Integrating the Healthcare Enterprise

IHE Patient Care Device Technical Framework Supplement

Waveform Content Module (WCM)

Rev. 1.3 –Trial Implementation

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Please verify you have the most recent version of this document. See here for Trial Implementation and Final Text versions and here for Public Comment versions.

Foreword

This is a supplement to the IHE Patient Care Device Technical Framework 7.0. Each supplement undergoes a process of public comment and trial implementation before being incorporated into the volumes of the Technical Frameworks.

This supplement is published on January 8, 2018 for trial implementation and may be available for testing at subsequent IHE Connectathons. The supplement may be amended based on the results of testing. Following successful testing it will be incorporated into the Patient Care Device Technical Framework. Comments are invited and can be submitted at http://www.ihe.net/PCD_Public_Comments.

This supplement describes changes to the existing technical framework documents.

"Boxed" instructions like the sample below indicate to the Volume Editor how to integrate the relevant section(s) into the relevant Technical Framework volume.

Amend Section X.X by the following:

Where the amendment adds text, make the added text **bold underline**. Where the amendment removes text, make the removed text **bold strikethrough**. When entire new sections are added, introduce with editor's instructions to "add new text" or similar, which for readability are not bolded or underlined.

General information about IHE can be found at www.ihe.net.

Information about the IHE Patient Care Device domain can be found at ihe.net/IHE_Domains.

Information about the organization of IHE Technical Frameworks and Supplements and the process used to create them can be found at http://ihe.net/IHE_Process and http://ihe.net/Profiles.

The current version of the IHE Patient Care Device Technical Framework can be found at http://ihe.net/Technical_Frameworks.

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Introduction

The Waveform Content Module defines the data structure and semantics to be used by IHE actors that desire to communicate waveforms and other time-series data sets within the context of IHE-PCD actors such as DOC, DOR, AR, AM, etc. Typical use cases include communication of time bounded waveforms (e.g., snapshots) as alarm evidentiary data or continuous waveforms for display.

Open Issues and Questions

- Do we need standard ways of handling data starvation or over-feeding due to the lack of exact clock alignment between data reporters and data consumers?
- Current IEEE 11073 Nomenclature needs to be expanded. The reader will notice a number of unassigned codes which are shown as 0^.
- Current WCM supplement requires the Consumer to consume all information that the Reporter decides to send. In the future we may need to consider filtering and querying schemes. Some possible parameters to filter include:

  Waveforms types to be sent

  Sampling rates

  Latency

  Duration of waveform snapshot

  Send only on demand

  Please note that this can also be accomplished by manual configuration and setup at the Reporter side in the absence of a defined Consumer to Reporter configuration approach.

Closed Issues

- First use case to be addressed will be to send the alarm waveform unsolicited when the alarm occurs…

  There would be a unique cross-links (s/n & session ID) between the ACM message and the corresponding WCM message

  The WCM message could be sent ‘some time’ after the ACM message but typically within a few seconds…

- Number of waveforms in the WCM package…

  <Phase 1 - Defined by source>

  Unlimited number of waveforms…

- Support different sampling rates

  Defined by source

- How often are the waveform messages sent?

  Interval TBD – defined by clinical requirements

- How many messages per set of waveforms?

  All waveforms (and parameter info) for a given time period have to be sent in one message.

  Multiple messages can be sent to cover a longer time period

  Example – a ten minute waveform snapshot can be broken into 20-30 second snapshots. Each snapshot must contain all the waveform data for that snapshot. All waveforms should be sent in one message, time aligned

- How to represent the waveform?

  HL7®[1] NA Data Type which is a series of NMs carat delimited

  Abnormal conditions (invalid data, out-of-range data, inop data, etc.) will have special values (e.g., 99998, -65,535, etc.) defined using OBXs

  Only one encoding scheme supported for now, however scheme type (0) will be reported in waveform message which allows for future schemes which would not break parser.

- Do we need an application level checksum?

  No

- What latency is acceptable to end-user, due to processing time?

  For alarm evidentiary data, the Consumer should expect the data to lag the alarm message due to clinical issues and not processing issues. For example, the waveform message may include a few seconds of data post-event.

  For continuous waveforms, the latency should be such that the consumer does not "starve" for lack of data. However, the consumer should have a buffer of at least one message.

- Format should be simple enough such that it could be processable by phone/display device.

  Decision is that this is not a high priority, most such devices will have an intermediary which can pre-process the data to reduce complexity on the end-device

- It is assumed that all samples in a message are time-wise aligned

Note:

The "caret" or "^" is used throughout as an example of the "component separator", and is not the only "component separator" supported.

[1] HL7 is the registered trademark of Health Level Seven International.

Profile Abstract

Waveform information can be optionally included in appropriate IHE PCD transactions. This supplement describes a Content Module which describes how to represent waveform data in DEC, ACM and other Profiles. It should also be noted that the current version of the does not necessarily cover all possible waveform use cases, which have been prioritized as follows:

1. Current Multi-Channel Waveform (MCW) snapshot as defined by the source is created/pushed by alarm source based on event occurrence
2. Current MCW snapshot as defined by source on request to source
3. Continuous MCW streams
4. Waveform MCW snapshot archive query
5. Periodic trend data (very slow waveform…) on request
6. 12-Lead ECG report (out of scope, implementers should refer to the Resting ECG Workflow (REWF) from the IHE Cardiology Domain)

The intent of this supplement is to specify a uniform way of representing waveform data in HL7 V2 messages to facilitate interoperability of systems from different vendors and to facilitate integration of waveform data delivery into other IHE PCD profiles.

Glossary

MCW: Multi-Channel Waveform

WCM: Waveform Content Module

Waveform Snapshot: A limited duration continuous block of waveform data. Typically less than 1 minute in duration.

Bounded Waveform: A limited duration continuous block of waveform data which is bounded in time, synonymous with waveform snapshot or waveform snippet.

Continuous Waveform: A continuous stream of waveform data terminated only on request, on patient disconnect or due to technical reasons.

RGB: Stands for "Red Green Blue." It refers to the three hues of light (red, green, and blue) that can mix together to form any color. When the highest intensity (255) of each color is mixed together, white light is created. When each hue is set to zero intensity, the result is black. Software specifies the specific R, G and B levels to generate specific colors per displayed pixel.

RTMMS: NIST Rosetta Terminology Mapping Management System that specifies specifies the IEEE 11073 nomenclature and co-constraints (units-of-measure, enumerated values and sites).

SCO: Stands for Source Cardinality, indicates the cardinality for a particular observation, for example: 0..1, 0..*, 1..1, 1..*, etc.)

XSD: W3C Schema, when referencing xs:integer and other datatypes.

Volume 1 – Integration Profiles

This section describes the changes required in Volume 1of the Technical Framework that result from including this Integration Profile.

1.7 History of Annual Changes

Add the following bullet to the end of the bullet list in Section 1.7 of Volume 1

- **[WCM] Waveform Content Module** will extend existing IHE PCD profiles to provide a method for passing near real-time waveform data using HL7 V2 observation messages.

Add the following section to Section 2.2 of Volume 1

2.2.X Waveform Content Module (WCM)

The Waveform Content Module defines the data structure and semantics to be used for communication of waveforms by IHE actors that require this functionality. Typical use cases include communication of waveform snapshots as alarm evidentiary data or continuous waveform display.

Update Section 3, Volume 1as indicated below

3 Overview of Actors and Transactions

The WCM Profile does not introduce any new actors or transactions. It can be used as an option for the DOR, DOC, AR and AM Actors.

This section shall be added as the latest chapter of Volume 1

X Waveform Content Module (WCM)

The Waveform Content Module defines the data structure and semantics to be used for communication of waveforms by IHE actors that require this functionality.

X.1 Problem Statement and Requirements

Waveform data is an important component of information coming from medical patient care devices. This information can be an important complement to assessing the current status of a patient or the status of a patient during a clinical event. As such, waveform information can be provided in a number of forms:

- <u>**Bounded waveforms**</u> - specific forms of waveform snapshots or snippets such as 12-lead ECG associated with a diagnostic encounter, or a snapshot associated with an alarm event

- **<u>Continuous waveforms</u>** - a continuous "real-time" stream of waveform data that would be used for a remote "real-time" waveform display

Independent of the form of waveform, the following information must be accommodated:

- Waveform type (e.g., ECG, Arterial Blood Pressure, CO2, etc.)
- Sampling rate
- Start time
- Event time
- Scaling (e.g., #bits/mmHg in the case of blood pressure)
- Annotations (e.g., pacer, beat-label, QRS, respiration, out-of-range, etc.)
- Status (e.g., lead-off, out-of-range, test mode, etc.)
- Filter status (e.g., low-pass, high-pass, etc.)
- Number of waveform samples
- Suggested waveform display color
- Units of measure
- Patient identification
- Clinician notes

This information also has structure, which will follow the IEEE 11073 Domain Information Model.

As a content profile, WCM only specifies how to represent waveforms in transaction profiles that have requirements to communicate waveform information, such as DEC and/or ACM.

X.2 Key Requirements

When considering the design of the WCM Profile, a number of key requirements were identified:

- Leverage existing IHE PCD Profiles and “principles”

  Use HL7 V2.6 message constructs, avoiding the definition of new datatypes

  Use ISO/IEEE Nomenclature and Information Model
- Message shall consist of sample values (structured data) and not bit-maps or PDF files

  Supports rendering at end-client or intermediary

  Supports further data analysis at end client

  Supports alternative display types (e.g., ventilation loops) at end-client
- Need to handle simultaneous alarms for same patient

- Support MCW “snapshots”, MCW “streams” as well as “periodic trend” snapshots
- Minimize optional fields and approaches in order to maximize interoperability
  Focus on simplicity and avoid complexity
- Need to be able to send waveform messages with parameter info, and vice versa
- Need to be able to send waveform messages with alarm info, and vice versa

X.3 Actors/ Transactions

WCM will be used as an option to existing and future transactions and does not define any new IHE actors or transactions. Existing actors (such as DOR, DOC, AR and AM) and Transactions (such as PCD-01 and PCD-04) can use WCM.

X.4 Integration Profile Options

WCM is an option to the DEC and ACM Profiles. There are no options to WCM.

X.5 Key Use Case(s)

Please note that to fully implement these Use Cases additional PCD workflows will need to be addressed which can then apply WCM for the communication of waveform information.

X.5.1 Use Case 1 – Alarm Waveform Snapshot

A patient, post heart attack, is walking in his room while being monitored using a patient telemetry system. The system detects a run of ventricular beats and generates an alarm at the central nurse station. In parallel, the alarm information including the waveform, parameter data and alarm information is acquired by a separate alarm communication system which then sends the appropriate information snapshot to a caregiver's portable device.

X.5.2 Use Case 2 – Real-Time Waveform Viewing

A physician would like to review the current status of a patient including his parameter information, waveforms, device settings, etc. He brings up an application on his PDA or personal computer and can view the current information delayed by a maximum of 10 seconds.

X.5.3 Use Case 3 – Archived Waveform Viewing

A physician starting his rounds would like to review the waveforms and associated data for a patient under his/her care. He/she accesses an archive which has stored the continuous waveforms and related vital signs and other parameter data over the past 24 (or more) hours.

X.5.4 Use Case 4 – Mixed Snapshot and Continuous Waveform Viewing

A Remote Monitoring Station, responsible for checking on monitored outpatients, receives an alert on one of its patients. The alert is accompanied by a waveform snippet at the time of the event. If further investigation of the current status of the patient is required, a continuous waveform can be viewed.

X.5.5 Use Case 5 – Waveform Snapshot to EHR

The user of an EHR requests a snapshot of a waveform from the device.

X.5.6 Use Case 6 – 12 Lead ECG

A patient enters the Emergency Room complaining of pressure on the chest wall. A 12-lead ECG is obtained and transmitted via WCM to the Cardiology Management System. The data is reviewed and annotated and sent via WCM to the hospital Clinical Information System as part of the patient's clinical record. (This use case is out of scope. Please refer instead to the Resting ECG Workflow Profile from the IHE Cardiology domain.)

X.6 WCM Security Considerations

WCM does not impose specific requirements for authentication, encryption, or auditing, leaving these matters to site-specific policy or agreement.

Appendix A – Actor Summary Definitions

WCM is an option which can be used by the DOR, DOC, AR and AM Actors, at this point in time.

Appendix B – Transaction Summary Definitions

WCM is an option which can be used in conjunction with the PCD-01 and PCD-04 transactions.

Volume 2 – Transactions

WCM does not introduce any new actors or transactions.

Volume 3 – Content

Add Section X.Y

X.Y Waveform Base Class

The Waveform Content Module defines the data structure and semantics to be used for communication of waveforms by IHE actors that require this functionality. Typical use cases include communication of time bounded waveform snapshots as alarm evidentiary data or for continuous waveform display.

