Digital Imaging and Communications in Medicine (DICOM)

Supplement 30: Waveform Interchange

DICOM Standards Committee, Working Group 1 - Cardiac and Vascular Information

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Introduction

DICOM Working Group 1 - Cardiac and Vascular Information has undertaken the work task to develop this proposed DICOM Supplement to address the robust interchange of waveform and related data in DICOM. This work primarily targets cardiology waveforms, including electrocardiographic and hemodynamic signals, but WG1 has endeavored to ensure it is applicable to a broad range of waveforms when acquired in a medical imaging environment.

DOMAIN OF APPLICATION

Waveform acquisition is part of both the medical imaging environment and the general clinical environment. Because of its broad use, there has been significant previous and complementary work in waveform standardization of which WG1 has taken note:

ASTM E31.16 - E1467 Specification for Transferring Digital Neurophysiogical Data Between Independent Computer Systems

CEN TC251 PT5-007 - prENV1064 draft Standard Communications Protocol for Computer-Assisted Electrocardiography (SCP-ECG).

CEN TC251 PT5-021 - draft Vital Signs Information Representation Standard (VITAL)

HL7 Automated Data SIG - HL7 Version 2.3, Chapter 7.14-20

IEEE P1073 - draft Medical Information Bus Standard (MIB)

DICOM - NEMA PS3.3, Section A.10 Standalone Curve Information Object Definition

The domain of this Supplement is waveform acquisition within the imaging context. It is specifically meant to address waveform acquisitions which will be analyzed with other data which is transferred and managed using the DICOM protocol. It allows the addition of waveform data to that context with minimal incremental cost. Further, it leverages the DICOM persistent object capability for maintaining referential relationships to other data collected in a multi-modality environment, including references necessary for multi-modality synchronization.

Waveform interchange in other clinical contexts may use different protocols more appropriate to those environments. In particular, HL7 may be used for transfer of waveform observations to general clinical information systems, and MIB may be used for real-time physiological monitoring and therapy.

The waveform information object definition herein has been specifically harmonized at the semantic level with the HL7 waveform message format. The use of a common object model allows straightforward transcoding and interoperation between systems that use DICOM for waveform interchange and those that use HL7, and may be viewed as an example of common semantics implemented in the differing syntaxes of two messaging systems.

Note: HL7 allows transport of DICOM SOP Instances (information objects) encapsulated within HL7 messages. Since the DICOM and HL7 waveform semantics are harmonized, DICOM Waveform SOP Instances need not be transported as encapsulated data, as they can be transcoded to native HL7 Waveform Observation format.

USE CASES

The following are specific use case examples for waveforms in the imaging environment.

Case 1: Catheterization Laboratory - During a cardiac catheterization, several independent pieces of data acquisition equipment may be brought together for the exam. An electrocardiographic subsystem records surface ECG waveforms; an X-ray angiographic subsystem records motion images; a hemodynamic subsystem records intracardiac pressures from a sensor on the catheter. These subsystems send their acquired data by network to a

repository. These data are assembled at an analytic workstation by retrieving from the repository. For a left ventriculographic procedure, the ECG is used by the physician to determine the time of maximum and minimum ventricular fill, and when coordinated with the angiographic images, an accurate estimate of the ejection fraction can be calculated. For a valvuloplasty procedure, the hemodynamic waveforms are used to calculate the pre-intervention and post-intervention pressure gradients.

Case 2: Electrophysiology Laboratory - An electrophysiological exam will capture waveforms from multiple sensors on a catheter; the placement of the catheter in the heart is captured on an angiographic image. At an analytic workstation, the exact location of the sensors can thus be aligned with a model of the heart, and the relative timing of the arrival of the electrophysiological waves at different cardiac locations can be mapped.

Case 3: Stress Exam - A stress exam may involve the acquisition of both ECG waveforms and echocardiographic ultrasound images from portable equipment at different stages of the test. The waveforms and the echocardiograms are output on an interchange disk, which is then input and read at a review station. The physician analyzes both types of data to make a diagnosis of cardiac health.

OVERVIEW OF THE WAVEFORM STANDARD

This Supplement was developed in accordance with the standard development process of the DICOM Standards Committee. It includes changes to Parts 3, 4, 5, 6, and 11 of the DICOM Standard (NEMA PS3).

DICOM has had a rudimentary mechanism to interchange waveform data, the Curve Information Entity, used within the Standalone Curve Information Object and within other composite image objects. This Supplement follows the general approach of that capability, but refines it for the specific requirements of time-based waveforms, and makes its syntax and semantics more robust.

The waveform information objects are generalization of the class of DICOM composite image information objects. The hierarchical structure of patient/study/series/object instances, represented by the canonical DICOM image information model, is unchanged. The changes to Part 3 of the DICOM Standard include modification of the Composite Image Information Model to include waveforms as well as pixel data, and an informative annex describing the waveform data model.

Digitization of waveform samples is defined within this proposal using linear scales, using 8- or 16-bit integer quantities. Provision has also been made for μ-law and A-law non-linear scaled data for audio data, as defined in ITU-T Recommendation G.711.

Note that in DICOM communications, compression is selected at the time of data transfer by negotiating a Transfer Syntax; a compressed Transfer Syntax for waveform data is thus independent of the waveform information object definition specified in this Supplement. While such a compressed waveform Transfer Syntax has not been proposed, that is an area for future work complementing this Supplement. In the meantime, the various uncompressed Transfer Syntaxes are available for waveforms (see DICOM Part 5).

The syntax proposed for waveform structures differs from data elements currently defined within the Curve Information Entity. In developing the Waveform definition, WG1 had the option of continuing the use of Repeating Groups (see DICOM Part 5, Section 7.6) for the syntax of curves, or of moving to the construct of Sequences. The latter approach was adopted based on an explicit intent stated in Part 5 to move away from Repeating Groups.

TIME SYNCHRONIZATION FRAME OF REFERENCE

Synchronization of acquisition across multiple modalities in a single study (e.g., angiography and electrocardiography) requires either a shared trigger, or a shared clock. This Supplement proposes a Synchronization Module within the Frame of Reference Information Entity to specify the synchronization mechanism. A common temporal environment used by multiple equipment is identified by a shared Synchronization Frame of Reference UID. How this UID is determined and distributed to the participating equipment is outside the scope of the standard.

The method used for time synchronization of equipment clocks is implementation or site specific, and therefore outside the scope of this proposal. If required, standard time distribution protocols are available (e.g., NTP, IRIG, GPS).

An informative description of time distribution methods can be found at: http://www.bancomm.com/cntpApp.htm

A second method of synchronizing acquisitions is to utilize a common reference channel (temporal fiducial), which is recorded in the data acquired from the several equipment units participating in a study, and/or which is used to trigger synchronized data acquisitions. For instance, the "X-ray on" pulse train which triggers the acquisition of frames for an X-ray angiographic SOP Instance can be recorded as a waveform channel in a simultaneously acquired hemodynamic waveform SOP Instance, and can be used to align the different object instances. Associated with this Supplement are proposed coded entry channel identifiers to specifically support this synchronization mechanism (DICOM Terminology Mapping Resource Context Group ID 3090).

ANNOTATION

WG1 has identified a common clinical use for waveform annotations. These annotations are typically generated automatically as part of the data acquisition, such as waveform maxima and minima (peak detection), or labeling of particular stimuli. These annotations are considered an integral to the presentation (display) of waveforms.

Within the current DICOM image information object data model there are two basic mechanisms for annotating an image, especially to describe a Region Of Interest (ROI) - overlays and outline curves. However, these mechasnisms operate at the display, rather than the semantic, level. Since waveform display is not specified in this Supplement, overlays are not an appropriate annotation construct.

This Supplement therefore introduces a new Waveform Annotation Module, which may be carried within the composite waveform information objects. The annotation is fundamentally a label, with a pointer to the ROI in the waveform. ROI references are provided for waveforms down to individual samples, and for absolute or relative temporal ROIs.

The format of annotation is consistent with that of Structured Report observations proposed in DICOM Supplement 23 - Structured Reporting. Labels may be textual; alternatively, annotations may make use of coded entries instead of text, with appropriate controlled vocabulary lists. The coded entry will describe the semantic concept carried by the label. In addition to the label concept, a quantitative value for that attribute can be specified in a numeric field, or a qualitative value can be specified using a controlled vocabulary in an associated coded entry.

WAVEFORMS IN IMAGE OBJECTS

In general, in DICOM an object is of a single modality. However, DICOM does allow object instances which include both image and curve data. In this case, the curve data is considered ancillary to the image data; so, for instance, the modality attribute will indicate the imaging modality.

Although the Waveform Module defined in this Supplement facilitates the update of IODs to allow use of the Waveform Module, rather than the Curve Module, to handle waveforms in image objects, such updates are not part of this Supplement. Such changes would require a new SOP Class UID for the objects of the updated definition, and are thus in the purview of the Working Groups responsible for the IODs of the various modalities.

WAVEFORM DISPLAY

How a workstation displays or processes data objects has generally been beyond the scope of the DICOM standard. In the current case, the waveform object carries the raw waveform sample data only, it does not specify how the waveforms are to be displayed. Determining an appropriate display is left to the ingenuity and innovation of manufacturers, who must take into account their knowledge of the clinical environment and effective user interfaces.

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Changes to:

242 ## NEMA Standards Publication PS 3.3-1999

Digital Imaging and Communications in Medicine (DICOM)

244 ## *Part 3: Information Object Definitions*

246

1. Add item to Section 2 Normative References

ITU-T Recommendation G.711 (1988) - Pulse code modulation (PCM) of voice frequencies

2. Add waveform IE to Figure A.1-1

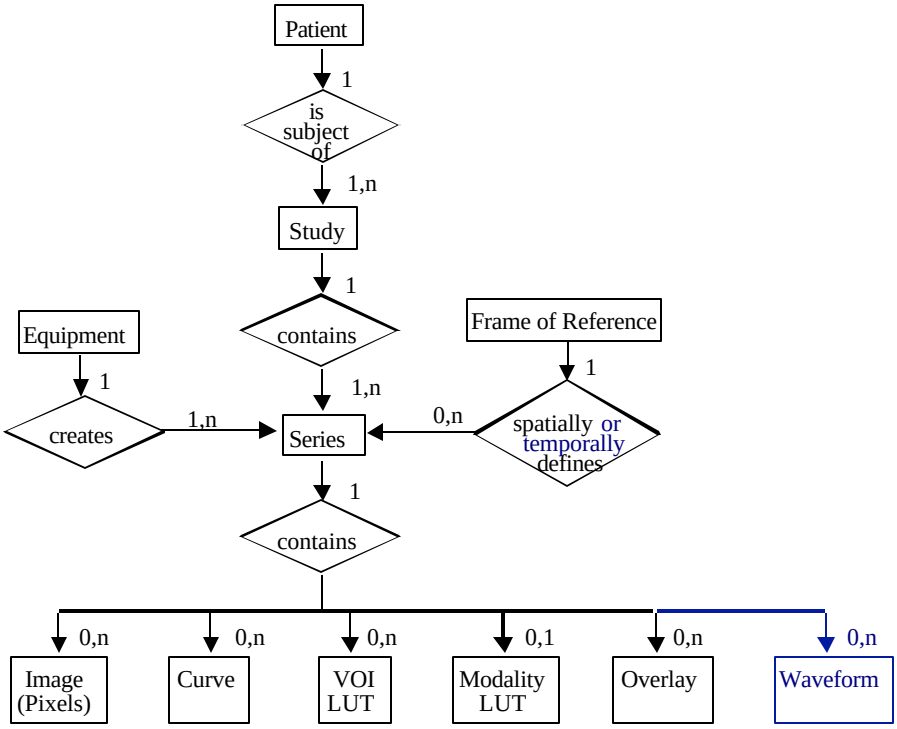


Figure A.1-1
DICOM Composite Image IOD Information Model

3. Modify section A.1.2.3 Series IE

A.1.2.3 SERIES IE

The Series IE defines the Attributes which are used to group ~~images, presentation states, overlays and/or curves~~ composite instances into distinct logical sets. Each series is associated with exactly one Study.

The following criteria groups ~~images~~ composite instances into a specific series:

a. All composite instances within a series must be of the same modality

b. If a specific Composite Instance IOD specifies the support of a Frame of Reference IE, all composite instances within the series shall be spatially or temporally related to each other; therefore, each series is associated with exactly one Frame of Reference IE

c. If a specific Composite Instance IOD specifies the support of the Equipment IE, all composite instances within the series shall be created by the same equipment; therefore, each series is associated with exactly one Equipment IE

d. All composite instances within a series shall have the same series information

Overlays and Curves may be grouped into a Series with or without Images. The Equipment IE and Frame of Reference IE are irrelevant to the Overlay IE and Curve IE.

Presentation States shall be grouped into Series without Images (i.e. in a different Series from the Series containing the Images to which they refer). The Frame of Reference IE is irrelevant to the Presentation State IE.

Note: The Series containing Presentation States and the Series containing the Images to which they refer are both contained within the same Study.

Waveforms shall be grouped into Series without Images. A Frame of Reference IE may apply to both Waveform Series and Image Series.

4. Add section A.1.2.11 Waveform IE

A.1.2.11 WAVEFORM IE

The Waveform IE represents a multi-channel time-based digitized waveform. The waveform consists of measurements of some physical qualities (e.g., electrical voltage, pressure, gas concentration, or sound), sampled at constant time intervals. The measured qualities may originate, for example, in any of the following sources:

a. the anatomy of the patient,

b. therapeutic equipment (e.g., a cardiac pacing signal or a radio frequency ablation signal),

c. equipment for diagnostic synchronization (e.g., a clock or timing signal used between distinct devices),

d. the physician's voice (e.g., a dictated report).

The sample data within a Waveform IE may represent one or more acquired channels. Several signal channels acquired at the same sampling rate can be multiplexed (by interleaving samples) in a single multiplex group. (See also Annex W.)

5. Modify Table A.1-1 to add Waveform Object column and Synchronization Module and Waveform Module rows

Specific change to add Waveform Object column and Synchronization Module and Waveform Module rows to the Composite Information Object Modules Overview table left to the discretion of the DICOM Standards Editor.

6. Add Section A.j to provide IODs for various waveform objects

A.J WAVEFORM INFORMATION OBJECT DEFINITIONS

A.j.1 Waveform IOD Entity-Relationship Model

The Waveform E-R Model is shown in Figure A.j-1. This model applies to a variety of Waveform IODs.

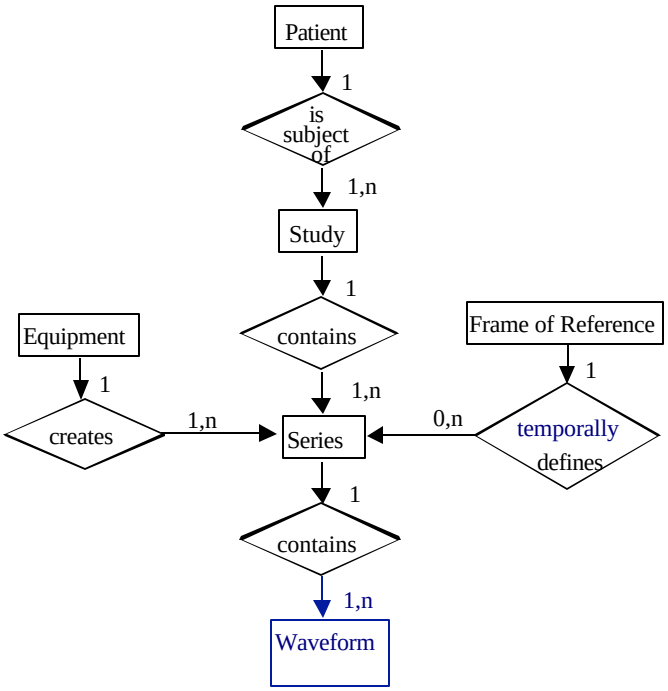


Figure A.j-1
DICOM Waveform IOD Information Model

A.j.2 Basic Voice Audio Information Object Definition

A.j.2.1 Basic Voice Audio IOD Description

The Basic Voice Audio IOD is the specification of a digitized sound which has been acquired or created by an audio modality or by an audio acquisition function within an imaging modality. A typical use is report dictation.

A.j.2.2 Basic Voice Audio IOD Entity-Relationship Model

The E-R Model in Section A.j.1 of this Part applies to the Basic Voice Audio IOD.

