Digital Imaging and Communications in Medicine (DICOM)

Supplement 177: Second Generation Radiotherapy –

Dose Objects

DICOM Standards Committee, Working Group 7, Radiation Therapy

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Foreword

This Supplement in its current state represents the remaining sections of Supplement 147, revision 42, which is being split into several smaller attributes.

Attribute definitions, CID definitions and DICOM Controlled terminology are currently not part of this document, but remain in their entirety in Supplement 147 until it is ready for Public Comment. Then the remaining parts of these chapters will be moved to this document.

This Supplement specifies the additional IODs necessary to support the new Second Generation Radiotherapy IODs and operations.

This document is an extension to the following parts of the published DICOM Standard:

PS 3.2	Conformance
PS 3.3	Information Object Definitions
PS 3.4	Service Class Specifications
PS 3.6	Data Dictionary
PS 3.16	Content Mapping Resource

Scope and Field of Application

Introduction

Existing radiotherapy IODs were designed to provide a set of containers for use in communicating radiation therapy data of all types, in a generic and flexible way.

Since the development of the initial IODs, both radiation therapy practice and the DICOM Standard itself have evolved considerably. In particular, workflow management is now a key aspect of DICOM's domain of application, and the introduction of Unified Worklist and Procedure Step (by Supplement 74 in conjunction with Supplement 96) have begun the growth of radiation therapy into workflow management.

This supplement addresses the need for a new generation of IODs and processes required for use in radiation therapy. The general principles under which these IODs and processes have been developed are documented below.

General Architectural Principles

The DICOM "STRATEGIC DOCUMENT Version 10.4, October 25, 2010" outlines a number of principles applicable across the entire DICOM standard. The key relevant points, and how this supplement addresses those concerns, are as follows:

- Image IOD development follows the "enhanced multi-frame" paradigm, rather than stacks of 2D SOP Instances. The new RT Dose Image follows this paradigm.

- Different representations of data are encoded in different IODs. This is in contrast to first-generation objects, where multiple different types of data are encoded in a single IOD, such as RT Structure Set.

- These new IODs do not define an architecture for the entire system, or functional requirements beyond behavior required for specific services. This is because the mode of manual exchange of objects (see PS3.17) supports an arbitrary system architecture. The worklist mode of operation does place some constraints on the architecture – for example, it implies the existence of one or more workflow servers that have knowledge of department-wide scheduling. The Radiation Oncology domain of the IHE initiative may adapt workflows that will utilize 2nd Generation Radiotherapy objects and define their usage in a clinical workflow, as it was done with Supplement 74 and the IHE-RO Technical Profile "Treatment and Delivery Workflow".

RT Architectural Principles

In addition to the general principles outlined above, additional principles specific to radiation therapy have been used in the development of this supplement:

- Support for available technologies: The new IODs are designed to support legacy and full-featured, modern equipment.

- Compatibility with First-Generation IODs: In general, where the technologies continue to be supported, it will be possible for the content of first-generation IODs to be re-encoded into the second generation IODs described in the supplement. However, such a translation will not be a basic re-encoding and will require additional information supplied by the translating device.

- New data representation approaches in DICOM: Where possible, use has been made of new and powerful approaches, such as 3D segmentation, mesh representation, rigid and deformable registrations.

- IODs specific to use cases: Explicit separate IODs have been developed for specific treatment modalities with the concept of RT Radiation IOD – for example, Tomotherapeutic, C-Arm, and Robotic beams are modeled separately. This allows more stringent conditions to be applied to the presence or absence of attributes within those IODs, and thereby increases the potential for interoperability.

- Expandability of concept: New treatment modalities currently not considered by this standard can be modeled along the existing RT Radiation IODs and be introduced later on, fitting into the existing concept.

- Workflow Management: The concept of workflow management using Unified Procedure Step has been fully integrated into the new IODs. However, specific instruction and result IODs needed for some of these workflows will be standardized in a subsequent supplement.

- New techniques in oncology: The existence of new treatment techniques (such as robotic therapy and tomotherapy) have been taken into account, along with new treatment strategies (such as image-guided therapy and adaptive therapy).

See Part 17 for descriptions of new radiotherapy entities and sample use cases.

