Digital Imaging and Communications in Medicine (DICOM)

Supplement 229: Photoacoustic Imaging

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Out of Scope

1	Photoacoustic specific SR file implementation is reserved for a later supplement.
2	If a PA device produces an image with no PA optical image, the SOP class of the structural image (e.g. the ultrasound) will be used
3	If a PA device creates a single image component by fusing the structural image to the PA image for display as a single image (burned in), it will use the SOP class of the structural image.
4	A closely related imaging modality is Thermoacoustic imaging (TAI) which uses microwave radiation to excite the tissue (in contrast to light pulses). The specific implication of this separate modality were ignored in this particular DRAFT and focus was given to photoacoustic imaging as defined herein, where excitation is limited to pulsed light. Hence, this modality is excluded in this supplement to limit the scope of the present supplement.

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Document History

Document Version	Date	Content
00	2022/XX/XX	Initial Version

To Do

1	Update examples to be actual PA examples once OIDs and tags are assigned
2	

3	

Open Issues

1	In the Use Cases/Example section, some mandatory attributes have been omitted for the sake of brevity. Determine if this is an acceptable practice.

Closed Issues

1	

Scope and Field of Application

This Supplement to the DICOM Standard introduces a new IOD and a new storage SOP Class for encoding and storing photoacoustic images.

Photoacoustic imaging (PAI) is an imaging modality that enables imaging optical absorption in biological tissues with acoustic resolution. Contrast is generated through absorption by chromophores that range from intrinsic absorbers such as hemoglobin and melanin to extrinsic agents such as indocyanine green (ICG) or diverse types of nano-particles. Excitation at multiple wavelengths allows the modality to discriminate individual chromophores. Prospective applications in the space of clinical imaging range from classification of breast cancer lesions through screening of sentinel lymph nodes to assessment of inflammation. Photoacoustic Imaging is in widespread use in preclinical research labs and is recently being translated to clinical applications in first commercial implementations.

Many (but not all) PAI implementations integrate active pulse/echo ultrasound in a hybrid imaging system to capitalize on well-established contrast for anatomical information. The scope of this IOD is the **Photoacoustic (PA)** images and processed images that may be derived from a combination of these PA images. Complementary **mechanical contrast** images such as pulse/echo ultrasound should be represented by their native DICOM IODs. Albeit fusing PA images with US images is the presently most common scenario, the particulars of the fusion are beyond the scope of this IOD but an example is provided. PA images represent image output generated by the input of one or more optical excitation wavelengths. PA images may result from excitation by light pulses at one or more wavelengths. PA image series are related by TemporalPositionTimeOffset (0020,930D) and may have a related presentation defined by an Advanced Blending Presentation State object (C.11.33).

If a PA device creates a single image component by fusing the structural image to the PA image for display as a single image (burned in), it shall use the SOP class of the structural image and not burn in any patient information that complicates de-identification.

Changes to NEMA Standards Publication PS 3.2

Digital Imaging and Communications in Medicine (DICOM)

Part 2: Conformance

Item: Add new SOP Class in Table A.1-2:

The SOP Classes are categorized as follows:

Table A.1-2. UID VALUES

UID Value	UID NAME	Category
…		
1.2.840.10008.xxx	**Photoacoustic Image Storage SOP Class**	**Transfer**
…		

Item: Add new Abbreviation to A.3.6:

Abbreviations should be listed here. These may be taken from the following list, deleting terms that are not used within the Conformance Statement, and adding any additional terms that are used:

…

PA

Photoacoustic

…

Changes to NEMA Standards Publication PS 3.3

Digital Imaging and Communications in Medicine (DICOM)

Part 3: Information Object Definitions
Part 3 Additions

Modify PS3.3

Add to PS3.3 Annex A

A.XX Photoacoustic Image IOD

A.XX.1 PA Image IOD Description

The Photoacoustic (PA) Image Information Object Definition specifies an image which has been generated by the input of light at one or more optical excitation wavelengths. PA images may result from excitation at one or more wavelengths and may represent the optical contrast as acquired or as processed after acquisition. PA image series are related by TemporalPositionTimeOffset (0020,930D) and may have a related presentation defined by an Advanced Blending Presentation State object (C.11.33).

If fusion of PA images or related mechanical contrast images is to be performed via the Advanced Blending Presentation State object (C.11.33), the objects to be fused shall share Study-level attributes (at a minimum Study Instance UID, (0020,000D)), Frame of Reference UID (0020,0052), and Multi-frame Dimension Indices specified in C.8.X.X. The study should include a Spatial Registration object (A.39.1.3) if spatial registration is not common between the series to be fused.

A.XX.2 PA IOD Description Entity-Relationship Model

The Photoacoustic (PA) Image IOD uses the DICOM Composite Instance IOD Entity-Relationship Information Model defined in Section A.1.2, with the Image IE and optionally the Presentation State IE below the Series IE.

A.XX.3 PA Image IOD Modules

Table A.XX-1 specifies the Modules of the PA Image IOD.

Table A.XX-1. PHOTOACOUSTIC IMAGE IOD MODULES

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Enhanced Series Module	C.7.3.3	U
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	U
	Synchronization	C.7.4.2	M
Equipment	General Equipment	C.7.5.1	M

	Enhanced General Equipment	C.7.5.2	M
Image	General Image	C.7.6.1	M
	General Reference	C.12.4	U
	Image Pixel	C.7.6.3	M
	Enhanced Contrast/Bolus	C.7.6.4b	C - Required if contrast media was used in this image
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Device	C.7.6.12	U
	Acquisition Context	C.7.6.14	U
	Enhanced Palette Color Lookup Table	C.7.6.23	U
	Photoacoustic Image	C.8.X.X	M
	Photoacoustic Detector Sequence Module	C.8.X.X	M
	Photoacoustic Reconstruction Module	C.8.X.X	M
	ICC Profile	C.11.15	U
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	U
	Frame Extraction	C.12.3	C - Required if the SOP Instance was created in response to a Frame-Level retrieve request

A.XX.4 PA Image IOD Content Constraints

A.XX.4.1 Modality

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

A.XX.4.2 ICC Profile Module

The ICC Profile Module may be present for color images. If the color space to be used is not calibrated (i.e., a device-specific ICC Input Profile is not available), then an ICC Input Profile specifying a well-known space (such as sRGB) may be specified.

A.XX.4.3 Acquisition Context Module

The Defined TID for Acquisition Context Sequence (0040,0555) is TID YYYYY “Skin Type Acquisition Context”.

Add new defined term to PS3.3 C.7.3.1.1.1 Modality

Defined Terms:

…

PA

Photoacoustic

…

Add macro to C.7.6.16.2 Common Functional Group Macros

C.7.6.16.2.X Photoacoustic Frame Macro

Table C.7.XX.1-2. Photoacoustic Frame Functional Group Attributes include per-frame PA attributes that may vary across frames.

