# Digital Imaging and Communications in Medicine (DICOM)

*Supplement 188: Multi-energy CT Images*

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# Table of Contents

72

# DOCUMENT HISTORY

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# OPEN ISSUES

| | |
|---|---|
| 1 | A naïve display system can receive a ME-image and will not recognize it as ME-image but rather display the image as a conventional CT image. What risks does this pose and how shall we mitigate them?<br><br>**Examples of potential clinical misinterpretation**<br><br>1. For virtual mono-energetic images (images similar to those obtained with mono-energetic x-ray beam, in keV), attenuation highly depends on the beam energy (keV), so CT pixel values in VMI images can be very different from those in conventional CT images. Without proper labeling of such images, including the specific keV value used, the reviewer can come to wrong conclusions.<br><br>2. HU-based ME images where CT pixel values have been modified for specific materials (suppressed, highlighted, etc.) look similar to conventional CT images. Without proper labeling of such images, including the identification of the affected materials and the way of modification, the reviewer can come to wrong conclusions.<br><br>3. In certain types of ME images (effective atomic number, electron density, material-specific image containing material concentration), CT pixel values do not represent HU values. Common ROI tools used on such an image will measure and display an average value. Since non-HU values are quite unusual in CT IOD images, there is a significant risk that a common “naïve” display will either omit the units of measurements (leaving user to assume the material or units), or (which is even worse) will display “HU” units instead.<br><br>4. In case of Virtual Non-Contrast images, the pixel values are modified (contrast is removed and pixel values may have been corrected for displacement of one material by another material). Since pixels are modified, there is a risk that the modification is incomplete or the replacement is not adequate. |
| 2 | Which condition for Multi-energy CT Image Characteristics can be defined to make it mandatory?<br><br>Multi-energy CT Image Characteristics for Enhanced CT Images is Type U, because it is very hard to define a condition. The different ME image families do not require a characteristic in all cases. |
| 3 | Is there a need to support synthetic KVP?<br><br>Currently we support the possibility to set the attributes for KVP in the standard CT Image. The KVP attribute can be used in case of synthetic KVP in a Multi-energy CT Image. This means the image is identical as if it was generated by a single energy acquisition. |
| 4 | Is there a reasonable value for Exposure ms and Exposure mAs for each phase when using a switching source?<br>Currently within the Multi-Energy Image the Exposure ms and Exposure mAs are excluded. The difficulty of providing an accurate exposure time (in ms) or exposure (tube current and time product, in mAs) lies in the fact that tube potential (kV) switching doesn’t happen immediately, it takes a short but non-zero time. This means there is a transition period that the tube potential is in between of the low and high kV. This transition period can’t be ignored as that would underestimate the exposure time and exposure for each kV. However, it is difficult to accurately determine which part of the transition period belongs to which kV, which consequently makes it difficult to provide accurate information about exposure time or exposure for the switching source technology. |

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| 5 | Are there sufficient codes for the different modification types defined in this supplement (see Material Modification Sequence (xxx8,yyy3))? |
| 6 | Is there any problem with defining Image Type value 1 and 2 for Multi-Energy images to be ORIGINAL/PRIMARY for all images? |
| 7 | Suggest an appropriate place in the standard for Section Z.4 CLASSIFICATION OF MULTI-ENERGY IMAGES. |
| 8 | Part 17 will be provided with letter ballot and will include:<br>• Add an Annex with examples of implementation (ME- Image Material Segmentation, Material Quantification, …)<br>• Examples for each ME-Image Type.<br>Is this sufficient, or do we need to add more information on Multi-energy images? |

## CLOSED ISSUES

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| 1 | DICOM does not enforce PACS/Display to present specific attributes, therefore there is little chance new important attributes we introduce here (e.g., keV for monochromatic image) will be presented to the users. It is suggested to contact IHE to advice on possible new or extension of an existing profile<br>There may be a risk that the ME images will be misinterpreted as the conventional ones when displayed on a PACS/Workstation.<br><br>For monochromatic images we stay with the existing CT IOD and Enhanced CT IODs.<br>No high risk is seen in discussion with WG06. If the Image Type and Series Description is filled correctly, the risk is mitigated enough. These are already standardized attributes which are commonly used. |
| 2 | Dual-Energy Ratio: does this belong to acquisition/recon rather than to Decomposition Macro?<br>Decision: This belongs to decomposition since one can get different ratios from the same acquisition |
| 3 | There are images that are similar to conventional CT image but created from Multi-energy raw data. Examples: Low Energy Image, High Energy Image, “QC” Image. Normally such images are intended as a basis to generate other types of images or for acquisition quality control, and not necessarily for diagnostic purposes.<br><br>There is a risk of mis-interpretation, for instance, when comparing “conventional” ME/CT images with prior exam scanned with no-ME acquisition. The risk is primarily with the measurements rather than with visual interpretation. Shall such images be identifiable (distinguishable from a conventional single-energy CT) in some way?<br><br>WG21 decision: to put these images out of scope of this supplement. |
| 4 | Image Type of VMI Images. It is defined use ORIGINAL unless there is a specific case requiring it to be DERIVED. WG6 recommends leaving it to the vendor to decide if the image is ORIGINAL or DERIVED.<br>Recommendation from WG21 is to set Image Type Value1 to ORIGINAL. |
| 5 | In order to extend CT IOD with ME attributes, we introduced a new module – “Multi-energy CT Image”. Alternatively we could put an optional ME sequence inside the existing CT Image Module. Is the later a better approach?<br>The recommendation is not to extend the CT IOD with a new module, but to extend the existing CT Image Module with optional macros or sequences. |

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| 6 | If we use CT IOD – are there any risks of re-using standard tags inside the new ME sequences when an application goes scrolling for a particular tag and assumes this instance of the tag is what it is looking for?<br>This is a known way how to reuse existing tags within different nesting levels. Therefore we see no risk. |
| 7 | Do we need to include conventional (equivalent) CT images generated by ME scanner? E.g., to include ME Acquisition attributes?<br>Yes we do want to use this explicitly. E.g. in case of the creation of conventional CT images out of two energy levels (100 KVP + 70 KVP = 90 KVP) |
| 8 | Rework of Segmentation into CT IOD (Standard and Enhanced)<br>WG21:<br><br>After discussion about the proposals of WG06 about the usage of Segmentation IOD, we came to the conclusion to skip this approach and follow the idea of self-contained objects. This was mainly because of the importance of the CT Acquisition parameters available for the interpretation of the images. We try to enrich the ME-Image section by the needed attributes for Discrete, Probability and Proportional Image Types. |
| 9 | We get strong wished that dose index, noise index, dose modulation and noise target should be defined. This is strongly related to CT physics and cannot be defined upfront by the DICOM WG21 group. We propose that the definition shall come from the CT standardization group or AAPM.<br>Come up with a definition within a ChangeProposal for the different mentioned topics.<br><br>We will not address this in this supplement. It is an open topic for the next wg21 work item. |
| 10 | As I could find out, the standard practice (including Radiotherapy) is to define Electron Density indeed as a relative (normalized to water) ED/EDWater ratio (N/Nw), where N is number of electrons per unit volume, and Nw is number of electrons in the same unit of water (3.47 *10^22 electrons per cubic centimeter) at standard temperature (room temperature of 25 centigrade, or, more accurately, 300 Kelvin ) and pressure (1 atmosphere).<br><br>The actual (World Value) range will be between 0 and 3 or 4. In order to allow sufficient dynamic range and accuracy for the ED values, and at the same time to align with the common usage of 12-bit values for CT IOD, I would suggest to use Rescale Intercept = 0 and Rescale Slope = 0.001, but of cause we can leave for a vendor to define the appropriate Rescale values.<br><br>Using Rescaling of 0.001 might give problems for systems that can't handle small (floating point) values for windowing as your window width will be in the range of 3 to 4.<br><br>It might be better to use the Real World Value Mapping Sequence (0040,9096) and make that mandatory to avoid this problem.<br><br>Would be the first but as you are introducing new type of data it might be good to make this step.<br><br>RealWorldValue Mapping may not solve this issue due to missing implementations. Otherwise PET images are widely spread and need a similar scaling capability. Therefore the risk is considered not high. |

# Scope and Field of Application

This Supplement defines new types of images generated by Multi-energy CT scanners.