A.j.2.3 Basic Voice Audio IOD Module Table

Table A.j.2-1
Basic Voice Audio IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
Series	General Series	C.7.3.1	M
Frame of Reference	Synchronization	C.7.4.2	U
Equipment	General Equipment	C.7.5.1	M
Waveform	Waveform Identification	C.10.4	M
	Waveform	C.10.5	M
	Acquisition Context	C.7.6.14	M
	Waveform Annotation	C.10.6	U
	SOP Common	C.12.1	M

A.j.2.4 Basic Voice Audio IOD Content Constraints

A.j.2.4.1 Modality

The value of Modality (0008,0060) shall be AU.

A.j.2.4.2 Waveform Sequence

The number of Waveform Sequence (5400,0100) Items shall be one.

A.j.2.4.3 Number of Channels

The value of the Number of Channels (003A,0005) in the Waveform Sequence Item shall be 1 or 2.

A.j.2.4.4 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in the Waveform Sequence Item shall be 8000.

A.j.2.4.5 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in the Waveform Sequence Item shall be UB, MB, or AB.

A.j.3 12-Lead Electrocardiogram Information Object Definition

A.j.3.1 12-Lead ECG IOD Description

The 12-Lead Electrocardiogram (12-Lead ECG) IOD is the specification of digitized electrical signals from the patient cardiac conduction system collected on the body surface, which has been acquired by an ECG modality or by an ECG acquisition function within an imaging modality.

A.j.3.2 12-Lead ECG IOD Entity-Relationship Model

The E-R Model in Section A.j.1 of this Part applies to the 12-Lead ECG IOD.

A.j.3.3 12-Lead ECG IOD Module Table

Table A.j.3-1
12-Lead ECG IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
Series	General Series	C.7.3.1	M
Frame of Reference	Synchronization	C.7.4.2	U
Equipment	General Equipment	C.7.5.1	M
Waveform	Waveform Identification	C.10.4	M
	Waveform	C.10.5	M
	Acquisition Context	C.7.6.14	M
	Waveform Annotation	C.10.6	C – required if annotation is present
	SOP Common	C.12.1	M

A.j.3.4 12-Lead ECG IOD Content Constraints

A.j.3.4.1 Modality

The value of Modality (0008,0060) shall be ECG.

A.j.3.4.2 Acquisition Context Module

For SOP Instances of ECG acquired in the cardiac catheterization lab, the Defined Template for Acquisition Context Sequence (0040,0555) is TID 3403. For routine resting or stress ECG, the Defined Template for Acquisition Context Sequence (0040,0555) is TID 3401.

A.j.3.4.3 Waveform Sequence

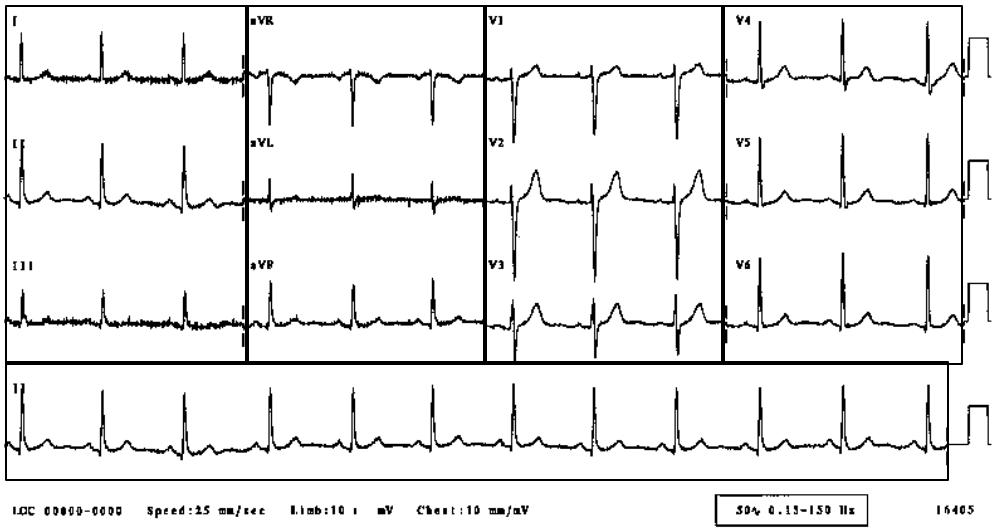
The number of Waveform Sequence (5400,0100) Items shall be between 1 and 5, inclusive.

A.j.3.4.4 Number of Channels

The value of the Number of Channels (003A,0005) in each Waveform Sequence Item shall be between 1 and 13, inclusive. The total number of channels encoded across all Items shall not exceed 13.

Note: This specialization provides for up to five Waveform Sequence Items (multiplex groups), with a total of 13 channels. This allows, for instance, encoding of four sets of three simultaneously recorded channels, the sets being acquired sequentially, plus one continuous channel for the duration of the other sets. This can be used

to emulate the behavior of classical 12-lead ECG strip chart recorders with 4x3 presentation, plus a continuous lead II recording (see figure).



Multiplex Group 1 – leads I, II, III; time offset 0; duration 2.5 s
Multiplex Group 2 – leads aVR, aVL, aVF; time offset 2.5 s; duration 2.5 s
Multiplex Group 3 – leads V1, V2, V3; time offset 5.0 s; duration 2.5 s
Multiplex Group 4 – leads V4, V5, V6; time offset 7.5 s; duration 2.5 s
Multiplex Group 5 – lead II; time offset 0; duration 9.84 s

FIGURE A.j.3-1 12-Lead ECG Example (Informative)

A.j.3.4.5 Number of Samples

The value of the Number of Samples (003A,0010) in each Waveform Sequence Item shall be less than or equal to 16384.

Note: This allows over 16 seconds per channel at the maximum sampling frequency; if longer recordings are required, the General ECG IOD may be used.

A.j.3.4.6 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in each Waveform Sequence Item shall be between 200 and 1000, inclusive.

A.j.3.4.7 Channel Source

The Baseline Context ID for the Channel Source (003A,0208) in each Channel Definition Sequence Item shall be CID 3001.

A.j.3.4.8 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in each Waveform Sequence Item shall be SS.

A.j.3.4.9 Waveform Annotation Module

The Defined Context ID for the Concept Name Code Sequence (0040,A043) in the Waveform Annotation Sequence (0040,B020) shall be CID 3335. This Context Group supports the annotation of suppressed pacemaker spikes in the ECG waveform.

A.j.4 General Electrocardiogram Information Object Definition

A.j.4.1 General ECG IOD Description

The General Electrocardiogram (ECG) IOD is the specification of digitized electrical signals from the patient cardiac conduction system collected on the body surface, which has been acquired by an ECG modality or by an ECG acquisition function within an imaging modality.

A.j.4.2 General ECG IOD Entity-Relationship Model

The E-R Model in Section A.j.1 of this Part applies to the General ECG IOD.

A.j.4.3 General ECG IOD Module Table

Table A.j.4-1
General ECG IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
Series	General Series	C.7.3.1	M
Frame of Reference	Synchronization	C.7.4.2	U
Equipment	General Equipment	C.7.5.1	M
Waveform	Waveform Identification	C.10.4	M
	Waveform	C.10.5	M
	Acquisition Context	C.7.6.14	M
	Waveform Annotation	C.10.6	C – required if annotation is present
	SOP Common	C.12.1	M

A.j.4.4 General ECG IOD Content Constraints

A.j.4.4.1 Modality

The value of Modality (0008,0060) shall be ECG.

A.j.4.4.2 Waveform Sequence

The number of Waveform Sequence (5400,0100) Items shall be between 1 and 4, inclusive.

A.j.4.4.3 Number of Channels

The value of the Number of Channels (003A,0005) in each Waveform Sequence Item shall be between 1 and 24, inclusive.

A.j.4.4.4 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in each Waveform Sequence Item shall be between 200 and 1000, inclusive.

A.j.4.4.5 Channel Source

The Defined Context ID for the Channel Source (003A,0208) in each Channel Definition Sequence Item shall be CID 3001.

Note: Terms from other Context Groups may also be used for extended specification of the Channel Source, as declared in the Conformance Statement for an application (see PS3.2).

A.j.4.4.6 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in each Waveform Sequence Item shall be SS.

A.j.4.4.7 Waveform Annotation Module

The Defined Context ID for the Concept Name Code Sequence (0040,A043) in the Waveform Annotation Sequence (0040,B020) shall be CID 3335. This Context Group supports the annotation of suppressed pacemaker spikes in the ECG waveform.

A.j.5 Ambulatory Electrocardiogram Information Object Definition

A.j.5.1 Ambulatory ECG IOD Description

The Ambulatory Electrocardiogram (ECG) IOD is the specification of digitized electrical signals from the patient cardiac conduction system collected on the body surface, which has been acquired by an ambulatory electrocardiography (Holter) device.

Note: The duration of acquisition represented in one SOP Instance is not specifically constrained, and is limited only by the maximum size of the Waveform Data attribute.

A.j.5.2 Ambulatory ECG IOD Entity-Relationship Model

The E-R Model in Section A.j.1 of this Part applies to the Ambulatory ECG IOD.

A.j.5.3 Ambulatory ECG IOD Module Table

Table A.j.5-1
Ambulatory ECG IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
Series	General Series	C.7.3.1	M
Frame of Reference	Synchronization	C.7.4.2	U
Equipment	General Equipment	C.7.5.1	M
Waveform	Waveform Identification	C.10.4	M
	Waveform	C.10.5	M
	Acquisition Context	C.7.6.14	U
	Waveform Annotation	C.10.6	C – required if annotation is present
	SOP Common	C.12.1	M

A.j.5.4 Ambulatory ECG IOD Content Constraints

A.j.5.4.1 Modality

The value of Modality (0008,0060) shall be ECG.

A.j.5.4.2 Waveform Sequence

The number of Waveform Sequence (5400,0100) Items shall be be 1.

A.j.5.4.3 Number of Channels

The value of the Number of Channels (003A,0005) in the Waveform Sequence Item shall be between 1 and 12, inclusive.

A.j.5.4.5 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in each Waveform Sequence Item shall be between 50 and 1000, inclusive.

A.j.5.4.6 Channel Source

The Defined Context ID for the Channel Source (003A,0208) in each Channel Definition Sequence Item shall be CID 3001.

A.j.5.4.7 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in each Waveform Sequence Item shall be SB or SS.

A.j.6 Hemodynamic Information Object Definition

A.j.6.1 Hemodynamic IOD Description

The Hemodynamic IOD is the specification of digitized pressure, electrical, and other signals from the patient circulatory system, which has been acquired by a hemodynamic modality.

Note: The duration of acquisition represented in one SOP Instance is not specifically constrained, and is limited only by the maximum size of the Waveform Data attribute.

A.j.6.2 Hemodynamic IOD Entity-Relationship Model

The E-R Model in Section A.j.1 of this Part applies to the Hemodynamic IOD.

A.j.6.3 Hemodynamic IOD Module Table

Table A.j.6-1
Hemodynamic IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
Series	General Series	C.7.3.1	M
Frame of Reference	Synchronization	C.7.4.2	C – Required if Waveform Originality (003A,0004) is ORIGINAL; may be present otherwise
Equipment	General Equipment	C.7.5.1	M
Waveform	Waveform Identification	C.10.4	M
	Waveform	C.10.5	M
	Acquisition Context	C.7.6.14	M
	Waveform Annotation	C.10.6	C – required if annotation is present
	SOP Common	C.12.1	M

A.j.6.4 Hemodynamic IOD Content Constraints

A.j.6.4.1 Modality

The value of Modality (0008,0060) shall be HD.

A.j.6.4.2 Acquisition Context Module

The Defined Template for Acquisition Context Sequence (0040,0555) is TID 3403.

A.j.6.4.3 Waveform Sequence

The number of Waveform Sequence (5400,0100) Items shall be between 1 and 4, inclusive.

A.j.6.4.4 Number of Channels

The value of the Number of Channels (003A,0005) in each Waveform Sequence Item shall be between 1 and 8, inclusive.

A.j.6.4.5 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in each Waveform Sequence Item shall be less than or equal to 400.

A.j.6.4.7 Channel Source

The Defined Context ID for the Channel Source Sequence (003A,0208) in each Channel Definition Sequence Item shall be CID 3003, CID 3001 for surface ECG channels, or CID 3090 for time synchronization channels. The Channel Source Code Value shall encode at minimum the metric (measured physical quality) and function (measurement or stimulus); unless otherwise specifically encoded, the default function shall be “measurement”.

The Channel Source Modifiers Sequence (003A,0209) in each Channel Definition Sequence Item shall be used to specify additional qualifiers of the semantics of the waveform source, including technique and anatomic location, if not encoded by the Channel Source Code Value. Technique, with terms from Defined Context ID 3241, shall be specified in Channel Source Modifiers Sequence Items prior to the cardiac anatomic location(s), with terms from Defined Context ID 3010, 3014, and 3019. If technique is pullback, the sequence of anatomic locations shall be specified in ordered Channel Source Modifiers Sequence Items (e.g., initial, transitional, and final locations).

Note: Terms from other Context Groups may also be used for extended specification of the Channel Source, as declared in the Conformance Statement for an application (see PS3.2).

A.j.6.4.8 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in each Waveform Sequence Item shall be SS.

A.j.6.4.9 Waveform Annotation Module

The Defined Context ID for the Concept Name Code Sequence (0040,A043) in the Waveform Annotation Sequence (0040,B020) shall be CID 3337.

A.j.7 Basic Cardiac Electrophysiology Information Object Definition

A.j.7.1 Basic Cardiac EP IOD Description

The Basic Cardiac Electrophysiology IOD is the specification of digitized electrical signals from the patient cardiac conduction system collected in the heart, which has been acquired by an EP modality.

Note: The duration of acquisition represented in one SOP Instance is not specifically constrained, and is limited only by the maximum size of the Waveform Data attribute.

A.j.7.2 Basic Cardiac EP IOD Entity-Relationship Model

The E-R Model in Section A.j.1 of this Part applies to the Cardiac EP IOD.

A.j.7.3 Basic Cardiac EP IOD Module Table

Table A.j.7-1
Basic Cardiac EP IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
Series	General Series	C.7.3.1	M
Frame of Reference	Synchronization	C.7.4.2	C – Required if Waveform Originality (003A,0004) value is ORIGINAL; may be present otherwise
Equipment	General Equipment	C.7.5.1	M
Waveform	Waveform Identification	C.10.4	M
	Waveform	C.10.5	M
	Acquisition Context	C.7.6.14	M
	Waveform Annotation	C.10.6	C – required if annotation is present
	SOP Common	C.12.1	M

A.j.7.4 Basic Cardiac EP IOD Content Constraints

A.j.7.4.1 Modality

The value of Modality (0008,0060) shall be EPS.

A.j.7.4.2 Acquisition Context Module

The Defined Template for Acquisition Context Sequence (0040,0555) is TID 3450.

A.j.7.4.3 Waveform Sequence

The number of Waveform Sequence (5400,0100) Items shall be between 1 and 4, inclusive.

A.j.7.4.4 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in each Waveform Sequence Item shall be less than or equal to 2000.

A.j.7.4.5 Channel Source

The Defined Context ID for the Channel Source Sequence (003A,0208) in each Channel Definition Sequence Item shall be CID 3011. The Channel Source Code Value shall encode at minimum the anatomic location of the channel source.

The Channel Source Modifiers Sequence (003A,0209) in each Channel Definition Sequence Item shall be used to specify additional qualifiers of the semantics of the waveform source, including metric (measured physical quality), function (measurement or stimulus), and technique from Defined Context ID 3240, and anatomic location qualifiers from Defined Context ID 3019, if not encoded by the Channel Source Code Value. If not explicitly encoded, the default metric and function shall be “voltage measurement”. If a differential signal is used, that shall be indicated in a Modifier Item, and the positive pole and negative pole identified in the subsequent two modifiers.

Notes:

1. Terms from other Context Groups may also be used for extended specification of the Channel Source, as declared in the Conformance Statement for an application (see PS3.2).

2. A differential signal from the high right atrium , where electrode 1 on the catheter is the positive pole and electrode 3 the negative pole, could be specified by coded terms meaning:

Channel Source: “High Right Atrium”

Channel Source Modifiers: “Differential”, “E1”, “E3”

(Implicit default modifier: “Voltage Measurement”)

A.j.7.4.6 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in each Waveform Sequence Item shall be SS.