Table C.7.XX.1-2. Photoacoustic Frame Macro Attributes

Attribute Name	Tag	Type	Attribute Description
PA Frame Sequence	(gggg,eee1)	1	Sequence of items that defines per-frame PA attributes. Only a single Item shall be included in this Sequence.
>Excitation Spectral Width	(gggg,eee2)	3	Width in FWHM of the emitted optical spectrum in nm.
>Excitation Energy	(gggg,eee3)	3	The optical energy of the illuminator in mJ at the time of image acquisition. The optical energy setting used for generation of the wavelength for the image accounts for systematic differences in different WAVELENGTH images.
>Excitation Pulse Duration	(gggg,eee4)	3	The pulse duration or pulse width of the excitation pulse, measured as the time interval between the half-power points on the leading and trailing edges of the pulse in ns.

Modify table C.7.6.16-3 Frame Content Macro Attributes as follows.

Table C.7.6.16-3. Frame Content Macro Attributes

Attribute Name	Tag	Type	Attribute Description
…			

>Frame Reference DateTime	(0018,9151)	1C	The point in time that is most representative of when data was acquired for this frame. See Section C.7.6.16.2.2.1 and Section C.7.6.16.2.2.2 for further explanation. **Note** The synchronization of this time with an external clock is specified in the synchronization Module in Acquisition Time synchronized (0018,1800). Required **if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.xxx" (Photoacoustic Image Storage) or** if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage). May be present otherwise.
>Frame Acquisition DateTime	(0018,9074)	1C	The date and time that the acquisition of data that resulted in this frame started. See Section C.7.6.16.2.2.1 for further explanation. Required **if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.xxx" (Photoacoustic Image Storage) or** if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage). May be present otherwise.
>Frame Acquisition Duration	(0018,9220)	1C	The actual amount of time [in milliseconds] that was used to acquire data for this frame. See Section C.7.6.16.2.2.1 and Section C.7.6.16.2.2.3 for further explanation. Required **if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.xxx" (Photoacoustic Image Storage) or** if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage). May be present otherwise.
…			
>Temporal Position Index	(0020,9128)	1C	Ordinal number (starting from 1) of the frame in the set of frames with different temporal positions. Required if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.5.1.4.1.1.130" **or "1.2.840.10008.xxx" (Photoacoustic Image Storage)** or Functional MR Sequence (0018,9621) is present. May be present otherwise. See Section C.7.6.16.2.2.6 and Section C.7.6.16.2.2.8.
>Stack ID	(0020,9056)	1C	Identification of a group of frames, with different positions and/or orientations that belong together, within a dimension organization. See Section C.7.6.16.2.2.4 for further explanation. Required if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.5.1.4.1.1.130" **or "1.2.840.10008.xxx" (Photoacoustic Image Storage)** or Functional MR Sequence (0018,9621) is present. May be present otherwise. See Section C.7.6.16.2.2.7 and Section C.7.6.16.2.2.8.

>In-Stack Position Number	(0020,9057)	1C	The ordinal number of a frame in a group of frames, with the same Stack ID (0020,9056). Required if Stack ID (0020,9056) or Functional MR Sequence (0018,9621) is present **if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.xxx" (Photoacoustic Image Storage)**. See Section C.7.6.16.2.2.4 and Section C.7.6.16.2.2.8 for further explanation.
…			

Add a new section to C.7.6.16.2.2 Frame Content Macro

C.7.6.16.2.2.X Usage of Stack ID and In-Stack Position Number in Photoacoustic Imaging

For PA imaging a single Stack ID (0020,9056) is used to show the grouping of a collection of frames across a set of PA series or a series of DERIVED images created through acquisition-time processing of PA frames. The frames within a given stack are generally acquired from the same spatial location, but the actual spatial location is specified by (0020,9301) Image Position (Volume). The acquisition times of frames within a stack may or may not be within a small time window, depending on how the acquisition of the varying types of PA Image data is sequenced; the per-frame acquisition time is found in Frame Acquisition DateTime (0018,9074). The dimension indexes (C.8.X.X) are Stack ID (0020,9056), In-Stack Position Number (0020,9057) and the Image Position (Volume) (0020,9301). The In-Stack Position Number (0020,9057) is constant in each series, ensuring that each stack contains a consistent ordering of PA ORIGINAL or DERIVED frames across the study. All frames in a stack should have the same value for Temporal Position Time Offset (0020,930d).

DERIVED image series shall set the per-frame Derivation Image Sequence (0008,9124) to describe the derivation method (C.7.6.16.2.6) including the "Source Image Sequence" (0008, 2112). Each DERIVED image shall carry the per-frame "Frame Acquisition Date Time" (0018,9074) of the first PA image that was used in the processing and the Stack ID (0020,9056) and "Temporal Position Time Offset (0020,930d) of the source images.

Add a new section to C.8 Modality Specific Modules

C.8.XX Photoacoustic Modules

Photoacoustic Image studies include one or more series of PA images. The relationship between the frames in the series is defined by Multi-frame Functional Groups (C.7.6.16) indexed with Multi-frame Dimensions (C.7.6.17).

Dimension Indices include:

- Stack ID (0020,9056)
- In-Stack Position Number (0020,9057).
- Image Position (Volume) (0020,9301)

See C.7.6.16.2.2.X for PA image usage of Stack ID (0020,9056) and In-Stack Position Number (0020,9057). Image Position (Volume) should be iterated also for the case of FREEHAND acquisition to signify the position might be different.

C.8.XX.1 Photoacoustic Image

This section describes the Photoacoustic Image Module. Original (as-acquired) PA image series are marked Image Type (0008,0008) of ORIGINAL and processed PA image series are marked Image Type (0008,0008) of DERIVED.

Table C.8.XX.2-1 contains IOD Attributes that describe Photoacoustic Images

Table C.8.XX.2-1. Photoacoustic Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
Excitation Wavelength	(gggg,eee5)	1C	The optical excitation wavelength (nm) of the image quantifies the wavelength λ that the illuminator was configured to generate at the time of the image acquisition. Required if Image Type (0008,0008) is ORIGINAL, may be present otherwise
Illumination Type Code Sequence	(gggg,eee6)	3	Description of the type of illumination used. Only a single Item is permitted in this Sequence. See C.8.X.1.1 for further explanation.
>Include Table 8.8-1 “Code Sequence Macro Attributes”			DCID XXYYY “Illumination Type”
Acoustic Coupling Agent Code Sequence	(gggg,eee7)	3	Acoustic coupling agent that was used to allow sound propagation from the imaged subject to the detector. Only a single Item is permitted in this Sequence. See C.8.X.1.2 for further explanation.
>Include Table 8.8-1 “Code Sequence Macro Attributes”			DCID XXYYZ “Acoustic Coupling Agent”
Coupling Medium Temperature	(gggg,eee8)	3	The temperature of the coupling medium the sound travels through before being detected in Celsius.
Acquisition DateTime	(0008,002A)	1	The date and time that the acquisition of data that resulted in this image started.
Acquisition Duration	(0018,9073)	3	Duration of the image acquisition in seconds. Specifically relevant for scanning systems.