It introduces a description of ME imaging techniques. While different vendors apply different techniques to achieve Multi-energy Images, there is large commonality in the generated diagnostic images.

## Z1. DEFINITIONS

**Multi-energy CT Imaging**:
CT Multi-energy (ME) imaging techniques including scanning, reconstruction, processing, when the scanner utilizes multiple energies from the X-Ray beam spectrum.

## Z.2 USE CASES

Key use cases of CT Multi-energy include:

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- Allowing better differentiation of materials that look similar on conventional CT images, e.g., to differentiate Iodine and Calcium in vascular structures
- Generate virtual non-contrast acquisition from a contrast image

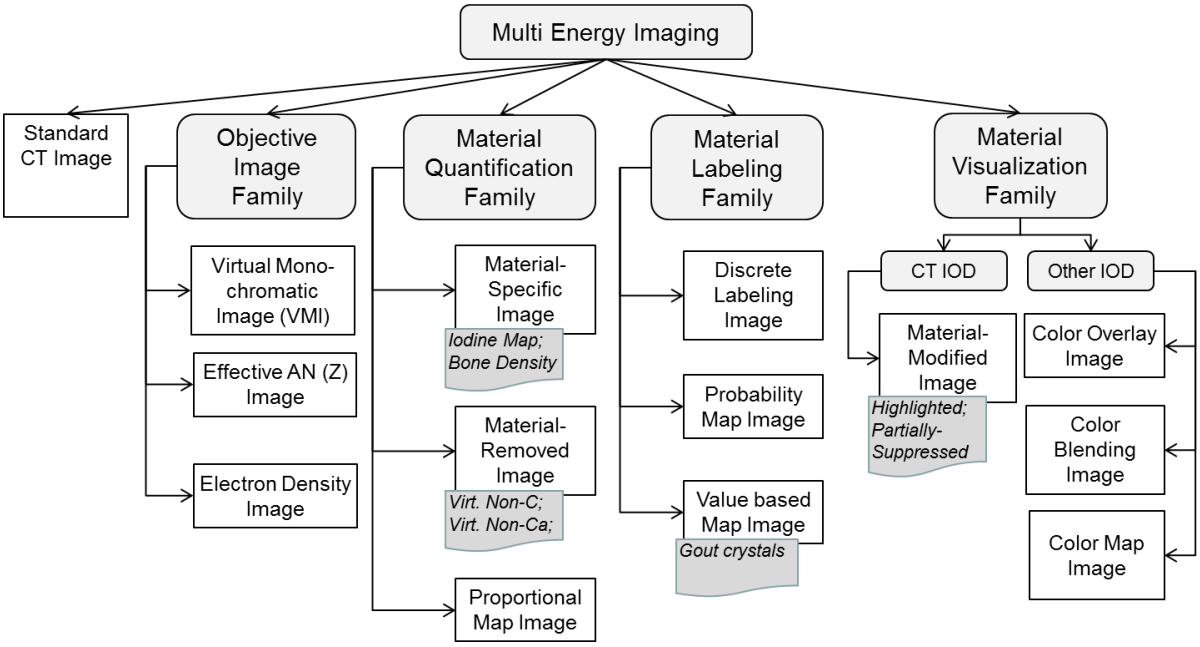
## Z.3 OBJECTIVES

When defining this supplement, the following objectives / goals have been considered:

1. Making Multi-energy information available to rendering, processing applications and clinical display
2. To provide new essential ME information (acquisition, reconstruction and processing attributes) within the IOD.
3. To facilitate fast and easy adoption of this supplement across the imaging community, both modalities and PACS/Displays.
4. To address (or at least to minimize) the risk of misinterpretation or incorrect measurements when the ME images are displayed by a display that does not support the new attributes of the ME-image.
5. To adapt existing attributes of the CT / Enhanced CT IOD to fit ME techniques.

## Z.4 CLASSIFICATION OF MULTI-ENERGY IMAGES

The following ME Image Types and families are addressed in this supplement:




- **Standard CT Image (CT Image IOD, Enhanced CT Image IOD).** Images created using ME techniques. E.g. in case of the creation of conventional CT images out of two energy levels or images created only one of the multiple energies acquired. No new image type definitions are needed but new optional attributes are needed.

**Objective Image Family:**

- **Effective Atomic Number Image**. Each pixel represents Effective Atomic Number (aka "Effective Z") of that pixel.

- **Electron Density Image**. Each pixel represents a number of electrons per unit volume (units $10^{23}$ /ml) or a relative $ED/ED_{Water}$ ratio (N/Nw). Electron density is used e.g. in radiotherapy.

- **Virtual Monochromatic Image.** Each pixel represents CT Hounsfield units and is analogous to a CT image created by a monochromatic (of a specific keV value) X-Ray beam. E.g. in certain cases the image impression (quality) will allow a better iodine representation and better metal artifact reduction.

**Material Quantification Image Family.** These image types characterize the elemental composition of materials in the image. They provide material quantification in a physical scale. Pixel values can be in HU or in equivalent material concentration (e.g., mg/ml). The following image types belong to this family:

- **Material-Specific Image.** Each pixel value represents the density of a specific material.

- **Material-Removed Image**. Each pixel represents CT Hounsfield units however some pixel values may have been corrected for replacement of one material by another material (i.e. VNC, VNCa). Image with one or more materials removed.

- **Proportional Map Image.** Each pixel represents a proportion of 1 of a material.

**Material Labeling Image Family**. These image types provide classification of the materials, where each pixel contains values indirectly describing identified material(s) in this pixel. They can serve as the basis for visualization of different materials e.g. coloring of specific material, enhancing/suppressing certain materials, etc. The following image types belong to this family:

- **Discrete Labeling Image.** Each pixel represents an index corresponding to one or more materials from a list/vector of the known materials

- **Probability Map Image.** Each pixel represents the probability as a ratio of 1, that this pixel contains certain specified material, regardless of its amount.

- **Value-Based Map Image.** Each pixel represents a certain value for a specified material range (the exact interpretation of the value has to be defined by the user).

**Material Visualization Image Family**. These image types allow visualizing material content, usually with colors (color maps, color overlays, blending, etc.)

- **Material-Modified Image.** CT Image where pixel values have been modified to highlight a certain target material (either by partially suppressing the background or by enhancing the target material), or to partially suppress the target material. The image is basically still HU-based, however the pixel values are modified HU, although they may be presented similarly. The Material-Modified image is primarily used for better visualization of the target materials. (i.e. tendon enhancement Image)

- **Color Image.** Implementations of Material Visualization Images use existing DICOM objects (Blending Presentation State, Secondary Capture Image (used as fallback)).

**Clinical Use Cases:**

- Gout crystals can be displayed with color encoding by using Blending Presentation State Objects. For interpretation a color legend shall be displayed to the user (e.g. as graphics overlay). A fallback solution could be the creation of Secondary Capture Images with RGB values.
- Export a color image to a legacy PACS can be realized with Secondary Capture Image

# Changes to NEMA Standards Publication PS 3.3

# Digital Imaging and Communications in Medicine (DICOM)

## Part 3: Information Object Definitions

*<Modify Enhanced CT Image IOD Module due to Multi-energy Image Format>*

### A.38.1.3 Enhanced CT Image IOD Module Table

Table A.38-1 specifies the Modules of the Enhanced CT Image IOD.