A.j.7.4.7 Waveform Annotation Module

The Defined Context ID for the Concept Name Code Sequence (0040,A043) in the Waveform Annotation Sequence (0040,B020) shall be CID 3339.

7. Modify Section C.7.3.1 General Series Module to define Waveform Modalities

C.7.3.1 General Series Module

…

C.7.3.1.1.1 Modality

…

Defined Terms for the Modality (0008,0060) are:

…

AU – Audio
ECG – Electrocardiography
EPS – Cardiac Electrophysiology
HD – Hemodynamic Waveform

8. Add Section C.7.4.2 to define temporal frame of reference synchronization module

C.7.4 Common Frame Of Reference Information Entity Modules

~~The following Frame of Reference IE Module is common to all Composite Image IODs which reference the Frame of Reference IE.~~

…

C.7.4.2 Synchronization Module

Table C.7.4.2-1 specifies the Attributes necessary to uniquely identify a frame of reference which establishes the temporal relationship of SOP Instances. A synchronized environment may be established based on a shared time of day clock, and/or on a shared trigger event or synchronization waveform channel.

Note: Within a synchronized environment, different devices may use the shared data differently. An electrical pulse, for example, may be treated as a trigger event by one device (e.g., an x-ray imaging system), but may be recorded as a synchronization waveform by another device (e.g., a hemodynamics system).

Table C.7.4.2-1
Synchronization Module Attributes

Attribute Name	Tag	Type	Attribute Description
Synchronization Frame of Reference UID	(0020,0200)	1	UID of common synchronization environment. See C.7.4.2.1.1.
Synchronization Trigger	(0018,106A)	1	Data acquisition synchronization with external equipment Enumerated Values: SOURCE - this equipment provides synchronization channel or trigger to other equipment EXTERNAL - this equipment receives synchronization channel or trigger from other equipment PASSTHRU - this equipment receives synchronization channel or trigger and forwards it NO TRIGGER - data acquisition not synchronized by common channel or trigger
Trigger Source or Type	(0018,1061)	3	Specifies equipment ID of trigger source and/or type of trigger

Synchronization Channel	(0018,106C)	1C	Identifier of waveform channel which records the synchronization channel or trigger, see C.7.4.2.1.3. Required if synchronization channel or trigger is encoded in a waveform in this SOP Instance
Acquisition Time Synchronized	(0018,1800)	1	Acquisition Datetime (0008,002A) synchronized with external time reference. Enumerated Values: Y, N See C.7.4.2.1.4
Time Source	(0018,1801)	3	ID of equipment or system providing time reference
Time Distribution Protocol	(0018,1802)	3	Method of time distribution used to synchronize this equipment. Defined Terms: NTP - Network Time Protocol IRIG - InterRange Instrumentation Group GPS - Global Positioning System

C.7.4.2.1 Synchronization Attribute Descriptions

C.7.4.2.1.1 Synchronization Frame of Reference UID

A set of equipment may share a common acquisition synchronization environment, which is identified by a Synchronization Frame of Reference UID. All SOP Instances which share the same Synchronization Frame of Reference UID shall be temporally related to each other. If a Synchronization Frame of Reference UID is present, all SOP Instances in the Series must share the same Frame of Reference.

Notes: 1. The Synchronization Frame of Reference UID defines an equipment synchronization environment, and does not need to be changed for each unrelated acquisiton. SOP Instances may therefore share a Synchronization Frame of Reference UID, but be clinically unrelated (e.g., apply to different patients).
2. When a synchronization environment is recalibrated, a new UID must be issued.
3. The method of distributing the Synchronization Frame of Reference UID to multiple devices is not specified.

C.7.4.2.1.2 Time Source and Time Distribution Protocol

Time may originate with a primary source (e.g., a national standards bureau) and be distributed through a chain of secondary distribution systems until reaching the imaging equipment. Time Distribution Protocol (0018,1802) specifies the immediate (last link) method used by the equipment to receive time from the immediately prior Time Source (0018,1801). It does not specify the ultimate time reference from which the Time Source may derive its synchronization.

C.7.4.2.1.3 Synchronization Channel

The Synchronization Channel (0018,106C) is specified as a pair of values (M,C), where the first value is the Sequence Item Number (0008,000A) of the Waveform Sequence (5400, 0002) attribute (i.e., the Multiplex Group), and the second value is the Sequence Item Number (0008,000A) of the Channel Definition Sequence (003A,0200) attribute (i.e., the Channel Number) within the multiplex group.

C.7.4.2.1.4 Acquisition Time Synchronized

The Acquisition Time Synchronized (0018,1800) attribute specifies whether the Acquisition Datetime (0008,002A) attribute of the Waveform Module represents an accurate synchronized timestamp for the acquisition of the waveform data .

Note: The degree of precision of the Acquisition Datetime and its accuracy relative to the external clock are not specified, but need to be appropriate for the clinical application.

9. Modify Table C.7-7 to rename the Image Date and Time attributes

C.7.6.1 General Image Module

…

Table C.7-7
General Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
…			
~~Image~~ Content Date	(0008,0023)	2C	The time the image pixel data creation started. Required if image is part of a series in which the images are temporally related. Note: this attribute was formerly known as Image Date.
~~Image~~ Content Time	(0008,0033)	2C	The time the image pixel data creation started. Required if image is part of a series in which the images are temporally related. Note: this attribute was formerly known as Image Time.
…			
Acquisition Datetime	(0008,002A)	3	The date and time that the acquisition of data that resulted in this image started. Note: The synchronization of this time with an external clock is specified in the Synchronization Module in Acquisition Time Synchronized (0018,1800).

10. Modify Section C.7.6.5 Cine Module to rename the Image Time attribute and to define cine image synchronization to a trigger

C.7.6.5 Cine Module

…

Table C.7-11
Cine Module Attributes

Attribute Name	Tag	Type	Attribute Description
…			
Frame Delay	(0018,1066)	3	Time (in msec) from ~~Image~~ Content Time (0008,0033) to the start of the first frame in a Multi-frame image.
…			
Image Trigger Delay	(0018,1067)	3	Delay time in milliseconds from trigger (e.g., X-ray on pulse) to the first frame of a multiframe image

11. Modify Note in Section C.8.4.9 to rename the Image Date and Time attributes

C.8.4.9 NM Image Module

…

Note: ~~Image~~ Content Date (0008,0023) and ~~Image~~ Content Time (0008,0033) are included in the General Image Module, Table C.7-7, whenever the images are temporally related. For this purpose, all NM Images are considered temporally related, so that these elements are included in an NM Image.

12. Modify Table C.8.12.1-1 to rename the Image Time attribute

C.8.12.1 VL Image Module

…

Table C. 8.12.1-1
VL Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
…			
~~Image~~ Content Time	(0008,0033)	1C	The time the image pixel data creation started. Required if image is part of a series in which the images are temporally related. Note: this attribute was formerly known as Image Time.
…			

13. Add Section C.10.4 to define the Waveform Identification Module

C.10 CURVE AND WAVEFORM

…

C.10.4 Waveform Identification Module

The table in this section contains Attributes that identify a Waveform as a separate information entity.

Table C.10-4
Waveform Identification Module Attributes

Attribute Name	Tag	Type	Attribute Description
Instance Number	(0020,0013)	1	A number that identifies this Waveform.
Content Date	(0008,0023)	1	The date the Waveform data was created.
Content Time	(0008,0033)	1	The time the Waveform data was created.
Acquisition Datetime	(0008,002A)	1	The date and time that the acquisition of data that resulted in this waveform started; the reference timestamp for the Multiplex Group Time Offset (0018,1068) for a waveform multiplex group Note: The synchronization of this time with an external clock is specified in the Synchronization Module in Acquisition Time Synchronized (0018,1800).
Referenced Instance Sequence	(0008,114A)	3	A sequence which provides reference to a set of SOP Class/Instance pairs significantly related to this Waveform. One or more Items may be included in this sequence.
>Referenced SOP Class UID	(0008,1150)	1C	Uniquely identifies the referenced SOP Class. Required if a Sequence Item is present.
>Referenced SOP Instance UID	(0008,1155)	1C	Uniquely identifies the referenced SOP Instance. Required if a Sequence Item is present.

Note: The Acquisition Datetime (0008,002A) is the time of the original waveform data capture. Derived waveforms which are processed (e.g., averaged or filtered) and encoded subsequent to the waveform Acquisition Datetime have a Content Date (0008,0023) and Content Time (0008,0033) representing the time of the processing. In all cases the actual date and time of creation of the SOP Instance for transmission or storage may be recorded in the Instance Creation Date (0008,0012) and Instance Creation Time (0008,0013) (see Section C.12.2).

14. Add Section C.10.5 to define the Waveform Module

C.10.5 Waveform Module

The table in this section contains Attributes that describe a time-based waveform. A waveform consists of one or more multiplex groups, each encoded into an Item in the Waveform Sequence. All channels within a multiplex group are synchronously digitized at a common sampling frequency.

Table C.10-5
Waveform Module Attributes

Attribute Name	Tag	Type	Attribute Description
Waveform Sequence	(5400,0100)	1	Sequence of one or more Items, each representing one waveform multiplex group. Ordering of Items in this Sequence is significant for external reference to specific multiplex groups.
> Multiplex Group Time Offset	(0018,1068)	1C	Offset time in milliseconds from a reference time (see C.10.5.1.1). Required if Acquisition Time Synchronized (0018,1800) value is Y; may be present otherwise.
> Trigger Time Offset	(0018,1069)	1C	Offset time in milliseconds from a synchronization trigger to the first sample of a waveform multiplex group. May be positive or negative. Required if waveform acquisition is synchronized to a trigger.
> Trigger Sample Position	(0018,106E)	3	Sample number whose time corresponds to a synchronization trigger (see C.10.5.1.2).
> Waveform Originality	(003A,0004)	1	See C.10.5.1.3. Enumerated values: ORIGINAL DERIVED
> Number of Channels	(003A,0005)	1	Number of channels for this multiplex group.
> Number of Samples	(003A,0010)	1	Number of samples per channel in this multiplex group.
> Sampling Frequency	(003A,001A)	1	Frequency in Hz
> Multiplex Group Label	(003A,0020)	3	Label for multiplex group
> Channel Definition Sequence	(003A,0200)	1	Sequence of one or more Items, with one Item per channel (see C.10.5.1.4). Ordering of Items in this Sequence is significant for reference to specific channels.
>> Channel Number	(003A,0202)	3	Equipment physical channel number used for acquisition.
>> Channel Label	(003A,0203)	3	Text label for channel which may be used for display purposes
>> Channel Status	(003A,0205)	3	One or more values for the status of this channel within this SOP Instance. Defined terms: OK TEST DATA DISCONNECTED QUESTIONABLE INVALID UNCALIBRATED UNZEROED Precise location of a change in status may be noted in an Annotation.

>> Channel Source Sequence	(003A,0208)	1	A coded descriptor of the waveform channel source (metric, anatomical position, function, and technique). Only a single Item shall be permitted in this sequence. (See C.10.5.1.4.1)
>>> Include 'Code Sequence Macro' Table 8.8-1.			Baseline Context ID determined by IOD specialization
>> Channel Source Modifiers Sequence	(003A,0209)	1C	Sequence of one or more Items which further qualify the Waveform Source. Required if Channel Source Sequence (003A,0208) does not fully specify the semantics of the source. Ordering of Items in this Sequence may be semantically significant.
>>> Include 'Code Sequence Macro' Table 8.8-1.			Baseline Context ID determined by IOD specialization
>> Source Waveform Sequence	(003A,020A)	3	A sequence which provides reference to a DICOM waveform from which this channel was derived. One or more Items may be included in this Sequence.
>>>Referenced SOP Class UID	(0008,1150)	1C	Identifies the referenced SOP Class. Required if a Sequence Item is present.
>>>Referenced SOP Instance UID	(0008,1155)	1C	Identifies the referenced SOP Instance. Required if a Sequence Item is present.
>>> Referenced Waveform Channels	(0040,A0B0)	1C	Identifies the waveform multiplex group and channel within the referenced SOP Instance. Pair of values (M,C). Required if a Sequence Item is present.
>> Channel Derivation Description	(003A,020C)	3	Additional description of waveform channel derivation
>> Channel Sensitivity	(003A,0210)	1C	Nominal numeric value of unit quantity of sample. Required if samples represent defined (not arbitrary) units.
>> Channel Sensitivity Units	(003A,0211)	1C	A coded descriptor of the Units of measure for the Channel Sensitivity. Only a single Item shall be permitted in this sequence. (see C.10.5.1.4.2) Required if Channel Sensitivity (003A,0210) is present.
>>> Include 'Code Sequence Macro' Table 8.8-1.			Defined Context ID = 3082
>> Channel Sensitivity Correction Factor	(003A,0212)	1C	Multiplier to be applied to encoded sample values to match units specified in Channel Sensitivity (003A,0210) (e.g., based on calibration data) (see C.10.5.1.4.2) Required if Channel Sensitivity (003A,0210) is present.
>> Channel Baseline	(003A,0213)	1C	Offset of encoded sample value 0 from actual 0 using the defined Channel Sensitivity Units (003A,0211). Required if Channel Sensitivity (003A,0210) is present.
>> Channel Time Skew	(003A,0214)	1C	Offset of first sample of channel from waveform multiplex group start time, in seconds (see C.10.5.1.4.3) Required if Channel Sample Skew is not present.
>> Channel Sample Skew	(003A,0215)	1C	Offset of first sample of channel from waveform multiplex group start time, in samples (see C.10.5.1.4.3) Required if Channel Time Skew is not present.
>> Channel Offset	(003A,0218)	3	Additional offset of first sample of channel to be used in aligning multiple channels for presentation or analysis, in seconds (see C.10.5.1.4.3)

>> Waveform Bits Stored	(003A,021A)	1	Number of significant bits within the waveform samples (see C.10.5.1.4.4)
>> Filter Low Frequency	(003A,0220)	3	Nominal 3dB point of lower frequency of pass band; in Hz
>> Filter High Frequency	(003A,0221)	3	Nominal 3dB point of upper frequency of pass band; in Hz
>> Notch Filter Frequency	(003A,0222)	3	Center frequency of notch filter(s); in Hz
>> Notch Filter Bandwidth	(003A,0223)	3	Nominal 3dB bandwidth of notch filter(s); in Hz
>> Channel Minimum Value	(5400,0110)	3	Minimum valid sample value as limited by the acquisition equipment (see C.10.5.1.4.5)
>> Channel Maximum Value	(5400,0112)	3	Maximum valid sample value as limited by the acquisition equipment (see C.10.5.1.4.5)
> Waveform Bits Allocated	(5400,1004)	1	Size of each waveform data sample within the Waveform Data; see section C.10.5.1.5
> Waveform Sample Interpretation	(5400,1006)	1	Data representation of the waveform data points. See C.10.5.1.5.
> Waveform Padding Value	(5400,100A)	1C	Value of waveform samples inserted in channels when input is absent or invalid. Required if acquisition equipment inserts padding. See C.10.5.1.6.
> Waveform Data	(5400,1010)	1	Encoded data samples - channel multiplexed See section C.10.5.1.7

C.10.5.1 Waveform Attribute Descriptions

C.10.5.1.1 Multiplex Group Time Offset

Multiplex Group Time Offset (0018,1068) specifies the offset time in milliseconds from a reference time to the first sample of the multiplex group. The reference time is the Acquisition Datetime (0008,002A), if present in the SOP Instance.

In all other cases, the offset is from an arbitrary reference time that is the same for all Multiplex Groups in the SOP Instance; i.e., the Multiplex Group Time Offset allows only relative time synchronization between Multiplex Groups in the SOP Instance. The arbitrary reference time may nominally be assumed to be the Content Time (0008,0033).

C.10.5.1.2 Trigger Sample Position

The Trigger Sample Position (0018,106E) specifies the sample which was digitized at the same time as a synchronization trigger. Sample positions are enumerated by channel, with the first sample enumerated 1. This provides a single trigger sample location for all channels of the multiplex group. Although channels may not have been sampled synchronously (as specified by Channel Time Skew or Channel Sample Skew), for the purpose of determining the location of the trigger with an integer value position, all channels are considered to be synchronous.

C.10.5.1.3 Waveform Originality

Waveform Originality (003A,0003) shall have the value ORIGINAL if the Waveform Data samples are the original or source data, and shall have the value DERIVED if the Waveform Data samples have been derived in some manner from the sample data of other waveforms.