Part 2 Addendum

Add new SOP Classes to PS3.2 Table A.1-2 UID Values:

UID Value	UID Name	Category
1.2.840.10008.5.1.4.1.1.481.XN.7.1	RT Dose Image Storage	Transfer
1.2.840.10008.5.1.4.1.1.481.XN.7.2	RT Dose Histogram Storage	Transfer
1.2.840.10008.5.1.4.1.1.481.XN.7.3	RT Dose Samples Storage	Transfer

Part 3 Addendum

Add the following columns in PS3.3 Section A.1.4, Table A.1-1 COMPOSITE INFORMATION OBJECT MODULES OVERVIEW – RADIOTHERAPY

IODs Modules	RT Dose Img	RT Dose Hist	RT Dose Samp
Patient	M	M	M
Clinical Trial Subject	U	U	U
General Study	M	M	M
Patient Study	U	U	U
Clinical Trial Study	U	U	U
General Series	M	M	M
Clinical Trial Series	U	U	U
Enhanced RT Series	M	M	M
General Equipment	M	M	M
Enhanced General Equipment	M	M	M
Frame Of Reference	M		M
Synchronization	C		
Radiotherapy Common Instance	M	M	M
Multi-Axial Beam			
Image Pixel	M		
Acquisition Context	M	M	M

IODs Modules	RT Dose Img	RT Dose Hist	RT Dose Samp
Enhanced RT Dose	M	M	M
RT Dose Image	M		
RT Dose Histogram		M	
RT Dose Samples			M
RT Patient Setup			
Multi-frame Functional Groups	M		
Multi-frame Dimension	M		
Respiratory Synchronization	C		
Common Instance Reference Module	M	M	M
SOP Common	M	M	M

Add the following to PS3.3 Annex A:

A.VV SECOND GENERATION RADIATION THERAPY

A.VV.1.1.1 Second Generation Radiation Therapy Entity-Relationship Model

The E-R Model in Figure A.VV.1.1.1-1 depicts those components of the DICOM Information Model that are relevant to second-generation RT IODs.