**Table A.38-1. Enhanced CT Image IOD Modules**

| IE | Module | Reference | Usage |
|---|---|---|---|
| Image | Image Pixel | C.7.6.3 | M |
| | … | | |
| | Frame Extraction | C.12.3 | C - Required if the SOP Instance was created in response to a Frame-Level retrieve request |
| | **Multi-energy CT Acquisition** | **C.8.15.X1** | **C - Required if the image is acquired by means of multi-energy technique.** |

*< Modify Enhanced CT Image Functional Group Macros due to Multi-energy CT Image Format>*

### A.38.1.4 Enhanced CT Image Functional Group Macros

Table A.38-2 specifies the use of the Functional Group Macros used in the Multi-frame Functional Group Module for the Enhanced CT Image IOD.

| | | |
|---|---|---|
| … | | |
| CT Additional X-Ray Source | C.8.15.3.11 | C - Required if the image is reconstructed from a system with multiple X-Ray sources |
| **Multi-energy CT Processing** | **C.8.15.3.X2** | **C - Required if the image pixel data contains the results of multi-energy material processing.** |
| **Multi-energy CT Characteristics** | **C.8.15.3.X1** | **U** |

*<Modify CT Contrast/Bolus Module due to Multi-energy Image Format>*

### C.7.6.4 Contrast/Bolus Module

**This Module shall be present even if images are processed where contrast information is removed from pixels, e.g. in Virtual Non-Contrast.**.

176

*<Modify CT Module due to Multi-energy Image Format>*

178 **C.8.2 CT Modules**

This Section describes the CT Image Module. This Module contains all Attributes that are specific to CT
180 images.

**C.8.2.1 CT Image Module**

182 The table in this Section contains IOD Attributes that describe CT images.

**Table C.8-3. CT Image Module Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Image Type | (0008,0008) | 1 | Image identification characteristics. See Section C.8.2.1.1.1 for specialization. |
| … | | | |
| Rescale Intercept | (0028,1052) | 1 | The value b in relationship between stored values (SV) and the output units.<br>Output units = m*SV+b<br>If Image Type (0008,0008) Value 1 is ORIGINAL and Value 3 is not LOCALIZER **and CT Multi-energy Flag (xxx2,yyy1) is either absent or N**, output units shall be Hounsfield Units (HU). |
| Rescale Type | (0028,1054) | 1C | Specifies the output units of Rescale Slope (0028,1053) and Rescale Intercept (0028,1052).<br>See Section C.11.1.1.2 for Defined Terms and further explanation.<br>Required if the Rescale Type is not HU (Hounsfield Units) **or CT Multi-energy Flag (xxx2,yyy1) is Y,**. May be present otherwise. |
| … | | | |
| KVP | (0018,0060) | 2 | Peak kilo voltage output of the X-Ray generator used.<br>**Shall be empty if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are different.** |
| … | | | |
| Scan Options | (0018,0022) | 3 | Parameters of scanning sequence.<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Data Collection Diameter | (0018,0090) | 3 | The diameter in mm of the region over which data were collected<br>**Shall be absent if this Attribute is present in** |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| | | | **Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| … | | | |
| Distance Source to Detector | (0018,1110) | 3 | Distance in mm from source to detector center.<br>**Note**<br>*This value is traditionally referred to as Source Image Receptor Distance (SID).*<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Exposure Time | (0018,1150) | 3 | Time of x-ray exposure in msec.<br>If Acquisition Type (0018,9302) equals SPIRAL, the value of this attribute shall be Revolution Time (0018,9305) divided by the Spiral Pitch Factor (0018,9311). See Section C.8.15.3.8.1 and Section C.8.15.3.2.1.<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| X-Ray Tube Current | (0018,1151) | 3 | X-Ray Tube Current in mA.<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Exposure | (0018,1152) | 3 | The exposure expressed in mAs, for example calculated from Exposure Time and X-Ray Tube Current.<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Exposure in µAs | (0018,1153) | 3 | The exposure expressed in µAs, for example calculated from Exposure Time and X-Ray Tube Current.<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Filter Type | (0018,1160) | 3 | Label for the type of filter inserted into the x-ray beam.<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in** |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| | | | **all Items.** |
| Generator Power | (0018,1170) | 3 | Power in kW to the x-ray generator.<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Focal Spot(s) | (0018,1190) | 3 | Size of the focal spot in mm. For devices with variable focal spot or multiple focal spots, small dimension followed by large dimension.<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Single Collimation Width | (0018,9306) | 3 | The width of a single row of acquired data (in mm).<br>**Note**<br>*Adjacent physical detector rows may have been combined to form a single effective acquisition row.*<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Total Collimation Width | (0018,9307) | 3 | The width of the total collimation (in mm) over the area of active x-ray detection.<br>**Note**<br>*This will be equal the number of effective detector rows multiplied by single collimation width.*<br>**Shall be absent if this Attribute is present in Multi-energy CT Acquisition Sequence (xxx2,yyy2) and the values are not the same in all Items.** |
| Isocenter Position | (300A,012C) | 3 | Isocenter coordinates (x,y,z), in mm. Specifies the location of the machine isocenter in the patient-based coordinate system associated with the Frame of Reference. It allows transformation from the equipment-based coordinate system to the patient-based coordinate system. |
| *Include Table 10-27 "RT Equipment Correlation Macro Attributes Description"* | | | |
| ***Include Table C.8-X2 "Multi-energy CT Macro Attributes"*** | | | |

184

*<Modify CT Image Attribute due to Multi-energy CT Image Format>*

### C.8.2.1.1 CT Image Attribute Descriptions

#### C.8.2.1.1.1 Image Type

For CT Images, Image Type (0008,0008) is specified to be Type 1.

Defined Terms for Value 3:

**AXIAL** ~~**identifies**~~ a CT Axial Image

**LOCALIZER** ~~**identifies**~~ a CT Localizer Image

Note:

Axial in this context means any cross-sectional image, and includes transverse, coronal, sagittal and oblique images.

**Defined Terms for Value 4 for Multi-energy CT Images:**

| | |
|---|---|
| **VMI** | **a Virtual Monochromatic Image. Each pixel represents CT Hounsfield units and is analogous to a CT image created by a monochromatic (of a specific keV value) X-Ray beam.** |
| **MAT_SPECIFIC** | **a Material-Specific Image. Each pixel value represents the density of a specific material.** |
| **MAT_REMOVED** | **a Material-Removed Image. Each pixel represents CT Hounsfield units however some pixel values may have been corrected for replacement of one material by another material. Image with one or more materials removed.** |
| **MAT_PROPORTIONAL** | **a Material-Proportional Image. Each pixel represents a proportion of 1 of a material.** |
| **EFF_ATOMIC_NUM** | **an Effective Atomic Number Image. Each pixel represents Effective Atomic Number** |
| **ELECTRON_DENSITY** | **an Electron Density Image. Each pixel represents a number of electrons per unit volume (units 1023 /ml) or a relative ED/EDWater ratio (N/Nw).** |
| **MAT_MODIFIED** | **a Material-Modified Image. CT Image where pixel values have been modified to highlight a certain target material (either by partially suppressing the background or by enhancing the target material), or to partially suppress the target material.** |
| **MAT_LABELING** | **a Material-Labeling Image. Each pixel represents a values indirectly describing identified material(s).** |

Note

Axial in this context means any cross-sectional image, and includes transverse, coronal, sagittal and oblique images.