Notes :

1. The Waveform Originality (003A,0003) attribute is comparable to the Image Type (0008,0008) attribute value 1 (see C.7.6.1.1.2). Within a single Multiplex Group, all channels shall have the same Originality value.
2. Waveform data which has been transcoded from a non-DICOM format may have Waveform Originality value ORIGINAL if the samples are unchanged from the originally acquired waveform samples.

C.10.5.1.4 Channel Definition Sequence

C.10.5.1.4.1 Channel Source and Modifiers

Channel Source (003A,0208) identifies the metric (quality being measured, e.g., voltage or pressure), the anatomical position of the sensor or probe, the function of the channel (e.g., measurement or stimulus), and any particulars of technique which affect those parameters (e.g., pull-back across multiple anatomic sites, or differential input from two distinct sites). If the full semantics of the source is not carried in a single coded entry (e.g., if it specifies the location but not the metric), additional qualifiers are identified in Channel Source Modifiers (003A,0209) coded entries.

When a single sensor channel is used to collect a waveform from two (or more) anatomic sites, e.g., in hemodynamic pull-back procedures, multiple Channel Source Modifier items will identify the sequence of sites, if not encoded in the semantics of the Channel Source Coded Entry. Transition times from one site to another may be indicated with an Annotation, or pull-back rate may be indicated with an Acquisition Context Sequence Item (see Section C.7.6.14).

The Baseline (default) Context IDs are defined by IOD in accordance with Section A.j. Restrictions in the IOD may also determine the pattern of specification of the waveform source, i.e., which item is to be encoded in the Channel Source sequence, and the order in which Channel Source Modifier items are to be encoded. Unless otherwise specified, pattern of specification of the waveform source shall be:

1. If the function of the channel is not measurement, the function (and optionally additional parameters of the channel source) shall be encoded in the Channel Source item.

2. If the function of the channel is measurement of a waveform originating in the patient (the implicit default function), the metric (and optionally additional parameters of the channel source) shall be encoded in the Channel Source item.

3. If not encoded in the Channel Source item, and a particular technique needs to be encoded, that technique shall be encoded in the first Channel Source Modifier item.

Note: For example, an intracardiac measurement of a pressure waveform across the mitral valve by means of a catheter pullback may be encoded in one of the following three ways (using pseudo-coded terminology), depending on the availability of coded terms with sufficient expressive power:

Channel Source	Channel Source Modifiers
X-2311 “pressure measurement”	T-7663 “pullback” C-2001 “mitral valve”
X-2123 “pressure measurement, pullback”	C-2001 “mitral valve”
X-1234 “pressure measurement, mitral valve, pullback”	(none required)

C.10.5.1.4.2 Channel Sensitivity and Channel Sensitivity Units

Channel Sensitivity is the nominal value of one unit (i.e., the least significant bit) of each waveform sample in the Waveform Data attribute (5400,1010). It includes both the amplifier gain and the analog-digital converter resolution. It does not relate the vertical scaling of a waveform on a particular display.

Note: The Defined (default) Context Group for Channel Sensitivity Units is CID 3082 Waveform Units of Measurement, which includes all the commonly used measurement values. Units of measurement not included in the default list can be specified using the more general CID 82 Units of Measurement, or a local Coding Scheme. The Defined Context ID may be replaced in a specialization of the IOD.

Channel Sensitivity Correction Factor (003A,0212) is the ratio of the actual (calibrated) value to the nominal Channel Sensitivity specified in Data Element (003A,0210). Thus a waveform sample value multiplied by the Channel Sensitivity value provides the nominal measured value in Channel Sensitivity Units, and that nominal value multiplied by the Channel Sensitivity Correction Factor provides the calibrated measured value.

C.10.5.1.4.3 Channel Skew and Channel Offset

Skew is also known as a sub-sample time delay, typically caused by using a multiplexed analog to digital converter which switches from channel to channel. For analysis it may be important to know if the analog channels were all

latched simultaneously or sequentially and then digitized. Skew may be represented as time offset in seconds, or a fractional number of samples.

Separate and additional to skew is an offset time adjustment (sometimes called latency) by which one waveform channel is displaced significantly relative to others before sampling.

Note: As an example, a hemodynamic pressure is measured at the external end of a catheter, and thus its measurement is delayed by the time for the pressure wave to propagate down the catheter. With a dual catheter measurement, two signals may be acquired at the same time, but one arrives by a longer distance (e.g., a pulmonary capillary wedge pressure, compared to a left ventricular pressure). To obtain an accurate comparison of the waveforms (e.g., the gradient across the mitral valve), one waveform has to be offset (perhaps as much as 30 ms) to synchronize them.

C.10.5.1.4.4 Waveform Bits Stored

Waveform Bits Stored (003A,021A) specifies the number of significant bits within the Waveform Bits Allocated of each sample, for signed or unsigned integers.

If Waveform Sample Value Representation is MB or AB, Waveform Bits Stored shall be 8.

C.10.5.1.4.5 Channel Minimum and Maximum Value

Channel Minimum and Maximum Value attributes (003A,0231) and (003A,0241) may be used to send the analog-to-digital converter limits (i.e., the clipping levels).

Note: These values do not represent the maximum and minimum values in the data set, but rather the valid range of values.

C.10.5.1.5 Waveform Bits Allocated and Waveform Sample Interpretation

Waveform Bits Allocated (5400,1004) specifies the number of bits allocated for each sample, and Waveform Sample Interpretation (5400,1006) specifies the data representation of each waveform sample. Waveform Bits Allocated shall be a multiple of 8. These data elements are related, and their defined terms are specified in Table C.10-5.

Table C.10-5
Waveform Bits Allocated and Waveform Sample Interpretation

Waveform Bits Allocated - Defined Terms	Waveform Sample Interpretation - Defined Terms	Waveform Sample Interpretation Meaning
8	SB	signed 8 bit linear
	UB	unsigned 8 bit linear
	MB	8 bit mu-law (in accordance with ITU-T Recommendation G.711)
	AB	8 bit A-law (in accordance with ITU-T Recommendation G.711)
16	SS	signed 16 bit linear
	US	unsigned 16 bit linear

Notes: 1. The set of valid values from within this table may be constrained by definition of the IOD (see Section A.j).
2. mu-law and A-law encoding is without the alternate bit inversion used for PCM transmission through the telephone nework.

This representation also applies to the Channel Minimum and Maximum Data Values, and Waveform Padding Value.

C.10.5.1.6 Waveform Padding Value

Equipment which produces digitized waveform curves may encode a specific value when the source is disconnected or otherwise invalid. This value is encoded like the Waveform Data attribute with one sample only.

The Waveform Padding Value need not be within the range specified by the Channel Minimum and Maximum Data Values.

C.10.5.1.7 Waveform Data

Each sample shall be encoded using the defined Waveform Sample Interpretation (5400,1006), using the defined number of Waveform Bits Stored (003A,021A) right justified in the sample. If the number of Waveform Bits Stored is less than the number of bits in Waveform Bits Allocated, the sign bit shall be extended to the highest order bit of the data sample.

Data values are encoded interleaved, incrementing by channel and then by sample (i.e., C1S1, C2S1,C3S1, ... CnS1, C1S2, C2S2, C3S2, ... CnSm), with no padding or explicit delimitation between successive samples. Cx denotes the channel defined in the Channel Definition Sequence Item in item number x.

Notes:

1. With 8-bit Waveform Data, there may be an odd number of channels and an odd number of samples; see PS3.5 for rules on encoding.
2. The sign bit extension rule differs from the rules for pixel data, which do not require sign extension.

15. Add Section C.10.6 to define Waveform Annotation Module

C.10.6 Waveform Annotation Module

The table in this section contains Attributes that identify annotations to the waveform of the current SOP Instance. Each annotation conceptually forms the equivalent of a overlay on a presentation display of the annotated entity. Annotations may represent a measurement or categorization based on the waveform data, identification of regions of interest or particular features of the waveform, or events during the data collection which may affect diagnostic interpretation (e.g., the time at which the subject coughed).

Each Annotation Item shall have the following components:

1. An annotation Text, Coded Name (only), Coded Name/Coded Value pair, or Coded Name/Numeric Measurement pair (mutually exclusive)

2. Temporal coordinates in the Waveform to which the annotation applies

Table C.10.6-1 – Waveform Annotation Module Attributes

Attribute Name	Tag	Type	Attribute Description
Annotation Sequence	(0040,B020)	1	Sequence of Annotation Items; one or more items shall be present
> Unformatted Text Value	(0070,0006)	1C	Text Observation Value (annotation). Mutually exclusive with Concept Name Code Sequence (0040,A043)
> Concept Name Code Sequence	(0040,A043)	1C	Code representing the fully specified name of the NUMERIC measurement or CODED concept. This sequence shall contain exactly one item. Mutually exclusive with Text Value (0070,0006).
>>Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID may be defined in IOD definition.
>> Modifier Code Sequence	(0040,A195)	1C	A sequence of items modifying or specializing the Concept Name. Any number of items may be present. Required if Concept Name Code Sequence (0040,A043) is sent and the value does not fully describe the semantics of the measurement or concept.
>>>Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID may be defined in IOD definition.
> Concept Code Sequence	(0040,A168)	3	A sequence that conveys the categorical coded nominal value.
>>Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID may be defined in IOD definition.
>> Modifier Code Sequence	(0040,A195)	1C	A sequence of items modifying or specializing the Concept. Any number of items may be present. Required if Concept Code Sequence (0040,A168) is sent and the value does not fully describe the semantics of the concept value.
>>>Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID may be defined in IOD definition.

> Numeric Value	(0040,A30A)	3	Numeric measurement value or values.
> Measurement Units Code Sequence	(0040,08EA)	3	Units of measurement. Coded entry sequence with one item only.
>> Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID 82
> Referenced Waveform Channels	(0040,A0B0)	1	List of channels in waveform to which annotation applies. See C.10.6.1.1
> Temporal Range Type	(0040,A130)	1C	See C.10.6.1.2 for Enumerated Values. Required if Annotation does not apply to entire Reference Waveform Channels; shall not be present if Annotation applies to entire temporal extent of referenced channels.
> Referenced Sample Positions	(0040,A132)	1C	List of samples within a multiplex group specifying temporal points for annotation. Position of first sample is 1. Required if Temporal Range Type (0040,A130) is present, and if Referenced Time Offsets (0040,A138) and Referenced Datetime (0040,A13A) are not present. See C.10.6.1.3
> Referenced Time Offsets	(0040,A138)	1C	Specifies temporal points for annotation by number of seconds after start of data. Required if Temporal Range Type (0040,A130) is present, and if Referenced Sample Positions (0040,A132) and Referenced Datetime (0040,A13A) are not present.
> Referenced Datetime	(0040,A13A)	1C	Specifies temporal points for annotation by absolute time. Required if Temporal Range Type (0040,A130) is present, and if Referenced Sample Positions (0040,A132) and Referenced Time Offsets (0040,A138) are not present.
> Annotation Group Number	(0040,A180)	3	Number identifying associated annotations (see C.10.6.1.4).

C.10.6.1 Annotation Attribute Descriptions

C.10.6.1.1 Referenced Channels

Referenced Channels (0040,A0B0) is a multi-value attribute which lists the channels to which an annotation of a waveform applies. Each channel is specified as a pair of values (M,C), where the first value is the sequence item number of the Waveform Sequence (5400,0100) attribute (i.e., the Multiplex Group Number), and the second value is the sequence item number of the Channel Definition Sequence (003A,0200) attribute (i.e., the Channel Number) within the multiplex group.

If the specified channel number is 0, the annotation applies to all channels in the multiplex group.

Note: As an example, an annotation which applies to the entire first multiplex group and channels 2 and 3 of the third multiplex group would have Referenced Channels value 0001 0000 0003 0002 0003 0003.

C.10.6.1.2 Temporal Range Type

This attribute defines the type of temporal extent of the annotated region of interest. A temporal point (or instant of time) may be defined by a waveform sample offset (for a single waveform multiplex group only), time offset, or absolute time.

The following terms are Enumerated Values for Temporal Range Type:

796 POINT = a single temporal point
MULTIPOINT = multiple temporal points
798 SEGMENT = a range between two temporal points
MULTISEGMENT = multiple segments, each denoted by two temporal points
800 BEGIN = a range beginning at one temporal point, and extending beyond the end of the acquired data
END = a range beginning before the start of the acquired data, and extending to (and including) the identified temporal
802 point

C.10.6.1.3 Referenced Sample Positions

804 Referenced Sample Positions (0040,A132) may be used only if Referenced Channels (0040,A0B0) refers to channels within a single multiplex group. The sample position is by channel, and applies to all channels specified in
806 Referenced Channels (0040,A0B0).

C.10.6.1.4 Annotation Group Number

808 The Annotation Group Number (0040,A180) allows the logical association of multiple annotations within the current SOP Instance. Such linked annotations share an Annotation Group Number, but each annotation is semantically
810 separable. The nature of the association is not defined. The number is not semantically significant.

Note: For instance, the R-wave in several waveform channels may be annotated, and all occurrences of the same R-
812 wave could be linked in an annotation group.

16. Update Table F.3-3 to include Waveform Directory Record type

F.3.2.2 DIRECTORY INFORMATION MODULE

…

Table F.3-3
DIRECTORY INFORMATION MODULE

Attribute Name	Tag	Type	Attribute Description
…			
>Directory Record Type	(0004,1430)	1C	Defines a specialized type of Directory Record by reference to its position in the Media Storage Directory Information Model (see Section F.4). Required if the Directory Record Sequence (0004,1220) is not zero length. Enumerated Values (see Section F.5): … WAVEFORM …
…			

17. Update Section F.4 to include Waveform Directory Record type

F.4 BASIC DIRECTORY IOD INFORMATION MODEL

…

Table F.4-1
RELATIONSHIP BETWEEN DIRECTORY RECORDS

Directory Record Type	Section	Directory Record Types which may be included in the next lower-level directory Entity
…		
SERIES	F.5.3	IMAGE, … , WAVEFORM, PRIVATE
…		
WAVEFORM	F.5.x	PRIVATE

18. Add new Section F.5.x to define Waveform Record in DICOMDIR

F.5.x Waveform_Directory Record Definition

The Directory Record is based on the specification of Section F.5.3. It is identified by a Directory Record Type of Value "WAVEFORM". Table F.5-X lists the set of keys with their associated Types for such a Directory Record Type. The description of these keys may be found in PS 3.3 of the DICOM Standard in the Modules related to the Waveform_IE. This Directory Record shall be used to reference a Waveform_SOP Instance. This Type of Directory Record may reference a Lower-Level Directory Entity which includes one or more Directory Records as defined in Table F.4-1.

Table F.5-X
WAVEFORM KEYS

Key	Tag	Type	Attribute Description
Specific Character Set	(0008,0005)	1C	Required if an extended or replacement character set is used in one of the keys.
Instance Number	(0020,0013)	1	
Content Date	(0008,0023)	1	
Content Time	(0008,0033)	1	
Any other Attribute of the Waveform IE Modules		3	

19. Add informative annex describing Waveforms

Annex W - Waveforms (Informative)

W.1 DOMAIN OF APPLICATION

Waveform acquisition is part of both the medical imaging environment and the general clinical environment. Because of its broad use, there has been significant previous and complementary work in waveform standardization of which the following are particularly important:

ASTM E31.16 - E1467 Specification for Transferring Digital Neurophysiogical Data Between Independent Computer Systems

CEN TC251 PT5-007 - prENV1064 draft Standard Communications Protocol for Computer-Assisted Electrocardiography (SCP-ECG).

CEN TC251 PT5-021 - draft Vital Signs Information Representation Standard (VITAL)

HL7 Automated Data SIG - HL7 Version 2.3, Chapter 7.14-20

IEEE P1073 - draft Medical Information Bus Standard (MIB)

DICOM - NEMA PS3.3, Section A.10 Standalone Curve Information Object Definition

For DICOM, the domain of waveform standardization is waveform acquisition within the imaging context. It is specifically meant to address waveform acquisitions which will be analyzed with other data which is transferred and managed using the DICOM protocol. It allows the addition of waveform data to that context with minimal incremental cost. Further, it leverages the DICOM persistent object capability for maintaining referential relationships to other data collected in a multi-modality environment, including references necessary for multi-modality synchronization.

Waveform interchange in other clinical contexts may use different protocols more appropriate to those domains. In particular, HL7 may be used for transfer of waveform observations to general clinical information systems, and MIB may be used for real-time physiological monitoring and therapy.