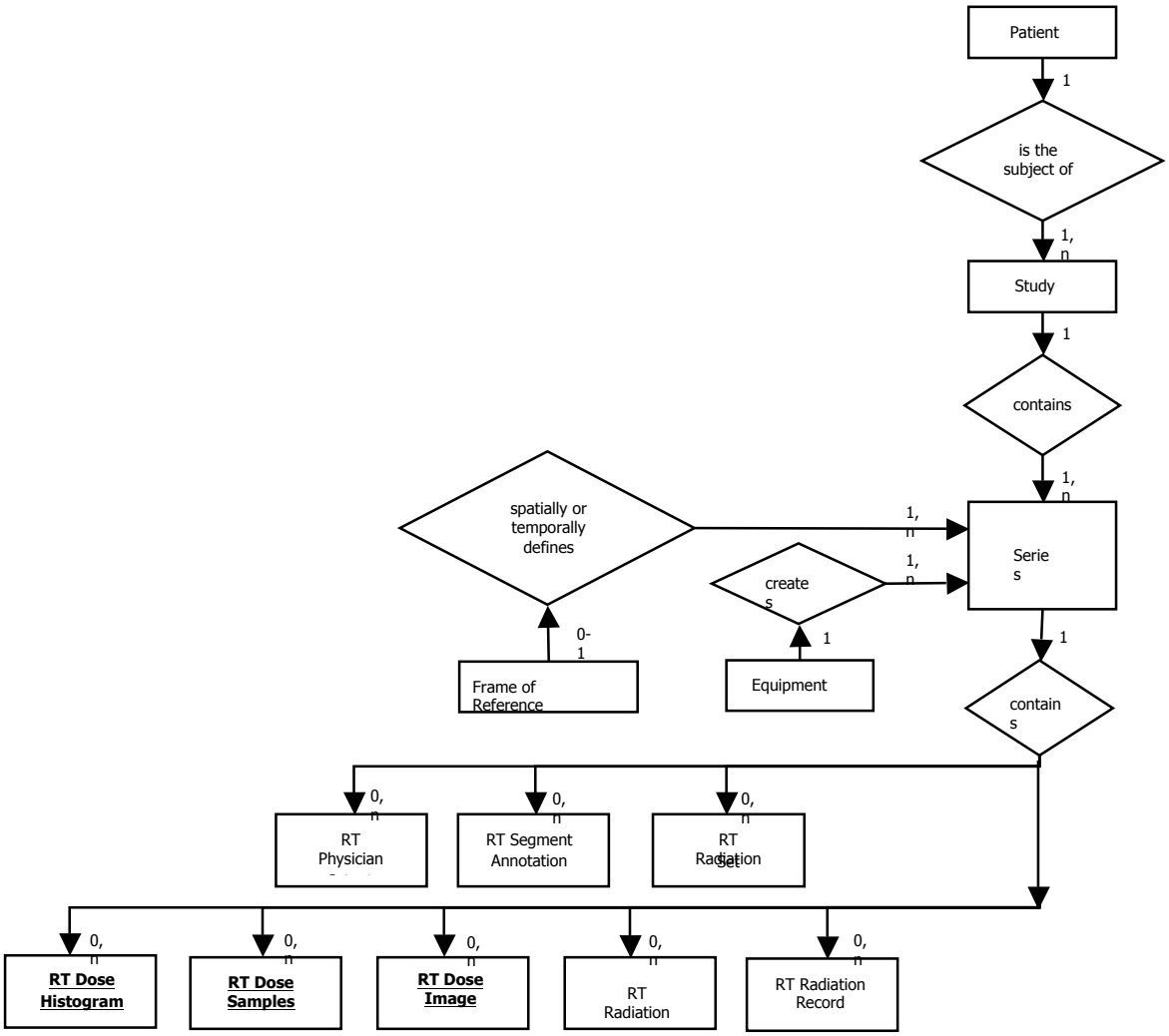

Figure A.VV.1.1.1-1 — RT Second Generation IOD information model

A.VV.1.12 RT Dose Image Information Object Definition

A.VV.1.12.1 RT Dose Image IOD Description

The RT Dose Image IOD represents 2D or 3D calculated or measured dose distributions in the DICOM Patient Coordinate System. This IOD does not provide for definition of doses in beam or other coordinate systems. The application is responsible for transforming data in other, non-patient based coordinate systems to the patient based coordinate system described in C.7.6.2.1.1.

A.VV.1.12.2 RT Dose Image IOD Entity-Relationship Model

See Figure A.VV.1.1.1-1.

A.VV.1.12.3 RT Dose Image IOD Module Table

Table A.VV.1.12-1
RT DOSE IMAGE IOD MODULES

IE	Module	Reference	Usage
Include 'RT Second Generation IOD Modules Macro' Table A.VV.1.1.1-1			
Frame of Reference	Frame of Reference	C.7.4.1	M
	Synchronization	C.7.4.2	C – Required if time synchronization was applied.
RT Dose Image	Image Pixel	C.7.6.3	M
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Respiratory Synchronization	C.7.6.18.2	C – Required if respiratory synchronization was applied.
	Acquisition Context	C.7.6.14	M
	Enhanced RT Dose	C.AA.M1	M
	RT Dose Image	C.AA.M2	M

A.VV.1.12.4 RT Dose Image IOD Content Constraints

The General Image Module, Overlay Plane Module, Curve Module and VOI LUT Module shall not be used in a Standard Extended SOP Class of the RT Dose Image IOD.

A.VV.1.12.5 RT Dose Image Functional Group Macros

Table A.VV.1.12-2
RT DOSE IMAGE FUNCTIONAL GROUP MACROS

Function Group Macro	Section	Usage
Pixel Measures	C.7.6.16.2.1	M – Shall be used as a Shared Functional Group
Plane Position (Patient)	C.7.6.16.2.3	M – Shall be used as a Per-Frame Functional Group
Plane Orientation (Patient)	C.7.6.16.2.4	M – Shall be used as a Shared Functional Group
Respiratory Trigger	C.7.6.16.2.17	C – Required if Respiratory Synchronization Technique is used. May be present otherwise.

RT Dose Image Frame Type	C.AA.M3.1	M
Real World Value Mapping	C.7.6.16.2.11	M – Shall be used as a Shared Functional Group Defined CID for Measurement Units Code Sequence (0040,08EA) shall be SUP147065.