X.Y.1 Data Model

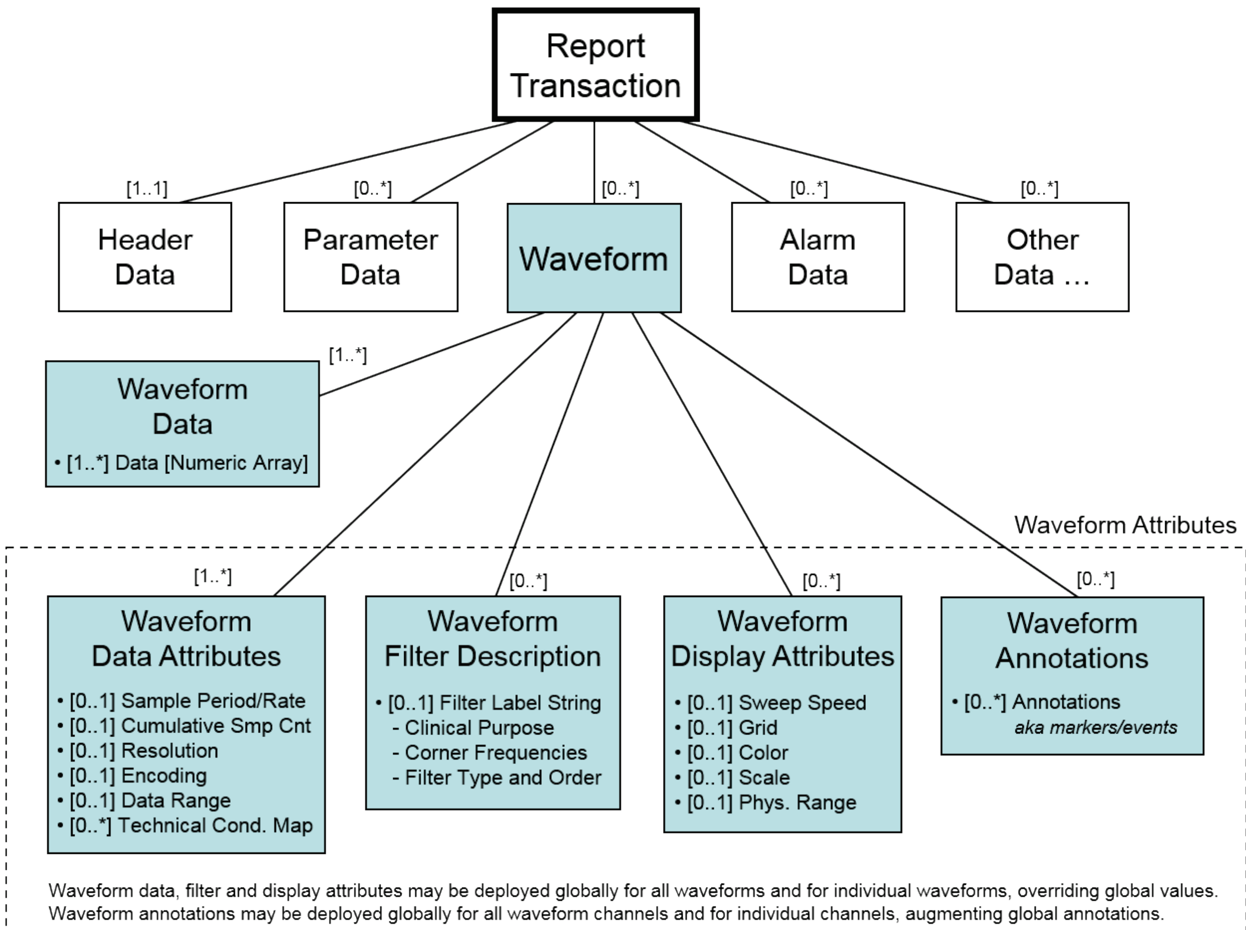

Figure X.Y.1-1: WCM Base Class Object Model

The Data Model follows the IEEE 11073 Domain Information Model, and is different from the previously released HL7 2.3 waveform representation model.

X.Y.2 Waveform Class Structure

WCM does not attempt to define a new HL7 message type. This section is for illustrative purposes, to demonstrate the high-level structure of the WCM content within the transaction that contains it.

The following table provides a static overview of the structure of the Waveform Content Module Option. Note that the facet level (of OBX-4) is used to distinguish between the various attributes of the structure.

Table X.Y.2-1: WCM Base Class Structure

Waveform Segment Structure	Waveform Attribute Structure	Usage	Card.
…other content…			
{	---WAVEFORM section begin	O	[0..*]
OBR	WAVEFORM OBSERVATION	R	[1..1]
[{OBX}]	*GLOBAL WAVEFORM ATTRIBUTES*	O	[0..*]
{OBX	**WAVEFORM DATA**	R	[1..*]
[OBX]	SAMPLE PERIOD	C	[0..1]
[OBX]	SAMPLE RATE	C	[0..1]
[OBX]	CUMULATIVE SAMPLE COUNT	O	[0..1]
[OBX]	MEASUREMENT RESOLUTION	C	[0..1]
[OBX]	WAVE ENCODING SCHEME	O	[0..1]
[OBX]	DATA RANGE	O	[0..1]
[{OBX}]	TECHNICAL CONDITION MAPPING(s)	O	[0..*]
[OBX]	FILTER LABEL STRING	O	[0..1]
[OBX]	SWEEP SPEED	O	[0..1]
[OBX]	VISUAL GRID DESCRIPTION	O	[0..1]
[OBX]	WAVE COLOR	O	[0..1]
[OBX]	WAVE SCALE	O	[0..1]
[OBX]	WAVE SCALE SIZE	O	[0..1]
[OBX]	WAVE PHYSIOLOGICAL RANGE	O	[0..1]
[{OBX}]}	WAVEFORM ANNOTATION(S)	O	[0..*]
[{OBX}]	*GLOBAL WAVEFORM ANNOTATION(S)*	O	[0..*]
}	---WAVEFORM section end		
… other content…			

Note 1 – In the Waveform Structure column:

- [square brackets] indicate item is optional
- {braces} indicate item is repeatable

Note 2 – Any of the attributes shown in the table above may be deployed as *global waveform attributes* by including them immediately after the OBR segment (but before any individual waveform data OBX segments). The global attributes apply to all waveforms unless overridden by attributes associated with an individual waveform channel.

Table X.Y.2-2: WCM Containment Hierarchy

BTYPE (in the 'base type' worksheet)	**OBX-4**	**Part::Code**	**CF_CODE10**	**Comments**
MDC MDS	M	·	·	
. MDC VMD	M.V	·	·	
. . MDC CHAN	M.V.C	·	·	
. . . . "MDC_WAVE_DATA"	M.V.C.I.	·	·	Waveform data
{Data attributes section}				
[OBR-7, OBR-8) *or*	OBR	n/a	n/a	Default start and end time
. . . . OBX-14 *and one of* ...	M.V.C.I	n/a	n/a	Start time specified by OBX-14
. . . . MDC_ATTR_TIME_PD_SAMP	M.V.C.I.1	1::2445	67981	Sample period (ns, µs, ms, ...)
. . . . MDC_ATTR_SAMPLE_RATE	M.V.C.I.1	1::2784	68320	Sample rate (typically /s or Hz)
. . . . MDC_ATTR_SAMPLE_COUNT	M.V.C.I.2	1::2785	68321	Cumulative sample count
OBX-6 *or*	M.V.C.I	n/a	n/a	Sample measurement resolution, expressed as the amplitude and units of the least significant bit (LSB) [2]
. . . . MDC_ATTR_SA_MSMT_RES *or* . . . . MDC_ATTR_NU_MSMT_RES	M.V.C.I.3 M.V.C.I.3	1::2409 1::2381	67945 67917	
. . . . MDC_ATTR_WAV_ENCODING	M.V.C.I.4	1::2786	68322	Default is signed decimal integer
. . . . MDC_ATTR_DATA_RANGE	M.V.C.I.5	1::2787	68323	Valid data range and tech conditions
. . . . . "MDC_EVT_INOP"	M.V.C.I.5.1	3::52	262144	· Inop, as an example
. . . . . "MDC_EVT_DATA_INVALID"	M.V.C.I.5.2	3::768	197376	· Invalid data, as an example
. . . . . "MDC_EVT_DATA_MISSING"	M.V.C.I.5.3	3::770	197378	· Missing data, as an example
. . . . MDC_ATTR_FILTER_LABEL_STRING	M.V.C.I.6	1::2626	68162	Structured filter label/description string, specified by PEG grammar
{Display attributes section}				
. . . . MDC_ATTR_SPD_SWEEP_DEFAULT	M.V.C.I.7	1::2431	67967	Default sweep speed, e.g., in mm/s
. . . . MDC_ATTR_GRID_VIS	M.V.C.I.8	1::2788	68324	NA of grid rows…
. . . . MDC_ATTR_VIS_COLOR	M.V.C.I.9	1::2789	68325	R^G^B
. . . . MDC_ATTR_SCALE_RANGE	M.V.C.I.10	1::2790	68326	Bottom and top of scale
. . . . MDC_ATTR_SCALE_RANGE_SIZE	M.V.C.I.11	1::2791	68327	Bottom to top of scale size, e.g., in mm
. . . . MDC_ATTR_PHYS_RANGE	M.V.C.I.12	1::2792	68328	Physiological range
{Annotations, events and markers section}				
. . . . from ISO/IEEE 11073-10101 MDC_EVT_*	M.V.C.I.13 ...	*	*	Events from MDC_EVT_*
. . . . from ISO/IEEE 11073-10102 MDC_ECG_*	M.V.C.I.13 ...	*	*	Annotations from MDC_ECG_*
. . . . other IEEE 11073 events and annotations	M.V.C.I.13 ...	*	*	Other events and annotations

[2] MDC_ATTR_SA_MSMT_RES is the preferred attribute if OBX-6 is not used. MDC_ATTR_NU_MSMT_RES shall be supported by DOCs to provide backwards compatibility with existing DORs.

Note 1: "M.V.C.I" in the OBX-4 column indicates a non-specific "MDS.VMD.Channel.Instance" of a waveform OBX at the dot-level-4 'METRIC' level with data and display attributes and annotations associated with an *individual* "M.V.C.I" waveform deployed at the dot-level-5 "M.V.C.I.*facet*" level.

Note 2: MDC_ATTR and their descendent OBXs may be deployed immediately following the OBR segment to specify *global* attributes that apply to all waveforms unless overridden by attributes associated with an *individual* waveform channel. It is recommended that the OBX-4 METRIC-level instance 'I' be set to zero (0) in this case.

X.Y.2.1 Optimized Waveform Structure

Atlhough each waveform could be contained in its own OBR Waveform "section", this can result in considerable repetition and duplicate information since similar waveforms often share many of the same attributes. For example, it is not uncommon to have all ECG waveforms share the same attributes such as sample rate, color, sweep speed, etc.

As an optimization, WCM allows the grouping of identical attributes at the beginning of a particular waveform OBR that apply as *global default* values for all waveforms in that OBR. Additional attributes, or those that have a different value than the global default value, are listed that are different with waveform type are grouped with the affected waveforms.

A similar strategy is used for annotations, except that *global annotations* (e.g., ECG beats and rhythms) are listed after the last waveform, rather than before the first waveform. Within the scope of an individual channel, *individual channel annotations* (e.g., onset of moderate noise in a specific lead) are listed after any individual attributes associated with that channel. Individual channel annotations *augment* the clinical information conveyed by global annotations.

The following examples illustrate the approach:

Example 1: ECG waveforms share the same set of common attributes except for the displayed scale, where the default value of 1 mV is used for ECG leads I and III and 0.5 mV is used for ECG lead II. The waveform snippet includes three beat annotations (as 'tpoints' with a specific time specified by OBX-14) listed *after* the last waveform plus an annotation for ECG lead II indicating the 'start' of moderate noise for that channel (at time specified by OBX-14).

Table X.Y.2.1-1: Optimized Waveform Structure - Example 1

Segment	OBR-4
OBR "WAVEFORM"	
. OBX Sample Rate (250/sec)	M.V.1.0.1
. OBX Valid Data Range (±5 mV)	M.V.1.0.2
. . OBX Tech_Cond Map (Missing Data)	M.V.1.0.2.1
. OBX Filter Description (0.05-150 Hz)	M.V.1.0.3
. OBX Sweep Speed (25 mm/sec)	M.V.1.0.4
. OBX Scale Range (1 mV)	M.V.1.0.5
. OBX Waveform Data (ECG lead I)	M.V.1.1
. OBX Waveform Data (ECG lead II)	M.V.1.2
. . OBX Scale Range (0.5 mV)	M.V.1.2.1
. . OBX 'moderate noise level' annotation (start-only)	M.V.1.2.2
. OBX Waveform Data – ECG lead III	M.V.1.3

Segment	OBR-4
. OBX 'normal beat' annotation (tpoint)	M.V.1.4
. OBX 'premature ventricular beat' annotation (tpoint)	M.V.1.5
. OBX 'normal beat' annotation (tpoint)	M.V.1.6

Example 2: A number of blood pressure waveforms each with different display colors and some with different display scales:

Table X.Y.2.1-2: Optimized Waveform Structure - Example 2

Segment	OBR-4
OBR "WAVEFORM"	
. OBX Sample Rate (50/sec)	M.V.1.0.1
. OBX Resolution (0.1 mmHg)	M.V.1.0.2
. OBX Valid Data Range	M.V.1.0.3
. OBX Sweep Speed (25 mm/sec)	M.V.1.0.4
OBX Wave Data (Arterial BP)	M.V.1.1
. OBX Color (Red)	M.V.1.1.1
. OBX Scale Range (0 – 300 mmHg)	M.V.1.1.2
OBX Wave Data (Femoral BP)	M.V.2.1
. OBX Color (Purple)	M.V.2.1.1
. OBX Scale Range (0 – 300 mmHg)	M.V.2.1.2
OBX Wave Data (Left Venous BP)	M.V.3.1
. OBX Color (Blue)	M.V.3.1.1
. OBX Scale Range (-10 – 20 mmHg)	M.V.3.1.2

X.Y.3 Waveform Observation Section

Each Waveform Section is contained by an OBR that marks the beginning of a single set of waveforms that typically share a common default start time and other attributes. Each Waveform Section stands on its own, which means that all relevant attributes for a waveform set must be restated in each OBR.

When reporting waveform data, the Observation Request Segment (OBR) serves as the 'report header' for the ORDER_OBSERVATION segment group, which in its simplest form is an OBR segment followed by one or more OBX segments that represent observations associated with the 'order' represented by the OBR segment.

