intended recipient. In addition, a mechanism to ensure data integrity should be provided so that the recipient can verify the received message is the same as the message that was originally sent. Identification of the data origin is essential to ensure that the message or transaction came from the person who is purported to have sent it. Non-repudiation is essential to ensure that a person who is claimed to have sent a message cannot later falsely deny having sent it. Finally, a form of user identification is essential. This may include passwords, biometric data, or digital signatures. Access control must be enforced to ensure that users have access only to those data that are specifically allowed by institutional policy and procedures.

In general, the security for remote sites will be governed by and should be in compliance with the policies and procedures for network security of the institution transmitting the images. For teleultrasonography, a virtual private network (VPN) is considered to be highly desirable to ensure privacy of electronic communications, including login and password information. In addition, all software communicating image data should encrypt or otherwise encode the image data and encrypt all text data. Compliance with institutional policies and procedures for protection of patient confidentiality in accord with HIPAA regulations is also required. Verification should be performed at the initiation of each teleultrasonography session.

APPENDICES

APPENDIX I DICOM REQUIREMENTS

1. Assumptions

These assumptions involve, in general, functions outside the scope of DICOM at present, but that are assumed in a teleonography system or for general support of the DICOM components needed.

A. Notification: Teleonography systems should have some way of notifying personnel at the site where studies are to be read that an examination has been sent.

B. Database: Depending on the receiving system design (stand-alone or PACS-based) it is assumed that at least a minimal database function exists so that, in the event that multiple examinations are sent to a site, that the site's system can retrieve them in a simple and fast manner for the radiologist. This may use the DICOM Query/Retrieve Service Class, but is not required to.

C. Storage: The storage of received studies should be set by agreements between the parties involved and be based on practice standards and regional legal requirements. Archival storage (if needed) may use the DICOM Storage Service Class, but is not required to.

2. General

The manufacturer of any device-claiming conformance to the DICOM Standard shall provide to the user (or potential user) a DICOM Conformance Statement for the device. This Conformance Statement shall meet the requirements set forth in DICOM PS 3.2-2000 (or, the most current version of the DICOM Standard) Part 2: Conformance¹⁹.

Conformance Level 1 as defined in this document should be considered a minimum requirement for all teleonography systems. In the event that the different components of a teleonography network do not all support the same levels, they must be able to default to Conformance Level 1.

3. Image acquisition

Three methods of acquiring images for teleonography as described in Specific Requirements, Data Acquisition, should conform to applicable parts of the DICOM Standard.

A. Film digitizer: Film digitizers are suitable for only Conformance Level 1 of this document (see General Requirements, section 3). Film digitizers shall

support the DICOM Storage Service Class as a Service Class User (SCU) for the following DICOM Information Object Definition:

1) Secondary Capture Image Information Object Definition

Note that the Secondary Capture Image Object Definition requires the General Image and Image Pixel modules (among others). The DICOM Image Pixel module does provide for color images, so a digitizer that can generate one of the color schemes supported by the Image Pixel module ²⁰ should be able to provide digitized color as well as black and white images.

B. Video digitizer: Video digitizers, or frame-grabbers, will typically support Conformance Level 1 of this document, though devices are available that can support Level 2 (with multiframe images). Conformance Level 3, with use of streaming video, requires use of services that are not yet part of the DICOM Standard.

Conformance Level 1: The video digitizer shall support the DICOM Storage Service Class as a Service Class User (SCU) for the following DICOM Information Object Definition:

1) Ultrasound Image Information Object Definition

Conformance Level 2: The video digitizer shall support the DICOM Storage Service Class as a Service Class User (SCU) for the following DICOM Information Object Definitions:

- 1) Ultrasound Image Information Object Definition
- 2) Ultrasound Multi-Frame Image Information Object Definition

Conformance Level 3: The video digitizer shall support the DICOM Storage Service Class as a Service Class User (SCU) for the following DICOM Information Object Definitions:

- 1) Ultrasound Image Information Object Definition
- 2) Ultrasound Multi-Frame Image Information Object Definition

In addition, Conformance Level 3 devices support real-time streaming video. There are no applicable DICOM Standards for this. However, it is expected that systems that can support streaming video will use existing Internet or videoconferencing standards.

C. Direct-capture ultrasound systems: Many currently available ultrasound machines have DICOM capability built-in. That is, they can output images that conform to the DICOM Standard over a DICOM Standard interface.

Most of these systems will support Conformance Levels 1 and 2 as now constituted.