A.VV.1.13 RT Dose Histogram Information Object Definition

A.VV.1.13.1 RT Dose Histogram IOD Description

The RT Dose Histogram IOD specifies dose-volume histogram (DVH) and dose-area histogram data and statistics, calculated by radiotherapy treatment planning systems.

A.VV.1.13.2 RT Dose Histogram IOD Entity-Relationship Model

See Figure A.VV.1.1.1-1.

A.VV.1.13.3 RT Dose Histogram IOD Module Table

Table A.VV.1.13-1
RT DOSE HISTOGRAM RADIATION IOD MODULES

IE	Module	Reference	Usage
Include 'RT Second Generation IOD Modules Macro' Table A.VV.1.1.1-1			
RT Dose Histogram	Acquisition Context	C.7.6.14	M
	Enhanced RT Dose	C.AA.M1	M
	RT Dose Histogram	C.AA.M4	M

A.VV.1.14 RT Dose Samples Information Object Definition

A.VV.1.14.1 RT Dose Samples IOD Description

The RT Dose Samples IOD specifies a list of spatial locations and associated dose values created by a treatment planning system or dose measurement device. Spatial locations are specified in the patient based coordinate system described in C.7.6.2.1.1.

A.VV.1.14.2 RT Dose Samples IOD Entity-Relationship Model

See Figure A.VV.1.1.1-1.

A.VV.1.14.3 RT Dose Samples IOD Module Table

Table A.VV.1.14-1
RT DOSE SAMPLES IOD MODULES

IE	Module	Reference	Usage
Include 'RT Second Generation IOD Modules Macro' Table A.VV.1.1.1-1			
Frame of Reference	Frame of Reference	C.7.4.1	M
	Synchronization	C.7.4.2	C – Required if time synchronization was applied.
RT Dose	Acquisition Context	C.7.6.14	M

Samples	Enhanced RT Dose	C.AA.M1	M
	Dose Samples	C.AA.M5	M

Add the following to PS3.3 Annex C:

C.AA.M1 Enhanced RT Dose Module

The Enhanced RT Dose module is used to convey non-image aspects of 2D or 3D radiation dose data generated from treatment planning systems or similar devices. The attributes defined within the module support dose for a single radiation instance (e.g. an external beam), one or more fractions of the planned dose of an RT Radiation Set, or composite dose derived from multiple RT Dose Image instances.

Table C.AA.M1-1
ENHANCED RT DOSE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Dose Type	(3004,0004)	1	Type of dose. Defined Terms: PHYSICAL = physical dose EFFECTIVE = dose after correction for biological effect using user-defined modeling technique
Effective Dose Method Code Sequence	(30xx,1132)	2C	The method used to calculate the effective dose. Required, if Dose Type (3004,0004) is EFFECTIVE. Zero or more Items shall be included in this sequence.
>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID SUP147035.*
>Effective Dose Method Modifier Code Sequence	(30xx,1137)	3	Modifier Code further defining the effective dose method. One or more Items are permitted in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			*No baseline CID defined.*
Referenced Dose Calculation Annotation Object Sequence	(30xx,1135)	3	Reference to SOP instances describing dose calculation methods, parameters and/or other information used in calculation and / or modification of the dose. One or more Items are permitted in this sequence.
>Include 'SOP Instance Reference Macro' Table 10-11			
>Purpose of Reference Code Sequence	(0040,A170)	1	Code describing the purpose of the reference to the Instance(s). Only a single Item shall be included in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID SUP147036.*

Effective Dose Method Description	(30xx,1134)	2C	The description of the method used to calculate the effective dose. Required, if Dose Type (3004,0004) is EFFECTIVE.
Dose Data Source	(30xx,1138)	1	The source of the dose data. Defined Terms: PLANNED = Dose calculated from Radiation(s) or Radiation Set(s). MEASUREMENT = Measured dose RECONSTRUCTED = Dose reconstructed from measured exit dose RECORD = Dose calculated using delivered dose values from radiation record IMAGE_ACQ = Dose record calculated for performed image acquisition
Dose Data Source Measurement Code Sequence	(30xx,113C)	1C	A detailed specification of the data source. Required, if Dose Data Source (30xx,1138) is MEASUREMENT. Only a single Item shall be included in this sequence.
>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID SUP147037.*
Radiation Absorption Model	(30xx,1130)	1C	List of patient heterogeneity characteristics used for calculating dose. This attribute shall be multi-valued if the computed dose has multiple correction techniques. Defined Terms: IMAGE = Image data ROI_OVERRIDE = One or more ROI (segment) densities override image or water values where they exist WATER = Entire volume treated as water equivalent OTHER = Mixed model usage (when not specified by multiple values), other or unspecified Shall be present if Dose Data Source (30xx,1138) is PLANNED. May be present otherwise.