Table X.Y.3-1: OBR segment

SEQ	LEN	DT	Usage	Card.	TBL#	Element name
1	4	SI	R	[1..1]		Set ID OBR

SEQ	LEN	DT	Usage	Card.	TBL#	Element name
2	427	EI	C	[0..1]		Placer Order Number
3	427	EI	R	[1..1]		Filler Order Number
4	705	CWE	R	[1..1]		Universal Service Identifier (Identifies this as a Waveform)
5	2	ID	X	[0..0]		Priority – OBR
6	24	DTM	X	[0..0]		Requested Date/Time
7	24	DTM	R	[1..1]		Observation Date/Time of the first sample
8	24	DTM	R	[1..1]		Observation End Date/Time of the end of the last sample *interval*

OBR-1 Set ID OBR

Definition: For the first waveform transmitted in a message, the sequence number shall be 1; for the second waveform, it shall be 2; and so on.

OBR-2 Placer Order Number

As specified in the PCD Technical Framework, Volume 2.

OBR-3 Filler Order Number

As specified in the PCD Technical Framework, Volume 2.

OBR-4 Universal Service ID

This field is used to identify the OBR and its following (OBX-4 descendant) OBX segments as part of a Waveform Observation Group.

For continuous waveforms the ID is set to “69121^MDC_OBS_WAVE_CTS^MDC”.

For non-continuous waveforms such as “snapshots” and “snippets” the ID is set to “69122^MDC_OBS_WAVE_NONCTS^MDC”.

OBR-7, OBR-8 Universal Service ID

For a waveform, OBR-7 specifies the default start time for the first waveform sample and OBR-8 specifies the default end time at the end of the last sample period, denoted as [OBR-7, OBR-8).

This is illustrated in Figure X.Y.3-1 shown below.[3]

[3] The waveform image can be downloaded from https://physionet.org/physiobank/charts/mitdb.png.

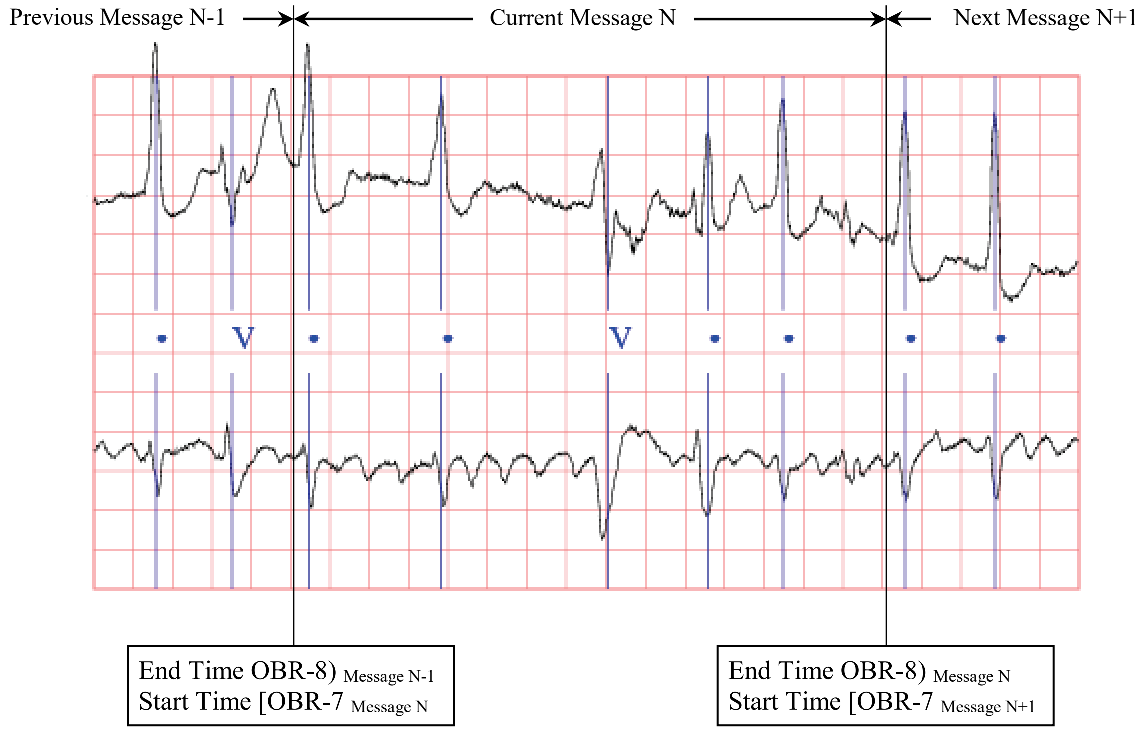

Figure X.Y.3-1: Waveform Timing

X.Y.4 Waveform Data and Attributes

Refer to HL7 V2.5: Section 7.4.2

The HL7 OBX segment is used to transmit a single observation, attribute or observation fragment. Guidance on the use of specific items in the OBX segment for the WCM Class is provided in this section.

Note that this is different than the current HL7 Chapter 7 Waveform approach. This was done for simpler harmonization with the IEEE 11073 Domain Information Model and facilitates the incorporation of additional attributes as necessary.

Table X.Y.4-1: General IHE PCD OBX segment

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[0..1]	0125	00570	Value Type
3	705	CWE	R	[1..1]		00571	Observation Identifier
4	20	ST	R	[1..1]		00572	Observation Sub-ID
5	99999	Varies	C	[0..1]		00573	Observation Value
6	705	CWE	C	[0..1]		00574	Units
7	60	ST	CE	[0..1]		00575	References Range
8	5	IS	CE	[0..1]	0078	00576	Abnormal Flags
9	5	NM	X	[0..0]		00577	Probability
10	2	ID	CE	[0..1]	0080	00578	Nature of Abnormal Test
11	1	ID	R	[1..1]	0085	00579	Observation Result Status
12	24	DTM	X	[0..0]		00580	Effective Date of Reference Range
13	20	ST	X	[0..0]		00581	User Defined Access Checks
14	24	DTM	RE	[0..1]		00582	Date/Time of the Observation
15	705	CWE	RE	[0..1]		00583	Producer's ID
16	250	XCN	RE	[0..1]		00584	Responsible Observer
17	705	CWE	RE	[0..1]		00936	Observation Method
18	22	EI	RE	[0..1]		01479	Equipment Instance Identifier
19	24	DTM	CE	[0..1]		01480	Date/Time of the Analysis
20	705	CWE	RE	[0..*]	0163	02179	Observation Site

OBX-1 Set ID - OBX (SI), required:

As specified in the PCD Technical Framework, Volume 2.

OBX-2 Value Type (ID), conditional:

This field will specify specific IDs per attribute type. In the case of the waveform data this field contains the metric ID for the waveform.

OBX-3 Observation Identifier (CWE), required:

As specified in PCD TF-2.

OBX-4 Observation Sub-ID (ST), required:

As specified in PCD TF-2. In addition WCM utilizes the Facet level to describe the hierachy between OBXs in the same waveform object.

OBX-5 Observation Value (varies), conditional.

Further guidance in this section per attribute.

OBX-6 Units (CWE), conditional

Further guidance in this section per attribute.

OBX-7 References Range (ST), required if available.

As specified in PCD TF-2.

OBX-8 Abnormal Flags (IS), required but may be empty:

As specified in PCD TF-2.

OBX-11 Observation Result Status (ID), required if available:

As specified in PCD TF-2.

OBX-14 Date/Time of the Observation (DTM), required but may be empty:

Further guidance in this section per attribute.

OBX-16 Responsible Observer (XCN), required but may be empty:

As specified in PCD TF-2.

OBX-17 Observation Method (CWE), conditional:

As specified in PCD TF-2.

OBX-18 Equipment Instance Identifier (EI), required but may be empty:

As specified in PCD TF-2.

OBX-19 Date/Time of the Analysis (DTM), conditional but may be empty:

As specified in PCD TF-2.

OBX-20 Observation Site (CWE), required but may be empty:

As specified in PCD TF-2.

X.Y.4.1 Waveform Data

The Waveform Data is conveyed at dot level 4 METRIC level (see Table 3), similar to how METRIC observations are conveyed in other PCD messaging profiles.

The OBX segment contains the waveform data. OBX-3 identifies the waveform and OBX-20 may also be used to specify additional measurement site information, e.g., a single *unipolar* or a pair of *bipolar* EEG measurement sites or a *bipolar* ECG lead.

Since the IEEE 11073 Nomenclature does not necessarily specify waveform IDs as distinct from parameter IDs, the RefID and Code associated with the waveform can be used in OBX-3. For example, the SpO2 measurement RefID and Code can be used, which are interpreted in this context as a waveform ID.

The *default* start time for the first waveform sample is specified by OBR-7 of the containing OBR segment. The *default* end time at the end of the sample time interval for the last waveform sample is specified by OBR-8. The sample period (or rate) can be determined by dividing the *default* time span [OBR-7, OBR-8) by the number of samples in the OBX 'NA' array (or by calculating the reciprocal for the rate). Additional attributes and/or OBX-14 may be used to override the default waveform timing information (described later).

The waveform data is conveyed by OBX-5 as a Numeric Array (NA) datatype restricted to unsigned or signed integer values of XSD type *xs:integer*, separated by "^".

The resolution of the analog-to-digital converter (ADC) is expressed as the amplitude and units of the least significant bit (LSB), equivalent to the total measurement range divided by the number of intervals. The resolution may be directly conveyed by OBX-6 or by using the 67945^MDC_ATTR_SA_MSMT_RES^MDC attribute at FACET level and leaving the METRIC OBX-6 empty if addition scaling for a MDC_DIM unit-of-measure is required. If the waveform is dimensionless, then OBX-6 should be "262656^MDC_DIM_DIMLESS^MDC".

Table X.Y.4.1-1: OBX segment for Waveform Data

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NA
3	705	CWE	R	[1..1]		00571	Observation identifier (e.g., ECG, ABP, Flow, EEG, etc.)
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[1..1]		00573	Waveform values (signed or unsigned integer) separated by "^"
6	705	CWE	C	[1..1]		00574	Units (MDC, UCUM, or UCUM scaled by a rational-fraction scale factor)
7							

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
8	5	IS	RE	[0..1]	0078		Abnormal Flags (populated with zero or more abnormal flag codes in PCD DEC TF-2 Rev 5.0). If empty, there were no abnormal technical conditions associated with this segment.
9-10							
11	1	ID	RE	[0..1]	0085		Observation Result Status (populated with a status code from PCD DEC TF-2 Rev 5.0). Typically indicated as 'R'.
12-13							
14	24	DTM	RE	[0..1]		00582	Date/Time of the Observation
15-19							
20	705	CWE	RE	[0..*]	0163	02179	Observation Site(s)

X.Y.4.2 Waveform Start and End Time and Sampling Period or Rate

There are several options for specifying the start time, end time and sampling period or rate for a waveform OBX segment. A Device Observation Reporter (DOR) may use any option and a Device Observation Consumer (DOC) must support all options listed in Table X.Y.4.2-1.

Table X.Y.4.2-1: Waveform Start and End Time and Sampling Period or Rate Options

#	OBX-14	P/R	[OBR-7	OBR-8)	Description
1	✓	✓	×	×	Start time is specified by OBX-14 and sampling period (or rate) is specified by MDC_ATTR_TIME_PD_SAMP (or MDC_ATTR_SAMPLE_RATE). [OBR-7, OBR-8) is ignored. OBX-14 can be used to specify sample skew between channels to a precision of 100 µs. MDC_ATTR_TIME_PD_SAMP (or MDC_ATTR_SAMPLE_RATE) specify the sample period (or rate) for all waveform segments within OBR or for a single waveform OBX as a facet of that OBX.
2	×	✓	✓	×	Start time is specified by [OBR-7 and sampling period (or rate) is specified by MDC_ATTR_TIME_PD_SAMP (or MDC_ATTR_SAMPLE_RATE).
3	×	×	✓	✓	Start time is specified by [OBR-7 and end time is specified by OBR-8). Sample rate or period is implied by number of samples in array(s). Does not require any additional attributes to define waveform timing.

✓ indicates that value is present, × indicates a "don't care" and the value is ignored by the DOR.

[OBR-7 or OBX-14 specifies time of first sample. OBR-8) indicates time at the end of sample interval for the last sample.

P/R indicates that either MDC_ATTR_TIME_PD_SAMP or MDC_ATTR_SAMPLE_RATE is specified.

The DOC shall use the first matching option of options 1, 2 or 3 where the OBX-14, P/R, OBR-7 and OBR-8 indicated by ✓ are present. For example, one or more ECG median templates can be sent as short waveform snippets specified by OBX-14 and P/R within the longer time interval specified by [OBR-7, OBR-8) associated with a 10-second rhythm episode.

If OBR-7 and OBR-8 are both specified, OBR-7 specifies the mathematically ‘closed’ interval boundary at the start of the sample array and OBR-8 specifies the mathematically ‘open’ boundary at the end of the sample array, including the sample time interval for the last waveform sample. The interval [OBR-7, OBR-8) serves as the default time interval for all OBX segments within its scope that do not specify an overriding time point in OBX-14.

A single-valued OBX-5 is assumed to occur at time OBR-7 by default, and a multi-valued OBX-5 numeric array containing N values is assumed to be divided into N equal time sub-intervals, with the Nth value occurring at the beginning of each sample time sub-interval.

The default time interval [OBR-7, OBR-8) is equivalent the HL7® V3 representation where inclusive="true" specifies a ‘closed’ boundary and inclusive="false" specifies an ‘open’ boundary for the ten second interval shown below.