The waveform information object definition in DICOM has been specifically harmonized at the semantic level with the HL7 waveform message format. The use of a common object model allows straightforward transcoding and interoperation between systems that use DICOM for waveform interchange and those that use HL7, and may be viewed as an example of common semantics implemented in the differing syntaxes of two messaging systems.

Note: HL7 allows transport of DICOM SOP Instances (information objects) encapsulated within HL7 messages. Since the DICOM and HL7 waveform semantics are harmonized, DICOM Waveform SOP Instances need not be transported as encapsulated data, as they can be transcoded to native HL7 Waveform Observation format.

W.2 USE CASES

The following are specific use case examples for waveforms in the imaging environment.

Case 1: Catheterization Laboratory - During a cardiac catheterization, several independent pieces of data acquisition equipment may be brought together for the exam. An electrocardiographic subsystem records surface ECG waveforms; an X-ray angiographic subsystem records motion images; a hemodynamic subsystem records intracardiac pressures from a sensor on the catheter. These subsystems send their acquired data by network to a repository. These data are assembled at an analytic workstation by retrieving from the repository. For a left ventriculographic procedure, the ECG is used by the physician to determine the time of maximum and minimum ventricular fill, and when coordinated with the angiographic images, an accurate estimate of the ejection fraction can

be calculated. For a valvuloplasty procedure, the hemodynamic waveforms are used to calculate the pre-intervention and post-intervention pressure gradients.

Case 2: Electrophysiology Laboratory - An electrophysiological exam will capture waveforms from multiple sensors on a catheter; the placement of the catheter in the heart is captured on an angiographic image. At an analytic workstation, the exact location of the sensors can thus be aligned with a model of the heart, and the relative timing of the arrival of the electrophysiological waves at different cardiac locations can be mapped.

Case 3: Stress Exam - A stress exam may involve the acquisition of both ECG waveforms and echocardiographic ultrasound images from portable equipment at different stages of the test. The waveforms and the echocardiograms are output on an interchange disk, which is then input and read at a review station. The physician analyzes both types of data to make a diagnosis of cardiac health.

W.3 TIME SYNCHRONIZATION FRAME OF REFERENCE

Synchronization of acquisition across multiple modalities in a single study (e.g., angiography and electrocardiography) requires either a shared trigger, or a shared clock. A Synchronization Module within the Frame of Reference Information Entity specifies the synchronization mechanism. A common temporal environment used by multiple equipment is identified by a shared Synchronization Frame of Reference UID. How this UID is determined and distributed to the participating equipment is outside the scope of the standard.

The method used for time synchronization of equipment clocks is implementation or site specific, and therefore outside the scope of this proposal. If required, standard time distribution protocols are available (e.g., NTP, IRIG, GPS).

An informative description of time distribution methods can be found at: http://www.bancomm.com/cntpApp.htm

A second method of synchronizing acquisitions is to utilize a common reference channel (temporal fiducial), which is recorded in the data acquired from the several equipment units participating in a study, and/or which is used to trigger synchronized data acquisitions. For instance, the “X-ray on” pulse train which triggers the acquisition of frames for an X-ray angiographic SOP Instance can be recorded as a waveform channel in a simultaneously acquired hemodynamic waveform SOP Instance, and can be used to align the different object instances. Associated with this Supplement are proposed coded entry channel identifiers to specifically support this synchronization mechanism (DICOM Terminology Mapping Resource Context Group ID 3090).

W.4 WAVEFORM ACQUISITION MODEL

Figure W.4-1 shows a canonical model of waveform data acquisition. A patient is the subject of the study. There may be several sensors placed at different locations on or in the patient, and waveforms are measurements of some physical quality (metric) by those sensors (e.g., electrical voltage, pressure, gas concentration, or sound). The sensor is typically connected to an amplifier and filter, and its output is sampled at constant time intervals and digitized. In most cases, several signal channels are acquired synchronously. The measured signal usually originates in the anatomy of the patient, but an important special case is a signal which originates in the equipment, either as a stimulus, such as a cardiac pacing signal, as a therapy, such as a radio frequency signal used for ablation, or as a synchronization signal.

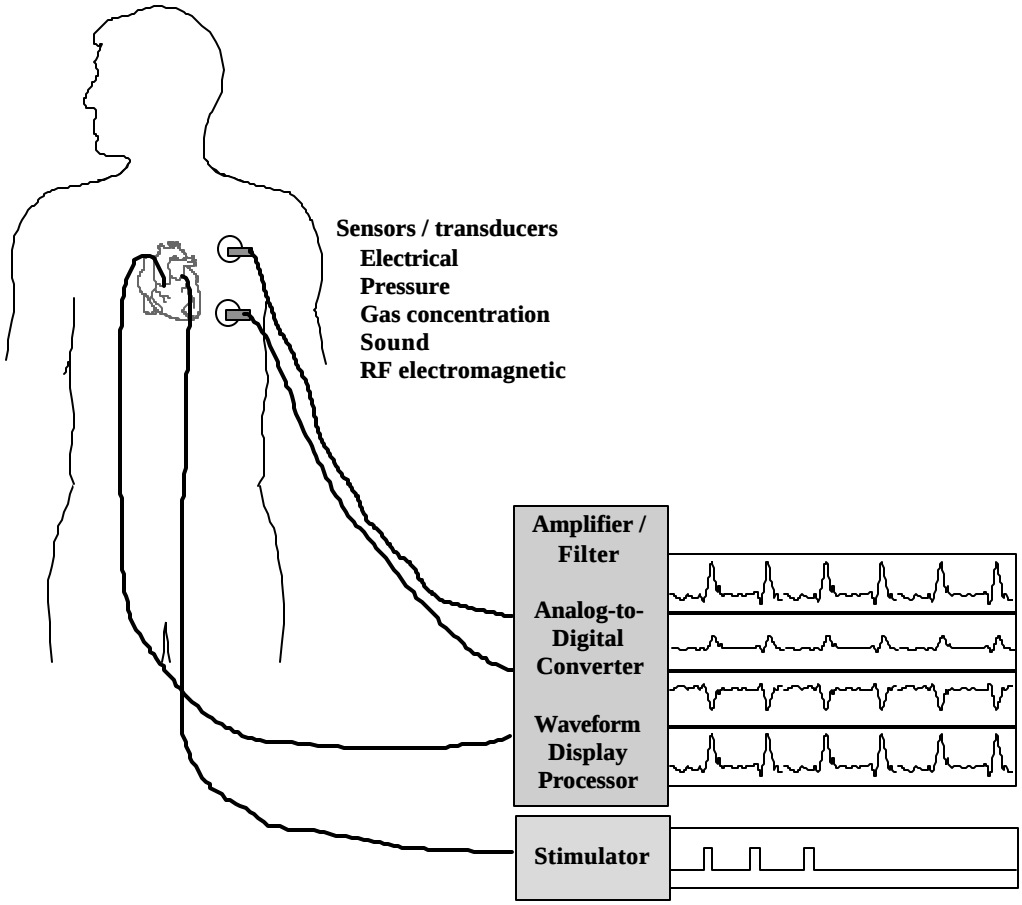


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Figure W.4-1 - Waveform Acquisition Model

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W.5 WAVEFORM INFORMATION MODEL

918 The part of the composite information object which carries the waveform data is the Waveform Information Entity (IE). The Waveform IE includes the technical parameters of waveform acquisition and the waveform samples.

920 The information model, or internal organizational structure, of the Waveform IE is shown in Figure W.5-1. A waveform information object includes data from a continuous time period during which signals were acquired. The object may
922 contain several multiplex groups, each defined by digitization with the same clock whose frequency is defined for the group. Within each multiplex group there will be one or more channels, each with a full technical definition. Finally,
924 each channel has its set of digital waveform samples.

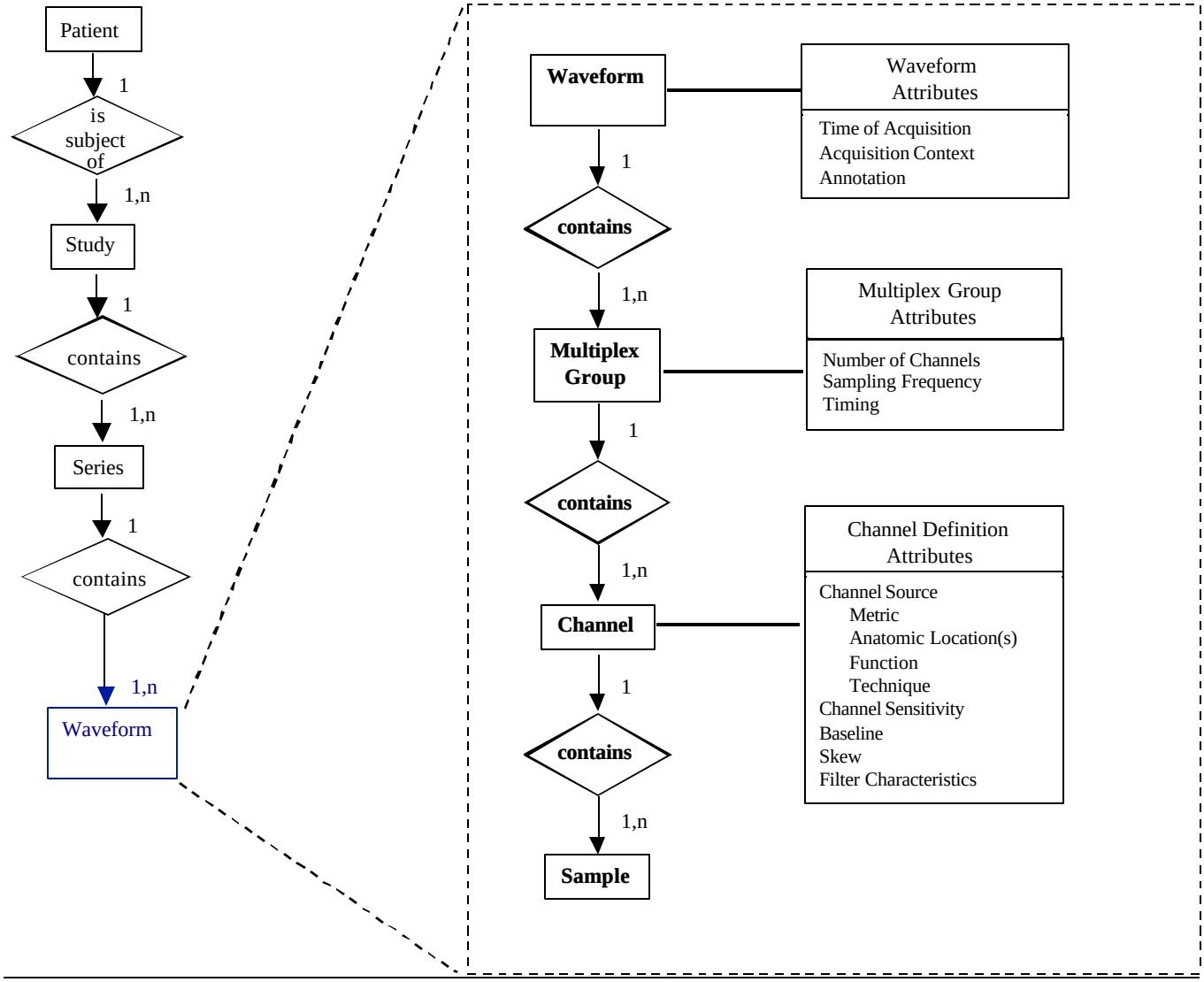

Figure W.5-1 DICOM Waveform Information Model

W.6 HARMONIZATION WITH HL7

This Waveform IE definition is harmonized with the HL7 waveform semantic constructs, including the channel definition attributes and the use of multiplex groups for synchronously acquired channels. The use of a common object model allows straightforward transcoding and interoperation between systems that use DICOM for waveform interchange and those that use HL7, and may be viewed as an example of common semantics implemented in the differing syntaxes of two messaging systems.

This section describes the congruence between the DICOM Waveform IE and the HL7 version 2.3 waveform message format (see HL7 version 2.3 Chapter 7, sections 7.14 – 7.20).

W.6.1 HL7 Waveform Observation

Waveforms in HL7 messages are sent in a set of OBX (Observation) Segments. Four subtypes of OBX segments are defined:

- The CHN subtype defines one channel in a CD (Channel Definition) Data Type

- The TIM subtype defines the start time of the waveform data in a TS (Time String) Data Type
- The WAV subtype carries the waveform data in an NA (Numeric Array) or MA (Multiplexed Array) Data Type (ASCII encoded samples, character delimited)
- The ANO subtype carries an annotation in a CE (Coded Entry) Data Type with a reference to a specific time within the waveform to which the annotation applies

Other segments of the HL7 message definition specify patient and study identification, whose harmonization with DICOM constructs is not defined in this Annex.

W.6.2 Channel Definition

The Waveform Module Channel Definition sequence attribute (003A,0200) is defined in harmonization with the HL7 Channel Definition (CD) Data Type, in accordance with the following Table. Each Item in the Channel Definition sequence attribute corresponds to an OBX Segment of subtype CHN.

Table W.6-1
Correspondence Between DICOM and HL7 Channel Definition

DICOM Attribute		HL7 CD Data Type Component
Channel Number	(003A,0202)	Channel Identifier (number&name)
Channel Label	(003A,0203)	
Channel Source	(003A,0208)	Waveform Source
Channel Source Modifier	(003A,0209)	
Channel Sensitivity	(003A,0210)	Channel Sensitivity and Units
Channel Sensitivity Units	(003A,0211)	
Channel Sensitivity Correction Factor	(003A,0212)	Channel Calibration Parameters
Channel Baseline	(003A,0213)	(correctionfactor&baseline&timeskew)
Channel Time Skew	(003A,0214)	
[Group] Sampling Frequency	(003A,001A)	Channel Sampling Frequency
Channel Minimum Value	(5400,0110)	Minimum and Maximum Data Values
Channel Maximum Value	(5400,0112)	(minimum&maximum)
Channel Offset	(003A,0218)	not defined in HL7
Channel Status	(003A,0205)	
Filter Low Frequency	(003A,0220)	
Filter High Frequency	(003A,0221)	
Notch Filter Frequency	(003A,0222)	
Notch Filter Bandwidth	(003A,0223)	

In the DICOM information object definition, the sampling frequency is defined for the multiplex group, while in HL7 it is defined for each channel, but is required to be identical for all multiplexed channels.

Note that in the HL7 syntax, Waveform Source is a string, rather than a coded entry as used in DICOM. This should be considered in any transcoding between the two formats.

W.6.3 Timing

In HL7, the exact start time for waveform data is sent in an OBX Segment of subtype TIM. The corresponding DICOM attributes, which must be combined to form the equivalent time string, are:

Acquisition Datetime	(0008,002A)
Multiplex Group Time Offset	(0018,1068)

W.6.4 Waveform Data

The DICOM binary encoding of data samples in the Waveform Data attribute (003A,1000) corresponds to the ASCII representation of data samples in the HL7 OBX Segment of subtype WAV. The same channel-interleaved multiplexing used in the HL7 MA (Multiplexed Array) Data Type is used in the DICOM Waveform Data attribute.

Because of its binary representation, DICOM uses several data elements to specify the precise encoding, as listed in the following Table. There are no corresponding HL7 data elements, since HL7 uses explicit character-delimited ASCII encoding of data samples.

Number of Channels	(003A,0005)
Number of Samples	(003A,0010)
Waveform Bits Stored	(003A,021A)
Waveform Bits Allocated	(5400,1004)
Waveform Sample Interpretation	(5400,1006)
Waveform Padding Value	(5400,100A)

W.6.5 Annotation

In HL7, Waveform Annotation is sent in an OBX Segment of subtype ANO, using the CE (Coded Entry) Data Type CE. This corresponds precisely to the DICOM Annotation using Coded Entry Sequences. However, HL7 annotation ROI is to a single point only (time reference), while DICOM allows reference to ranges of samples delimited by time or by explicit sample position.

W.7 HARMONIZATION WITH SCP-ECG

The SCP-ECG standard is designed for recording routine resting electrocardiograms. Such ECGs are reviewed prior to cardiac imaging procedures, and a typical use case would be for SCP-ECG waveforms to be translated to DICOM for inclusion with the full cardiac imaging patient record.

SCP-ECG provides for either simultaneous or non-simultaneous recording of the channels, but does not provide a multiplexed data format (each channel is separately encoded). When translating to DICOM, each subset of simultaneously recorded channels may be encoded in a Waveform Sequence Item (multiplex group), and the delay to the recording of each multiplex group shall be encoded in the Multiplex Group Time Offset (0018,1068).