			See C.AA.M1.1.2.
Effective Tissue Composition	(30xx,113E)	1	Tissue composition used for dose reporting. Defined Terms: WATER = Dose calculated assuming tissue has atomic characteristics similar to water MUSCLE = Dose calculated assuming that tissue has atomic characteristics similar to muscle. MEDIUM = Dose calculated using known characteristics of the material OTHER = Methodology used for the dose calculation is not defined or unknown
Algorithm Type Code Sequence	(30xx,1144)	1C	The dose algorithm class. Shall be present if Dose Data Source (30xx,1138) is PLANNED. May be present otherwise. One or more items shall be present in this sequence.
>Include 'Algorithm Identification Macro' Table 10-19			*Defined CID for Algorithm Family Code shall be SUP147041.*
Dose Scope	(30xx,113A)	1	The Scope of the entities represented by that dose. Defined Terms: PARTIAL = Dose for zero or more complete fractions and for partial delivery of one or more partial fractions of a single radiation instance. RADIATION = Dose for one or more complete fractions of a single radiation instance. RADIATION_SET = Dose for one or more complete fractions of a single RT Radiation Set. ACCUMULATED = Dose for zero or more complete fractions and for partial delivery of one or more partial fractions of one or more RT Radiation Sets. COMPOSITE = Composition of separate doses for one or more courses.
Dose Contribution Accumulation	(30xx,1124)	1C	The operator used to accumulate the

Type			dose from the referenced Instance(s). Required, if Contributing Radiation Sequence (30xx,1118), Contributing Radiation Set Sequence (30xx,1102), Composite Dose Sequence (30xx,1100) or Contributing RT Radiation Record Sequence (30xx,1128) includes more than one item. Defined terms: LINEAR = Contributions are summed linearly. OTHER = Unspecified/non-linear contribution to the dose.
Contributing Radiation Sequence	(30xx,1118)	1C	Reference to the SOP Instance of Radiation that contributes to the dose. Required if the Dose Scope is RADIATION or PARTIAL. Only a single Item shall be included in this sequence.
>Include 'SOP Instance Reference Macro' Table 10-11			
>Number of Complete Fractions Contributing	(30xx,1120)	1	Number of complete fractions of the RT Radiation contributing to the dose. May be 0 if only a partial delivery is represented.
>Partial Delivery Limits Sequence	(30xx,1122)	1C	Reference to the cumulative meterset value(s) to which the dose is calculated for the partial fractions included. If several partial fractions are included in that dose, the segments defined by Start Meterset (30xx,1140) and Stop Meterset (30xx,1141) within that sequence may overlap. Required if Dose Scope (30xx,113A) is PARTIAL. One or more Items shall be included in this sequence.
>>Start Meterset	(30xx,1140)	1	Value of Cumulative Meterset at which partial delivery of the referenced Radiation SOP Instance starts.
>>Stop Meterset	(30xx,1141)	1	Value of Cumulative Meterset at which partial delivery of the referenced Radiation SOP Instance stops.