**Note:**

**Multi-energy CT images except Material Labeling Images are not necessarily DERIVED and may be ORIGINAL\PRIMARY.**

When an image is created by a generic transformation an implementation specific Value 4 may be provided.

*< Add Multi-energy Rescale Type mapping table to CT Image Attribute Descriptions due to Multi-energy CT Image Format>*

### C.8.2.1.1.X1 Recommended Rescale Type for Multi-energy CT Image

In case of Multi-energy CT Images for recommended assignment of Rescale Types to Image Type attributes.

Each Multi-energy Image Type may have multiple recommended Rescale Types.

**Table C.8-X1. Recommended Rescale Type for Multi-energy CT Image**

| Multi-energy Image Family | Recommended Rescale Type | Image Type Value 4 |
|---|---|---|
| **Objective Image Family** | | |
| Virtual Mono-chromatic Image | HU | VMI |
| Effective AN (Z) Image | Z_EFF | EFF_ATOMIC_NUM |
| Electron Density Image | ED | ELECTRON_DENSITY |
| | EDW | ELECTRON_DENSITY |
| **Material Quantification Family** | | |
| Material-Specific Image | MGML | MAT_SPECIFIC |
| | HU | MAT_SPECIFIC |
| Material-Removed Image | HU | MAT_REMOVED |
| | HU_MOD | MAT_REMOVED |
| Proportional Map Image | PCT | MAT_PROPORTIONAL |
| **Material Labeling Family** | | |
| Discrete Labeling Image | US | MAT_LABELING |
| Probability Map Image | PCT | MAT_LABELING |
| Value-based Map Image | US | MAT_LABELING |
| **Material Visualization Family** | | |
| Material-Modified Image | HU_MOD | MAT_MODIFIED |

< *Add sections due to Multi-energy CT Image Format*>

### C.8.2.1.X1 Multi-energy CT Macro

Table C.8-X2 specifies the Multi-energy attributes to enhance the CT Image Module

**Table C.8-X2. Multi-energy CT Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| CT Multi-energy Flag | (xxx2,yyy1) | 1C | Indicates whether the image is created by means of Multi-energy technique<br>Enumerated Values:<br>Y<br>N<br>Required if the image is acquired by means of multi-energy technique.<br>May be present otherwise |
| Multi-energy CT Acquisition Sequence | (xxx2,yyy2) | 1C | The attributes of a Multi-energy Image acquisition.<br>Required if CT Multi-energy Flag (xxx1,yyy1) is equal Y<br>One Item shall be included in this Sequence. |
| >*Include Table C.8-X3 "Multi-energy CT X-Ray Source Macro Attributes"* | | | See C.8.2.1.X1.1 |
| >*Include Table C.8-X4 "Multi-energy CT X-Ray Detector Macro Attributes"* | | | See C.8.2.1.X1.2 |
| >*Include Table C.8-X5 "Multi-energy CT Pairing Macro Attributes"* | | | See C.8.2.1.X1.3 |
| >*Include Table C.8-124. "CT Exposure Macro Attributes"* | | | See C.8.15.3.8 |
| >*Include Table C.8-125. "CT X-Ray Details Sequence Macro Attributes"* | | | See C.8.15.3.9 |
| >*Include Table C.8-119. "CT Acquisition Details Macro Attributes"* | | | See C.8.15.3.3 |
| >*Include Table C.8-122. "CT Geometry Macro Attributes"* | | | See C.8.15.3.6 |
| Multi-energy CT Processing Macro Sequence | (xxx2,yyy3) | 3 | Method and result of the processing of Multi-energy data.<br>Only a single Item is permitted in this Sequence. |
| >*Include Table C.8-X10 "Multi-energy CT Processing Macro Attributes"* | | | |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Multi-energy CT Characteristics Macro Sequence | (xxx2,yyy4) | 1C | The attributes of a Multi-energy Image.<br>Required if CT Multi-energy Flag (**xxx2**,yyy1) is Y.<br>Only a single Item shall be included in this Sequence. |
| *>Include Table C.8-X7 "Multi-energy CT Characteristics Macro Attributes"* | | | |

220 **C.8.2.1.X1.1 Multi-energy CT X-Ray Source Macro**

This macro specifies the attributes for CT Image X-Ray Source.

222 **Table C.8-X3. Multi-energy CT X-Ray Source Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Multi-energy CT X-Ray Source Sequence | (xxx3,yyy1) | 1 | X-Ray Source information.<br>One or more Items shall be present. |
| >X-Ray Source Index | (xxx3,yyy2) | 1 | Identification number of this item in the Multi-energy CT X-Ray Source Sequence. The number shall be 1 for the first Item and increase by 1 for each subsequent Item. |
| >X-Ray Source ID | (xxx3,yyy3) | 1 | Identifier of the X-Ray source. The X-Ray Source ID (xxx3,yyy3) will have the same value for different values of X-Ray Source Index (xxx3,yyy2) if the single source generates different nominal energies. |
| >Multi-energy Source Technique | (xxx3,yyy4) | 1 | Technique used to acquire Multi-energy data.<br>Defined Terms:<br>SWITCHING_SOURCE an X-Ray source (tube) is used with beam mode switching<br>CONSTANT_SOURCE a X-Ray source (tube) using a beam with constant characteristics |
| >Switching Phase Number | (xxx3,yyy5) | 1C | A number unique within the sequence to identify the switching phase.<br><br>Required if Multi-energy Source Technique (xxx3,yyy4) is "SWITCHING_SOURCE". |
| >Switching Phase Nominal Duration | (xxx3,yyy6) | 3 | Duration, in microseconds, that the energy is in the target KV for this switching phase.<br>Note<br>Applicable if Multi-energy Source Technique (xxx3,yyy4) is "SWITCHING_SOURCE". |
| >Switching Phase Transition Duration | (xxx3,yyy7) | 3 | Duration, in microseconds, that the energy has left the target KV for this switching phase, but has not yet reached the target KV for the next phase. |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| | | | Note<br>Applicable if Multi-energy Source Technique (xxx3,yyy4) is “SWITCHING_SOURCE”. |
| >Generator Power | (0018,1170) | 3 | Power in kW to the x-ray generator. |

224 **C.8.2.1.X1.2 Multi-energy CT X-Ray Detector Macro**

This macro specifies the attributes for CT Image X-Ray Detector.

226 **Table C.8-X4. Multi-energy CT X-Ray Detector Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Multi-energy CT X-Ray Detector Sequence | (xxx4,yyy1) | 1 | X-Ray Detector information.<br>One or more Items shall be present. |
| >X-Ray Detector Index | (xxx4,yyy2) | 1 | Identification number of this item in the Multi-energy CT X-Ray Detector Sequence. The number shall be 1 for the first Item and increase by 1 for each subsequent Item. |
| >X-Ray Detector ID | (xxx4,yyy3) | 1 | Identifier of the X-Ray detector. The X-Ray Detector ID (xxx4,yyy3) will have the same value for different values of X-Ray Detector Index (xxx4,yyy2) if the single detector discriminates different energies. |
| >Multi-energy Detector Type | (xxx4,yyy4) | 1 | Technology used to detect multiple energies.<br>Defined Terms:<br>**INTEGRATING** detector integrates the full X-Ray spectrum.<br>**MULTILAYER** detector layers absorb different parts of the X-Ray spectrum<br>**PHOTON_COUNTING** detector counts photons with energy discrimination capability |
| >Nominal Bin Energy | (xxx4,yyy7) | 1C | Nominal Bin energy in keV of detected photons in this bin.<br>Required if Multi-energy Detector Type (xxx4,yyy4) is PHOTON_COUNTING |
| >Max Bin Energy | (xxx4,yyy8) | 3 | Nominal maximum energy in keV of photons that are integrated/counted by the detector in this bin. |
| >Min Bin Energy | (xxx4,yyy9) | 3 | Nominal minimum energy in keV of photons that are integrated/counted by the detector in this bin. |

228 **C.8.2.1.X1.3 Multi-energy CT Pairing Macro**

This macro specifies the attributes for CT Image Reference Acquisition.