Conformance Level 1: The direct capture ultrasound machine shall support the DICOM Storage Service Class as a Service Class User (SCU) for the following DICOM Information Object Definition:

- 1) Ultrasound Image Information Object Definition

Conformance Level 2: The direct capture ultrasound machine shall support the DICOM Storage Service Class as a Service Class User (SCU) for the following DICOM Information Object Definitions:

- 1) Ultrasound Image Information Object Definition
- 2) Ultrasound Multi-Frame Image Information Object Definition

Conformance Level 3: The direct capture ultrasound machine shall support the DICOM Storage Service Class as a Service Class User (SCU) for the following DICOM Information Object Definitions:

- 1) Ultrasound Image Information Object Definition
- 2) Ultrasound Multi-Frame Image Information Object Definition

In addition, Conformance Level 3 devices support real-time streaming video. There are no applicable DICOM Standards for this. However, it is expected that systems that can support streaming video will use existing Internet or videoconferencing standards.

4. Networking and communications systems

Conformance to DICOM requires the use of a compatible communications network. DICOM presently specifies the TCP/IP protocol operating over an IEEE 802.3 (ISO 8802-3) CSMA/CD network (commonly referred to as Ethernet). Teleonography systems may employ other communications networks, but if they do, the sending and receiving ends may require a device to perform protocol translation to and from TCP/IP to connect to DICOM-conformant devices.

The communications requirements for DICOM are described in DICOM PS3.5-2000 (Data Structures and Encoding), PS3.7-2000 (Message Exchange), and PS3.8-2000 (Network Support for Message Exchange).

5. Display systems (workstations)

For all conformance levels, support of the DICOM Grayscale Display Function Standard should be the base method for display standardization (DICOM PS3.14-2000).

Specific requirements:

A. Conformance Level 1: The workstation shall support the DICOM Storage Service Class as a Service Class Provider (SCP) for the following DICOM Information Objects:

- 1) Secondary Capture Image Information Object Definition
- 2) Ultrasound Image Information Object Definition

B. Conformance Level 2: The workstation shall support the DICOM Storage Service Class as a Service Class Provider (SCP) for the following DICOM Information Objects:

- 1) Secondary Capture Image Information Object Definition
- 2) Ultrasound Image Information Object Definition
- 3) Ultrasound Multi-Frame Image Information Object Definition

C. Conformance Level 3: The workstation shall support the DICOM Storage Service Class as a Service Class Provider (SCP) for the same Information Objects as for Conformance Level 2. In addition, for support of streaming video, there are no currently applicable DICOM standards. Such applications should use publicly available standard specifications (e.g., those for Internet streaming video or videoconferencing).

6. Use with PACS:

Some telemedicine applications will operate with a PACS as the device receiving the images. In this case, the interface device on the PACS (the device to which the remote systems send images; it may be a particular workstation, the PACS storage system, or a specific interface device) shall support the DICOM Storage Service Class as a Service Class Provider (SCP) for the same DICOM Information Object Definitions as for display systems (workstations). PACS may have a heterogeneous display environment; that is, workstations may be tailored to specific applications. In this case, if telemedicine applications are one of the classes to be supported, then at least one workstation at the reading site should support the DICOM requirements in Section 5 above.

7. Optional DICOM support

In some instances, either systems sending images or those receiving them (or both) may have information system infrastructure that supports additional

DICOM features. A radiology information system (RIS) that is integrated with a PACS or that has interfaces to imaging equipment may support features that potentially improve operational efficiency. Some of these features involve the use of DICOM Standard parts. Examples include (but are not limited to):

A. DICOM Modality Work list: Support of this DICOM component allows ultrasound machines to load appropriate patient demographic information directly to the machine. This obviates sonographer manual data entry.

B. DICOM Performed Procedure Step: Support this DICOM component allows an ultrasound machine to report back to another information system that a particular examination has been completed. This can replace several manual steps on the part of the sonographer.

C. DICOM Storage Commitment Service Class: Allows an application receiving DICOM images as part of DICOM Storage to notify the sending device that the receiving device has received the images and will take responsibility for them. In some environments, this allows the local sending device to delete the examination from its temporary storage.

D. DICOM Grayscale Softcopy Presentation State Storage Service Class: Allows a conformant application to store information related to how an image was displayed so that those display conditions may be reproduced for subsequent display of that image.

E. DICOM Structured Reporting: support of these information objects may potentially allow ultrasound systems to include measured values (e.g., obstetrical fetal biometry) with the images. Other applications (outside of the scope of DICOM) may then use this information to produce structured reports automatically or with reduced radiologist effort.