Contributing Radiation Set Sequence	(30xx,1102)	1C	Reference to one or more RT Radiation Sets instances that contribute to the dose. Required if Dose Scope is RADIATION_SET or ACCUMULATED. If Dose Scope is RADIATION_SET, only a single Item shall be included in this sequence. Otherwise, one or more Items shall be included in this sequence.
>Include 'SOP Instance Reference Macro' Table 10-11			
>Number of Complete Fractions Contributing	(30xx,1120)	1	The number of complete fractions of the RT Radiation Set contributing to the dose. May be 0 if only a partial delivery is represented.
>Fraction Completion Status	(30xx,1123)	1C	Whether the dose contribution from the current RT Radiation Set includes an incomplete fraction. Defined terms: COMPLETE = Dose represents contribution of an integral number of complete fractions INCOMPLETE = Dose represents contribution of one or more incomplete fractions Required if Dose Scope (30xx,113A) is ACCUMULATED.
>Contributing Radiation Sequence	(30xx,1118)	1C	Reference to the SOP Instances of RT Radiation that contributes to the dose. Required if the Fraction Completion Status (30xx,1123) is INCOMPLETE. One or more Items shall be included in this sequence.
>>Include 'SOP Instance Reference Macro' Table 10-11			
>>Radiation Completion Status	(30xx,1125)	1	Whether the dose contribution from the current RT Radiation is complete. Defined terms: COMPLETE = Dose represents contribution of the complete radiation. INCOMPLETE = Dose represents contribution of one or more meterset intervals of a single incomplete fraction

>>Partial Delivery Limits Sequence	(30xx,1122)	1C	Reference to the cumulative meterset value(s) to which the dose is calculated. If several partial fractions are included in that dose, the segments defined by Start Meterset (30xx,1140) and Stop Meterset (30xx,1141) within that sequence may overlap. Required if the Radiation Completion Status (30xx,1125) is INCOMPLETE. One or more Items shall be included in this sequence.
>>>Start Meterset	(30xx,1140)	1	Value of Cumulative Meterset at which partial delivery of the referenced Radiation SOP Instance starts.
>>>Stop Meterset	(30xx,1141)	1	Value of Cumulative Meterset at which partial delivery of the referenced Radiation SOP Instance stops.
Composite Dose Sequence	(30xx,1100)	1C	RT Dose Image SOP Instance or RT Dose SOP instances that contribute to the dose. Required if the Dose Scope (30xx,113A) is COMPOSITE. One or more Items shall be included in this sequence.
>Include 'SOP Instance Reference Macro' Table 10-11			
>Dose Contribution Weight	(30xx,1110)	1C	A numeric value representing the scale factor used in compositing the referenced dose Instance. Negative values maybe used for dose differences. Required if the Dose Contribution Accumulation Operator Type (30xx,1124) is LINEAR.
Contributing RT Radiation Record Sequence	(30xx,1128)	1C	RT Radiation Record SOP instances used to calculate the dose. Required if Dose Data Source (30xx,1138) is RECORD. One or more Items shall be included in this sequence.
>Include 'SOP Instance Reference Macro' Table 10-11			
>Treatment Session UID	(30xx,6000)	1	The UID identifying a treatment session. This UID serves as a key to collect all Radiation Record instances, which have been delivered within the same treatment

			session.
Spatial Transform of Dose	(3004,0005)	3	The use of transformation in the calculation of the combined dose. Defined Terms: NONE: No transformation. Calculated on the original image set RIGID: Only Rigid transform used (see definition in C.20.2.1.2) NON_RIGID: Any other transform used
Referenced Spatial Registration Sequence	(0070,0404)	2C	Reference to a Spatial Registration SOP Instance or a Deformable Spatial Registration SOP Instance, which defines the transformation used to transform the dose. Required, if Spatial Transform of Dose (3004,0005) is provided and has a value of RIGID or NON_RIGID. Zero or one Item shall be included in this sequence. See Section C.8.8.3.5
>Include 'SOP Instance Reference Macro' Table 10-11			
Referenced RT Segment Annotation Sequence	(30xx,0874)	2C	Reference to a RT Segment Annotation SOP Instance containing structures used to calculate the content of the current IOD. Required if Radiation Absorption Model(30xx,1130) contains ROI_OVERRIDE or if the module is used in the RT Dose Histogram IOD. May be present otherwise. Only a single Item shall be included in this sequence.
>Include 'SOP Instance Reference Macro' Table 10-11			

C.AA.M1.1 Enhanced RT Dose Attribute Description

C.AA.M1.1.1 Dose Scope

The scope of the dose described in this module is given by the referenced SOP instances included in the actual reference sequences as required by the Dose Scope (30xx,113A).