Position Measuring Device Used	(0018,980C)	1C	Describes the type of position measuring device used in the acquisition of the image, if any. This gives an indication of the degree of precision of Pixel Spacing (0028,0030) and the spacing between adjacent planes. Enumerated Values: RIGID The image was acquired with a position measuring device. FREEHAND The image was acquired without a position measuring device. Required if Volumetric Properties (0008,9206) is VOLUME and Volume Based Calculation Technique (0008,9207) is NONE. May be present otherwise.
Lossy Image Compression	(0028,2110)	1	Specifies whether an Image has undergone lossy compression (at a point in its lifetime). Enumerated Values: 00 Image has NOT been subjected to lossy compression. 01 Image has been subjected to lossy compression. Once this value has been set to 01 it shall not be reset. See Section C.7.6.1.1.5.

Lossy Image Compression Ratio	(0028,2112)	1C	Describes the approximate lossy compression ratio(s) that have been applied to this image. See Section C.7.6.1.1.5.2. Required if Lossy Image Compression (0028,2110) is "01".
Lossy Image Compression Method	(0028,2114)	1C	A label for the lossy compression method(s) that have been applied to this image. See Section C.7.6.1.1.5.1. Required if Lossy Image Compression (0028,2110) is "01".
Presentation LUT Shape	(2050,0020)	1	Specifies an identity transformation for the Presentation LUT, such that the output of all grayscale transformations defined in the IOD containing this Module are defined to be P-Values. Enumerated Values: IDENTITY output is in P-Values.
Event Timer Sequence	(0008,2133)	3	Sequence of time intervals of significance to this image. Each Item describes one time interval either beginning or ending at Acquisition DateTime (0008,002A). One or more Items are permitted in this Sequence.
>Event Time Offset	(0008,2134)	1	Signed value of the time between Acquisition DateTime (0008,002A) and the event, in milliseconds. Positive values indicate the event occurs after Acquisition DateTime (0008,002A).

>Event Code Sequence	(0008,2135)	1	Type of event. Only a single Item shall be included in this Sequence.
>>*Include Table 8.8-1 "Code Sequence Macro Attributes"*			*DCID 12031 "Protocol Interval Events".*
>Event Timer Name(s)	(0008,2132)	3	Name that identifies the event timer. May be used in addition to Event Time Code Sequence to offer site-specific user-readable event time names. Only a single value shall be included.

C.8.XX.2 Photoacoustic Detector Module

This section describes the Photoacoustic Detector Module. This module contains Attributes that are specific to Photoacoustic Detectors.

Table C.8.XX.2-1 contains IOD Attributes that describe Photoacoustic Detectors.

Table C.8.XX.2-1. Photoacoustic Detector Module Attributes

Attribute Name	Tag	Type	Attribute Description
Transducer Geometry Code Sequence	(0018,980D)	1	Geometric structure of the transducer. Only a single item shall be permitted in this sequence.
>Include 'Code Sequence Macro' Table 8.8-1			DCID 12033 "Ultrasound Transducer Geometry"
Detector Response Description	(gggg,eee9)	2	Text describing the frequency range (e.g. through center frequency and fractional bandwidth including T/R or R). If the value is of shape [c, b] then it is assumed to be interpreted in the form c=center frequency and b=bandwidth (measured at -6 dB in T/R).
Detector Technology Description	(gggg,ee10)	3	Descriptive Text describing the detector technology

C.8.XX.3 Photoacoustic Reconstruction Module

This section describes the Photoacoustic Reconstruction Module. This module contains Attributes that are specific to Photoacoustic Reconstruction.

Table C.8.XX.3-1 contains IOD Attributes that describe Photoacoustic Reconstruction.

Table C.8.XX.3-1. Photoacoustic Reconstruction Module Attributes

Attribute Name	Tag	Type	Attribute Description
Speed of Sound Correction Mechanism	(gggg,ee14)	1C	Text description of the Speed of sound correction mechanism. A single value represents the assumed speed of sound in the entire imaging medium used in image reconstruction, covering both the imaged object and the coupling agent or two values [C, O] represent two separate speeds of sound in coupling medium (C) and imaged object (O). In case an image is used for speed of sound modeling in reconstruction it may be stored as a separate "Speed of Sound Map". See C.7.6.16.2.24.1 for further information on storing a speed of sound map. Condition: Needs to be filled in case "Speed of Sound" map flag is YES, may be present otherwise.
Speed of Sound Map	(gggg,ee15)	3	Flag to indicate whether a speed of sound map was used in the reconstruction of the image.
Image Filtering	(gggg,ee16)	3	Text field to describe the specific image processing methods that were applied.

Changes to NEMA Standards Publication PS 3.4

Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

Add SOP to Table B.5-1 in PS3.4 Annex B.5.

Table B.5-1 STANDARD SOP CLASSES

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
…		
Photoacoustic Image Storage	**1.2.840.10008.XXXX**	**Photoacoustic Image IOD**
…		

Changes to NEMA Standards Publication PS 3.6

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

Add the following Data Elements to Table 6-1, Section 6, Registry of DICOM data elements:

Tag	Name	Keyword	VR	VM
…				
(gggg,eee1)	**PA Frame Sequence**	**PAFrameSequence**	**SQ**	**1**
(gggg,eee2)	**Excitation Spectral Width**	**ExcitationSpectralWidth**	**FL**	**1**
(gggg,eee3)	**Excitation Energy**	**ExcitationEnergy**	**FL**	**1**
(gggg,eee4)	**Excitation Pulse Duration**	**ExcitationPulseDuration**	**FL**	**1**
(gggg,eee5)	**Excitation Wavelength**	**ExcitationWavelength**	**FL**	**1**
(gggg,eee6)	**Illuminator Type Code Sequence**	**IlluminatorTypeCodeSequence**	**SQ**	**1**
(gggg,eee7)	**Acoustic Coupling Agent Code Sequence**	**AcousticCouplingAgentCodeSequence**	**SQ**	**1**
(gggg,eee8)	**Coupling Medium Temperature**	**CouplingMediumTemperature**	**FL**	**1**
(gggg,eee9)	**Detector Response Description**	**DetectorResponseDescription**	**UT**	**1**
(gggg,ee10)	**Detector Technology Description**	**DetectorTechnologyDescription**	**ST**	**1**
(gggg,ee11)	**Detector Sequence**	**DetectorSequence**	**SQ**	**1**
(gggg,ee12)	**Frequency Response**	**FrequencyResponse**	**ST**	**1**
(gggg,ee13)	**Angular Response**	**AngularResponse**	**ST**	**1**
(gggg,ee14)	**Speed of Sound Correction Mechanism**	**SpeedOfSoundCorrectionMechanism**	**ST**	**1**
(gggg,ee15)	**Speed of Sound Map**	**SpeedOfSoundMap**	**OB**	**1**
(gggg,ee16)	**Image Filtering**	**ImageFiltering**	**ST**	**1**
…				

Add to Table A-1 PS3.6 Annex A

UID Value	UID Name	UID Keyword	UID Type	Part
…				
1.2.840.10008.xxx	**Photoacoustic Image Storage**	**PhotoacousticImageStorage**	**SOP Class**	**PS 3.4**
…				