<effectiveTime>

<low value="20100101091820.000" inclusive="true" />

<high value="20100101091830.000" inclusive="false" />

</effectiveTime>

X.Y.4.3 Sampling Period or Rate – *Conditional*

This segment communicates sampling period or the number of samples per unit time for an OBR group of or an individual OBX waveform segment. It is required for any waveform array that does not precisely start and end at the default interval specified by [OBR-7, OBR-8).

Table X.Y.4.3-1: OBX segment for Sample Rate

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NM
3	705	CWE	R	[1..1]		00571	67981^**MDC_ATTR_TIME_PD_SAMP**^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[1..1]		00573	time
6	705	CWE	C	[1..1]		00574	Units – typically ns, us, ms
3	705	CWE	R	[1..1]		00571	68320^**MDC_ATTR_SAMPLE_RATE**^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[1..1]		00573	#samples per unit time
6	705	CWE	C	[1..1]		00574	Units – typically /s or /min

X.Y.4.4 Cumulative Sample Count - *Optional*

The cumulative sample count, MDC_ATTR_SAMPLE_COUNT, specifies the number of sampling intervals for a specific waveform group (or channel) since data acquisition began for that channel, expressed as an unsigned decimal integer. This segment is optional for both the Data Observation Reporter (DOR) and Data Observation Consumers (DORs).

This segment establishes the time relationship between the cumulative sample count in OBX-5 and the date-time specified by OBX-14. Referencing the sample count provides a highly accurate and reliable indication of time, especially from a signal processing standpoint and keeping track of missing data.

OBX-18 may be used to identify the hardware component the provides the sampling clock to support applications where a single clock reference is used to synchronize multiple data acquisition subsystems.

Table X.Y.4.4-1: OBX segment for Cumulative Sample Count

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NM, unsigned integer
3	705	CWE	R	[1..1]		00571	68321^MDC_ATTR_SAMPLE_COUNT^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[1..1]		00573	Cumulative sample count, e.g., 12345678
6	705	CWE	C	[1..1]		00574	Empty
7							
8							
9							
10							
11							
12							
13							
14	24	DTM	RE	[1..1]		00582	Date/Time of the Observation
15							
16							
17							
18	199	EI	O	[0..1]			Equipment identifier (clock source)

X.Y.4.5 Measurement Resolution – *Conditional*

The resolution of the analog-to-digital converter (ADC) is expressed as the amplitude and units of the least significant bit (LSB), equivalent to the total measurement range divided by the number of intervals. A Device Observation Reporter (DOR) may use any option and a Device Observation Consumer (DOC) must support all three options shown below:

Case 1: If the resolution can be precisely expressed by the unit-of-measure in OBX-6 of the OBX segment containing the waveform samples, then OBX-6 conveys the unit of measure.

Example: *MDC units precisely expresses the resolution of the analog-to-digital converter (e.g., 1 uV)*

OBX|1|**NA**|131329^MDC_ECG_ELEC_POTL_I^MDC|1.7.4.13|1220^517^305^...^849^878|266419^MDC_DIM_**MICRO_VOLT**^MDC

Case 2: If a scale factor is required and MDC_DIM units-of-measure are used, the scale factor shall be conveyed by the 67945^MDC_ATTR_SA_MSMT_RES^MDC attribute at the FACET level as a value of type 'NM' in OBX-5 and the base unit-of-measure in OBX-6. The waveform OBX-6 shall be ignored by receivers if the MDC_ATTR_SA_MSMT_RES attribute is present.

Example: *MDC units using child MDC_ATTR_SA_MSMT_RES and NM datatype to convey scaled UoM*

OBX|1|**NA**|131329^MDC_ECG_ELEC_POTL_I^MDC|1.7.4.13|500^212^125^...^348^360|262656^MDC_DIM_DIMLESS^MDC
OBX|2|**NM**|67945^MDC_ATTR_SA_MSMT_RES^MDC|1.7.4.13.1|**2.44**|266419^MDC_DIM_**MICRO_VOLT**^MDC

Case 3: If a scale factor is required and UCUM units-of-measure are used, the scale factor may be expressed as a rational fraction embedded in the unit. For example, the A/D resolution for a 12-bit converter spanning 10 mV would be «10.mV/4096», corresponding to 2.44 uV.

Example: *UCUM units expressing 2.44 uV as a rational-fraction scale factor, i.e., «10.mV/4096»* [4, 5]

OBX|1|**NA**|131329^MDC_ECG_ELEC_POTL_I^MDC|1.7.4.13|500^212^125^...^348^360|10.mV/4096^10.mV/4096^UCUM

[4] UCUM already allows integer factors in the numerator and denominator; we are simply profiling their use. Note that other UCUM alternatives such as «10000.uV/4096» could also be used.

[5] *INFORMATIVE NOTE:* The NIST RTMMS units-of-measure tables list the decade-scaled MDC and UCUM units-of-measure that can be used on a per-parameter basis in messages. For example, only 'uV' or 'mV' (and their MDC equivalents) are listed for ST deviation (and not 'kV' or 'mm').

One benefit of enumerating the allowed units for each observation identifier is that it provides an unambiguous statement regarding what senders may send and what receivers should expect to receive and process.

Specifying every possible *scaled* UCUM unit is impractical at best. Instead, during message conformance testing, the rational-fraction UCUM scale factor can be removed by applying one or more regexes (or equivalent processing) and comparing the residual string with the RTMMS list of approved base UCUM terms using the two steps below:

(1) remove instances of of «*nnn*.» and tail-end «/*nnn*», e.g., «10000.uV/4096» → «uV».
(2) remove surrounding parenthesis (*exp*) from the result from the previous step if *exp* is a single unit of measure, i.e., it does not contain a '.' (multiply) or '/' (divide) symbol, e.g., «1/(5.L)» → «1/(L)» → «1/L».

The two steps handle practically every UCUM unit 'in the wild' and would be suitable for preprocessing the original UCUM string for comparison against the RTMMS list of UCUM base units. The conventions for applying integer scale factor(s) to a UCUM base unit sent in a message are relatively simple: the integer value(s) should precede the base term(s) in the numerator, denominator or within a parenthesis.

X.Y.4.6 Waveform Encoding Specification – *Optional*

Waveforms can be encoded in many different ways. While the HL7 default is decimal, hexadecimal, binary, floating point or integer formats could be used. In addition there are numerous ways of compressing waveforms.

Currently WCM only supports a single encoding scheme: *signed or unsigned decimal* ***integer***, which is a restriction of the HL7 default decimal. *Signed or unsigned decimal* ***integer*** is the default encoding if this segment is omitted.

MDC_ATTR_WAV_ENCODING = 0 Signed or unsigned decimal integer

MDC_ATTR_WAV_ENCODING = 1..n Future use

If this field is not included, then a default value of "0" is assumed.

Table X.Y.4.6-1: OBX segment for Specifying Waveform Encoding Scheme

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NM
3	705	CWE	R	[1..1]		00571	68322^MDC_ATTR_WAV_ENCODING^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[1..1]		00573	= 0 for signed or unsigned decimal integer

X.Y.4.7 Waveform Data Range – *Optional*

These optional segments specify the data acquisition range for a waveform or waveform group, expressed in terms of sample values. [These values do not necessarily represent the maximum and minimum values of the encoded waveform data *and* technical conditions, but rather the valid range of values of the analog-to-digital converter.]

Table X.Y.4.7-1: OBX segment for Data Range

SEQ	LEN	DT	Usage	Card.	TBL #	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NR
3	705	CWE	R	[1..1]		00571	68323^MDC_ATTR_DATA_RANGE^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[2..2]		00573	Lowest data value^Highest data value

X.Y.4.8 Waveform Technical Condition Mapping Section – *Optional*

Waveform technical or data error conditions can occur anytime in the waveform data stream. WCM requires that these are encoded in the Waveform Observation Data using MDC_EVT codes from the MDC_PART_EVT (3) partition, declared by zero or more OBX segments. OBX-3 specifies the coded MDC_EVT representation of the error condition and OBX-5 specifies the value as it would appear in the numeric waveform array.

The following example illustrates a waveform source that reserves the five values 99995 through 99999 as follows:

Table X.Y.4.8-1: OBX segment for Specifying Technical Condition Mapping

OBX-3	Technical Error Condition	OBX-5
262196^MDC_EVT_INOP^MDC	Inop (52+262144)	99999
262300^MDC_EVT_RANGE_OVER^MDC	Out of Range–High (166+262144)	99998
262302^MDC_EVT_RANGE_UNDER^MDC	Out of Range–Low (168+262144)	99997
262166^MDC_EVT_DISCONN^MDC	Disconnected (22+262144)	99996
262626^MDC_EVT_DATA_ACQN_ERR^MDC	Error (482+262144)	99995

This would require five MDC_EVT technical error condition OBX segments to convey.

Additional MDC_EVT codes have been defined to express invalid and missing data, regardless of the underlying technical condition:

Table X.Y.4.8-2: OBX segment for Specifying Invalid Data Mapping

OBX-3	Technical Error Condition	OBX-5
197376^MDC_EVT_DATA_INVALID^MDC	Invalid (or missing) data	-32768
197378^MDC_EVT_DATA_MISSING^MDC	Missing data	-32767

MDC_EVT technical error condition(s) shall *not* be rendered as part of a waveform segment; instead, a waveform 'gap' or other indication shall be shown on the display or hardcopy output.[6]

Additional MDC_EVT technical error conditions may be defined in the future and shall be identified by MDC_EVT codes in MDC_PART_EVT (3) partition to facilitate decoding.

MDC_EVT codes received as part of a WCM OBR ***are <u>not</u> intended to report alert conditions***; the Alert Communication Management (ACM) and Event Communication (EC) Profiles should be used instead (we are simply leveraging and extending the existing MDC_EVT codes).

[6] The only exception to this rule occurs when MDC_EVT_RANGE_UNDER or MDC_EVT_RANGE_OVER specify an OBX-5 value that is immediately adjacent to the data acquisition range [low^high] specified by MDC_ATTR_DATA_RANGE; if true, the out-of-range value *may* be rendered as part of the waveform trace.

The total span of the waveform data range specified by 68323^MDC_ATTR_DATA_RANGE^MDC and MDC_EVT technical and invalid data conditions specified by OBX-5 above determine the total encoding range and the number of bits required to store this information in a binary integer format. It is often useful to consider this when assigning the MDC_EVT technical and invalid data mappings in OBX-5, such as mapping all technical and invalid data conditions to unused codes within the interval [-32768, 32767] to fit in a signed 16-bit binary representation.

Table X.Y.4.8-3: OBX segment for Specifying a Technical Condition Mapping

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NM
3	705	CWE	R	[1..1]		00571	MDC_EVT code for special condition
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[1..1]		00573	Value in waveform data stream which will be used to represent the special condition.
11	1	ID	R	[1..1]	0085	00579	Observation Result Status = O

* * *

There are three ways to indicate technical error conditions for waveform sample array data.

The first option, ***technical condition mapping***, is well-suited for representing waveform dropouts, such as short wireless dropouts in waveform records that are sent every few seconds.

The second option, using ***OBX-8 and OBX-11***, provides the overall status for the entire waveform OBX segment while preserving the original waveform sample values, facilitating clinical and technical troubleshooting. For example, OBX-8 = ‘CAL’ indicates that a waveform channel is currently being calibrated and should not be used, while making the waveform data available for display.

Table X.Y.4.8-4: WCM options for specifying technical conditions

#	Method	Time resolution	Comment
1	Technical condition mapping	Sample	Replaces actual sample
2	OBX-8 and OBX-11	OBX waveform segment	Preserves original samples
3	Annotations	Sample	Preserves original samples and can provide detailed information.

The third option, using ***annotations***, is described later in this document. It offers excellent time resolution and can convey detailed information about the technical (or physiologic) condition without hiding or modifying the original data samples, a major plus. Although this option is more complex than the first two, it provides a single and consistent interface for representing event-like information.

X.Y.4.9 Waveform Signal Filter(s) – *Optional*

Waveform signal filter information is optional. If it is not specified, however, receiving applications may not be able to determine whether the waveform data can support specific clinical use cases, including suitability for review and interpretation by either clinician or machine, in near real-time or retrospectively.

The signal filter that was applied to the original waveform data is conveyed as a *single string* whose content and structure is defined and validated by an EBNF-style grammar specification, described later. The string provides a summary of its essential properties for display and printing plus additional detailed information as {annotations} regarding the suitability of the waveform data for subsequent review and interpretation as well as technical details about the filter.

The waveform filter string is conveyed by the OBX segment defined below.

Table X.Y.4.9-1: OBX segment for Filter Description Attribute

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = ST
3	705	CWE	R	[1..1]		00571	68162^MDC_ATTR_FILTER_LABEL_STRING^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	ST	C	[1..1]		00573	Structured text string, defined below.
6	705	CWE	C	[0..1]		00574	Empty

An example of a waveform filter string with {annotations} is shown below:

«Diagnostic{ecgDiag} 60~ 0.05{Butterworth_2}-150{Butterworth_2} Hz»

The {annotations} can be removed to produce a string suitable for display or printing:

«Diagnostic 60~ 0.05-150 Hz»

The string is structured to facilitate extraction of coded information such as a vendor-specific localizable descriptive string such as «**Diagnostic**» as well as a coded annotation **«{ecgDiag}»** that indicates suitability for review and interpretation (for waveform data where this has been formally defined by clinical and technical standards). Additional filter information such as corner and notch frequencies, filter type and other information can also be specified to support advanced clinical and research applications.

The following sections describe the various components of the string, followed by a more formal definition using EBNF-style grammar specification

X.Y.4.9.1 First filter substring – clinical purpose and/or capability

The first substring in our earlier example, «**Diagnostic**{**ecgDiag**}», indicates the clinical purpose or capability of the filter. The displayed «**Diagnostic**» string may be vendor-specific and localized (translated) provided that it is consistent with the coded annotation, e.g., «{**ecgDiag**}».