APPENDIX II BANDWIDTH REQUIREMENTS AND EXAMPLES

Conformance Level 1 (Static images only):

Assumptions: A typical study consists of 30 gray scale (8 bit) and 6 color (24 bit) images having a matrix of 640 x 480 pixels. Under these assumptions, the following transmission times are typical at the compression levels indicated:

Transmission	Compression		
	1:1	3:1 Lossless	10:1 Lossy
56k modem	37min 14sec	12min 25sec	3min 43sec
ISDN (2BRI)	15min 00sec	05min 00sec	1min 30sec
ISDN(6BRI)	05min 00sec	01min 40sec	0min 30sec
Cable Modem / DSL	03min 00sec	01min 00sec	0min 18sec
T1	01min 05sec	00min 25sec	0min 08sec
10 MB Ethernet	00min 11sec	00min 04sec	0min 01sec

Conformance Level 2 (Static images plus multiframe sequences (cine loops))

Assumptions: The following table estimates the time to transmit 3 to 6 second video loops, each 640 x 480 x 24 bit obtained at 15 frames per second. This time is in addition to the time to transmit still images (Level 1). The addition of video loops (multi-frame US objects) will necessarily increase the bandwidth requirements for teleonography.

Transmission	Compression		
	10:1	50:1	100:1
56k modem	62min 50sec	12min 34sec	6min 17sec
ISDN (2BRI)	25min 19sec	05min 04sec	2min 32sec
ISDN(6BRI)	08min 26sec	01min 41sec	0min 51sec
Cable Modem / DSL	05min 04sec	01min 01sec	0min 30sec
T1	02min 07sec	00min 25sec	0min 13sec
10 MB Ethernet	00min 19sec	00min 04sec	0min 02sec

Conformance Level 3:

The addition of real-time video further increases bandwidth requirements. The feasibility of transmitting real time video is estimated, assuming 640 x 480 x 24-bit images transmitted at 15 frames per second. As a point of reference, DVDs use approximately 25:1 compression, and typical web video is compressed 1000:1 or more. The table (below) shows whether transmission is possible for different compression factors and different bandwidths.

Transmission	Compression				
	10:1 lossy	50:1 lossy	100:1 lossy	500:1 lossy	1000:1 lossy
56k modem	No	No	No	No	No
ISDN (2BRI)	No	No	No	No	Yes
ISDN(6BRI)	No	No	No	Yes	Yes
Cable Modem / DSL	No	No	No	Yes	Yes
T1	No	No	Yes	Yes	Yes
10 MB Ethernet	No	Yes	Yes	Yes	Yes
100 MB Ethernet	Yes	Yes	Yes	Yes	Yes

For conformance level 3, the minimum acceptable bandwidth at various levels of compression is summarized below:

Compression	Minimum Bandwidth
10:1 Lossy	100 Mb Ethernet
50:1 Lossy	10 Mb Ethernet
100:1 Lossy	T1 (1.5 Mbs)
500:1 Lossy	ISDN (6BRI – 384 Kbs)
1000:1 Lossy	ISDN (2BRI – 128 Kbs)

Another approach currently in use is the sending of ultrasound video over real-time (H.320) video conferencing equipment by putting the US video output into an auxiliary input in the video code. This has been shown to be effective for fetal US and echocardiograms at 768Kbps.

APPENDIX III: TROUBLE SHOOTING GUIDELINES

If the image verification methods outlined in Appendix IV indicate a loss of diagnostic image quality in the transmitted image compared to the reference image, the following steps may aid in isolating the problem:

1. If the source images are film or print hardcopy, evaluate the film digitizer by re scanning and comparing scanner output to original image.
2. If the source images are acquired by a video frame grabber, repeat the frame grab and compare result with source scanner image.
3. If the film digitizer and video frame grabber show no errors, evaluate transmission/compression link by retransmission of the clinical image in question back to originating site for comparison with source image.
4. If problems persist, retransmit without compression.

As an additional step, mean squared errors for a series of degraded conditions (resolution degradation, added noise, color shift, geometric distortion) could be computed as a basis for establishing acceptance/rejection criteria.

APPENDIX IV - VERIFICATION PROCEDURES

A: Static video frame grabber performance

Video frame grabbers for static images should be evaluated with a commercial video test pattern generator and color bar generator. A video test pattern generator is substituted for the ultrasound machine as the input to the video frame grabber.¹⁰ An appropriate SMPTE,^{11,12,13} NTSC color bars, or custom pattern is then captured by the frame grabber and sent to the receiving site where comparison is made with a locally stored image of the same test pattern.

B: Multiframe image sequences

The video frame grabber for video loops (cine loops) should be evaluated with a dynamic test pattern generator designed to output a digitally stored sequence of video frames through a precision time base and digital to analog converter. A pattern consisting of a rotating image with a known angular increment per frame with the rotation rate determined by the video frame rate is suggested. In use, the dynamic video test pattern generator would be connected to the cine-loop capable video frame grabber and a sequence of images is sent to the receiving site. At the receiving workstation, the sequence is examined in real-time and frame-by-frame to check for out-of-sequence frames, discontinuities, or nonlinearities in the motion from frame to frame. For ultrasound systems that have direct DICOM Storage Service Class Support (US Multiframe object), an internally stored version of the cine loop would be transmitted to the receiving site.