Changes to NEMA Standards Publications PS 3.15

Digital Imaging and Communications in Medicine (DICOM)

Part 15: Security and System Management Profiles

Add new Data Elements to PS 3.15 Annex E table

Table E.1-1. Application Level Confidentiality Profile Attributes

Attribute Name	Tag	Retd. (from PS 3.6)	In Std. Comp. IOD (from PS3. 3)	Basic Prof.	Rtn. Safe Priv. Opt.	Rtn. UIDs Opt.	Rtn. Dev. Id. Opt.	Rtn. Inst. Id. Opt.	Rtn. Pat. Chars. Opt.	Rtn. Long. Full Dates Opt.	Rtn. Long. Modif. Dates Opt.	Clean Desc. Opt.	Clean Struct. Cont. Opt.	Clean Graph. Opt.
…														
Detector Technology	**(gggg,ee10)**	**N**	**Y**	**X**			**K**							
Image Filtering	**(gggg,ee16)**	**N**	**Y**	**X**			**K**							
…														

Changes to NEMA Standards Publication PS 3.16

Digital Imaging and Communications in Medicine (DICOM)

Part 16 Content Mapping Resource

Modify tables in PS3.16 Annex B

CID 29 Acquisition Modality

Resources:

HTML | FHIR JSON | FHIR XML | IHE SVS XML

Type:

Extensible

Version:

~~**20190327**~~**yyyymmdd**

UID:

1.2.840.10008.6.1.19

Table CID 29. Acquisition Modality

Coding Scheme Designator	Code Value	Code Meaning
…		
DCM	**PA**	**Photoacoustic**
…		

CID 12033 Ultrasound Transducer Geometry

Resources:

HTML| FHIR JSON|FHIR XML|IHE SVS XML

Type:

Extensible

Version:

~~**20090409**~~**yyyymmdd**

UID:

1.2.840.10008.6.1.808

Table CID 12033. Ultrasound Transducer Geometry

Coding Scheme Designator	Code Value	Code Meaning
DCM	125251	Non-imaging Doppler ultrasound transducer geometry
DCM	125252	Linear ultrasound transducer geometry
DCM	125253	Curved linear ultrasound transducer geometry

DCM	125254	Sector ultrasound transducer geometry
DCM	125255	Radial ultrasound transducer geometry
DCM	125256	Ring ultrasound transducer geometry
DCM	**XXXXX8**	**Planar matrix transducer geometry**
DCM	**XXXXX9**	**Hemispherical detector geometry**

Add in PS3.16 Annex B

CID XXYYY Illumination Type

Resources:

HTML| FHIR JSON|FHIR XML|IHE SVS XML

Type:

Extensible

Version:

yyyymmdd

UID:

1.2.840.10008.6.1.XXX

Table CID XXYYY. Illumination Type

Coding Scheme Designator	Code Value	Code Meaning
DCM	**XXXXX1**	**Single side-illumination**
DCM	**XXXXX2**	**Dual side-illumination**
DCM	**XXXXX3**	**Through-detector-illumination**

CID XXYYZ Acoustic Coupling Agent

Resources:

HTML| FHIR JSON|FHIR XML|IHE SVS XML

Type:

Extensible

Version:

yyyymmdd

UID:

1.2.840.10008.6.1.XXX

Table CID XXYYZ. Acoustic Coupling Agent

Coding Scheme Designator	Code Value	Code Meaning
DCM	XXXXX4	Water (H2O)
DCM	XXXXX5	Heavy Water (Deuterium Oxide, D2O)
DCM	XXXXX6	Ultrasound Coupling Gel
DCM	XXXXX7	Direct Contact (no coupling agent used)

Add the following TID to Part 16 Annex C Acquisition Context Module, Protocol and Workflow Context Templates (Normative)

TID YYYYY Skin Type Acquisition Context

This Template defines an Acquisition Context Template for Skin Types. The attributes in this template represent values known at the time of image acquisition. Hence, these values may subsequently change.

Type:

Extensible

Order:

Non-Significant

Root:

No

Table TID YYYYY. Skin Type Acquisition Context

	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint

1	CODE	EV (443635002, SCT, "Fitzpatrick Skin Type")	1	U		DCID 4401 "Fitzpatrick Skin Type"

Add the following definitions to Part 16 Annex D DICOM Controlled Terminology Definitions (Normative) – Modify Table D-1

Annex D DICOM Controlled Terminology Definitions (Normative)

Table D-1. DICOM Controlled Terminology Definitions (Coding Scheme Designator "DCM" Coding Scheme Version "01")

Code Value	Code meaning	Definition	Notes
…			
PA	Photoacoustic	An acquisition device, process or method that performs photoacoustic imaging by means of tissue excitation through short light pulses.	Explicitly excludes thermoacoustic imaging (excitation due to the absorption of microwaves), which in academia is often considered closely related, but has not yet seen preclinical or clinical application through any commercial entity.
XXXXX8	Planar matrix transducer geometry	A transducer geometry with a planar surface that has multiple detection elements arranged in a matrix-like arrangement	
XXXXX9	Hemispherical detector geometry	A transducer geometry with a hemispherical surface that may or may not be interrupted for illumination of the subject	
XXXXX1	Single side-illumination	A illumination type where the subject is illuminated from a single illumination angle. This includes illumination types where the incident light beam is orthogonal to the surface of the sample, as long as incident	

		light does not pass through the detector (see XXXXX3).	
XXXXX2	**Dual side-illumination**	**A illumination type where the subject is illuminated from two clearly distinct illumination angles**	
XXXXX3	**Through-detector-illumination**	**A illumination type where the illumination is done through the detector. Light may pass through the detector at one or more localisations.**	
XXXXX4	**Water (H2O)**	**Water is used as a coupling medium between the imaging device and the subject. This code is only to be used for pure water without additives that change either the optical or acoustic properties.**	
XXXXX5	**Heavy Water (Deuterium Oxide, D2O)**	**Heavy water (Deuterium Oxide, D2O) is used as a coupling medium between the imaging device and the subject. This code is only to be used for pure heavy water without additives that change either the optical or acoustic properties.**	
XXXXX6	**Ultrasound Coupling Gel**	**Ultrasound coupling gel as commonly used in clinical practice is used as a coupling agent between the imaging device and the subject.**	
XXXXX7	**Direct Contact (no coupling agent used)**	**No coupling agent is used to couple acoustic waves from the subject into the detector. Coupling through air is excluded from this code as also air signifies a coupling agent.**	
…			

Changes to NEMA Standards Publication PS 3.17

Digital Imaging and Communications in Medicine (DICOM)
Part 17: Explanatory Information

Add to PS3.17 Annex XXXX

Annex XXXX Photoacoustic Imaging (Informative)

XXXX.1 Use Cases / Examples

Unless otherwise specified, the Dimension Index Sequence for these examples is:

Module	Attribute Name	Attribute ID	Content
Multi-frame Dimension	Dimension Organization Sequence[0]		
	> Dimension Organization UID	(0020,9164)	Generated UID (same for all dimensions in this table)
	> Dimension Index Pointer	(0020,9165)	(0020,9056) - Stack ID
	> Functional Group Pointer	(0020,9167)	(0020,9111) - Frame Content Sequence
	Dimension Organization Sequence[1]		
	> Dimension Organization UID	(0020,9164)	Generated UID (same for all dimensions in this table)
	> Dimension Index Pointer	(0020,9165)	(0020,9057) - In-Stack Position
	> Functional Group Pointer	(0020,9167)	(0020,9111) - Frame Content Sequence
	Dimension Organization Sequence[2]		
	> Dimension Organization UID	(0020,9164)	Generated UID (same for all dimensions in this table)

	> Dimension Index Pointer	(0020,9165)	(0020,9301) Image Position (Volume)
	> Functional Group Pointer	(0020,9167)	(0020,930e) - Plane Position (Volume) Sequence

Use Case 1: PA Standalone Image

Photoacoustic data may be captured and displayed without a conventional ultrasound system in either handheld or stationary acquisition mode.

Where multiple optical excitation wavelengths are used, each sweep or set of the selected wavelengths is grouped in a stack (C.7.6.16.2.2.9). A consecutive number shall be assigned to each Stack and stored in the Stack ID (0020,9056) attribute in the Frame Content Macro. The In-Stack Position Number (0020,9057) will correspond to the wavelength image stack entries for each wavelength. The “Image Type” attribute will be set to “ORIGINAL” and the “Excitation Wavelength” attribute set to the particular wavelength. In this scenario, the wavelength is effectively the second dimension, with images from each wavelength grouped in a separate series.

In the example Table XXXX.1.1 PA Standalone Example, some mandatory attributes have been omitted for the sake of brevity.

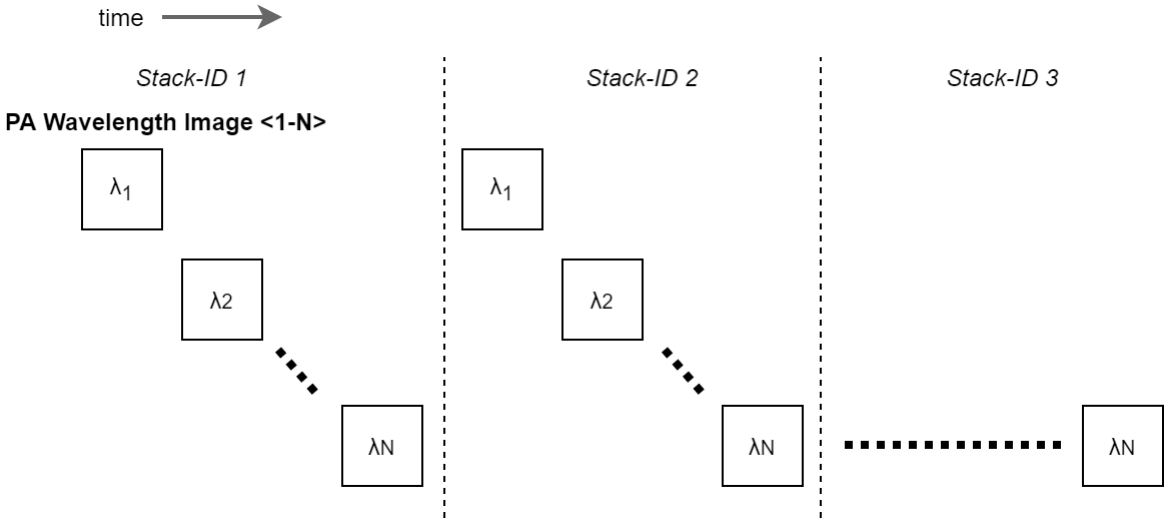


Table XXXX.1.1 PA Standalone Example - First Two Frames, Variation in Excitation Wavelength and Optical Energy

Module	**Attribute Name**	**Attribute ID**	***Content***
General Series	Series Number	(0020,0011)	1
General Image	Image Type	(0008,0008)	ORIGINAL
Photoacoustic Image	Excitation Wavelength	(gggg,eee5)	800nm

	Position Measuring Device Used	(0018,980C)	RIGID
	Illuminator Type Code Sequence	(gggg,eee6)	
	Code Value	(0008,0100)	XXXXX1
	Code Meaning	(0008,0104)	Dual side-illumination
Photoacoustic Detector	Transducer Geometry Code Sequence	(0018,980D)	
	Code Value	(0008,0100)	125253
	Code Meaning	(0008,0104)	Curved linear ultrasound transducer geometry
	Detector Frequency	(gggg,eee9)	4MHz at 60% BW T/R
Frame Content	> Dimension Index Value	(0020,9157)	1\1\1
	> Stack ID	(0020,9056)	1
	> In-Stack Position Number	(0020,9057)	1
Temporal Position	> Temporal Position Time Offset	(0020,930d)	0
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\0
Photoacoustic Frame	PA Frame Sequence	(gggg,eee2)	
	> Excitation Energy	(gggg,eee3)	11mJ
	> Excitation Pulse Duration	(gggg,eee4)	8ns
General Series	Series Number	(0020,0011)	2
General Image	Image Type	(0008,0008)	ORIGINAL
Photoacoustic Image	Excitation Wavelength	(gggg,eee5)	1064nm
	Position Measuring Device Used	(0018,980C)	RIGID

	Illuminator Type Code Sequence	(gggg,eee6)	
	Code Value	(0008,0100)	XXXXX1
	Code Meaning	(0008,0104)	Dual side-illumination
Photoacoustic Detector	Transducer Geometry Code Sequence	(0018,980D)	
	Code Value	(0008,0100)	125253
	Code Meaning	(0008,0104)	Curved linear ultrasound transducer geometry
	Detector Frequency	(gggg,eee9)	4MHz at 60% BW T/R
Frame Content	> Dimension Index Value	(0020,9157)	1\2\1
	> Stack ID	(0020,9056)	1
	> In-Stack Position Number	(0020,9057)	2
Temporal Position	> Temporal Position Time Offset	(0020,930d)	0
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\0
Photoacoustic Frame	PA Frame Sequence	(gggg,eee2)	
	> Excitation Energy	(gggg,eee3)	43mJ
	> Excitation Pulse Duration	(gggg,eee4)	8ns

The Dimension Index Value (0020,9157) iterates in the following manner:

1. In the first dimension (Stack ID) with a new Stack ID representing each instance of a stack. Each frame within the stack has a unique In-Stack Position number. Each frame within the stack shares the same Temporal Position Time Offset. The second stack would have indices of (2\1\1, 2\1\2, 2\1\3….)
2. In the second dimension (In-Stack Position) representing each Excitation Wavelength ($\boldsymbol{\lambda}_1$ ..$\boldsymbol{\lambda}_N$) (1\1\1, 1\2\1, 1\3\1…).
3. The third dimension (Image Position (Volume)) is held constant throughout the data set if the acquisition is stationary or if the coordinates are unknown. If the acquisition device is being scanned, the Image Position (Volume) dimension could be updated by the acquisition device if the scan coordinates are known(1\1\1, 1\1\2, 1\1\3…).