Table X.Y.4.9-2: First filter substring examples

Signal	First substring	Description	Examples
Any	F{}	Filtering enabled	F{ecgRhy+ST}
ECG	Diagnostic{}	Diagnostic ECG	Diagnostic{ecgDiag} *(also implies ST capability)*
ECG	Rhythm+ST{}	Rhythm+ST	Rhythm+ST{ecgRhy+ST}
ECG	Rhythm{}	Rhythm	Rhythm{ecgRhy}
ECG	Monitoring{}	Monitoring	Monitoring{ecgRhy}
ECG	Pediatric{}	Pediatric	Pediatric{ecgDiag}

The first substring `FirstStr` must start with a letter [A-Za-z]. For the ECG parameter, the {annotation} shall include a *single token* representing the fundamental clinical purpose or capability of the filter. Additional tokens may be defined for other parameters in the future, with the requirement that only a *single token* (possibly structured like 'ecgRhy+ST') is sent and that they are based on published clinical standards and profiles.

Table X.Y.4.9-3: Filter clinical purpose or capability

Token	Description
ecgDiag	'diagnostic' ECG, including ST analysis *(0.05 to 150 Hz)*;
ecgRhy	'rhythm' analysis, using a narrower passband to reduce artifact *(0.67 to 40 Hz); or*
ecgRhy+ST	'rhythm' or 'monitoring' of the ECG, including **ST** analysis capability. *The '**ST**' flag indicates that the low-frequency amplitude and phase response are equivalent to a traditional 0.05 Hz single-pole high-pass filter **or** that the voltage offset (displacement) and slope immediately following a 0.3 mV•s (3 mV for 100 ms) impulse input does not exceed 0.1 mV and 0.30 mV/s immediately after the impulse.*
ecgSigAvg	Signal averaged ECG, without support for ST analysis (AAMI TIR23:1999).
ecgSigAvg+ST	Signal averaged ECG, with support for ST analysis (AAMI TIR23:1999).

The first three ECG categories reflect the recommendations of both clinical guidelines (AHA, ACC, HRS-ISCE and ESC) and industry standards (IEC and AAMI) regarding ECG frequency and impulse/phase requirements for three broad clinical categories: for *diagnostic 12-lead ECGs*, for *heart rate measurement and arrhythmia monitoring* (patient monitors and ambulatory ECG monitors), and for *ST measurement*.

The {annotation} FirstAnn for the first substring specifies the clinical capability for the *entire filter* as a coded text string. If the {annotation} contains the string '**ecgDiag**', for example, the ECG waveform data source asserts that the ECG waveform data has sufficient bandwidth and linear phase response to support diagnostic 12 lead ECG analysis (including ST analysis).[7] If the {annotation} contains the '**ST**' flag, the ECG waveform data source asserts that the waveform has sufficient low-frequency and linear phase response to support ST analysis but not necessarily diagnostic QRS morphology analysis.

The {annotations} for subsequent filter substrings *should* indicate '**Diag**' and/or '**ST**' capability to facilitate parameter-specific consistency checks with the {annotation} of the first substring.

X.Y.4.9.2 Filter substrings for subsequent filter stages

The first filter substring may be followed by zero or more filter substrings, one for each filter stage, plus addition tokens such as 'Hz' to indicate the default unit of measure for frequency.

The notch/bandstop, high-pass and low-pass filters are identified by a tilda '~' and hyphen '-' characters, respectively, to directly support a readable displayed or printed string. Specialized filters are indicated by single letters, such as 'B' for *baseline* (wander), 'I' for *interpolator* and 'A' for *artifact* filter. Each filter may have an {annotation} to specify addition information.

Table X.Y.4.9-4: Subsequent filter substrings

Base	Description	{...} | = choice	Example
#{}~	Notch/bandstop [8]	NotchFreq{(Fixed|Adaptive)(+Diag)?}	60{Adaptive+Diag}~
#{}-	High-Pass [9]	HighPassFreq{NamedFilterType(_\d+)?(+ST)?}	0.05{Butterworth_2}-
-#{}	Low-Pass	LowPassFreq{NamedFilterType(_\d+)?}	-150{Butterworth_2}
Hz	Hertz	Hz	Hz
B{}	Baseline	B{BaselineAnn(+ST)?}	B{Spline}
I{}	Interpolator	I{InterpolatorAnn(+ST)?}	I{Lagrange}
A	Artifact	A{ArtifactAnn(+ST)?}	A{ge:FRF}

\# indicates a positive decimal or decimal integer value conforming to the regex \d+([\.,]\d+)?, supporting . and, decimal points.
{ } indicates an optional «{...}» annotation using coded text and/or vendor identifiers with vendor namespace prefixes.
[ ] indicates an optional flag, e.g., «+ST» or filter order, e.g., «_2», expressed as a positive integer.

[7] The first filter substring indicates the clinical suitability of the waveform data as *data*. It does not address the clinical suitability of how the data is rendered on a display or hardcopy output, e.g., for visual interpretation.

[8] The notch/bandstop filter may be listed before or after the primary bandpass range. If the bandstop filter is supported in the future, the low and high frequencies will be located before and after the tilde '~'.

[9] The high-pass and low-pass filters share a common hyphen and are listed in separate rows for clarity.

Table X.Y.4.9-5 lists the standard filter type names [10] and optional suffixes, the latter expressed as a regex. The suffixes '+ST' and '+Diag' *should* be used to indicate the capability of an individual filter stage to facilitate ECG parameter-specific consistency checks with the {annotation} of the first filter substring.

The filter order *may* also be specified as a positive integer, e.g., «_2», conforming to the regex «_\d+». If omitted, the filter order is unknown.

Table X.Y.4.9-5 may be expanded in the future to support additional standard filter type names as well as additional type suffixes. Vendor-specific filter type names can also be specified by prefixing them with a vendor namespace prefix, e.g., «ge:FRF» for GE's 'Finite Residual Filter' that is used to reduce baseline wander and muscle noise in ECG stress test data.

Table X.Y.4.9-5: Filter types

S	Filter type	type suffixes (optional) as regex	Discussion
-	RC	_1(+ST)?	
-	Bessel	(_FIR|_IIR)?(_\d+)?(+ST)?	Constant or zero delay, *aka* linear phase
-	Butterworth	(_FIR|_IIR)?(_\d+)?(+ST)?	
-	Chebyshev	(1|2)?(_FIR|_IIR)?(_\d+)?(+ST)?	
-	Elliptic	(_FIR|_IIR)?(_\d+)?(+ST)?	
-	Legendre	(_FIR|_IIR)?(_\d+)?(+ST)?	
-	FIR	(_\d+)?(+ST)?	
-	IIR	(_\d+)?(+ST)?	
~	Fixed	(+Diag)?	Append +Diag if IEC 60601-2-25 diagnostic gain flatness satisfied
~	Adaptive	(+Diag)?	Append +Diag if IEC 60601-2-25 diagnostic gain flatness satisfied
B	Spline	(+ST)?	Append +ST if AHA/ACC/ESC or AAMI/IEC ST-impulse test satisfied
B	Parabolic	(+ST)?	Append +ST if AHA/ACC/ESC or AAMI/IEC ST-impulse test satisfied
I	Linear	(+ST)?	
I	Spline	(+ST)?	
I	Lagrange	(+ST)?	
I	Hermite	(+ST)?	
A	*vendor-prefix:vendor-identifier*(+ST)?		*Example:* A {ge:FRF}

[10] The high-pass and low-pass filter types listed in Table X.Y.4.8-3 obtain their high-pass or low-pass context based on their relationship to the '-' hyphen. If stand-alone filter type names are preferred, we could adopt standardized prefixes such as 'hp' for high-pass and 'lp' for low-pass. One reason for not adopting this convention, however, is that other domains such as neuromonitoring use 'low-frequency' and 'high-frequency' rather than 'high-pass' and 'low-pass', reversing the sense of 'high' and 'low'. *Comments?*

X.Y.4.9.3 Parsing Expression Grammar (PEG) for waveform filter string

The **parsing expression grammar**, or **PEG**, for the waveform filter string is shown below. PEGs are a type of analytic formal grammar that describe a formal language in terms of a set of rules for recognizing strings in the language. Unlike context-free grammars (CFGs), the choice operator «**/**» selects the first match in a PEG, resulting in a *single* valid parse tree.[11]

An on-line parser generator and validator http://pegjs.org/online is available for the PEG, and can run on most major browsers as JavaScript. The parser generated from the PEG below can be used to validate the filter strings in Table X.Y.4.9-8 as well as additional filter strings.

The PEG shown in Table X.Y.4.9-6 defines the waveform filter strings and PEGjs (or other parser generator and validator) may be used to validate them. That said, ***PEGjs is not required at runtime*** to extract the essential information from the waveform filter string; that can be done far more simply using a regex or other text processing to (1) remove the {annotations} and (2) extract essential filter capability information from {FirstAnn} annotation for the first substring.

Table X.Y.4.9-6: Parsing Expression Grammar (PEG)

Parsing Expression Grammar, using PEGjs on-line parser and validator available at *http://pegjs.org/online*
Filter =
(FirstStr? FirstAnn? ' ' / FirstAnn?)?
(NotchFreq NotchAnn? '~ ')?
(HighPassFreq FilterAnn? '-' LowPassFreq FilterAnn?)
(' ' NotchFreq NotchAnn? '~')?
(' Hz')?
(' B' BaselineAnn?)?
(' I' InterpolatorAnn?)?
(' A' ArtifactAnn?)?
/ FirstStr FirstAnn? / FirstAnn
FirstStr = [A-Za-z][A-Za-z0-9._+]*
FirstAnn = '{' ('ecgDiag' / 'ecgRhy+ST' / 'ecgRhy' / 'ecgSigAvg+ST' / 'ecgSigAvg') '}'
NotchFreq = Number
HighPassFreq = Number
LowPassFreq = Number
NotchAnn = '{' ('Fixed' / 'Adaptive')? '+Diag'? '}'
FilterAnn = '{' (NamedFilterType / GenericFilterType / PrefixedName) ('_' Digits)? '+ST'? '}'
NamedFilterType = ('RC' / 'Bessel' / 'Butterworth' / 'Chebyshev1' / 'Chebyshev2' / 'Elliptic' / 'Legendre') ('_FIR' / '_IIR')?
GenericFilterType = ('FIR' / 'IIR')?
BaselineAnn = '{' ('Spline' / 'Parabolic' / PrefixedName)? '+ST'? '}'
InterpolatorAnn = '{' ('Linear' / 'Spline' / 'Lagrange' / 'Hermite' / PrefixedName)? '+ST'? '}'
ArtifactAnn = '{' (PrefixedName)? '+ST'? '}'
PrefixedName = [A-Za-z][A-Za-z0-9]* ':' [A-Za-z][A-Za-z0-9]*
Number = Digits (('.' / ',') Digits?)?
Digits = [0-9]+

[11] https://en.wikipedia.org/wiki/Parsing_expression_grammar

Table X.Y.4.9-7: Parsing Expression Grammar (with notes)

line	Parsing Expression Grammar
1	Filter =
2	(FirstStr? FirstAnn? ' ' / FirstAnn?)?
3	(NotchFreq NotchAnn? '~ ')?
4	(HighPassFreq FilterAnn? '-' LowPassFreq FilterAnn?)
5	(' ' NotchFreq NotchAnn? '~')?
6	(' Hz')?
7	(' B' BaselineAnn?)?
8	(' I' InterpolatorAnn?)?
9	(' A' ArtifactAnn?)?
10	/ FirstStr FirstAnn? / FirstAnn
11	**FirstStr** = [A-Za-z][A-Za-z0-9._+]* *Descriptive token that summarizes clinical purpose or capability of the filter, e.g., 'Diagnostic', 'Rhythm+ST', 'Rhythm', 'Pediatric'.* *This is a vendor-specified string and may be localized; standard coded information is conveyed by {FirstAnn}.*
12	**FirstAnn** = '{' ('ecgDiag' / 'ecgRhy+ST' / 'ecgRhy' / 'ecgSigAvg+ST' / 'ecgSigAvg') '}' *First {annotation} token that specifies parameter and filter capability, asserted by waveform source:* 'ecgDiag' *waveform data can support diagnostic ECG interpretation, including ST analysis (0.05 to 150 Hz).* 'ecgRhy+ST' *waveform data can support ECG rhythm and ST analysis using narrower passband to reduce artifact (≈0.5 to 40 Hz).* 'ecgRhy' *waveform data can only support ECG rhythm analysis using narrower passband to reduce artifact (≈0.5 to 40 Hz).* 'ecgSigAvg+ST' *waveform data can support signal-averaged ECG with sufficient, including ST analysis.* 'ecgSigAvg' *waveform data can support signal-averaged ECG, excluding ST analysis.*
13	**NotchFreq** = Number
14	**HighPassFreq** = Number
15	**LowPassFreq** = Number *Notch and high-pass and low-pass corner frequencies, e.g., «0.05», «0,05», «60». (may use «.» or «,» for decimal point)*
16	**NotchAnn** = '{' ('Fixed' / 'Adaptive')? '+Diag'? '}' *Notch filter type. For ECG, append «+Diag» flag if IEC 60601-2-25 diagnostic gain flatness requirements are satisfied.*
17	**FilterAnn** = '{' (NamedFilterType / GenericFilterType / PrefixedName) ('_' Digits)? '+ST'? '}' *Coded standard filter names and prefixed proprietary filter names, followed by their order (degree of approximating polynomial).* *For ECG, append «+ST» flag if filtered waveform can support ST analysis.*
18	**NamedFilterType** = ('RC' / 'Bessel' / 'Butterworth' / 'Chebyshev1' / 'Chebyshev2' / 'Elliptic' / 'Legendre') ('_FIR' / '_IIR')? *Standard traditional filter names, apply to high-pass and/or low-pass filter.*
19	**GenericFilterType** = ('FIR' / 'IIR')? *Generic digital FIR and IIR filter types, apply to high-pass and/or low-pass filter.* *The order, if specified, is the degree of the approximating polynomial.*
20	**BaselineAnn** = '{' ('Spline' / 'Parabolic' / PrefixedName)? '+ST'? '}' *Specifies type of baseline filter, and may include prefixed vendor-specific filters.* *For ECG, append «+ST» flag if the baseline filter can support ST analysis.*
21	**InterpolatorAnn** = '{' ('Linear' / 'Spline' / 'Lagrange' / 'Hermite' / PrefixedName)? '+ST'? '}' *Specifies type of interpolator filter, and may include prefixed vendor-specific filters.* *For ECG, append «+ST» flag if the interpolator filter can support ST analysis.*
22	**ArtifactAnn** = '{' (PrefixedName)? '+ST'? '}' *Specifies prefixed vendor-specific artifact filter. For ECG, append «+ST» flag if the artifact filter can support ST analysis.*

line	Parsing Expression Grammar
23	**PrefixedName** = [A-Za-z][A-Za-z0-9]* ':' [A-Za-z][A-Za-z0-9]* *Prefixed vendor-specific filter name, e.g., «ge:FRF» for GE's 'Finite Residual Filter' used for ECG stress test data.*
24	**Number** = Digits (('.' / ',') Digits?)? *Specifies an unsigned decimal or integer value; may use «.» or «,» for decimal point.*
25	**Digits** = [0-9]+

X.Y.4.9.4 Filter examples

Table X.Y.4.9-8 shows examples of filter strings with {annotations} in the 'String' column and with the {annotations} removed in the 'Display-Print' column.