Verification of dynamic performance (multi-frame and streaming video) could also be evaluated through the use of an *.AVI or *.QTW clip stored on the remote computer at a frame rate appropriate for the real time study being interpreted. This could be used to demonstrate the expected performance. This would permit the user be able to see what the proper display, frame-rate etc. would look like and then watch the streaming or multi-frame display to verify performance.

C - Real-time streaming video

A dynamic test pattern generator is required and is used with the same equipment as for the video frame grabber with loop capability. In this case, the dynamic generator should be capable of operation at the ultrasound image refresh rate (typically 7.5 to 30 frames per second depending upon the application, transducer frequency, or pulse frequency.) For some echocardiographic applications higher frame rates may be required. In use, the dynamic video test pattern generator is connected to the streaming video capture system and the dynamic test pattern is allowed to run. The dynamic video test pattern generator is set to generate frames at the rate the streaming video system is designed to support. The video stream is sent to the receiving site. At the site, the real-time video is viewed and a segment is captured. After capture, it is

examined frame-by-frame for out-of-sequence frames, discontinuities, or nonlinearities in the motion from frame to frame.

D – Static hardcopy images

Digitizers used for film or hard-copy color prints (e.g. color Doppler) should be calibrated using a film test pattern such as the SMPTE RP 133-1991 Test Image standard (<http://www.smpte.org/standards/medical.cfm>). In use, the calibrated film test pattern is digitized and sent to the interpretation site. At the site, the image of the test pattern is compared with a locally stored version. This is done visually.

E - Display Evaluation

A standard test image, such as the SMPTE test pattern, should be used to evaluate display contrast, brightness, resolution, noise, uniformity, focus, dynamic range, color display, color fidelity and aspect ratio.¹⁴ The test image(s) would be displayed both full screen and at the resolution and size of the clinical images to be evaluated. In use, a visual assessment of each parameter would be performed in accord with instructions specific for the test pattern used. For example, with the SMPTE test pattern the resolution for each area of the image (corners and center), the presence of noise in the image, the uniformity of the background gray-scale and the contrast scale, could be quickly evaluated along with grid and color patterns. Monitor adjustments to correct performance would be made to meet the minimum performance standard.

APPENDIX V-DISPLAY SET-UP AND DISPLAY FUNCTION

The following procedures are recommended for initial display set-up and periodic display quality assurance. Prior to testing, it is desirable to turn off the pedestal, an option on some display controllers, in order to allow brightness and contrast to be controlled independently.

1. Adjust room lighting to levels to be used during interpretation. (The level of illumination for interpretation should be low enough to permit the monitor to replicate all necessary brightness and contrast levels).
2. Set brightness and contrast controls to zero, then slowly increase the brightness control until the scanned raster on the otherwise dark CRT is barely visible. This luminance level is called the black level. If there is noticeable ambient, set the black level slightly above the ambient level.
3. Increase the contrast control until the maximum luminance; the working luminance or white level is reached. (For reference, a good white level is about 300 cd/m^2 , while a good black level is between 0.5 and 1 cd/m^2).
4. When practical for initial calibration, the preferred display function is the DICOM 14 Display Function Standard¹⁵. In general, this can be achieved only with a Calibration Software Package and a photometer such as the Dome TQA Package or the Image-Smiths VeriLUM Version 4.2. The DICOM test pattern^{15, 16}, consists of a white square in the center of the display, (the area of which is 10 % of the total display area), and a background area (the area outside the white square), the luminance of which is 20 % of the maximum luminance of the white square. The DICOM 14 Display Function Standard is generated by the respective calibration program. This program generates various luminance values in the white square, which are measured with the photometer while it is held firmly against the white square. These luminance values are used to generate look-up tables on the display controllers which in turn produce the DICOM 14 Display Function Standard.
5. After the calibration procedure the user should display the SMPTE pattern and make sure that the 0 to 5% and the 95 to 100% contrast patches are clearly visible.

**APPENDIX VI - AAPM TASK GROUP 18
ASSESSMENT OF DISPLAY PERFORMANCE FOR MEDICAL IMAGING
SYSTEMS.**

For some time a task group organized by the American Association of Physicists in Medicine (AAPM) worked on a report, concerned with the assessment of display performance for medical imaging systems¹⁷. It is expected that this report will be completed and accepted by the appropriate channels at AAPM early in the year 2002¹⁸. This report will be of particular interest to the Pilot Project to Develop a Process for Defining Teleradiology Protocols for Diagnostic Sonography because of advanced test patterns, which go beyond the SMPTE pattern and permit image quality assessment to be made more easily.

It is recommended that as soon as the report of the AAPM Task Group 18 is completed the "Pilot Project to Develop a Process for Defining Teleradiology Protocols for Diagnostic Sonography" be revised to include appropriate test patterns and assessment procedures of the report of the AAPM Task Group 18.

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