230 **Table C.8-X5. Multi-energy CT Pairing Macro Attributes**

| **Attribute Name** | **Tag** | **Type** | **Attribute Description** |
|---|---|---|---|
| Multi-energy CT Pairing | (xxx5,yyy1) | 1 | Describes the pairing of the source and detector |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Sequence | | | and associated details.<br>Two or more Items are required if the image is acquired by means of multi-energy technique |
| >Multi-energy CT Pairing Index | (xxx5,yyy2) | 1 | Identification number of the element in the Multi-energy CT Pairing Sequence. The number shall be 1 for the first Item and increase by 1 for each subsequent Item. |
| >X-Ray Source Index | (xxx3,yyy2) | 1 | Identifying number corresponding to the X-Ray Source Index described in the Multi-energy CT X-Ray Source Macro. |
| >X-Ray Detector Index | (xxx4,yyy2) | 1 | Identifying number corresponding to the X-Ray Detector Index described in the Multi-energy CT X-Ray Detector Macro. |
| > Scan Pass Number | (xxx5,yyy4) | 1C | A number identifying the single continuous gathering of data over a period of time.<br>This is not the ID of this item of the Sequence<br>Required if more than one scan pass is used, May be present otherwise |
| >Scan Pass Date Time | (0008,0022) | 1C | The date and time the acquisition of data started.<br>Required if more than one scan pass is used, May be present otherwise |
| >Energy Weighting Factor | (xxx4,yy11) | 1C | The weighting factor of the data from this Sequence Item in a Multi-energy weighted average image. The value shall be between 0.0 and 1.0.<br><br>Required if one Derivation Code Sequence (0008,9215) Item value is (113097, DCM, "Multi-energy proportional weighting")<br>Sum of Energy Weighting Factors shall be 1 |
| | | | |
| >Multi-energy Acquisition Description | (xxx5,yyy3) | 3 | Human readable description of the Multi-Energy Acquisition |

232 < *Modify CT Exposure Macro due to Multi-energy CT Image Format*>

234 **C.8.15.3.8 CT Exposure Macro**

Table C.8-124 specifies the attributes of the CT Exposure Functional Group Macro.

236 **Table C.8-124. CT Exposure Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| CT Exposure Sequence | (0018,9321) | 1 | Contains the attributes defining exposure information.<br>**One or more Items shall be included in this** |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| | | | **Sequence if the image is acquired by means of multi-energy technique otherwise only~~Only~~** a single Item shall be included in this Sequence. |
| **> Multi-energy Source Index** | **(xxx5,yyy2)** | **1C** | **References the Item in the Multi-energy CT Source Macro for which exposure details are specified here.**<br>**Required if this image is acquired by means of multi-energy technique.** |
| >Exposure Time in ms | (0018,9328) | 1C | Duration of exposure for this frame in milliseconds.<br>If Acquisition Type (0018,9302) equals SPIRAL the duration of the exposure time for this frame shall be Revolution Time (0018,9305) divided by the Spiral Pitch Factor (0018,9311). See Section C.8.15.3.8.1.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL.<br>**Shall not be present if Multi-energy Source Technique (xxx3,yyy4) is "SWITCHING_SOURCE".**<br>May be present otherwise. |
| >X-Ray Tube Current in mA | (0018,9330) | 1C | Nominal X-Ray tube current in milliamperes.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Exposure in mAs | (0018,9332) | 1C | The exposure expressed in milliampere seconds, for example calculated from exposure time and X-Ray tube current.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL.<br>**Shall not be present if Multi-energy Source Technique (xxx3,yyy4) is "SWITCHING_SOURCE".**<br>May be present otherwise. |
| >Exposure Modulation Type | (0018,9323) | 1C | A label describing the type of exposure modulation used for the purpose of limiting the dose.<br>Defined Terms:<br>**NONE**<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Estimated Dose Saving | (0018,9324) | 2C | A percent value of dose saving due to the use of Exposure Modulation Type (0018,9323). A |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| | | | negative percent value of dose savings reflects an increase of exposure.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and Exposure Modulation Type (0018,9323) is not equal to NONE.<br>Otherwise may be present if Frame Type (0008,9007) Value 1 of this frame is DERIVED and Exposure Modulation Type (0018,9323) is not equal to NONE. |
| >CTDIvol | (0018,9345) | 2C | Computed Tomography Dose Index ($CTDI_{vol}$), in mGy according to IEC 60601-2-44, Ed.2.1 (Clause 29.1.103.4), The Volume $CTDI_{vol}$. It describes the average dose for this frame for the selected CT conditions of operation.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >CTDI Phantom Type Code Sequence | (0018,9346) | 3 | The type of phantom used for CTDI measurement according to IEC 60601-2-44.<br>Only a single Item is permitted in this Sequence. |
| *>>Include Table 8.8-1 "Code Sequence Macro Attributes"* | | | *Defined CID 4052 "Phantom Devices".* |
| >Water Equivalent Diameter | (0018,1271) | 3 | The diameter, in mm, of a cylinder of water having the same X-Ray attenuation as the patient for this reconstructed slice (e.g., as described in [AAPM Report 220]). |
| >Water Equivalent Diameter Method Code Sequence | (0018,1272) | 1C | The method of calculation of Water Equivalent Diameter (0018,1271).<br>Required if Water Equivalent Diameter (0018,1271) is present.<br>Only a single Item is permitted in this Sequence. |
| *>>Include Table 8.8-1 "Code Sequence Macro Attributes"* | | | *Defined CID 10024 "Water Equivalent Diameter Method".* |

238 *< Modify CT X-Ray Details Macro due to Multi-energy CT Image Format>*

240 **C.8.15.3.9 CT X-Ray Details Macro**

Table C.8-125 specifies the attributes of the CT X-Ray Details Functional Group Macro.