The electrode configuration of SCP-ECG Section 1 may be translated to the DICOM Acquisition Context (0040,055) sequence items using DICOM Terminology Mapping Resource Template 3401 and Context Groups 3263 and 3264.

The lead identification of SCP-ECG Section 3, a term coded as an unsigned integer, may be translated to the DICOM Waveform Channel Source (003A,0208) coded sequence using Context Group 3001.

Pacemaker spike records of SCP-ECG Section 7 may be translated to Annotations (0040,B020) with a code term from Context Group 3335. The annotation sequence item may record the spike amplitude in its Numeric Value and Measurement Units attributes.

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Changes to:

998 ## NEMA Standards Publication PS 3.4-1999

Digital Imaging and Communications in Medicine (DICOM)

1000 ## *Part 4: Service Class Specifications*

1002

20. Modify Section B.5 to define Waveform SOP Classes for Network

B.5 STANDARD SOP CLASSES

The SOP Classes in the Storage Service Class identify the Composite IODs to be stored. Table B.5-1 identifies Standard SOP Classes.

Table B.5-1 Standard SOP Classes

SOP Class Name	SOP Class UID
…	
12-lead ECG Waveform Storage	1.2.840.10008.5.1.4.1.1.9.1.1
General ECG Waveform Storage	1.2.840.10008.5.1.4.1.1.9.1.2
Ambulatory ECG Waveform Storage	1.2.840.10008.5.1.4.1.1.9.1.3
Hemodynamic Waveform Storage	1.2.840.10008.5.1.4.1.1.9.2.1
Cardiac Electrophysiology Waveform Storage	1.2.840.10008.5.1.4.1.1.9.3.1
Basic Voice Audio Waveform Storage	1.2.840.10008.5.1.4.1.1.9.4.1

21. Modify Section I.4 to define Waveform SOP Classes for Media

I.4 MEDIA STORAGE STANDARD SOP CLASSES

The SOP Classes in the Media Storage Service Class identify the Composite and Normalized IODs to be stored. Table I.4-1 identifies Standard SOP Classes.

Table I.4-1 Media Storage Standard SOP Classes

SOP Class Name	SOP Class UID	IOD Specification
…		
12-lead ECG Waveform Storage	1.2.840.10008.5.1.4.1.1.9.1.1	IOD defined in PS 3.3
General ECG Waveform Storage	1.2.840.10008.5.1.4.1.1.9.1.2	IOD defined in PS 3.3
Ambulatory ECG Waveform Storage	1.2.840.10008.5.1.4.1.1.9.1.3	IOD defined in PS 3.3
Hemodynamic Waveform Storage	1.2.840.10008.5.1.4.1.1.9.2.1	IOD defined in PS 3.3
Cardiac Electrophysiology Waveform Storage	1.2.840.10008.5.1.4.1.1.9.3.1	IOD defined in PS 3.3
Basic Voice Audio Waveform Storage	1.2.840.10008.5.1.4.1.1.9.4.1	IOD defined in PS 3.3

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Changes to:

1024 **NEMA Standards Publication PS 3.5-1999**

Digital Imaging and Communications in Medicine (DICOM)

1026 ***Part 5: Data Structures and Encoding***

1028

22. Modify Section 7.5 NESTING OF DATA SETS

7.5 NESTING OF DATA SETS

The VR identified "SQ" shall be used for Data Elements with a Value consisting of a Sequence of zero or more Items, where each Item contains a set of Data Elements. SQ provides a flexible encoding scheme that may be used for simple structures of repeating sets of Data Elements, or the encoding of more complex Information Object Definitions often called folders. SQ Data Elements can also be used recursively to contain multi-level nested structures.

Items present in an SQ Data Element shall be an ordered set where each Item may be referenced by its ordinal position. Each Item shall be implicitly assigned an ordinal position starting with the value 1 for the first Item in the Sequence, and incremented by 1 with each subsequent Item. The last Item in the Sequence shall have an ordinal position equal to the number of Items in the Sequence.

Notes:

1- This clause implies that item ordering is preserved during transfer and storage.

2- An IOD or Module Definition may choose to not use this ordering property of a Data Element with VR of SQ. This is simply done by not specifying any specific semantics to the ordering of Items, or by not specifying usage of the referencing of Items by ordering position.

…

23. Modify PS 3.5 Section 8 to address Waveform use:

Section 8 Encoding of Pixel, ~~and~~ Overlay, and Waveform Data

8.1 PIXEL AND OVERLAY DATA, AND RELATED DATA ELEMENTS

The Pixel Data Element (7FE0,0010) and Overlay Data Element (60xx,3000) shall be used for the exchange of encoded graphical image data. …

~~8.1 PIXEL AND OVERLAY DATA ENCODING OF RELATED DATA ELEMENTS~~

8.1.1 Pixel data encoding of related data elements

Encoded Pixel Data of various bit depths shall be accommodated. The following three Data Elements shall define the Pixel structure:

…

8.3 WAVEFORM DATA AND RELATED DATA ELEMENTS

The DICOM protocol provides for the exchange of encoded time-based signals, or waveforms, encoded in the Waveform Data Element (5400,1010).

Note: Per Section 7.6, an IOD supporting multiple sets of Waveform Data will encapsulate Data Element (5400,1010) within a Sequence.

Encoded Waveform Data of various bit depths is accommodated through the Waveform Bits Allocated (5400,1004) Data Element. This element defines the size of each waveform data sample within the Waveform Data (5400,1010). Allowed values are 8 and 16 bits.

The Value Representation of the Waveform Data (5400,1010) shall be OW; OB shall be used in cases where Waveform Bits Allocated has a value of 8, but only with Transfer Syntaxes where the Value Representation is explicitly conveyed.

Notes:

1. Under the Default Transfer Syntax, OB and OW VRs have the identical byte transfer order.
2. Conversion of a SOP Instance from the Default Transfer Syntax to an Explicit VR Transfer Syntax (uncompressed) requires the interpretation of the Waveform Bits Allocated (5400,1004) Data Element, to determine the proper VR of the Waveform Data.

The following data elements related to Waveform Data shall be encoded with the same VR as Waveform Data: Channel Minimum Value (5400,0110), Channel Maximum Value (5400,0112), Waveform Padding Value (5400,100A).

24. Modify PS 3.5 Annex A to address encoding of waveform data with OB/OW VR:

A.1 DICOM IMPLICIT VR LITTLE ENDIAN TRANSFER SYNTAX

…

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

— For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.

— For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:

— Data Element (7FE0,0010) Pixel Data has the Value Representation OW and shall be encoded in Little Endian.

— Data Element (60xx,3000) Overlay Data has the Value Representation OW and shall be encoded in Little Endian.

— Data Element (50xx,3000) Curve Data has the Value Representation OB with its component points (n-tuples) having the Value Representation specified in Data Value Representation (50xx,0103). The component points shall be encoded in Little Endian.

— Data Element (5400,1010) Waveform Data shall have Value Representation OW and shall be encoded in Little Endian.

…

A.2 DICOM LITTLE ENDIAN TRANSFER SYNTAX (EXPLICIT VR)

…

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

— For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.

— For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:

— Data Element (7FE0,0010) Pixel Data

— where Bits Allocated (0028,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Little Endian;

— where Bits Allocated (0028,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Little Endian.

— Data Element (60xx,3000) Overlay Data

— where Bits Allocated (60xx,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Little Endian;

— where Bits Allocated (60xx,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Little Endian.

— Data Element (50xx,3000) Curve Data has the Value Representation specified in its Explicit VR Field. See the specification of the Curve Data Module in PS 3.3 for the enumerated list of allowable VRs. The component points shall be encoded in Little Endian.

— Data Element (5400,1010) Waveform Data has the Value Representation specified in its Explicit VR Field. The component points shall be encoded in Little Endian.

…

A.3 DICOM BIG ENDIAN TRANSFER SYNTAX (EXPLICIT VR)

…

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

— For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Big Endian as specified in Section 7.3.

— For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:

  — Data Element (7FE0,0010) Pixel Data

    — where Bits Allocated (0028,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Big Endian;

    — where Bits Allocated (0028,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Big Endian.

  — Data Element (60xx,3000) Overlay Data

    — where Bits Allocated (60xx,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Big Endian;

    — where Bits Allocated (60xx,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Big Endian.

  — Data Element (50xx,3000) Curve Data has the Value Representation specified in its Explicit VR Field. See the specification of the Curve Data Module in PS 3.3 for the enumerated list of allowable VRs. The component points shall be encoded in Big Endian.

  — Data Element (5400,1010) Waveform Data has the Value Representation specified in its Explicit VR Field. The component points shall be encoded in Big Endian.

…

A.4 TRANSFER SYNTAXES FOR ENCAPSULATION OF ENCODED PIXEL DATA

…

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

— For all Value Representations defined in this part of the DICOM Standard, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.

— For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:

  …

  — Data Element (50xx,3000) for Curve Data has the Value Representation specified in its Explicit VR Field. See the specification of the Curve Data Module in PS 3.3 for the enumerated list of allowable VRs. The component points shall be encoded in Little Endian.

  — Data Element (5400,1010) Waveform Data has the Value Representation specified in its Explicit VR Field. The component points shall be encoded in Little Endian.

…

Changes to:

NEMA Standards Publication PS 3.6-1999

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

25. Add new Attributes to Section 6

6 Registry of DICOM data elements

Tag	Attribute Name	VR	VM
(0008,000A)	Sequence Item Number	US	1
(0008,0023)	~~Image~~ Content Date	DA	1
(0008,0033)	~~Image~~ Content Time	TM	1
(0008,114A)	Referenced Instance Sequence	SQ	1
(0008,114B)	Reference Description	LO	1
(0018,1067)	Image Trigger Delay	DS	1
(0018,1068)	Multiplex Group Time Offset	DS	1
(0018,1069)	Trigger Time Offset	DS	1
(0018,106A)	Synchronization Trigger	CS	1
(0018,106C)	Synchronization Channel	US	2
(0018,106E)	Trigger Sample Position	UL	1
(0018,1800)	Acquisition Time Synchronized	CS	1
(0018,1802)	Time Distribution Protocol	CS	1
(0018,1801)	Time Source	SH	1
(0018,1810)	Acquisition Timestamp	DT	1
(0020,0200)	Synchronization Frame of Reference UID	UI	1
(003A,0004)	Waveform Originality	CS	1
(003A,0005)	Number of Channels	US	1
(003A,0010)	Number of Samples	UL	1
(003A,001A)	Sampling Frequency	DS	1
(003A,0020)	Multiplex Group Label	SH	1
(003A,0200)	Channel Definition Sequence	SQ	1
(003A,0202)	Channel Number	IS	1
(003A,0203)	Channel Label	SH	1
(003A,0205)	Channel Status	CS	1-n
(003A,0208)	Channel Source Sequence	SQ	1
(003A,0209)	Channel Source Modifiers Sequence	SQ	1
(003A,020A)	Source Waveform Sequence	SQ	1
(003A,020C)	Channel Derivation Description	LO	1
(003A,0210)	Channel Sensitivity	DS	1
(003A,0211)	Channel Sensitivity Units	SQ	1

Tag	Attribute Name	VR	VM
(003A,0212)	Channel Sensitivity Correction Factor	DS	1
(003A,0213)	Channel Baseline	DS	1
(003A,0214)	Channel Time Skew	DS	1
(003A,0215)	Channel Sample Skew	DS	1
(003A,0218)	Channel Offset	DS	1
(003A,021A)	Waveform Bits Stored	US	1
(003A,0220)	Filter Low Frequency	DS	1
(003A,0221)	Filter High Frequency	DS	1
(003A,0222)	Notch Filter Frequency	DS	1
(003A,0223)	Notch Filter Bandwidth	DS	1
(0040,A0B0)	Referenced Waveform Channels	US	2-2n
(0040,A130)	Temporal Range Type	CS	1
(0040,A132)	Referenced Sample Positions	UL	1-n
(0040,A138)	Referenced Time Offsets	DS	1-n
(0040,A13A)	Referenced Datetime	DT	1-n
(0040,A180)	Annotation Group Number	US	1
(0040,A195)	Concept Name Code Sequence Modifier	SQ	1
(0040,B020)	Annotation Sequence	SQ	1
(5400,0100)	Waveform Sequence	SQ	1
(5400,0110)	Channel Minimum Value	OB or OW	1
(5400,0112)	Channel Maximum Value	OB or OW	1
(5400,1004)	Waveform Bits Allocated	US	1
(5400,1006)	Waveform Sample Interpretation	CS	1
(5400,100A)	Waveform Padding Value	OB or OW	1
(5400,1010)	Waveform Data	OB or OW	1

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26. Add new SOP Classes to Table A-1

Annex A Registry of DICOM unique identifiers (UID)

…

Table A-1
UID VALUES

UID Value	UID NAME	UID TYPE	Part
…			
1.2.840.10008.5.1.4.1.1.9.1.1	12-lead ECG Waveform Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.9.1.2	General ECG Waveform Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.9.1.3	Ambulatory ECG Waveform Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.9.2.1	Hemodynamic Waveform Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.9.3.1	Cardiac Electrophysiology Waveform Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.9.4.1	Basic Voice Audio Waveform Storage	SOP Class	PS 3.4

27. Add new Annexes to define Context Groups and Templates

Notes:

1. ***A new DICOM Supplement 53 will address the DICOM Terminology Maping Resource, and this section is subject to revision at the time of Final Text preparation based on that Supplement. The following notes describe some of those possible revisions.***
2. ***The DTMR codes used in this section are temporary, and will be replaced with formal assigned codes from the DTMR. The list of terms, however, is complete.***
3. ***The SCP-ECG codes used in this section are based on an unapproved draft, and are hence provisional.***
4. ***The format of the Context Group and Template tables will be modified, athough the basic content will remain the same.***
5. ***These proposed Annexes may be placed in a new Part 16 of the DICOM Standard, rather than in Part 6.***
6. ***The Terminology, Context Groups, and Templates will have a version control scheme applied.***

Annex B – DICOM Terminology Mapping Resource
Registry of Context Groups and Controlled Terminology

Table B-1 defines the Coding Schemes utilized in the controlled terminology specified in this Annex.