The 'ST' column indicates whether the filter and waveform data supports ST analysis and review based on whether the «ecgDiag», «ecgRhy+ST» or «ecgSigAvg+ST» was present in FirstAnn (or, for that matter, is contained anywhere in the waveform filter string).

Table X.Y.4.9-8: Filter examples

String	Display-Print	ST
F{ecgDiag} 60~ 0.05-150 Hz	F 60~ 0.05-150 Hz	YES
F{ecgDiag} 60~ 0.05{Butterworth_2}-150{Butterworth_2} Hz B{Spline}	F 60~ 0.05-150 Hz B	YES
F{ecgDiag} 60{Adaptive+Diag}~ 0.05{Butterworth_2}-150{Butterworth_2} Hz B{Spline}	F 60~ 0.05-150 Hz B	YES
{ecgRhy+ST} 0.5{FIR_2+ST}-40 Hz	0.5-40 Hz	YES
{ecgRhy+ST}0.5{FIR_2+ST}-40 Hz	0.5-40 Hz	YES
{ecgRhy}0.5{FIR_2}-40 Hz	0.5-40 Hz	no
Diagnostic{ecgDiag} 0.05-150 Hz	Diagnostic 0.05-150 Hz	YES
Rhythm+ST{ecgRhy+ST} 0.5{FIR_2+ST}-40 Hz	Rhythm+ST 0.5-40 Hz	YES
Rhythm{ecgRhy} 0.5{FIR_2}-25 Hz	Rhythm 0.5-25 Hz	no
Diagnostic{ecgDiag}	Diagnostic	YES
Diagnostic	Diagnostic	×
Rhythm+ST	Rhythm+ST	×
Rhythm	Rhythm	×
SAECG{ecgSigAvg+ST} 0.05-300 Hz	SAECG 0.05-300 Hz	YES
SAECG{ecgSigAvg} 40{Butterworth_IIR_4}-250{Butterworth_2} Hz	SAECG 40-250 Hz	no
Pediatric{ecgDiag} 0.05-250 Hz	Pediatric 0.05-250 Hz	YES
Diagnostic{ecgDiag} 0.05-150 Hz	Diagnostic 0.05-150 Hz	YES
Monitoring{ecgRhy+ST} 0.05-40 Hz	Monitoring 0.05-40 Hz	YES
Moderate{ecgRhy+ST} 0.5{FIR_2+ST}-40 Hz	Moderate 0.5-40 Hz	YES

String	Display-Print	ST
Moderate{ecgRhy+ST} 0.5{+ST}-40 Hz	Moderate 0.5-40 Hz	YES
Moderate{ecgRhy+ST} 0.5-40 Hz	Moderate 0.5-40 Hz	YES
Maximum{ecgRhy} 5-25 Hz	Maximum 5-25 Hz	no
{ecgDiag}60~ 0.05-150 Hz	60~ 0.05-150 Hz	YES
{ecgDiag}0.05-150 60.0~ Hz	0.05-150 60.0~ Hz	YES
{ecgDiag}0,05-150 60,0~ Hz	0,05-150 60,0~ Hz	YES

A key principle is that **the display-print string can be obtained by removing all {annotations}** using this representation. The display-print format is consistent with how this information is typically displayed and printed.

The device or system sourcing the data has a high degree of control over the text, such as what is {annotated} and what is not, as well as the content of the first substring that can include vendor filter identifiers and translations. The {annotation} for the first substring conveys the clinical capability of the filter and waveform data using coded tokens, such as «ecgRhy+ST».

X.Y.4.10 Waveform Displayed Sweep Speed - *Optional*

This optional segment specifies the default sweep speed for waveform data viewed on an interactive display or hardcopy output. Support for this segment is optional for both the reporter and consumer and there is no requirement for the receiver to display waveforms at the specified sweep speed.

Table X.Y.4.10-1: OBX segment for Sweep Speed

SEQ	LEN	DT	Usage	Card.	TBL #	ITEM #	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NM
3	705	CWE	R	[1..1]		00571	67967^MDC_ATTR_SPD_SWEEP_DEFAULT^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[1..1]		00573	Example – 12.5 or 25 or 50
6	705	CWE	C	[1..1]		00574	Units – typically mm/sec

X.Y.4.11 Waveform Displayed Grid - *Optional*

This optional segment describes the vertical position(s) of horizontal reference lines for an individual or a group of waveforms. They are described in terms of data counts (see MDC_ATTR_DATA_RANGE) so that if the scale is different in actual value for two different waveforms, the grid can still be the same. There is no requirement that the consumer use the specified grid information.

Table X.Y.4.11-1: OBX segment for Grid Lines

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM #	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NA
3	705	CWE	R	[1..1]		00571	68324^MDC_ATTR_GRID_VIS^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[2..*]		00573	Series of Data Counts separated by "^"
6	705	CWE	X	[1..1]		00574	Empty

X.Y.4.12 Waveform Displayed Color - *Optional*

This optional segment specifies the color to be used when displaying the waveform or waveform group. The RGB (Red, Green, Blue) encoding scheme is used. Each of R,G and B has a range from 0 to 255. (Please refer to the glossary for a definition). There is no requirement that the consumer use the specified color.

Table X.Y.4.12-1: OBX segment for Displayed Color

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NA
3	705	CWE	R	[1..1]		00571	68325^MDC_ATTR_VIS_COLOR^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[3..3]		00573	R^G^B; Example – 124^69^243
6	705	CWE	X	[0..1]		00574	Empty

X.Y.4.13 Waveform Displayed Scale Range - *Optional*

This optional segment specifies the lowest value and highest value for the display scale of a scaled waveform. For example, the displayed scale for an arterial blood pressure waveform may range from a low value of -30 mmHg to a high value of +270 mmHg. There is no requirement on the consumer to use the specified scale ranges.

Table X.Y.4.13-1: OBX segment for Displayed Scale Range

SEQ	LEN	DT	Usage	Card.	TBL #	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NR
3	705	CWE	R	[1..1]		00571	68326^MDC_ATTR_SCALE_RANGE^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[2..2]		00573	Lower scale value^Upper scale value
6	705	CWE	R	[1..1]		00574	Units

X.Y.4.14 Waveform Displayed Scale Range Preferred Size - *Optional*

This segment specifies the preferred display or printed size for waveform data viewed on an interactive display or hardcopy output, corresponding to the difference between the lowest and highest values specified by MDC_ATTR_SCALE_RANGE. For example, the displayed scale for an arterial blood pressure may range from a low value of -30 mmHg to a high value of +270 mmHg that spans a distance of 6 cm, corresponding to 50 mmHg/cm. This information, when used with other display and sweep rate attributes, can be used to preserve the display aspect ratio on larger displays. There is no requirement on the consumer to use the specified preferred size.

Table X.Y.4.14-1: OBX segment for Displayed Scale Range

SEQ	LEN	DT	Usage	Card.	TBL #	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NR
3	705	CWE	R	[1..1]		00571	68327^MDC_ATTR_SCALE_RANGE_SIZE^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	Varies	C	[1..1]		00573	Physical distance between lower^upper scale values of MDC_ATTR_SCALE_RANGE.
6	705	CWE	R	[1..1]		00574	Units of distance: mm, cm.

X.Y.4.15 Waveform Physiological Range - *Optional*

This optional segment specifies the range of expected physiological values for the waveform. For example, whereas the displayed scale for an arterial blood pressure waveform may range from a low value of -30 mmHg to a high value of +270 mmHg, the physiological range could be -40 to +350 mmHg. There is no requirement on the consumer to use the specified waveform physiologic range information.

Table X.Y.4.15-1: OBX segment for Physiological Range

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = NR
3	705	CWE	R	[1..1]		00571	68328^MDC_ATTR_PHYS_RANGE^MDC
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy
5	99999	Varies	C	[2..2]		00573	Lowest expected Physiological Value^Highest expected Physiological Value
6	705	CWE	R	[1..1]		00574	Units

X.Y.4.16 Waveform Annotations, Markers and Events – *Optional*

The Device Observation Reporter (DOR) may specify events, annotations and other markers associated with the waveform. Examples include pace pulse, start of breath, J-point fiducial, start of asystole, etc.

MDC_EVT events defined in Tables A.9.2.1 and A.9.3.1 of ISO/IEEE 11073-10101:2004 and MDC_ECG annotations defined in Tables A.7, A.8, A.9, A.10 and A.11 of ISO/IEEE 11073-10102:2012 'Annotated ECG' may be used. Additional event and annotation identifiers may be defined in the future and should be used in conformance with the NIST RTMMS and test tools.

MDC_EVT event and MDC_ECG_ annotation types received as part of a WCM annotation stream or sequence ***are <u>not</u> intended to report alert conditions***; the Alert Communication Management (ACM) and Event Communication (EC) Profiles should be used instead. That said, the existing event terminology and PCD-04 and PCD-10 messaging conventions are leveraged by this Supplement and are extended to support advanced clinical research applications and algorithm development and testing.

X.Y.4.16.1 Top-level OBX segment for time-point and interval annotations

Top-level annotations are conveyed at the dot-level-4 METRIC level using the OBX segment and content shown below. Additional information is conveyed by OBXs at the dot-level-5 FACET level and possibly deeper levels.

The MDC_EVT event and MDC_ECG annotation *identifier* is conveyed by OBX-3 and the annotation *phase* (e.g., tpoint, start, end, etc.) is conveyed by OBX-5.[12] The *timestamp* is conveyed by OBX-14.

The { *identifier*, *phase*, *timestamp* } tuple provides practically all the essential information needed to display this information and support additional analysis and review. For example, a time-point event such as an 'early-cycle' PVC can be conveyed as a single OBX using the 'tpoint' phase whereas an interval event such as asystole would be conveyed as a pair of OBXs using the 'start' and 'end' phases.

The content model for the top-level OBX segment for time-point and interval annotations is shown in Table X.Y.4.16-1 on the following page and is primarily intended for non-numeric 'named' events and annotations.[13]

Table X.Y.4.16-1: Top-level OBX segment for time-point and interval annotations

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
1	4	SI	R	[1..1]		00569	Set ID – OBX
2	3	ID	C	[1..1]	0125	00570	Value Type = ST

[12] Although ISO/IEEE 11073-10102-2012 aECG pre-coordinates the phase information { _TIME_POINT, _ONSET, _ONSET_IMPLIED, _OFFSET, _OFFSET_IMPLIED } into the REFID, the appropriate phase identifier string must be specified in OBX-5. The base REFID *without* pre-coordinated phase information will be conveyed in OBX-3 to simplify processing and promote alignment between the various IEEE 11073 annotation sub-vocabularies.

[13] Numeric limit events can also be sent as annotations by using MDC_EVT_LO or MDC_EVT_HI (and possibly other MDC_EVT terms) as the 'top-level' dot-level-4 METRIC level identifier and then specifying the numeric observation immediately following at the dot-level-5 FACET level. It should be noted that numeric limit events are typically *not* sent as annotations; instead, they are included as evidentiary information in a 'named' annotation such as 'bradycardia', 'tachycardia', 'apnea' and other widely recognized clinical terms.