Use Case 2: Handheld PA/US Fusion

Photoacoustic data may be captured and displayed as a fused set of images coregistered with "contrast" data from another modality (frequently ultrasound). Separate contrast can be integrated with the PA data during presentation. Data sets to be fused can include data from a single PA Excitation Wavelength, multiple PA Excitation Wavelengths, multispectral images or ultrasound images as well as processed images, e.g. parametric map or absorber images derived from multispectral unmixing of ORIGINAL acquired PA data.

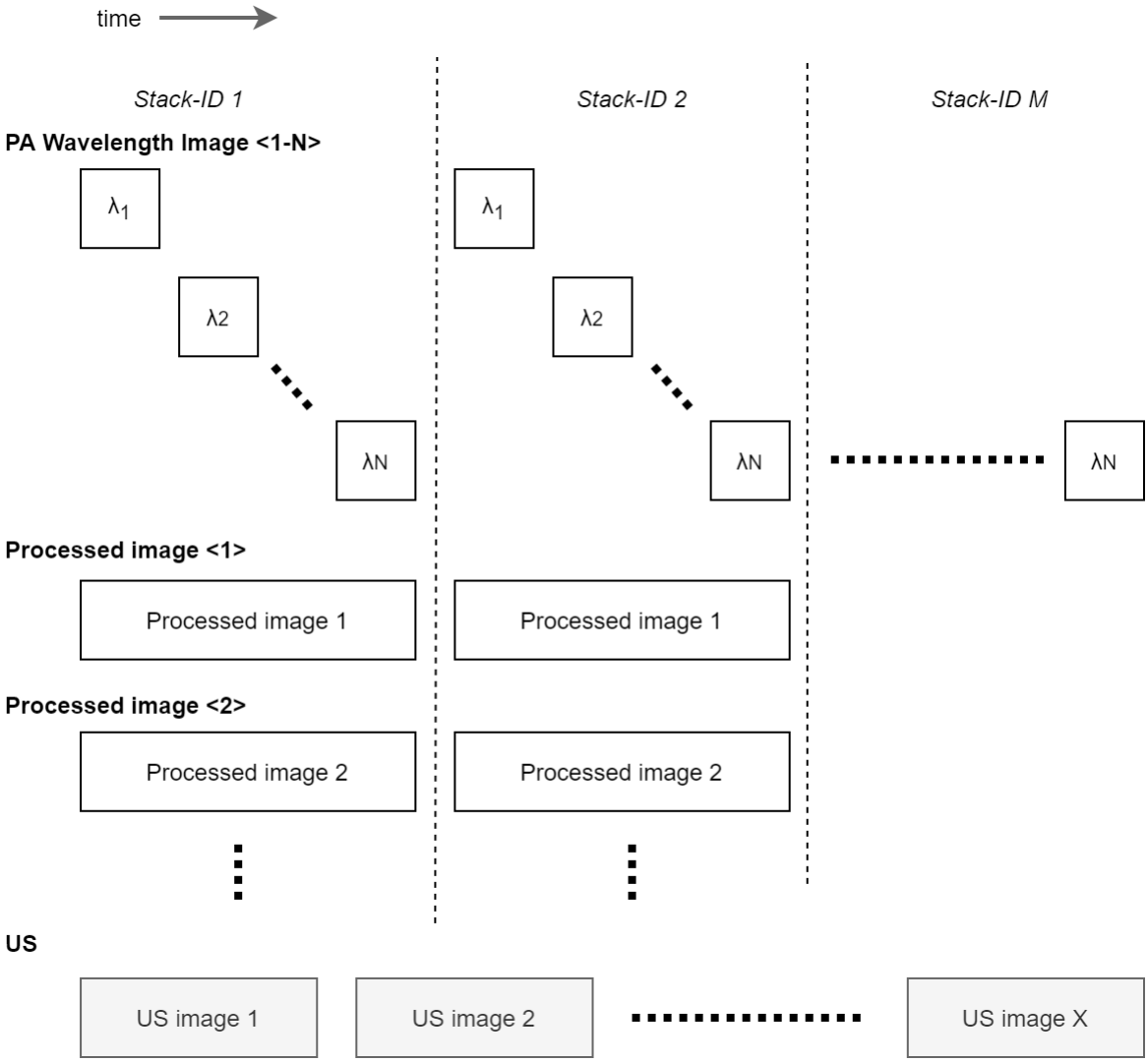
Processed Images

In order to temporally relate PROCESSED PA Images to ORIGINAL PA images, each PROCESSED image shall carry the per-frame "Frame Acquisition Date Time" (0018,9074) of the first ORIGINAL image that was used in the processing and the Stack ID (0020,9056) and "Temporal Position Time Offset (0020,930d) of the source images. Any processed image shall have "Image Type" attribute set to "PROCESSED" and use the per-frame Derivation Image Sequence (0008,9124) to describe the derivation method (C.7.6.16.2.6) including the "Source Image Sequence" (0008, 2112).

Ultrasound Images

In order to temporally relate ultrasound images to wavelength images, per-frame "Frame Acquisition Date Time" (0018,9074) shall be used. The Stack ID (0020,9056) will link related US images and Wavelength images and each unique Stack ID will correspond with a unique Temporal Position Time Offset (0020,930d). If fusion of PA images or related mechanical contrast images is to be performed via the Advanced Blending Presentation State object (C.11.33), the objects to be fused shall share Study-level attributes (at a minimum Study Instance UID, (0020,000D)), Frame of Reference UID (0020,0052), and Multi-frame Dimension Indicies specified in C.8.X.X. The study should include a Spatial Registration object (A.39.1.3) if spatial registration is not common between the series to be fused.

In the example Table XXXX.2.1 Handheld PA/US Fusion Example, some mandatory attributes have been omitted for the sake of brevity.



Potential display functionality. When displaying a photoacoustic imaging study, the Referenced Image Sequence (0008,1140) may provide a method for relating photoacoustic and ultrasound images.