242 **Table C.8-125. CT X-Ray Details Sequence Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| CT X-Ray Details Sequence | (0018,9325) | 1 | Contains the attributes defining the x-ray information. |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| | | | **One or more Items shall be included in this Sequence if the image is acquired by means of multi-energy technique otherwise only~~Only~~** a single Item shall be included in this Sequence. |
| **> Multi-energy Pairing Index** | **(xxx5,yyy2)** | **1C** | **Identifying number corresponding to the Multi-energy Acquisition Index (xxx5,yyy2) described in the Multi-energy CT Pairing Macro**<br>**Required if the image is acquired by means of multi-energy technique.** |
| >KVP | (0018,0060) | 1C | **Nominal** Peak kilo voltage output of the x-ray generator used.<br>**If Multi-energy Source Technique (xxx3,yyy4) is "SWITCHING_SOURCE", this value is the target KV for a switching phase. The switching phase is identified by the X-Ray Source Index value in the Multi-energy CT Pairing Sequence (xxx5,yyy2) identified by the Multi-energy CT Pairing index value in this Sequence.**<br>**Due to limitations of the generating hardware the actual voltage may not reach the nominal peak value**<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Focal Spot(s) | (0018,1190) | 1C | Used nominal size of the focal spot in mm. The attribute may only have one or two values, for devices with variable focal spot, small dimension followed by large dimension<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Filter Type | (0018,1160) | 1C | Type of filter(s) inserted into the X-Ray beam.<br>Defined Terms:<br>**WEDGE**<br>**BUTTERFLY**<br>**MULTIPLE**<br>**FLAT**<br>**SHAPED**<br>**NONE**<br><br>Note<br>Multiple type of filters can be expressed by a combination, e.g., BUTTERFLY+WEDGE.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| >Filter Material | (0018,7050) | 1C | The X-Ray absorbing material used in the filter. May be multi-valued.<br>Defined Terms:<br>**MOLYBDENUM**<br>**ALUMINUM**<br>**COPPER**<br>**RHODIUM**<br>**NIOBIUM**<br>**EUROPIUM**<br>**LEAD**<br>**MIXED**<br><br>Note<br>MIXED may be used to indicate a filter type of complex composition for which listing the individual materials would be excessive or undesirable; it is not intended to mean "unknown".<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the value of Filter Type (0018,1160) is other than NONE. May be present otherwise. |
| >Calcium Scoring Mass Factor Patient | (0018,9351) | 3 | The calibration factor for the calcium mass score. These factors incorporate the effects of<br>KV value of the CT image<br>the patient size.<br>machine specific corrections<br>See Section C.8.2.1.1.7. |
| >Calcium Scoring Mass Factor Device | (0018,9352) | 3 | The calibration factors for the calcium mass score of the device. These factors incorporate the effects of<br>KV value of the CT image<br>machine specific corrections<br>This a multi-value attribute, the first value specifies the mass factor for a small patient size, the second value for a medium patient size and the third value for a large patient size.<br>See Section C.8.2.1.1.7. |
| >Energy Weighting Factor | (0018,9353) | 1C | The weighting factor of the data from the primary source in a multiple energy composition image. This factor incorporates the effects of<br>the specific X-Ray source and kV value<br>examination specific characteristics.<br>Required if Required if Frame Type (0008,9007) Value 4 of this frame is ENERGY_PROP_WT. May be present otherwise. |

244

< *Modify CT Acquisition Details Macro due to Multi-energy CT Image Format*>

246

### C.8.15.3.3 CT Acquisition Details Macro

248 Table C.8-119 specifies the attributes of the CT Acquisition Details Functional Group Macro.

**Table C.8-119. CT Acquisition Details Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| CT Acquisition Details Sequence | (0018,9304) | 1 | Contains the attributes defining the details of the acquisition.<br>**One or more Items shall be included in this Sequence if the image is acquired by means of multi-energy technique otherwise only~~Only~~** a single Item shall be included in this Sequence. |
| **> Multi-energy Acquisition Index** | **(xxx5,yyy2)** | **1C** | **Identifying number corresponding to the Multi-energy Acquisition Index (xxx5,yyy2) described in the Multi-energy CT Pairing Macro**<br>**Required if the image is acquired by means of multi-energy technique.** |
| >Rotation Direction | (0018,1140) | 1C | Direction of rotation of the source about the gantry, as viewed while facing the gantry where the table enters the gantry.<br>Enumerated Values:<br>CW clockwise<br>CC counter clockwise<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and Acquisition Type (0018,9302) is other than CONSTANT_ANGLE.<br>Otherwise may be present if Frame Type (0008,9007) Value 1 of this frame is DERIVED and Acquisition Type (0018,9302) is other than CONSTANT_ANGLE. |
| >Revolution Time | (0018,9305) | 1C | The time in seconds of a complete revolution of the source around the gantry orbit. This value is independent of the Reconstruction Angle (0018,9319) of the frame.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and Acquisition Type (0018,9302) is other than CONSTANT_ANGLE.<br>Otherwise may be present if Frame Type (0008,9007) Value 1 of this frame is DERIVED and Acquisition Type (0018,9302) is other than CONSTANT_ANGLE. |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| >Single Collimation Width | (0018,9306) | 1C | The width of a single row of acquired data (in mm).<br>Note<br>Adjacent physical detector rows may have been combined to form a single effective acquisition row.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Total Collimation Width | (0018,9307) | 1C | The width of the total collimation (in mm) over the area of active x-ray detection.<br>Note<br>This will be equal to the number of effective detector rows multiplied by single collimation width.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Table Height | (0018,1130) | 1C | The distance in mm from the top of the patient table to the center of rotation of the source (i.e., the data collection center or isocenter). The distance is positive when the table is below the data collection center.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Gantry/Detector Tilt | (0018,1120) | 1C | Nominal angle of tilt in degrees of the scanning gantry. Not intended for mathematical computations. Zero degrees means the gantry is not tilted, negative degrees are when the top of the gantry is tilted away from where the table enters the gantry.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Data Collection Diameter | (0018,0090) | 1C | The diameter in mm of the region over which data were collected. See Section C.8.15.3.6.1.<br>Note<br>In the case of an Acquisition Type (0018,9302) of CONSTANT_ANGLE, the diameter is that in a plane normal to the central ray of the diverging X-Ray beam as it passes through the data collection center.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |

< *Modify CT Geometry Macro due to Multi-energy CT Image Format*>

### C.8.15.3.6 CT Geometry Macro

Table C.8-122 specifies the attributes of the CT Geometry Functional Group Macro.

**Table C.8-122. CT Geometry Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| CT Geometry Sequence | (0018,9312) | 1 | Contains the attributes defining the CT geometry.<br>**One or more Items shall be included in this Sequence if the image is acquired by means of multi-energy technique otherwise only~~Only~~** a single Item shall be included in this Sequence. |
| **> Multi-energy Acquisition Index** | **(xxx5,yyy2)** | **1C** | **Identifying number corresponding to the Multi-energy Acquisition Index (xxx5,yyy2) described in the Multi-energy CT Pairing Macro**<br>**Required if the image is acquired by means of multi-energy technique.** |
| >Distance Source to Detector | (0018,1110) | 1C | Distance in mm from source to detector center. See Section C.8.15.3.6.1.<br>Note<br>This value is traditionally referred to as Source Image Receptor Distance (SID).<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |
| >Distance Source to Data Collection Center | (0018,9335) | 1C | Distance in mm from source to data collection center. See Section C.8.15.3.6.1.<br>Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise. |

<*Add Multi-energy CT Acquisition sections due to Multi-energy Image Format*>

### C.8.15.X1 Multi-energy CT Acquisition Module

Table C.8-X6 specifies the Attributes that describe the Multi-energy acquisition technique in the Enhanced Image.

**Table C.8-X6. Multi-energy CT Acquisition Module Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| >*Include Table C.8-X3 "Multi-energy CT X-Ray Source Macro Attributes"* | | | See C.8.2.1.X1.1 |
| >*Include Table C.8-X4 "Multi-energy CT X-Ray Detector Macro Attributes"* | | | See C.8.2.1.X1.2 |
| >*Include Table C.8-X5 "Multi-energy CT Pairing Macro Attributes"* | | | See C.8.2.1.X1.3 |

264

### C.8.15.3.X1 Multi-energy CT Characteristics Macro

266 This macro specifies the attributes for CT Image Characteristics.

**Table C.8-X7. Multi-energy CT Characteristics Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Monochromatic Energy Equivalent | (xxx7,yyy1) | 1C | Single energy equivalent in keV.<br><br>Required if Type Value 4 is EQUAL to VMI. May be present otherwise.<br><br>Note: If the Image Type Value 4 is (MAT_REMOVED, MAT_MODIFIED) and a VMI image was used as the source then this value reflects the keV Value of the VMI image. |
| Monochromatic Algorithm Sequence | (xxx7,yyy2) | 3 | Algorithm used to create the monochromatic image. |
| >*Include Table 10-19 Algorithm Identification Attributes* | | | |
| Multi-energy CT Quantification Sequence | (xxx7,yyy3) | 1C | Contains the attributes providing material quantification information.<br><br>Required if Type Value 4 is MAT_SPECIFIC or MAT_REMOVED MAT_MODIFIED or MAT_PROPORTIONAL. May be present otherwise.<br><br>Only a single Item is permitted in this sequence. |
| >*Include Table C.8-X8 "Multi-energy CT Quantification Macro Attributes"* | | | |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Multi-energy CT Labeling Sequence | (xxx7,yyy4) | 1C | Contains the attributes providing classification information of materials.<br><br>Required if Type Value 4 is MAT_LABELING. May be present otherwise.<br><br>Only a single Item is permitted in this sequence. |
| >*Include Table* C.8-X9 *"Multi-energy CT Labeling Macro Attributes"* | | | |