It is important, that a dose provided in absolute values (i.e the Real World Value Mapping C.7.6.16.2.11 macro containing the code (Gy, UCUM, “Gray”) for the unit) is consistent with the absolute planned or delivered Meterset values as specified by Cumulative Meterset (30xx,5021) in those referenced SOP instances.

C.AA.M1.1.2 Radiation Absorption Model

The multipicity of the value shall be 1 for dose objects which represent a dose having been directly calculated based on image data. For doses which have been calculated by compositing several other doses, this attribute shall contain each value found in the the composited doses once and only once.

C.AA.M2 RT Dose Image Module

The RT Dose Image module describes specializations of attributes in the General Image Module and provides information to position the image planes in the axial dimension and to scale the pixel data values to real-world dose values. It provides the mechanism to transmit a 3D array of dose data as a multi-frame image whose frames represent 2D dose image planes that may or may not be related to CT or MR image planes.

Table C.AA.M2-1
RT DOSE IMAGE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. See C.AA.M2.1.1.
Samples per Pixel	(0028,0002)	1	Number of samples (planes) in this image. This value shall be 1.
Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. It shall have the enumerated value of MONOCHROME2.
Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Each sample shall have the same number of bits allocated which shall be the Enumerated Value of 32.
Bits Stored	(0028,0101)	1	Number of bits stored for each pixel sample. Each sample shall have the same number of bits stored which shall be the Enumerated Value of 32.
High Bit	(0028,0102)	1	Most significant bit for each pixel sample. Each sample shall have the same high bit which shall be the Enumerated Value of 31.
Pixel Representation	(0028,0103)	1	Data representation of the pixel samples. Each sample shall have the same pixel representation. It shall use the following enumerated value: 0000H = unsigned integer
Dose Grid Geometry	(30xx,1150)	1	Geometry of the Dose Grid array. Specifies whether the dose grid planes form a cuboid or a sheared parallelepiped. Enumerated values: NON_SHEARED = planes of

			dose grid form a cuboid, i.e. a rectangular parallelepiped. SHEARED= successive planes of dose grid form a sheared parallelepiped. See C.AA.M2.1.2.
Source Image Sequence	(0008,2112)	1C	Reference to images from which the dose has been calculated. Required if Dose Data Source (30xx,1138) in the Enhanced RT Dose Module is PLANNED or RECORD. May be present otherwise. One or more Items shall be included in this sequence.
>Include 'Image SOP Instance Reference Macro' Table 10-3			

C.AA.M2.1 RT Dose Image Attribute Description

C.AA.M2.1.1 Image Type and Frame Type

Value 1 of Image Type (0008,0008) and Frame Type (0008,9007) shall be used as follows: Value 1 shall be DERIVED.

C.AA.M2.1.1.1 Patient Examination Characteristics

Value 2 of Image Type (0008,0008) and Frame Type (0008,9007) shall be used as follows: Value 2 shall be SECONDARY.

C.AA.M2.1.1.2 Image Flavor

Value 3 of Image Type (0008,0008) and Frame Type (0008,9007) is discussed in C.8.16.1.3. No additional requirements. The value shall be VOLUME.

C.AA.M2.1.1.3 Derived Pixel Contrast

Value 4 of Image Type (0008,0008) and Frame Type (0008,9007) is discussed in C.8.16.1.4. The value shall be NONE.

C.AA.M2.1.2 Dose Grid Geometry

If Dose Grid Geometry (30xx,1150) is NON_SHEARED, the Image Position (Patient) values of all frames are co-linear and lie along a vector normal to each of the planes. Mathematically, all dose grid frames shall be aligned such that the vector difference (Xm-Xn, Ym-Yn, Zm-Zn) of Image Position (Patient) vectors (Xm, Ym, Zm) and (Xn, Yn, Zn) in the Plane Position Functional Group of any pair of frames is proportional to the cross product of row and column direction cosine vectors specified by Image Orientation (Patient) in the Shared Plane Orientation Functional Group.

C.AA.M2.1.3 Dose Grid Real World Values

C.AA.M2.1.3.1 Dose Grid Scaling

The real world values of the dose grid shall be derived from the stored pixel values by scaling according to the Real World Intercept (0040,9224) and Real World Value Slope (0040,9225). See C.7.6.16.2.11.1.2.