Table XXXX.2.1 Handheld PA/US Fusion Example - First Frames in Series for PA ORIGINAL, PA PROCESSED, and US images (Optical, Processed, and US frames)

N = Number of Series of PA ORIGINAL images (per wavelength), P = Number of Series of PA PROCESSED images

Module	**Attribute Name**	**Attribute ID**	***Content***
General Series	Modality	(0008,0060)	PA
	Series Number	(0020,0011)	1
General Image	Image Type	(0008,0008)	ORIGINAL
Photoacoustic Image	Excitation Wavelength	(gggg,eee5)	800nm

	Position Measuring Device Used	(0018,980C)	FREEHAND
	Illuminator Type Code Sequence	(gggg,eee6)	
	Code Value	*(0008,0100)*	XXXXX1
	Code Meaning	*(0008,0104)*	Single side-illumination
	Acoustic Coupling Agent Code Sequence	(gggg,eee7)	
	Code Value	*(0008,0100)*	XXXXX4
	Code Meaning	*(0008,0104)*	Water (H2O)
Photoacoustic Detector	*Transducer Geometry Code Sequence*	*(0018,980D)*	
	Code Value	*(0008,0100)*	125252
	Code Meaning	*(0008,0104)*	Linear ultrasound transducer geometry
	Detector Frequency	*(gggg,eee9)*	9MHz at 60% BW T/R
Frame Content	> Dimension Index Value	(0020,9157)	1\1\1
	> Stack ID	(0020,9056)	1
	> In-Stack Position Number	(0020,9057)	1
	Frame Acquisition Date Time	(0018,9074)	20220130150251.005768
Temporal Position	> Temporal Position Time Offset	(0020,930d)	0
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\0
Photoacoustic Frame	PA Frame Sequence	(gggg,eee2)	
	> Excitation Energy	(gggg,eee3)	11mJ
	> Excitation Pulse Duration	(gggg,eee4)	8ns

General Series	Modality	(0008,0060)	PA
	Series Number	(0020,0011)	N+1
General Image	Image Type	(0008,0008)	PROCESSED
General Reference	Derivation Description	(0008,2111)	Parametric map as a surrogate measure for tissue oxygenation
Frame Content	> Dimension Index Value	(0020,9157)	1\N+1\1
	> Stack ID	(0020,9056)	1
	> In-Stack Position Number	(0020,9057)	N+1
	Frame Acquisition Date Time	(0018,9074)	20220130150251.005768
Temporal Position	> Temporal Position Time Offset	(0020,930d)	0
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\0
General Series	Modality	(0008,0060)	US
	Series Number	(0020,0011)	N+P+1
Frame Content	> Dimension Index Value	(0020,9157)	1\N+P+1\1
	> Stack ID	(0020,9056)	1
	> In-Stack Position Number	(0020,9057)	N+P+1
Temporal Position	> Temporal Position Time Offset	(0020,930d)	0
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\0

The Dimension Index Value (0020,9157) iterates in the following manner:

1. In the first dimension (Stack ID) with a new Stack ID representing each instance of a stack. Each frame within the stack has a unique In-Stack Position number. Each frame within the stack shares the same Temporal Position Time Offset. The second stack would have indices of (2\1\1, 2\1\2, 2\1\3….)
2. In the second dimension (In-Stack Position) representing each Excitation Wavelength ($\boldsymbol{\lambda}_1$ ..$\boldsymbol{\lambda}_N$), Processed PA Image type, or US mechanical contrast image (1\1\1, 1\2\1, 1\3\1…).
3. The third dimension (Image Position (Volume)) is held constant throughout the data set if the acquisition is stationary or if the coordinates are unknown. If the acquisition device is being scanned, the Image Position (Volume) could be updated by the acquisition device if the scan coordinates are known (1\1\1, 1\1\2, 1\1\3…).

Use Case 3: Stationary tomographic 3D PA acquisition

Photoacoustic images may be acquired through a scanning setup, where either the acquisition unit or the imaged object is spatially translated to form a three-dimensional representation of the imaged object. For these cases the use of the “Frame of Reference” Module (C7.4.1) shall be used in addition to the examples above.

Specifically, the Multi-Frame Dimension Module provides the essential information relating to spatial arrangement, while the individual Image Series are related as in the above examples

In the example Table XXXX.3.1 Stationary tomographic 3D PA Example, some mandatory attributes have been omitted for the sake of brevity.

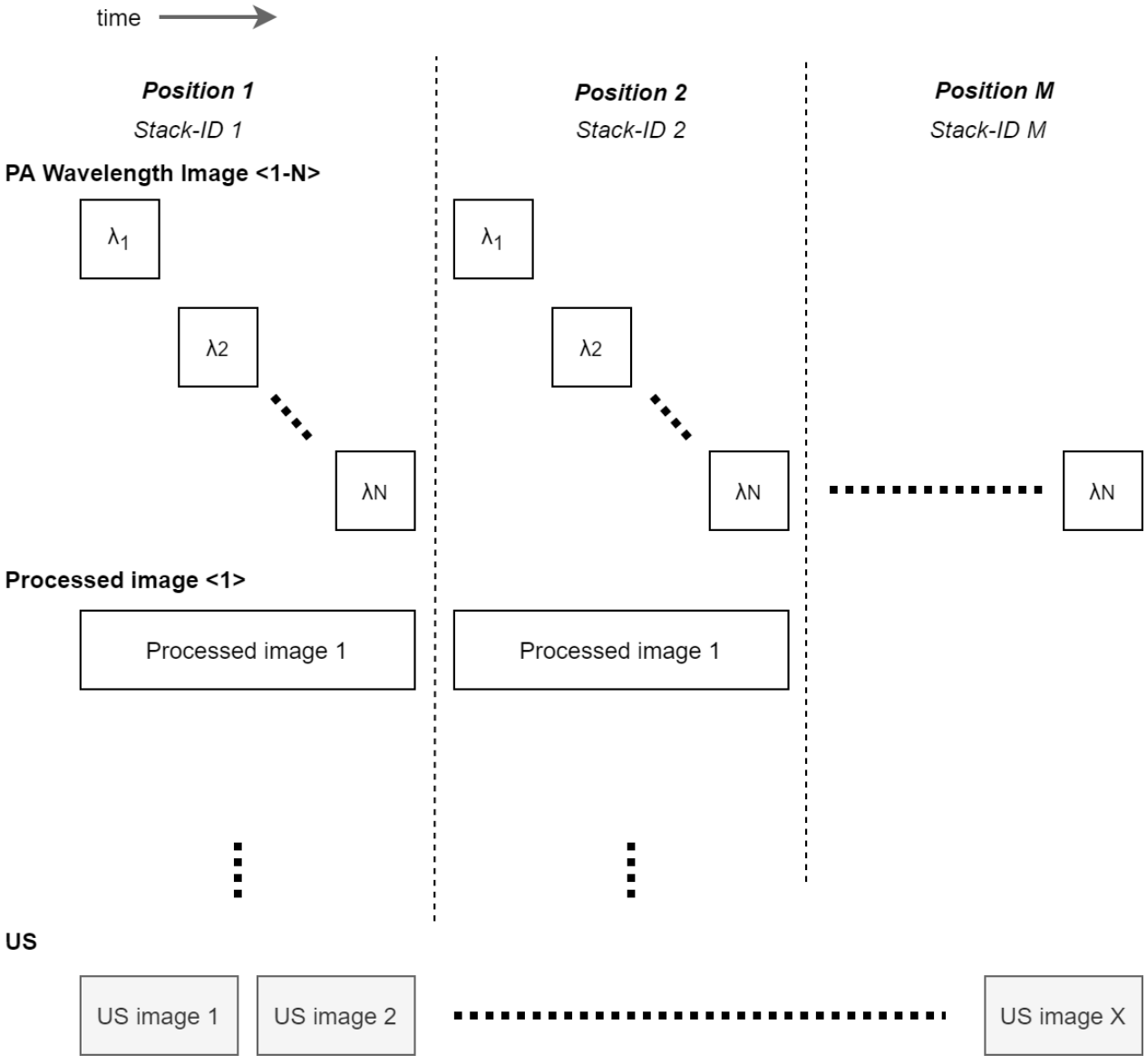


Table XXXX.3.1 Stationary tomographic 3D PA Example - First Two Frames, Variation in Image Position (Volume)