268

### C.8.15.3.X1.1 Multi-energy CT Quantification Macro

270 This macro specifies the attributes that describe a Multi-energy CT Quantification Image.

**Table C.8-X8. Multi-energy CT Quantification Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Material Quantification Description | (xxx8,yyy1) | 3 | Human-readable description of the material quantification process used to generate this image |
| Specific Material Code Sequence | (xxx8,yyy2) | 1C | The specific material present in this image.<br>Only a single item shall be present.<br><br>Required if Image Type Value 4 is MAT_SPECIFIC or MAT_PROPORTIONAL |
| >*Include Table 8.8-1-a "Basic Code Sequence Macro Attributes"* | | | Baseline CID is CID-X1 |
| Material Modification Sequence | (xxx8,yyy3) | 1C | Materials that have been intentionally affected when the image was created.<br><br>Required if Image Type Value 4 is MAT_MODIFIED or MAT_REMOVED<br><br>One or more items shall be present. |
| >Modification Type | (xxx8,yyy4) | 1 | Type of modification applied to this material<br><br>Defined Terms:<br><br>**SUBTRACTED** – Image with one or more materials subtracted, i.e. set to a fixed value.<br>**HIGHLIGHTED** – Image where pixel values have been modified to highlight a certain target material by partially suppressing the background and/or by enhancing the modified material<br>**SUPPRESSED** – CT Image where pixel values |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| | | | have been modified to partially suppress the modified material (opposite to HIGHLIGHTED)<br><br>**COMPENSATED** – CT Image where pixel values have been modified to remove specific material components.<br>**RECALCULATED** – pixels are recalculated by vendor-specific method |
| >Material Code Sequence | (xxx8,yyy5) | 2 | The modified material.<br>Only a single item shall be present. |
| *>>Include Table 8.8-1-a "Basic Code Sequence Macro Attributes"* | | | Baseline CID is CID-X1 |
| >Correction Value | (xxx8,yyy6) | 1C | The constant value used to replace the affected pixels<br>Required if Modification Type is SUBTRACTED |
| >Modification Description | (xxx8,yyy7) | 3 | Common description of the modification action on the image pixels. |

272

### C.8.15.3.X1.2 Multi-energy CT Labeling Macro

274 This macro specifies the attributes that describe a Multi-energy CT Labeling Image.

**Table C.8-X9. Multi-energy CT Labeling Macro Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Material Labeling Type | (xxx9,yyy1) | 1 | Describes the type of material labeling.<br><br>Defined Terms:<br><br>**DISCRETE** – Image where pixel value is an index corresponding to one or more materials specified by the Material Labeling Sequence attribute<br><br>**PROPORTIONAL** – Image where pixel value describes proportional part of the material (mass mixing fraction/ration) comprising this pixel. This material is specified by the Specific Material Code Sequence attribute. Rescale Slope is used to express the fraction value.<br><br>**PROBABILITY** – Image where pixel value describes the probability that this pixel is classified as the material specified by the Specific Material Code Sequence attribute. Rescale Slope is used to express the fraction value.<br><br>**VALUEBASED** – Image pixel with concrete values which represent a characteristic of the |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| | | | chemical differences, optimized for the materials coded in the Specific Material Code Sequence attribute. |
| Material Labeling Sequence | (xxx9,yyy2) | 1 | Materials that are labeled in this image.<br><br>IF Material Labeling Type is PROPABILITY only a single Item shall be present |
| *>Include Table 8.8-1-a "Basic Code Sequence Macro Attributes"* | | | Baseline CID is CID-X1 |
| >Material Index | (xxx9,yyy3) | 1C | Index that is used in image pixel values. Index 0 is used to indicate no material.<br>Required if Material Labeling Type is DESCRETE |
| >Material Value Range | (xxx9,yyy4) | 3 | Typical multi value range definition for the specific material MIN/MAX for Material Labeling Type VALUEBASED |

276

278 **C.8.15.3.X2 Multi-energy CT Processing Macro**

This macro defines the attributes for Multi-energy CT processing.

280 **Table C.8-X10. Multi-energy CT Processing Attributes**

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Decomposition Method | (xx10,yyy1) | 1 | Defined Terms:<br>**PROJECTION_BASED** the acquired projection data was decomposed into basis projection data (i.e. sinograms)<br><br>**IMAGE_BASED** the acquired projection data was reconstructed into images before being decomposed into basis image data<br><br>**Notes:**<br>1) Basis Images and basis projection data are not necessarily instantiated as DICOM instances.<br>2) There may be additional processing steps (e.g. linear combination of basis data) creating the result image |
| Decomposition Description | (xx10,yyy2) | 3 | Description of decomposition method |

| Attribute Name | Tag | Type | Attribute Description |
|---|---|---|---|
| Decomposition Algorithm Identification Sequence | (xx10,yyy3) | 3 | Algorithm used for decomposition of the acquired data<br><br>One or more Items are permitted in this Sequence. |
| >Decomposition Algorithm Identification Description | (xx10,yyy4) | 3 | Description of decomposition algorithm |
| Decomposition Sequence | (xx10,yyy5) | 3 | Materials used to create result images. |
| >Material Code Sequence | (xxx8,yyy5) | 1 | Nominal material for Multi-energy CT processing<br>Only a single Item shall be included in this Sequence |
| >>*Include Table 8.8-1-a "Basic Code Sequence Macro Attributes"* | | | Baseline CID is CID-X1 |
| > Material Attenuation Sequence | (xx10,yyy7) | 3 | Attenuation curve of the material<br>Two or more Items shall be included in this Sequence.<br><br>Note: Attenuation curves for non standard materials can be generated by NIST http://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html |
| >> Photon Energy | (xx10,yyy8) | 1 | Photon energy in keV |
| >>X-Ray Mass Attenuation Coefficient | (xx10,yyy9) | 1 | Attenuation of this material at the specific Photon energy. Normalized to material density. |

*< Modify C.11.1.1.2 Modality LUT and Rescale Type due to Multi-energy CT Image Format>*

### C.11.1.1.2 Modality LUT and Rescale Type

Specifies the units of the output of the Modality LUT or rescale operation. Defined Terms:

OD The number in the LUT represents thousands of optical density. That is, a value of 2140 represents an optical density of 2.140.

HU Hounsfield Units (CT)

US Unspecified

**MGML mg/ml**

**Z_EFF Effective Atomic Number (i.e. Effective-Z)**

**ED $10^{23}$ electrons/ml**

**EDW Electron density normalized to water in units of N/Nw where N is number of electrons per unit volume. And Nw is number of electrons in the same unit of water at standard temperature and pressure.**

**HU_MOD Modified Hounsfield Unit;**

**PCT Percentage (%)**

Other values are permitted, but are not defined by the DICOM Standard.