SEQ	LEN	DT	Usage	Card.	TBL#	ITEM#	Element name
3	705	CWE	R	[1..1]		00571	MDC_EVT_* events from -10101, MDC_ECG_* annotations from -10102 and other IEEE 11073 events and annotations.
4	20	ST	R	[1..1]		00572	See Table X.Y.2-2: WCM Containment Hierarchy…
5	99999	ST	C	[1..1]		00573	Annotation phase: *tpoint, start, continue, end, start-only, present, update, start-implied, end-implied* and possibly other phase identifiers from ACM, EC and aECG.
6	705	CWE	X	[0..0]		00574	Units (not used)
7	60	ST	CE	[0..1]		00575	Reference Range (may be used to provide device measurement range capability relevant to a non-metric device annotation).
8	5	IS	CE	[0..*]	0078	00576	Abnormal Flags (populated with zero or more abnormal flag codes defined in PCD DEC TF-2 Rev 5.0).
9	5	NM	X	[0..0]		00577	Probability (not used)
10	2	ID	CE	[0..1]	0080	00578	Nature of Abnormal Test (not used)
11	1	ID	R	[1..1]	0085	00579	Observation Result Status (populated with a code from PCD DEC TF-2 Rev 5.0).
12	24	DTM	X	[0..0]		00580	Effective Date of Reference Range (not used)
13	20	ST	X	[0..0]		00581	User Defined Access Checks (not used)
14	24	DTM	RE	[1..1]		00582	Date/Time of the Observation
15	705	CWE	RE	[0..1]		00583	Producer's ID (typically not used)
16	250	XCN	RE	[0..1]		00584	Responsible Observer (typically not used)
17	705	CWE	RE	[0..1]		00936	Observation Method (typically not used)
18	22	EI	RE	[0..1]		01479	Equipment Instance Identifier
19	24	DTM	CE	[0..1]		01480	Date/Time of the Analysis
20	705	CWE	RE	[0..*]	0163	02179	Observation Site

The annotation phases conveyed by OBX-5 are listed in Table X.Y.4.16-2. They are a subset of the phases supported by ACM but are not intended to report alert conditions. Two additional phases, *start-implied* and *end-implied*, are intended to support applications where the actual start and end of an event is not visible or contained by a finite-length waveform record.

Table X.Y.4.16-2: Annotation Phases

Phase	Description
tpoint	*time-point* event, e.g., R-on-T PVC beat (event active only for a moment in time)
start	*start* of an interval event, e.g., atrial fibrillation (placing the event in the ‘active’ state)
continue	*continuation* of an interval event (event remains in the ‘active’ state)
end	*end* of an interval event (placing the event in the ‘inactive’ state)
start-only	Indicates the *start* of an interval event, but actual *end* will not be reported.

Phase	Description
	The event state following the *start-only* phase is unknown.[14]
present	Indicates that the event is '*present*' (active) at this point in time, but the actual end will not be reported. Previous and future event state are unknown.
update	*Update* due to status or data change (remains in the 'active' state)
start-implied	Indicates that the actual *start* (onset) of an event occurred before the beginning of a finite-length record (e.g., a rhythm strip) and therefore cannot be displayed as an actual *start*.
end-implied	Indicates that the actual *end* (offset) of an event occurs after the end of a finite-length recorded, and therefore cannot be displayed as an actual *end*.

X.Y.4.16.2 Additional OBX segments for evidentiary information

Annotations may also include additional evidentiary information, e.g., QRS morphology class number, artifact and noise level measurements, respiratory and ventilator data associated with inspiration and expiration, and countless other items. This information is conveyed as descendent nodes of the 'top-level' annotation OBX.[15]

X.Y.5 Comparison with IEEE 11073-10201

IEEE Std 11073-10201 is the 11073 series Domain Information Model. It provides an object model for a Sample Array object which then is specialized into a Real-Time Sample Array for continuous waveforms and a Time Sample Array for waveform snapshots. The constructs in the 11073 Standard are used as guidance in the WCM Profile, however there is not a one-to-one mapping in all cases.

The following table compares the 11073 Model with the current WCM model. Future updates to the WCM may add additional attributes if implementations require them.

Table X.Y.5-1: Comparison of 11073 with WCM

11073 SA Attribute	WCM Attribute	Comment
Sample Array object	**WCM object**	
Sa-Observed-Value	Supported	Supported by combination of the OBX that conveys the waveform array and a separate list of MDC_EVT technical condition mappings.

[14] We could consider supporting the identification of a small number of *groups* of mutually-exclusive interval events (e.g., ECG rhythms) such that the **start-*nn*** phase for an interval event in group ***nn*** identifies the end of the previous interval event of the same group. The ***-nn*** suffix could also be applied to ***start-implied-nn***. Although this could potentially reduce the number of rhythm and noise-state phases in half, it may introduce scoping issues if deployed across multiple parameters and messages. [Another alternative is to assign symbolic suffixes, e.g., start-ecg-rhythm, but here we would need to consider vendor differences, such as whether underlying atrial fibrillation/flutter is modeled as a separate and independent annotation sub-stream relative to ventricular rhythm, or not.]

[15] The additional evidentiary information items will be captured and documented in containment models.

11073 SA Attribute	WCM Attribute	Comment
Compound-Sa-Observed-Value	Supported	Use the HL7 "NA" Data Type
Sa-Specification	Not directly supported	# of samples can be counted in message
Compression	Supported	Replaced with WAV_ATTR_WAV_ENCODING. While WCM initially supports integer encoding only, future implementations could support other encoding and compression schemes.
Scale-and-Range-Specification	Supported	
Sa-Physiological-Range	Supported	Mapped into an OBX that specifes the low and high values for the physiologic data range.
Visual-Grid	Supported	Mapped into an OBX that specifes the low and high values for the visually displayed grid rows.
Sa-Calibration-Data	Not supported	
Filter-Specification	Supported	Comprehensive filter information is represented as a single structured text string, listed as Filter-Label-String below.
Filter-Label-String	Supported	Comprehensive filter information is represented as a single structured text string.
Sa-Signal-Frequency	Not directly supported	This information can be determined from the information provided by the Filter-Label-String, especially when the clinical purpose or capability of the filter is declared.
Filter Type	Supported (optional)	Filter Type can be specified by Filter-Label-String.
Filter Order	Supported (optional)	Filter Order can be specified by Filter-Label-String.
Sa-Measure-Resolution	Supported	This information can be conveyed by MDC_ATTR_SA_MSMT_RES *or* MDC_ATTR_NU_MSMT_RES.
Sa-Marker-List	Supported	Use Annotation mechanism
	Supported in v2	Use the MDC_ATTR_VIS_COLOR attribute.
Real Time SA object		
Sample-Period	Supported	Report sample period with MDC_ATTR_TIME_PD_SAMP Report sample rate with MDC_ATTR_SMAPLE_RATE
Sweep-Speed	Supported	Use the MDC_ATTR_SPD_SWEEP_DEFAULT attribute.
Average-Reporting-Delay	Not supported	
Sample-Time-Sync	Supported in v2	Report MDC_ATTR_SAMPLE_COUNT and coincident time stamp in OBX-14, similar how coincident hi-res and other time stamps are reported.
HiRes-Sample-Time-Sync	Supported (indirectly)	This is specified in the PCD DEC TF-2 and applies to the WCM Profile.
Time SA object		
Absolute-Time-Stamp	Supported (indirectly)	This is specified in the PCD DEC TF-2 and applies to the WCM Profile.
Relative-Time-Stamp	Supported (indirectly)	This is specified in the PCD DEC TF-2 and applies to the WCM Profile.

11073 SA Attribute	WCM Attribute	Comment
HiRes-Time-Stamp	Supported (indirectly)	This is specified in the PCD DEC TF-2 and applies to the WCM Profile.
Sample-Period	Supported	Sample rate is used instead of Sample Period
Sweep-Speed	Supported	Use the MDC_ATTR_SPD_SWEEP_DEFAULT attribute.
Tsa-Marker-List	Not supported	Use annotations.

X.Y.6 Applying the Waveform Module to Use Cases

Inclusion of waveform data in an HL7 message also creates some additional requirements on other segments of that message. This depends on the waveform type and Use Case.

X.Y.6.1 General Guidance

In any transaction with a Waveform Group Section, specific use of the MSH and OBR segments are Required.

X.Y.6.1.1 Frequency of Transmission

Currently the DEC Profile limits transmission of PCD-01 messages to no more than six times per minute (i.e., every 10 seconds). Faster rates for waveform transmissions may be desirable, especially of continuous waveforms associated with alerts, where an update rate of once every second may be appropriate.

X.Y.6.2 Waveform Snapshot – Alarm Trigger

When an alarm occurs, evidentiary data such as the parameter set and waveforms may be sent with the alarm. In some cases this information is available at the time of the alarm and can be included directly in the Alarm Message. In many other cases the waveforms may be delayed, since it is desirable include waveform data that preceded the event as well as a number of seconds of waveform data post-event. Rather than delay communicating the alarm event itself, a separate message may be sent Associated with the Alarm Message, delayed by several seconds.

X.Y.6.2.1 Directly in the Alarm Message

If the waveform data is available at the time of the alarm, the Alarm Reporter can include any number of Waveform Group Sections in the PCD-04 transaction.

X.Y.6.2.2 Associated with the Alarm Message

If the waveform data is not available at the time of the alarm, the Alarm Reporter can send additional transaction(s) when the data is available. In order to associate these Observations with the appropriate Alarm, the OBR-3 field of a separate PCD-04 Transaction is filled with the Filler Order # which corresponds to the original Placer Order # of the appropriate alarm.

X.Y.6.3 Continuous Waveform

Continuous waveform data will typically be embedded in PCD-01 transactions. In order to support applications which desire near real-time access to the waveform data, it is recommended that messages be sent approximately every second. Outside of the guidance mentioned for the MSH and OBR segments there are no additional requirements.

X.Y.6.4 Waveform Snapshot – Request Trigger

Out of scope in current version.

X.Y.6.5 Waveform Snapshot – Archive Query

Out of scope in current version.

X.Y.6.6 Waveform Snapshot – ECG 12 Lead

Out of scope in current version.

Appendix Y – Example Messages

<u>Example 1</u>: Snapshot Waveform Data in ACM message

An observation result, including 20 seconds of waveform data, from a simple finger plethysmographic pulse monitor with no other VMDs or channels. Minimal information beyond required fields populated.

MSH|||||20080515123100-0400||ORU^R01^OR_R01|MSGID5432346754|P|2.5|||NE|AL|||||IHE PCD ORU-R01 208^HL7^2.16.840.1.113883.9.n.m^HL7

PID|||123456789||Doe^John^Joseph||19630415

PV1|||SICU^301^2||||||||||||||11772233

/* Since this message has a waveform with a duration of 20 seconds, the OBR segment specifies both the start time and end time of the waveform. In this case the precision is milli-seconds. */

OBR|1||09780979a9879^ACME HEALTH^ABCD002343785379^EUI-64|MDC_ALARM_EXAMPLE^Sample alarm^MDC^979879-9879^Example^SNM3|||20080515121000.100-0400|20080515121020.100-0400||||||||800 555 2323

/* This alarm message contains the current Pleth Pulse Rate observation. */

OBX|1|NM|149538^MDC_PLETH_PULS_RATE^MDC|1.1.1.1|83|264896^MDC_DIM_PULS_PER_MIN^MDC|||||R|||20060713095715-0400|||264896^MDC_UPEXT_FINGER^MDC

/* This alarm message contains the Pleth Pulse Rate at the time of alarm, as well as the related event information. */

OBX|2|ST|196648^MDC_EVT_HI^MDC|1.1.1.1.1|PLETH PULSE HIGH|||H~PM~SP||||||20050515121010||||CD12345^ORIGatewayInc ICU-04^AECF114477885323^EUI-64|20080515121000

OBX|3|NM|149538^MDC_PLETH_PULS_RATE^MDC|1.1.1.1.2|160|264896^MDC_DIM_PULS_PER_MIN^MDC|40-140|H~PM~SP||||||20080515121000||||||264896^MDC_UPEXT_FINGER^MDC

OBX|4|ST|68481^MDC_ATTR_EVENT_PHASE^MDC|1.1.1.1.3|start

OBX|5|ST|68482^MDC_ATTR_ALARM_STATE^MDC 1.1.1.1.4|active

OBX|6|ST|68483^MDC_ATTR_ALARM_INACTIVATION_STATE^MDC|1.1.1.1.5|audio-paused

/* This alarm message also contains the Finger Pulse waveform information which starts here. Note that some optional segments and fields are not included since they do are not usually available for a Finger Pulse Waveform. These include filters, data resolution, grids, scales, etc. The pulse waveform is unitless, and ranges from 0 to 16383.

OBR|2||09780979a9879^ACME HEALTH^ABCD002343785379^EUI-64|69122^MDC_OBS_WAVE_NONCTS^MDC|||20080515121000.100-0400|20080515121001.100-0400

/* The actual waveform raw data, as 50 delimited signed integers */

OBX|7|NA|150452^MDC_PULS_OXIM_PLETH^MDC|1.1.1.2| 1027^3504^4586^6612^8234^10592^11250^12183^11490…(etc.)||||||||20080515121000.100-0400

/* Sample rate is 50 samples/sec. MDC code is 262144+2464 */

OBX|8|NM|68320^MDC_ATTR_SAMPLE_RATE^MDC|1.1.1.2.1|50|264608^MDC_DIM_PER_SEC^MDC

/* Waveform encoding is default – integer */

OBX|9|NM|68322^MDC_ATTR_WAV_ENCODING^MDC|1.1.1.2.2|0

/* Range of raw data (i.e., A/D) values to be encountered. */

OBX|10|NR|0^MDC_ATTR_DATA_RANGE^MDC|1.1.1.2.3|0^16383||

/* The next 3 messages map special waveform values to specific abnormal conditions. This starts with a group delimiter. */

OBX|12|NM|262196^MDC_EVT_INOP^MDC|1.1.1.2.3.1|32767||

OBX|13|NM|262166^MDC_EVT_DISCONN^MDC|1.1.1.2.3.2|32766||

/* Sweep speed, in this case 25 mm/sec. Units are m/sec (2816) + milli (18) + offset (262144) */

OBX|14|NM|2431^MDC_ATTR_SPD_SWEEP_DEFAULT^MDC|1.1.1.2.4|25|264978^MDC_DIM_MILLI_M_PER_SEC^MDC|

/* Waveform display color at source, in this case a shade of purple */

OBX|15|NA|68325^MDC_ATTR_VIS_COLOR^MDC|1.1.1.2.5|124^69^243||

<u>Example 2:</u> Continuous Waveform Data including Multiple Waveforms

The following example is an observation result, including one second of waveform data which is part of a continuous waveform stream. The data includes heart rate and blood pressure vital signs as well as multi-lead ECG and a single invasive blood pressure waveform.