Table B-1
CODING SCHEME VALUES

SNM3	SNOMED Version 3
DTMR	DICOM Terminology Maping Resource
SCPECG	Standard Communications Protocol for Computer-Assisted Electrocardiography, Draft proposal for ISO Standard, AAMI, Revision 1.3
BARI	Bypass Angiography Revascularization Investigation, Alderman, EL and Stadius, M, Coronary Artery Disease 1992,3:1189-1207; endorsed by ACC/AHA Guidelines for Coronary Angiography, J Am Coll Cardiol 1999,33:1791

Context Group ID **3001**
Context Group Name **ECG leads**

Coding Scheme	Concept Name Termcode	Meaning
SCPECG	LEAD-0	Unspecified lead
SCPECG	LEAD-1	Lead I (Einthoven)
SCPECG	LEAD-2	Lead II
SCPECG	LEAD-3	Lead V1
SCPECG	LEAD-4	Lead V2
SCPECG	LEAD-5	Lead V3
SCPECG	LEAD-6	Lead V4
SCPECG	LEAD-7	Lead V5
SCPECG	LEAD-8	Lead V6
SCPECG	LEAD-9	Lead V7

SCPECG	LEAD-10	Lead V2R
SCPECG	LEAD-11	Lead V3R
SCPECG	LEAD-12	Lead V4R
SCPECG	LEAD-13	Lead V5R
SCPECG	LEAD-14	Lead V6R
SCPECG	LEAD-15	Lead V7R
SCPECG	LEAD-16	Lead X
SCPECG	LEAD-17	Lead Y
SCPECG	LEAD-18	Lead Z
SCPECG	LEAD-19	Lead CC5
SCPECG	LEAD-20	Lead CM5
SCPECG	LEAD-21	Lead Left Arm
SCPECG	LEAD-22	Lead Right Arm
SCPECG	LEAD-23	Lead Left Leg
SCPECG	LEAD-24	Lead I (Frank)
SCPECG	LEAD-25	Lead E
SCPECG	LEAD-26	Lead C
SCPECG	LEAD-27	Lead A
SCPECG	LEAD-28	Lead M
SCPECG	LEAD-29	Lead F
SCPECG	LEAD-30	Lead H
SCPECG	LEAD-31	Lead I-cal (Einthoven)
SCPECG	LEAD-32	Lead II-cal
SCPECG	LEAD-33	Lead V1-cal
SCPECG	LEAD-34	Lead V2-cal
SCPECG	LEAD-35	Lead V3-cal
SCPECG	LEAD-36	Lead V4-cal
SCPECG	LEAD-37	Lead V5-cal
SCPECG	LEAD-38	Lead V6-cal
SCPECG	LEAD-39	Lead V7-cal
SCPECG	LEAD-40	Lead V2R-cal
SCPECG	LEAD-41	Lead V3R-cal
SCPECG	LEAD-42	Lead V4R-cal
SCPECG	LEAD-43	Lead V5R-cal
SCPECG	LEAD-44	Lead V6R-cal
SCPECG	LEAD-45	Lead V7R-cal
SCPECG	LEAD-46	Lead X-cal
SCPECG	LEAD-47	Lead Y-cal
SCPECG	LEAD-48	Lead Z-cal

SCPECG	LEAD-49	Lead CC5-cal
SCPECG	LEAD-50	Lead CM5-cal
SCPECG	LEAD-51	Lead Left Arm-cal
SCPECG	LEAD-52	Lead Right Arm-cal
SCPECG	LEAD-53	Lead Left Leg-cal
SCPECG	LEAD-54	Lead I-cal (Frank)
SCPECG	LEAD-55	Lead E-cal
SCPECG	LEAD-56	Lead C-cal
SCPECG	LEAD-57	Lead A-cal
SCPECG	LEAD-58	Lead M-cal
SCPECG	LEAD-59	Lead F-cal
SCPECG	LEAD-60	Lead H-cal
SCPECG	LEAD-61	Lead III
SCPECG	LEAD-62	Lead aVR
SCPECG	LEAD-63	Lead aVL
SCPECG	LEAD-64	Lead aVF
SCPECG	LEAD-65	Lead -aVR
SCPECG	LEAD-66	Lead V8
SCPECG	LEAD-67	Lead V9
SCPECG	LEAD-68	Lead V8R
SCPECG	LEAD-69	Lead V9R
SCPECG	LEAD-70	Lead D (Nehb – Dorsal)
SCPECG	LEAD-71	Lead A (Nehb – Anterior)
SCPECG	LEAD-72	Lead J (Nehb – Inferior)
SCPECG	LEAD-73	Defibrillator lead: anterior-lateral
SCPECG	LEAD-74	External pacing lead: anterior-posterior
SCPECG	LEAD-75	Lead A1 (Auxiliary unipolar lead 1)
SCPECG	LEAD-76	Lead A2 (Auxiliary unipolar lead 2)
SCPECG	LEAD-77	Lead A3 (Auxiliary unipolar lead 3)
SCPECG	LEAD-78	Lead A4 (Auxiliary unipolar lead 4)
SCPECG	LEAD-79	Lead V8-cal
SCPECG	LEAD-80	Lead V9-cal
SCPECG	LEAD-81	Lead V8R-cal
SCPECG	LEAD-82	Lead V9R-cal
SCPECG	LEAD-83	Lead D-cal (cal for Nehb – Dorsal)
SCPECG	LEAD-84	Lead A-cal (cal for Nehb – Anterior)
SCPECG	LEAD-85	Lead J-cal (cal for Nehb – Inferior)

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Context Group ID **3003**

Context Group Name **Hemodynamic waveform sources**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0010	Hemodynamic pressure, NOS
DTMR	TEMP-1-0011	Hemodynamic flow
DTMR	TEMP-1-0012	Hemodynamic oxygen saturation
DTMR	TEMP-1-0013	Respiration impedance
DTMR	TEMP-1-0014	Temperature
DTMR	TEMP-1-0015	Left Ventricle pressure
DTMR	TEMP-1-0016	Right Ventricle pressure
DTMR	TEMP-1-0017	Right Atrium pressure
DTMR	TEMP-1-0018	Left Atrium pressure
DTMR	TEMP-1-0019	Femoral artery pressure
DTMR	TEMP-1-0020	Pulmonary artery pressure
DTMR	TEMP-1-0021	Aortic pressure
DTMR	TEMP-1-0022	Central Venous pressure
DTMR	TEMP-1-0023	Arterial pressure, NOS
DTMR	TEMP-1-0024	Pulmonary artery O2 saturation
DTMR	TEMP-1-0025	Pulmonary Capillary Wedge pressure; Pulmonary Artery Wedge pressure
DTMR	TEMP-1-0026	Mitral valve pullback pressure
DTMR	TEMP-1-0027	Tricuspid valve pullback pressure
DTMR	TEMP-1-0028	Pulmonary valve pullback pressure
DTMR	TEMP-1-0029	Aortic valve pullback pressure
DTMR	TEMP-1-0030	Thermal cardiac output
DTMR	TEMP-1-0031	Dye dilution cardiac output

Context Group ID **3010**

Context Group Name **Cardiovascular anatomic locations**

Coding Scheme	Concept Name Termcode	Meaning
SNM3	T-32200	Right Atrium
SNM3	T-32210	Right auricular appendage
SNM3	T-32300	Left Atrium
SNM3	T-32310	Left auricular appendage
SNM3	T-32320	Coronary sinus
SNM3	T-32500	Right ventricle
SNM3	T-32540	Right ventricle inflow
SNM3	T-32550	Right ventricle outflow tract

SNM3	T-32600	Left ventricle
SNM3	T-32640	Left ventricle inflow
SNM3	T-32640	Left ventricle outflow tract
SNM3	T-41000	Artery (NOS)
SNM3	T-42000	Aorta
SNM3	T-42070	Thoracic aorta
SNM3	T-42100	Ascending aorta
SNM3	T-42300	Aortic Arch
SNM3	T-42400	Descending aorta
SNM3	T-42500	Abdominal aorta
SNM3	T-43000	Coronary Artery (NOS)
SNM3	T-44000	Pulmonary artery
SNM3	T-44200	Right pulmonary artery
SNM3	T-44400	Left pulmonary artery
SNM3	T-45010	Carotid Artery
SNM3	T-45700	Vertebral artery
SNM3	T-46010	Innominate artery
SNM3	T-46100	Subclavian Artery
SNM3	T-46200	Internal mammary artery
SNM3	T-46420	Hepatic artery
SNM3	T-46600	Renal artery
SNM3	T-46700	Iliac artery
SNM3	T-47100	Axillary Artery
SNM3	T-47160	Brachial artery
SNM3	T-47300	Radial artery
SNM3	T-47400	Femoral artery
SNM3	T-47410	Right femoral artery
SNM3	T-48000	Vein (NOS); Vena anonyma
SNM3	T-48170	Vena jugularis interna
SNM3	T-48330	Subclavian vein
SNM3	T-48340	Azygos vein
SNM3	T-48500	Pulmonary Vein
SNM3	T-48510	Superior right pulmonary vein
SNM3	T-48520	Inferior right pulmonary vein
SNM3	T-48530	Superior left pulmonary vein
SNM3	T-48540	Inferior left pulmonary vein
SNM3	T-48610	Superior vena cava
SNM3	T-48620	Innominate vein
SNM3	T-48710	Inferior Vena cava

SNM3	T-48740	Renal vein
SNM3	T-48817	Umbilical vein
SNM3	T-49110	Axillary vein
SNM3	T-49350	Brachial vein
SNM3	T-49410	Femoral vein
SNM3	T-49530	Saphenous vein
DTMR	TEMP-1-0040	Anomalous pulmonary vein
DTMR	TEMP-1-0041	Antecubital Vein (NOS)
DTMR	TEMP-1-0042	Systemic collateral artery to lung
DTMR	TEMP-1-0043	Common atrium
DTMR	TEMP-1-0044	Common ventricle
DTMR	TEMP-1-0045	Conduit
DTMR	TEMP-1-0046	Aortic fistula
DTMR	TEMP-1-0047	Fistula coronary to LA
DTMR	TEMP-1-0048	Fistula coronary to LV
DTMR	TEMP-1-0049	Fistula coronary to RA
DTMR	TEMP-1-0050	Fistula coronary to RV
DTMR	TEMP-1-0051	Pulmonary arteriovenous fistula
DTMR	TEMP-1-0052	Inferior baffle
DTMR	TEMP-1-0053	Juxtaposed appendage
DTMR	TEMP-1-0054	Left ventricle apex
DTMR	TEMP-1-0055	Left ventricle outflow chamber
DTMR	TEMP-1-0056	Neo-aorta
DTMR	TEMP-1-0057	Neonatal pulmonary artery
DTMR	TEMP-1-0058	Pulmonary artery conduit
DTMR	TEMP-1-0059	Patent ductus arteriosus
DTMR	TEMP-1-0060	Pulmonary chamber in cor triatriatum
DTMR	TEMP-1-0061	Pulmonary venous atrium
DTMR	TEMP-1-0062	Pulmonary vein confluence
DTMR	TEMP-1-0063	Right ventricle apex
DTMR	TEMP-1-0064	Right ventricle outflow chamber
DTMR	TEMP-1-0065	Superior baffle
DTMR	TEMP-1-0066	Truncus Arteriosus Communis
DTMR	TEMP-1-0067	Umbilical artery
DTMR	TEMP-1-0068	Systemic venous atrium

Context Group ID **3011**

Context Group Name **Electrophysiology anatomic locations**

Coding	Concept Name	Meaning

Scheme	Termcode	
SNM3	T-32200	Right Atrium
DTMR	TEMP-1-0070	High Right Atrium
DTMR	TEMP-1-0071	Lateral High Right Atrium
DTMR	TEMP-1-0072	Mid Right Atrium
DTMR	TEMP-1-0073	Low Right Atrium
SNM3	T-32210	Right auricular appendage
SNM3	T-32300	Left Atrium
SNM3	T-32310	Left auricular appendage
SNM3	T-32330	Coronary Sinus
SNM3	T-32400	Common ventricle
SNM3	T-32500	Right ventricle
DTMR	TEMP-1-0063	Right ventricle apex
SNM3	T-32540	Right ventricle inflow
SNM3	T-32550	Right ventricle outflow tract
SNM3	T-32600	Left ventricle
DTMR	TEMP-1-0054	Left ventricle apex
SNM3	T-32640	Left ventricle inflow
SNM3	T-32640	Left ventricle outflow tract
SNM3	T-32810	Sino-Atrial Node
SNM3	T-32820	Atrioventricular node
SNM3	T-32830	Atrioventricular bundle, bundle of HIS
SNM3	T-32831	Right branch of AV bundle
SNM3	T-32832	Left branch of AV bundle
DTMR	TEMP-1-0064	Left anterior fasicular branch of left bundle branch
DTMR	TEMP-1-0065	Left posterior fasicular branch of left bundle branch
SNM3	T-32840	Purkinje fibers
SNM3	T-32850	Accessory AV bundle, bundle of Kent
SNM3	T-35110	Tricuspid ring
SNM3	T-35120	Right AV ostium
SNM3	T-35210	Pulmonic ring
SNM3	T-35310	Mitral ring
SNM3	T-39010	Epicardium
SNM3	T-48411	Ostium of Coronary Sinus
SNM3	T-48420	Great cardiac vein
SNM3	T-48430	Middle cardiac vein
SNM3	T-48500	Pulmonary Vein
SNM3	T-48510	Superior right pulmonary vein
SNM3	T-48520	Inferior right pulmonary vein

SNM3	T-48530	Superior left pulmonary vein
SNM3	T-48540	Inferior left pulmonary vein
DTMR	TEMP-1-0066	Tendon of Todaro

1216 **Context Group ID** **3014**
Context Group Name **Coronary artery segments**

Coding Scheme	Concept Name Termcode	Meaning
BARI	1	Proximal Right Coronary Artery
BARI	1A	Right Coronary Artery Ostium
BARI	2	Mid Right Coronary Artery
BARI	3	Distal Right Coronary Artery
BARI	4	Posterior Descending Right Coronary Artery
BARI	5	Right posterior AV
BARI	6	1st Right posterolateral
BARI	7	2nd Right posterolateral
BARI	8	3rd Right posterolateral
BARI	9	Posterior descending septal perforators
BARI	10	Acute Marginal
BARI	11	Left Main Coronary Artery
BARI	11A	Left Main Coronary Artery Ostium
BARI	12	Proximal Left Anterior Descending Coronary Artery
BARI	13	Mid Left Anterior Descending Coronary Artery
BARI	14	Distal Left Anterior Descending Coronary Artery
BARI	15	1st Diagonal Coronary Artery
BARI	15A	Lateral 1st Diagonal Coronary Artery
BARI	16	2nd Diagonal Coronary Artery
BARI	16A	Lateral 2nd Diagonal Coronary Artery
BARI	17	1st Septal Coronary Artery
BARI	18	Proximal Circumflex Coronary Artery
BARI	19	Mid Circumflex Coronary Artery
BARI	20	1st Marginal Coronary Artery
BARI	20A	Lateral 1st Marginal Coronary Artery
BARI	21	2nd Marginal Coronary Artery
BARI	21A	Lateral 2nd Marginal Coronary Artery
BARI	22	3rd Marginal Coronary Artery
BARI	22A	Lateral 3rd Marginal Coronary Artery
BARI	19A	Distal Circumflex Coronary Artery
BARI	23	AV groove continuation

BARI	27	Left Posterior Descending Artery
BARI	28	Ramus
BARI	28A	Lateral Ramus
BARI	24	1st Left Posterolateral Coronary Artery
BARI	25	2nd Left Posterolateral Coronary Artery
BARI	26	3rd Left Posterolateral Coronary Artery
BARI	29	3rd diagonal
BARI	29A	Lateral 3rd Diagonal

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Context Group ID **3019**

1220 **Context Group Name** **Cardiovascular Anatomic Location Modifiers**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0070	Ostium
DTMR	TEMP-1-0071	Proximal
DTMR	TEMP-1-0072	Mid
DTMR	TEMP-1-0073	Distal
DTMR	TEMP-1-0074	Lateral from cited segment
DTMR	TEMP-1-0075	Right
DTMR	TEMP-1-0076	Left
DTMR	TEMP-1-0077	Superior, or high
DTMR	TEMP-1-0078	Inferior, or low
DTMR	TEMP-1-0079	Anterior
DTMR	TEMP-1-0080	Posterior
DTMR	TEMP-1-0081	Graft to cited segment, aortic or proximal anastomosis
DTMR	TEMP-1-0082	Graft to cited segment, body
DTMR	TEMP-1-0083	Graft to cited segment, distal anastomosis
DTMR	TEMP-1-0084	Arterial graft to cited segment
DTMR	TEMP-1-0085	Venous graft to cited segment

1222 **Context Group ID** **3082**
Context Group Name **Waveform Units of Measurement**

Coding Scheme	Concept Name Termcode	Concept Name
SNM3	Y-U0001	%
SNM3	Y-U0009	hb/min
SNM3	Y-U0140	kPa
SNM3	Y-U0156	l/min
SNM3	Y-U0221	ml/min
SNM3	Y-U0222	ml/s

SNM3	Y-U0224	mm(Hg)
SNM3	Y-U0016	degrees Celsius
SNM3	Y-U0005	arbitrary units
SNM3	Y-U0352	volts
SNM3	Y-U0249	mv
SNM3	Y-U0350	uv
SNM3	Y-U0353	W
SNM3	Y-U0112	J
DTMR	TEMP-1-0088	Metabolic equivalents (Mets)
SNM3	Y-U0054	dB
SNM3	Y-U0226	mm/s
SNM3	Y-U0387	miles/h
SNM3	Y-U0431	km/h

Context Group ID **3090**
Context Group Name **Time Synchronization channel types**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0090	X-ray Fluoroscopy On Signal
DTMR	TEMP-1-0091	X-ray On Trigger
DTMR	TEMP-1-0092	ECG-based gating signal, processed
DTMR	TEMP-1-0093	Digital timecode (NOS)
DTMR	TEMP-1-0094	IRIG-B timecode

Context Group ID **3240**
Context Group Name **Electrophysiology measurement functions and techniques**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0100	Voltage measurement, NOS
DTMR	TEMP-1-0101	Pacing (electrical) stimulus, voltage
DTMR	TEMP-1-0102	Radio frequency ablation, power
DTMR	TEMP-1-0103	His bundle electrogram
DTMR	TEMP-1-0104	Voltage measurement by mapping catheter
DTMR	TEMP-1-0105	Voltage measurement by basket catheter
DTMR	TEMP-1-0106	Differential signal
DTMR	TEMP-1-0107	Monopole signal