**For Rescale Types recommended to be used in case of Multi-energy CT Images see Section C.8.2.1.1.X1**

# Changes to NEMA Standards Publication PS 3.6-2011

# Digital Imaging and Communications in Medicine (DICOM)

# Part 6: Data Dictionary

***Add the following rows to Section 6***

| Tag | Name | Keyword | VR | VM |
|---|---|---|---|---|
| (xxx2,yyy1) | CT Multi-energy Flag | CTMultiEnergyFlag | CS | 1 |
| (xxx2,yyy2) | Multi-energy CT Acquisition Sequence | MultiEnergyCTAcquisitionSequence | SQ | 1 |
| (xxx2,yyy3) | Multi-energy CT Processing Macro Sequence | MultiEnergyCTProcessingMacroSequence | SQ | 1 |
| (xxx2,yyy4) | Multi-energy CT Characteristics Macro Sequence | MultiEnergyCTCharacteristicsMacroSequence | SQ | 1 |
| (xxx3,yyy1) | Multi-energy CT X-Ray Source Sequence | Multi-energyCTX-RaySourceSequence | SQ | 1 |
| (xxx3,yyy2) | X-Ray Source Index | X-RaySourceIndex | US | 1 |
| (xxx3,yyy3) | X-Ray Source ID | X-RaySourceID | US | 1 |
| (xxx3,yyy4) | Multi-energy Source Technique | Multi-energySourceTechnique | CS | 1 |
| (xxx3,yyy5) | Switching Phase Number | SwitchingPhaseNumber | US | 1 |
| (xxx3,yyy6) | Switching Phase Nominal Duration | SwitchingPhaseNominalDuration | DS | 1 |
| (xxx3,yyy7) | Switching Phase Transition Duration | SwitchingPhaseTransitionDuration | DS | 1 |
| (xxx4,yy10) | Bin Weighting Factor | BinWeightingFactor | DS | 1 |

| Tag | Name | Keyword | VR | VM |
|---|---|---|---|---|
| (xxx4,yy11) | Energy Weighting Factor | EnergyWeightingFactor | DS | 1 |
| (xxx4,yyy1) | Multi-energy CT X-Ray Detector Sequence | Multi-energyCTX-RayDetectorSequence | SQ | 1 |
| (xxx4,yyy2) | X-Ray Detecor Index | X-RayDetecorIndex | US | 1 |
| (xxx4,yyy2) | X-Ray Detector Index | X-RayDetectorIndex | US | 1 |
| (xxx4,yyy3) | X-Ray Detector ID | X-RayDetectorID | US | 1 |
| (xxx4,yyy4) | Multi-energy Detector Type | Multi-energyDetectorType | CS | 1 |
| (xxx4,yyy5) | Energy Bin Sequence | EnergyBinSequence | SQ | 1 |
| (xxx4,yyy6) | Bin ID | BinID | US | 1 |
| (xxx4,yyy7) | NominalBinEnergy | NominalBinEnergy | DS | 1 |
| (xxx4,yyy8) | Max Bin Energy | MaxBinEnergy | DS | 1 |
| (xxx4,yyy9) | Min Bin Energy | MinBinEnergy | DS | 1 |
| (xxx5,yyy1) | Multi-energy CT Pairing Sequence | Multi-energyCTPairingSequence | SQ | 1 |
| (xxx5,yyy2) | Multi-energy Acquisition Index | Multi-energyAcquisitionIndex | US | 1 |
| (xxx5,yyy3) | Multi-energy Acquisition Description | MultiEnergyAcquisitionDescription | ST | 1 |
| (xxx7,yyy1) | Monochromatic Energy Equivalent | MonochromaticEnergyEquivalent | DS | 1 |
| (xxx7,yyy2) | Monochromatic Algorithm Sequence | MonochromaticAlgorithmSequence | SQ | 1 |
| (xxx7,yyy3) | Multi-energy Quantification CT Image Sequence | Multi-energyQuantificationCTImageSequence | SQ | 1 |
| (xxx7,yyy4) | Multi-energy Labeling CT Image Sequence | Multi-energyLabelingCTImageSequence | SQ | 1 |
| (xxx8,yyy1) | Material Modification Description | MaterialModificationDescription | ST | 1 |
| (xxx8,yyy2) | Specific Material Code Sequence | SpecificMaterialCodeSequence | SQ | 1 |
| (xxx8,yyy3) | Material Modification Sequence | MaterialModificationSequence | SQ | 1 |
| (xxx8,yyy4) | Modification Type | ModificationType | CS | 1 |
| (xxx8,yyy5) | Material Code Sequence | MaterialCodeSequence | SQ | 1 |
| (xxx8,yyy6) | Correction Value | CorrectionValue | DS | 1 |
| (xxx8,yyy7) | Modification Description | ModificationDescription | ST | 1 |
| (xxx9,yyy1) | Material Labeling Type | MaterialLabelingType | CS | 1 |

| Tag | Name | Keyword | VR | VM |
|---|---|---|---|---|
| (xxx9,yyy2) | Material Labeling Sequence | MaterialLabelingSequence | SQ | 1 |
| (xxx9,yyy3) | Material Index | MaterialIndex | US | 1 |
| (xxx9,yyy4) | Material Value Range | MaterialValueRange | DS | 2 |
| (xx10,yyy1) | Decomposition Method | DecompositionMethod | CS | 1 |
| (xx10,yyy2) | Decomposition Description | DecompositionDescription | ST | 1 |
| (xx10,yyy3) | Decomposition Algorithm Identification Sequence | DecompositionAlgorithmIdentification Sequence | SQ | 1 |
| (xx10,yyy4) | Decomposition Algorithm Identification Description | DecompositionAlgorithmIdentification Description | ST | 1 |
| (xx10,yyy5) | Decomposition Sequence | DecompositionSequence | SQ | 1 |
| (xx10,yyy7) | Material Attenuation Sequence | MaterialAttenuationSequence | SQ | 1 |
| (xx10,yyy8) | Photon Energy | PhotonEnergy | DS | 1 |
| (xx10,yyy9) | X-Ray Mass Attenuation Coefficient | X-RayMassAttenuationCoefficient | DS | 1 |

# Changes to NEMA Standards Publication PS 3.16-2011

# Digital Imaging and Communications in Medicine (DICOM)

# Part 16: Content Mapping Resource

**CID NewCID-1 Multi-energy Material Codes**

Codes for materials used in Multi-energy Images.

**Table CID-X1**
**Multi-energy Material Codes**
**Type : Extensible Version : yymmdd**

| Coding Scheme Designator (0008,0102) | Code Value (0008,0100) | Code Meaning (0008,0104) |
|---|---|---|
| SRT | C-11400 | Iodine |
| SRT | C-17800 | Gadolinium |
| SRT | C-12200 | Barium |
| SRT | C-10120 | Water |
| SRT | C-130F9 | Iron |
| SRT | T-D008A | Fat |
| DCMXXX | NewCode1-01 | **Calcium** |
| DCMXXX | NewCode1-02 | **Uric Acid** |
| DCMXXX | NewCode1-03 | **HAP** |

**CID NewCID-2 Multi-energy Material Units Codes**

Codes for material units used in Multi-energy Images.

**Table CID-X2**
**Multi-energy Material Units Codes**
**Type : Extensible Version : yymmdd**

| Coding Scheme Designator (0008,0102) | Code Value (0008,0100) | Code Meaning (0008,0104) |
|---|---|---|
| UCUM | mg/cm3 | mg/cm^3 |
| UCUM | hnsf'U | Hounsfield Unit |
| DCMXXX | cnt/cc | Electron Density |
| DCMXXX | NewCode2-02 | Effective Atomic Number |
| DCMXXX | NewCode2-03 | Modified Hounsfield Unit |
| DCMXXX | mg/ml | Milligram per milliliter |

**Changes to NEMA Standards Publication PS 3.17-2011**

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

Add the following New Annex to Part 17 (WW is a placeholder)