MSH|^~\&|ORIGatewayInc^ACDE48234567ABCD^EUI-64|ICU-04|EnterpriseEHRInc|DowntownCampus|20060713095730-0400||ORU^R01^ORU_R01|MSGID1233456789|P|2.5|2||NE|AL|USA|ASCII|EN^English^ISO639||IHE PCD ORU-R01 2006^HL7^2.16.840.1.113883.9.n.m^HL7

PID|||12345^^^^PI^Downtown Campus||Doe^John^Joseph^JR^^^L^A^^^G|Jones^Mary^Roberta^^^^^G^^^G|19440712|M||2028-9^Asian^HL70005|10&Market Street^^San Fransisco^CA^94111^USA^M||^PRN^PH^^1^415^1234567||EN^English^ISO639|M^Married^HL70002

OBR|1|AB12345^ORIGatewayInc ICU-04^ACDE48234567ABCD^EUI-64|CD12345^ORIGatewayInc ICU-04^ACDE48234567ABCD^EUI-64||||20060713095715-0400|20080515121000.100-0400|20080515121001.100-0400

OBX|1|NM|16770+^MDC_ECG_HEART_RATE^MDC|1.1.1.1|83|264896^MDC_DIM_PULS_PER_MIN^MDC|||||R|||20080515121000.600-0400

/* In this example the pulse rate is derived from the invasive blood pressure. Ref ID is 18442 + offset (131072) */
OBX|2|NM|149514^MDC_BLD_PULS_RATE_INV^MDC|1.1.1.2|83|264896^MDC_DIM_PULS_PER_MIN^MDC|||||R|||20080515121000.600-0400

/* Arterial Blood Pressure – Systolic. Ref ID is MDC_PRESS_BLD_ART (18960) + offset for systolic (1) + coding space offset (131072) */
OBX|3|NM|150033^MDC_PRESS_BLD_ART^MDC|1.1.1.3|153|3872+^MDC_DIM_MMHG^MDC|||||R|||20080515121000.600-0400

/* Arterial Blood Pressure - Mean */
OBX|4|NM|150035^MDC_PRESS_BLD_ART^MDC|1.1.1.4|111|3872+^MDC_DIM_MMHG^MDC|||||R|||20080515121000.600-0400

/* Arterial Blood Pressure - Diastolic */
OBX|5|NM|150034^MDC_PRESS_BLD_ART^MDC|1.1.1.5|94|3872+^MDC_DIM_MMHG^MDC|||||R|||20080515121000.600-0400

/* Three ECG waveforms, sent in a single OBR with shared common attributes immediately following the OBR */

OBR|2||09780979a9879^ACME HEALTH^ABCD002343785379^EUI-64|69121^MDC_OBS_WAVE_CTS^MDC|||20080515121000.100-0400|20080515121001.100-0400

/* The ECG waveform is in uV, and ranges from -16382 to +16383. Per-lead ECG identifiers start at 256 with offsets for the various leads. For example, ECG I is 131072+256+1. */

/* Sample rate is 250 samples/sec. Unit of measurement MDC code is 262144+2464 */

OBX|6|NM|68320^MDC_ATTR_SAMPLE_RATE^MDC|1.1.1.6.1|250|264608^MDC_DIM_PER_SEC^MDC

/* Data resolution: 1 mV = 2048 counts. Unit of measure MDC code is volts (4256) + milli (18) + offset (262144) */

OBX|7|NM|67945^MDC_ATTR_SA_MSMT_RES^MDC|1.1.1.6.2|2048|266418^MDC_DIM_MILLI_VOLT^MDC

/* Waveform encoding is default – integer */

OBX|8|NM|68322^MDC_ATTR_WAV_ENCODING^MDC|1.1.1.6.3|0

/* Range of raw data (i.e., A/D) values to be encountered. */

OBX|9|NR|0^MDC_ATTR_DATA_RANGE^MDC|1.1.1.6.4|-16382^+16383||

/* The next two messages map special waveform values to specific abnormal conditions. */

OBX|10|NM|262196^MDC_EVT_INOP^MDC|1.1.1.6.4.1|32767||

OBX|11|NM|262166^MDC_EVT_DISCONN^MDC|1.1.1.6.4.2|32766||

/* The following OBX describes the filter applied to the ECG, a low-pass of 50 Hz and a high-pass of 0.5 Hz that satisfies the AHA/ACC requirements for low-frequency amplitude and phase response for ST analysis. */

OBX|12|ST|68162^MDC_ATTR_FILTER_LABEL_STRING^MDC|1.1.1.6.5|Monitoring{ecgRhy+ST} 0.5{FIR_2+ST}-40 Hz

/* Waveform sweep rate */

OBX|18|NM|2431^MDC_ATTR_SPD_SWEEP_DEFAULT^MDC|1.1.1.6.6|25|264978^MDC_DIM_MILLI_M_PER_SEC^MDC|

/* Waveform display color at source, in this case a shade of blue */

OBX|19|NA|68325^MDC_ATTR_VIS_COLOR^MDC|1.1.1.6.7|0^102^255||

/* Range of displayed data, in this case +/- 1 mV . Unit of measure is volts (4256) + milli (18) + offset (262144) */

OBX|20|NR|68326^MDC_ATTR_SCALE_RANGE^MDC|1.1.1.6.8|-1^+1|266418^MDC_DIM_MILLI_VOLT^MDC

/* Range of physiological data, in this case +/- 5 mV */

OBX|21|NR|68328^MDC_ATTR_PHYS_RANGE|1.1.1.6.9|-5^+5|266418^MDC_DIM_MILLI_VOLT^MDC

/* First ECG Waveform (250 samples) */

**OBX|21|NA|131329^MDC_ECG_ELEC_POTL_I^MDC|1.1.1.7|
24^72^12^-24^-56^200^1250^1900^2056^1432…(etc.)||||||||20080515121000.100-0400** /* Second ECG Waveform (250 samples) */

**OBX|22|NA|131330^MDC_ECG_ELEC_POTL_II^MDC|1.1.1.8|
24^72^12^-24^-56^200^1250^1900^2056^1432…(etc.)||||||||20080515121000.100-0400** /* Third ECG Waveform (250 samples) */

**OBX|22|NA|131389^MDC_ECG_ELEC_POTL_III^MDC|1.1.1.9|
24^72^12^-24^-56^200^1250^1900^2056^1432…(etc.)||||||||20080515121000.100-0400**

/* Arterial pressure Waveform, where the filter and display attributes are deployed as a FACET of the waveform */

**OBR|3||09780979a9879^ACME HEALTH^ABCD002343785379^EUI-64|69121^MDC_OBS_WAVE_CTS^MDC|
||20080515121000.100-0400|20080515121001.100-0400**

/* This message also contains an Arterial Blood Pressure waveform which starts here, with the waveform raw data. The ABP waveform is in mmHg, and ranges from -100 to +400 mmHg. */

**OBX|23|NA|18960+0+(…)^MDC_PRESS_BLD_ART^MDCI^MDC|1.1.2.9|
1027^3504^4586^6612^8234^10592^11250^12183^11490…(etc.)||||||||20080515121000.100-0400**/* Sample rate is 50 samples/sec. MDC code is 262144+2464 */

OBX|24|NM|68320^MDC_ATTR_SAMPLE_RATE^MDC|1.1.2.9.1|50|264608^MDC_DIM_PER_SEC^MDC

/* Data resolution – 1 mmHg = 16 counts. Unit of measure is mmHg (3872) + offset (262144) */

OBX|25|NM|67945^MDC_ATTR_SA_MSMT_RES^MDC|1.1.2.9.2|16|266016^MDC_DIM_MMHG^MDC

/* Waveform encoding is default – integer */

OBX|26|NM|68322^MDC_ATTR_WAV_ENCODING^MDC|1.1.2.9.3|0

/* Range of raw data (i.e., A/D) values to be encountered. */

OBX|27|NR|0^MDC_ATTR_DATA_RANGE^MDC|1.1.2.9.4|-8192^+8191||

/* The next 3 messages map special waveform values to specific abnormal conditions.*/

OBX|28|NM|262590^MDC_EVT_SIG_OUT_OF_RANGE^MDC|1.1.2.9.4.1|32767||

OBX|29|NM|262166^MDC_EVT_DISCONN^MDC|1.1.2.9.4.2|32766||

OBX|30|NM|268334^MDC_EVT_STAT_UNCALIB^MDC|1.1.2.9.4.3|32766||

/* The following section describes the filters applied to this pressure waveform, a second-order 16 Hz FIR low-pass */

OBX|31|ST|68162^MDC_ATTR_FILTER_LABEL_STRING^MDC|1.1.2.9.5|0-16{FIR_2} Hz

/* Sweep speed, in this case 25 mm/sec. Units are m/sec (2816) + milli (18) + offset (262144) */

OBX|34|NM|2431^MDC_ATTR_SPD_SWEEP_DEFAULT^MDC|1.1.2.9.6|25|264978^MDC_DIM_MILLI_M_PER_SEC^MDC|

/* Waveform display color at source, in this case a shade of red */

OBX|35|NA|68325^MDC_ATTR_VIS_COLOR^MDC|1.1.2.9.7|255^51^0||

/* Range of displayed data, in this case -30 mmHg to +270 mmHg */

OBX|36|NR|68326^MDC_ATTR_SCALE_RANGE^MDC|1.1.2.9.8|-30^+270|266016^MDC_DIM_MMHG^MDC

/* Range of physiological data, in this case -50 mmHg to +350 mmHg */

OBX|37|NR|68328^MDC_ATTR_PHYS_RANGE^MDC|1.1.2.9.9|-50^+350|266016^MDC_DIM_MMHG^MDC

<u>Example 3:</u> Minimal Waveform Message

The following example is a minimal waveform message that uses [OBR-7, OBR-8) as the default time interval (spanning 1.000 second) for an ECG waveform containing 250 data samples (with 235 omitted for brevity). The implied (and actual) sampling rate is 250 Hz. OBX-6 uses a UCUM unit-of-measure with a rational-fraction scale factor for a 12-bit converter spanning ±5 mV, or 2.44 µV per least-significant A/D converter count.

OBR||IHE_TEST_PDC_WCM^GATEWAY^0054674000000001^EUI-64|69121^MDC_OBS_WAVE_CTS^MDC|99999^GATEWAY^MDC|||20130426132052.548|20130426132053.548|

OBX|12|ST|68162^MDC_ATTR_FILTER_LABEL_STRING^MDC|1.1.1.1.1|Rhythm+ST{ecgRhy+ST} 0.5{FIR_2+ST}-40 Hz

OBX|1|NA|131329^MDC_ECG_ELEC_POTL_I^MDC|1.1.1.2|-10^-10^-5^1^14^22^21^4^-12^-24^-18^-5^2^*...235omittedsamples...*^4^7|10.mV/4096^10.mV/4096^UCUM|||||F|

Although optional, a signal filter label string should be provided if this information is known. The filter string above would be displayed as 'Rhythm+ST 0.5-40 Hz' after the {annotation}s are removed, indicating that it was suitable for ECG rhythm *and* ST analysis, even though it does not meet the traditional low-frequency bandwidth requirement for diagnostic ECG.

Note: Most modern electrocardiographs only send ECG limb leads I and II and precordial leads V1, V2, V3, V4, V5 and V6. Limb lead III and augmented leads aVR, aVL and aVF can be derived using III = II – I, aVR = -(1/2)(I + II), aVL = I – (1/2) II and aVF = II – (1/2) I.

Appendix Z – References

[**AHA2007**] Recommendations for the Standardization and Interpretation of the Electrocardiogram: Part I: The Electrocardiogram and Its Technology: A Scientific Statement From the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Casrdiology Foundation; and the Heart Rhythm Society Endorsed by the International Society for Computerized Electrocardiology. Paul Kligfield, Leonard S. Gettes, James J. Bailey, Rory Childers, Barbara J. Deal, E. William Hancock, Gerard van Herpen, Jan A. Kors, Peter Macfarlane, David M. Mirvis, Olle Pahlm, Pentti Rautaharju and Galen S. Wagner, *Circulation* 2007:115;1306-1324; originally published on Feb 23, 2007 and published online on March 13, 2007. Available at: http://circ.ahajournals.org/cgi/content/full/115/10/1306.

[**AHA1990**] Bailey JJ, Berson AS, Garson A Jr, Horan LG, Macfarlane PW, Mortara DW, Zywietz C. Recommendations for standardization and specifications in automated electrocardiography: bandwidth and digital signal processing: a report for health professionals by an ad hoc writing group of the Committee on Electrocardiography and Cardiac Electrophysiology of the Council on Clinical Cardiology, American Heart Association. *Circulation*. 1990;81:730 –739. *Note: This Special Report is referenced by subsequent AHA Clinical Recommendations, such as [AHA2007] listed immediately above*.

[**IEC2011**] IEC 60601-2-25, 2nd edition 2011-10, Medical electrical equipment – Part 2-25: Particular requirements for the basic safety and essential performance of electrocardiographs, *International Electrotechnical Commission*, ISBN 978-2-88912-719-1, 2011. *Note: See Section 201.12.4.107.1.1.2 Low frequency (impulse) response.*