Context Group ID **3241**
Context Group Name **Hemodynamic measurement techniques**

Coding	Concept Name	Meaning

Scheme	Termcode	
DTMR	TEMP-1-0110	Dual catheter
DTMR	TEMP-1-0111	Pulmonary capillary wedge
DTMR	TEMP-1-0112	Pullback
DTMR	TEMP-1-0113	Computed derivation (from multiple simultaneous measurements)
DTMR	TEMP-1-0114	Composite derivation (from multiple independent measurements)
DTMR	TEMP-1-0115	Static catheter
DTMR	TEMP-1-0116	Wedge
DTMR	TEMP-1-0117	Averaged
DTMR	TEMP-1-0118	Fluid filled catheter
DTMR	TEMP-1-0119	Tip manometer

Context Group ID **3249**
Context Group Name **Catheterization Acquisition Context Concepts**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0120	Catheterization Procedure Phase
DTMR	TEMP-1-0121	Procedure Step Number
DTMR	TEMP-1-0122	Contrast Phase
DTMR	TEMP-1-0123	Physiological challenges

Context Group ID **3250**
Context Group Name **Catheterization Procedure Phase**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0130	Baseline
DTMR	TEMP-1-0131	Right heart diagnostic cath
DTMR	TEMP-1-0132	Left heart diagnostic cath
DTMR	TEMP-1-0133	Pre-intervention
DTMR	TEMP-1-0134	Intervention
DTMR	TEMP-1-0135	Drug intervention or therapy
DTMR	TEMP-1-0136	Post-intervention
DTMR	TEMP-1-0137	Bailout

Context Group ID **3251**
Context Group Name **Contrast Phase**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0138	Post-contrast

Context Group ID **3254**
Context Group Name **Electrophysiology Procedure Phase**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0130	Baseline
DTMR	TEMP-1-0140	Sinus Node Recovery Time, evaluation of
DTMR	TEMP-1-0141	Atrial Effective Refactory Period, evaluation of
DTMR	TEMP-1-0142	Ventricular Effective Refactory Period, evaluation of
DTMR	TEMP-1-0143	RF Ablation procedure phase
DTMR	TEMP-1-0144	Carotid Sinus Massage
DTMR	TEMP-1-0145	Post-defibrilation
DTMR	TEMP-1-0146	EP Mapping
DTMR	TEMP-1-0147	Post-ablation

Context Group ID **3261**
Context Group Name **Stress Protocols**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0150	Bruce
DTMR	TEMP-1-0151	Modified Bruce
DTMR	TEMP-1-0152	Balke
DTMR	TEMP-1-0153	Ellestad
DTMR	TEMP-1-0154	Ramp
DTMR	TEMP-1-0155	Pepper
DTMR	TEMP-1-0156	Naughton
DTMR	TEMP-1-0157	Modified Naughton

Context Group ID **3262**
Context Group Name **ECG Patient State Values**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0130	Baseline
DTMR	TEMP-1-0160	Supine
DTMR	TEMP-1-0161	Resting
DTMR	TEMP-1-0162	Exercising
DTMR	TEMP-1-0163	Post-exercise

Context Group ID **3263**
Context Group Name **Electrode Placement Values**

Coding Scheme	Concept Name Termcode	Meaning
SCPECG	ELEC-1-0	Unspecified
SCPECG	ELEC-1-1	Standard 12-lead positions: RA, RL, LA, and LL placed at limb extremities; V1 to V6 placed at standard positions on the chest. All electrodes are placed individually.
SCPECG	ELEC-1-2	Mason-Likar positions: RA, RL, LA, and LL placed on the torso. V1 to V6 placed at standard positions on the chest. All electrodes are placed individually.
SCPECG	ELEC-1-3	Mason-Likar with V pad: RA, RL, LA, and LL individually placed on the torso. V1 to V6 placed on the chest as part of a single electrode pad (not placed individually).
SCPECG	ELEC-1-4	Single electrode pad: All electrodes placed on the chest in a single electrode pad. None of the electrodes are placed individually
SCPECG	ELEC-1-5	12-lead ECG derived from Frank XYZ leads
SCPECG	ELEC-1-6	12-lead ECG derived from non-standard leads

Context Group ID **3264**
Context Group Name **XYZ Electrode Placement Values**

Coding Scheme	Concept Name Termcode	Meaning
SCPECG	ELEC-2-0	Unspecified
SCPECG	ELEC-2-1	Frank lead system (Frank, 1956; 13:737)
SCPECG	ELEC-2-2	McFee-Parungao lead system (Benchimol, Vectorcardiography, Williams & Wilkins, Baltimore, 1973, Fig 1.6 on page 6)
SCPECG	ELEC-2-3	Cube lead system (Grishman et al, Amer Heart J 1951; 41:483).
SCPECG	ELEC-2-4	Bipolar uncorrected XYZ lead system
SCPECG	ELEC-2-5	Pseudo-orthogonal XYZ lead system (as used in Holter recording)
SCPECG	ELEC-2-6	XYZ leads derived from standard 12-lead ECG

Context Group ID **3271**
Context Group Name **Hemodynamic Physiological Challenges**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0170	Valsalva
DTMR	TEMP-1-0171	Head up
DTMR	TEMP-1-0172	Leg up

DTMR	TEMP-1-0173	Handgrip
DTMR	TEMP-1-0174	Negative lower body pressure
DTMR	TEMP-1-0175	Exercise
DTMR	TEMP-1-0176	Vagal
DTMR	TEMP-1-0177	Held inspiration
DTMR	TEMP-1-0178	Held ventilation
DTMR	TEMP-1-0179	Post volume challenge

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Context Group ID **3335**

1262 **Context Group Name** **ECG Annotations**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0180	Pacemaker spike, suppressed
DTMR	TEMP-1-0181	P wave onset
DTMR	TEMP-1-0182	P wave peak
DTMR	TEMP-1-0183	P wave end
DTMR	TEMP-1-0184	PR segment (isoelectric point)
DTMR	TEMP-1-0185	Fiducial point
DTMR	TEMP-1-0186	QRS onset
DTMR	TEMP-1-0187	QRS end
DTMR	TEMP-1-0188	Q wave
DTMR	TEMP-1-0189	R wave peak
DTMR	TEMP-1-0190	R' peak
DTMR	TEMP-1-0191	S wave
DTMR	TEMP-1-0192	S' wave
DTMR	TEMP-1-0193	T wave onset
DTMR	TEMP-1-0194	T wave peak
DTMR	TEMP-1-0195	T wave end
DTMR	TEMP-1-0196	J point
DTMR	TEMP-1-0197	J point + 20 msec
DTMR	TEMP-1-0198	J point + 60 msec
DTMR	TEMP-1-0199	J point +80 msec
DTMR	TEMP-1-0200	U wave peak

1264 **Context Group ID** **3337**
Context Group Name **Hemodynamic Annotations**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0201	Systolic peak
DTMR	TEMP-1-0202	Systolic average

DTMR	TEMP-1-0203	Mean pressure
DTMR	TEMP-1-0204	Diastolic nadir
DTMR	TEMP-1-0205	Diastolic average
DTMR	TEMP-1-0206	End diastole
DTMR	TEMP-1-0207	Max dp/dt
DTMR	TEMP-1-0208	Max neg dp/dt
DTMR	TEMP-1-0209	A wave
DTMR	TEMP-1-0210	A wave average
DTMR	TEMP-1-0211	V wave
DTMR	TEMP-1-0212	V wave average
DTMR	TEMP-1-0213	Valve open
DTMR	TEMP-1-0214	Valve close
DTMR	TEMP-1-0215	Start of thermal CO
DTMR	TEMP-1-0216	Peak of thermal CO
DTMR	TEMP-1-0217	70% of thermal CO
DTMR	TEMP-1-0218	35% of thermal CO
DTMR	TEMP-1-0219	Start of inspiration
DTMR	TEMP-1-0220	End of inspiration
DTMR	TEMP-1-0221	Start of expiration
DTMR	TEMP-1-0222	End of expiration
DTMR	TEMP-1-0223	Beat detected (accepted)
DTMR	TEMP-1-0224	Beat detected (rejected)

Context Group ID **3339**
Context Group Name **Electrophysiology Annotations**

Coding Scheme	Concept Name Termcode	Meaning
DTMR	TEMP-1-0230	Start of atrial contraction
DTMR	TEMP-1-0231	Start of atrial contraction (subsequent)
DTMR	TEMP-1-0232	HIS bundle wave
DTMR	TEMP-1-0211	V wave
DTMR	TEMP-1-0233	V wave of next beat
DTMR	TEMP-1-0234	Stimulation at rate 1 interval
DTMR	TEMP-1-0235	Stimulation at rate 2 interval
DTMR	TEMP-1-0236	Stimulation at rate 3 interval
DTMR	TEMP-1-0237	Stimulation at rate 4 interval
DTMR	TEMP-1-0238	P wave
DTMR	TEMP-1-0188	Q wave
DTMR	TEMP-1-0239	R wave

DTMR	TEMP-1-0240	S wave
DTMR	TEMP-1-0241	T wave
DTMR	TEMP-1-0242	Ablation on
DTMR	TEMP-1-0243	Ablation off

Annex C – Registry of Templates

Table C-1 defines the Value Type codes used in this Annex.

Table C-1
VALUE TYPES

C	Coded Entry
N	Numeric Value and Coded Unit of Measurement
T	Free Text

Template ID **3401**
Template Name **ECG Acquisition Context**

Concept Name	Coding Scheme	Concept Name Termcode	Type	Multiplicity	Value Type	Concept Value CID	Notes
Electrode Placement	DTMR	TEMP-1-0300	3	1	C	3263	
XYZ Electrode Configuration	DTMR	TEMP-1-0301	3	1	C	3264	
Patient State	DTMR	TEMP-1-0302	3	1	C	3262	
Stress Protocol	DTMR	TEMP-1-0303	3	1	C	3261	
Protocol Stage	DTMR	TEMP-1-0304	3	1	N		

Template ID **3403**
Template Name **Catheterization Acquisition Context**

Concept Name	Coding Scheme	Concept Name Termcode	Type	Multiplicity	Value Type	Concept Value CID	Notes
Catheterization Procedure Phase	DTMR	TEMP-1-0120	3	1	C	3250	
Procedure Step Number	DTMR	TEMP-1-0121	3	1	N		
Contrast Phase	DTMR	TEMP-1-0122	3	1	C	3251	
Physiological challenges	DTMR	TEMP-1-0123	3	1	C	3271	

Template ID **3450**

Template Name **Cardiac Electrophysiology Acquisition Context**

Concept Name	Coding Scheme	Concept Name Termcode	Type	Multiplicity	Value Type	Concept Value CID	Notes
EP Procedure Phase	DTMR	TEMP-1-0305	3	1	C	3254	
Procedure Step Number	DTMR	TEMP-1-0121	3	1	N		
Pulse train definition	DTMR	TEMP-1-0306	3	1	T		

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1292 **Changes to:**

NEMA Standards Publication PS 3.11-1999

1294 ***Digital Imaging and Communications in Medicine (DICOM)***

Part 11: Media Storage Application Profiles

1296

28. Add new Annex for waveform on 1.44 MB floppy disk

Annex X (Normative) - Waveform Diskette Interchange Profile

X.1 PROFILE IDENTIFICATION

This Annex defines a class of Application Profiles for interchange of Waveform SOP Instances via 1.44 MB Diskette (floppy disk) media.

The identifier for this class shall be STD-WVFM.

The specific Application Profiles in this class are shown in the Table X.1.

Table X.1 - Waveform Application Profiles

Application Profile	Identifier	Description
12-lead ECG Interchange on Diskette	STD-WVFM-ECG-FD	Uncompressed ECG waveform data
Hemodynamic Waveform Interchange on Diskette	STD-WVFM-HD-FD	Uncompressed hemodynamic waveform data

X.2 CLINICAL CONTEXT

This Application Profile facilitates the interchange of waveforms and related data on floppy disk media.

This primary clinical context for this profile is the transfer of waveforms, such as electrocardiograms, from non-networked equipment (mobile or remote acquisition units) to archive or display equipment.

X.2.1 Roles and Service Class Options

This class of Application Profile uses the Media Storage Service Class defined in PS3.4 with the Interchange Option.

The Application Entity shall support one or more of the roles of File Set Creator (FSC), File Set Reader (FSR), and File Set Updater (FSU), defined in PS 3.10.

The role of File Set Creator shall be used by Application Entities which generate a File Set under this Class of Application Profiles. FSCs shall be able to generate the Waveform SOP Instances defined for this Application Profile, and the Basic Directory SOP Instance in the DICOMDIR file with all the subsidiary Directory Records related to the Waveform SOP Instances stored in the File Set.

The role of File Set Reader shall be used by Application Entities which receive a transferred File Set under this Class of Application Profiles. File Set Readers shall be able to read the DICOMDIR directory file and all the SOP Instance files defined for this Application Profile, using the defined Transfer Syntax.

The role of File Set Updater is used by Application Entities which receive a transferred File Set under this Class of Application Profiles, and update it by the addition (or deletion) of waveforms or ancillary information to (or from) the medium. FSUs shall be able to read and update the DICOMDIR file, and optionally to generate the Waveform SOP Instances defined for this Application Profile.

X.4 STD-WVFM-ECG-FD PROFILE

X.4.1 SOP Classes and Transfer Syntaxes

This Application Profile is based on the Media Storage Service Class with the Interchange Option (see PS 3.4).

The SOP Classes and corresponding Transfer Syntax supported by this Application Profile are specified in the Table X.4.1-1. The supported Storage SOP Classes shall be listed in the Conformance Statement using a table of the same form.

Table X.4.1-1 STD-WVFM-ECG-FD SOP Classes and Transfer Syntaxes

Information Object Definition	Service Object Pair Class UID	Transfer Syntax and UID	FSC Requirement	FSR Requirement	FSU Requirement
Basic Directory	1.2.840.10008.1.3.10	Explicit VR Little Endian Uncompressed 1.2.840.10008.1.2.1	Mandatory	Mandatory	Mandatory
12-lead ECG Waveform Storage	1.2.840.10008.5.1.4.1.1.9.1.1	Explicit VR Little Endian Uncompressed 1.2.840.10008.1.2.1	Mandatory	Mandatory	Optional

X.4.2 Physical Medium And Medium Format

The STD-WVFM-ECG-FD application profile requires the 1.44 MB Diskette physical medium with the PC File System Media Format, as defined in PS3.12 Annex B.

X.4.3 Directory Information in DICOMDIR

Conformant Application Entities shall include in the DICOMDIR File the Basic Directory IOD containing Directory Records at the Patient and the subsidiary Study and Series levels, appropriate to the SOP Classes in the File Set. All DICOM files in the File Set incorporating SOP Instances defined for the specific Application Profile shall be referenced by Directory Records.

X.5 STD-WVFM-HD-FD PROFILE

X.5.1 SOP Classes and Transfer Syntaxes

This Application Profile is based on the Media Storage Service Class with the Interchange Option (see PS 3.4).

The SOP Classes and corresponding Transfer Syntax supported by this Application Profile are specified in the Table X.5.1-1. The supported Storage SOP Classes shall be listed in the Conformance Statement using a table of the same form.

Table X.5.1-1 STD-WVFM-HD-FD SOP Classes and Transfer Syntaxes

Information Object Definition	Service Object Pair Class UID	Transfer Syntax and UID	FSC Requirement	FSR Requirement	FSU Requirement
Basic Directory	1.2.840.10008.1.3.10	Explicit VR Little Endian Uncompressed 1.2.840.10008.1.2.1	Mandatory	Mandatory	Mandatory
Hemodynamic Waveform Storage	1.2.840.10008.5.1.4.1.1.9.2.1	Explicit VR Little Endian Uncompressed 1.2.840.10008.1.2.1	Mandatory	Mandatory	Optional

X.5.2 Physical Medium And Medium Format

The STD-WVFM-HD-FD application profile requires the 1.44 MB Diskette physical medium with the PC File System Media Format, as defined in PS3.12 Annex B.

X.5.3 Directory Information in DICOMDIR

Conformant Application Entities shall include in the DICOMDIR File the Basic Directory IOD containing Directory Records at the Patient and the subsidiary Study and Series levels, appropriate to the SOP Classes in the File Set. All DICOM files in the File Set incorporating SOP Instances defined for the specific Application Profile shall be referenced by Directory Records.