Module	Attribute Name	Attribute ID	Content

General Series	Modality	(0008,0060)	PA
	Series Number	(0020,0011)	1
General Image	Image Type	(0008,0008)	ORIGINAL
Photoacoustic Image	Excitation Wavelength	(gggg,eee5)	800nm
	Position Measuring Device Used	(0018,980C)	RIGID
	Illuminator Type Code Sequence	(gggg,eee6)	
	Code Value	(0008,0100)	XXXXX1
	Code Meaning	(0008,0104)	Single side-illumination
Photoacoustic Detector	Transducer Geometry Code Sequence	(0018,980D)	
	Code Value	(0008,0100)	125256
	Code Meaning	(0008,0104)	Ring ultrasound transducer geometry
	Detector Frequency	(gggg,eee9)	5MHz at 60% BW T/R
Frame Content	> Dimension Index Value	(0020,9157)	1\1\1
	> Stack ID	(0020,9056)	1
	> In-Stack Position Number	(0020,9057)	1
Temporal Position	> Temporal Position Time Offset	(0020,930d)	0
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\0mm
Photoacoustic Frame	PA Frame Sequence	(gggg,eee2)	
	> Excitation Energy	(gggg,eee3)	11.0mJ
	> Excitation Pulse Duration	(gggg,eee4)	8ns
Frame Content	> Dimension Index Value	(0020,9157)	1\1\2\
	> Stack ID	(0020,9056)	1

	> In-Stack Position Number	(0020,9057)	1
Temporal Position	> Temporal Position Time Offset	(0020,930d)	0
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\1mm
Photoacoustic Frame	PA Frame Sequence	(gggg,eee2)	
	> Excitation Energy	(gggg,eee3)	11.2mJ
	> Excitation Pulse Duration	(gggg,eee4)	8ns

The Dimension Index Value (0020,9157) iterates in the following manner:

1. In the first dimension (Stack ID) with a new Stack ID representing each instance of a stack. Each frame within the stack has a unique In-Stack Position number. Each frame within the stack shares the same Temporal Position Time Offset. The second stack would have indices of (2\1\1, 2\1\2, 2\1\3….).
2. In the second dimension (In-Stack Position) representing each Excitation Wavelength (λ_1 ..λ_N), Processed PA Image type, or US mechanical contrast image (1\1\1, 1\2\1, 1\3\1…).
3. The third dimension (Image Position (Volume)) is iterated if each stack is a position in a volume (1\1\1, 1\1\2, 1\1\3…).

Use Case 4: Microscopy type PA system

Photoacoustic images may be acquired using a microscopy set-up, in which a single focussed detector is raster-scanned across an object and the (processed) time series are used directly to form a 2D or 3D image. Here a fast optical resolution photoacoustic microscopy 2D set-up is envisaged.

In the example Table XXXX.4.1 Microscopy type PA system Example, some mandatory attributes have been omitted for the sake of brevity.

PA Wavelength Image

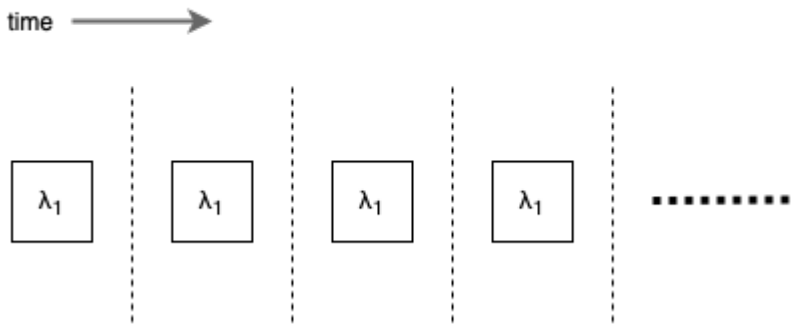


Table XXXX.4.1 Microscopy type PA system Example - First Two Frames, Variation in Temporal Position Time Offset

Module	Attribute Name	Attribute ID	Content

General Series	Modality	(0008,0060)	*PA*
	Series Number	(0020,0011)	*1*
General Image	Image Type	(0008,0008)	*ORIGINAL*
Photoacoustic Image	Excitation Wavelength	(gggg,eee5)	*532nm*
	Position Measuring Device Used	(0018,980C)	*RIGID*
	Illuminator Type Code Sequence	(gggg,eee6)	
	Code Value	(0008,0100)	XXXXX3
	Code Meaning	(0008,0104)	Through-detector illumination
Photoacoustic Detector	Transducer Geometry Code Sequence	(0018,980D)	
	Code Value	(0008,0100)	125252
	Code Meaning	(0008,0104)	Linear ultrasound transducer geometry
	Detector Frequency	(gggg,eee9)	50MHz at 100% BW
Frame Content	> Dimension Index Value	(0020,9157)	1\1\1
	> Stack ID	(0020,9056)	1
	> In-Stack Position Number	(0020,9057)	1
Temporal Position	> Temporal Position Time Offset	(0020,930d)	0
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\0
Photoacoustic Frame	PA Frame Sequence	(gggg,eee2)	
	> Excitation Energy	(gggg,eee3)	100 nJ
	> Excitation Pulse Duration	(gggg,eee4)	2ns
Frame Content	> Dimension Index Value	(0020,9157)	2\1\2
	> Stack ID	(0020,9056)	2

	> In-Stack Position Number	(0020,9057)	1
Temporal Position	> Temporal Position Time Offset	(0020,930d)	1
Plane Position (Volume)	> Image Position (Volume)	(0020,9301)	0\0\0.1
Photoacoustic Frame	PA Frame Sequence	(gggg,eee2)	
	> Excitation Energy	(gggg,eee3)	100 nJ
	> Excitation Pulse Duration	(gggg,eee4)	2ns

The Dimension Index Value (0020,9157) iterates in the following manner:

1. In the first dimension (Stack ID) with a new Stack ID representing each instance of a stack (1\1\1, 2\1\1, 3\1\1…). Each stack has a single frame with an In-Stack Position number of “1”. Each stack has a unique Temporal Position Time Offset.
2. In the second dimension (In-Stack Position) representing each Excitation Wavelength ($\boldsymbol{\lambda}_1$ ..$\boldsymbol{\lambda}_N$), Processed PA Image type, or US mechanical contrast image (1\1\1, 1\2\1, 1\3\1…).
3. The third dimension index (Image Position (Volume)) is changed to represent the scan position of each stack (2D or 3D), (1\1\1, 1\1\2, 1\1\3…).