C.AA.M2.1.3.2 Dose Grid Pixel Padding

Long Dose Grid Padding Value (0028,xxxx) is used to identify pixels for which dose grid values are not specified (see C.7.5.1.1.2). Applications consuming RT Dose Image instances shall handle pixel padding correctly to avoid misinterpreting the pixel padding as dose. In particular:

1. Long Dose Grid Padding Value (0028,xxxx) specifies a single value of this padding value.

2. The value of Long Pixel Padding Value (0028,xxxx) shall be valid values within the objectives defined by Bits Allocated (0028,0100) Bits Stored (0028,0101) and High Bit (0028,0102).

3. No points within the native dose grid shall have a value equal to pixel padding value. Values within the pixel padding range shall lie outside the range between the minimum and maximum values of valid dose values in the dose grid.

The applicable parts of section C.7.6.16.2.11.2 apply.

The tag Pixel Padding Value (0028,0120) shall not be used.

C.AA.M3 RT Dose Image Functional Group Macros

The following sections contain Functional Group macros specific to the RT Dose Image IOD.

Note: The attribute descriptions in the Functional Group Macros are written as if they were applicable to a single frame (i.e., the macro is part of the Per-frame Functional Groups Sequence). If an attribute is applicable to all frames (i.e. the macro is part of the Shared Functional Groups Sequence) the phrase "this frame" in the attribute description shall be interpreted to mean "for all frames".

C.AA.M3.1 RT Dose Image Frame Type Macro

Table C.AA.M3.1-1 specifies the attributes of the RT Dose Image Frame Type Functional Group macro.

Table C.AA.M3.1-1
RT DOSE IMAGE FRAME TYPE MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
RT Dose Image Frame Type Sequence	(30xx,1116)	1	Identifies the characteristics of this frame. Only a single Item shall be included in this sequence.
>Frame Type	(0008,9007)	1	Type of Frame. A multi-valued attribute analogous to the Image Type (0008,0008). Enumerated Values and Defined Terms are the same as those for the four values of the Image Type (0008,0008) attribute. See C.8.16.1 and C.AA.M2.1.

C.AA.M4 RT Dose Histogram Module

The RT Dose Histogram module provides for the inclusion of dose volume histogram (DVH), dose area histogram (DAH) and natural dose volume histogram (NDVH) data. Any combination of these dose histogram types may be contained within this module.

Table C.AA.M4-1
RT DOSE HISTOGRAM MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Dose Histogram Normalization Dose Value	(30xx,1201)	3	Nominal Dose Reference Value indicating prescribed dose.
Dose Histogram Sequence	(30xx,1202)	1	Dose Histograms. One or more Items shall be included in this sequence.
>Dose Histogram Referenced Segment Sequence	(30xx,1203)	1	Referenced anatomies used to calculate the Dose Histogram. See C.AA.M4.1.3. One or more Items shall be included in this sequence.
>>Include ' Conceptual Volume Segmentation Reference and Combination Macro' Table C.AA.2.6-1			*The value of Conceptual Volume Segmentation Defined Flag (30xx,1311) shall be YES.*
>Dose Histogram Type	(30xx,1210)	1	Type of Dose Histogram: Defined Terms: VOLUME = dose-volume histogram AREA = dose-area histogram
>Histogram Tally Type	(30xx,1205)	1	Method of tallying spatial quantity in constructing dose histogram Defined Terms: DIFFERENTIAL = differential dose histogram NATURAL = natural dose (volume) histogram
>Dose Histogram Dose Unit Code Sequence	(30xx,1207)	1	Units of measurement for the dose dimension of the histogram. Only a single Item shall be included in this sequence. See C.7.6.16.2.11.1 for further explanation.
>>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID SUP147065*
>Dose Histogram Spatial Unit Code Sequence	(30xx,1206)	1	Units of measurement for the spatial dimension of the histogram. Only a single Item shall be included in this sequence.

Attribute Name	Tag	Type	Attribute Description
>>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID SUP147039*
>Segment Total Size	(30xx,1209)	1	Total size of all segments referenced in Dose Histogram Referenced Segment Sequence (30xx,1203), in units of Dose Histogram Spatial Units (30xx,1206)
>Dose Histogram Data	(30xx,1204)	1	A data stream describing the dose bin widths D_n and associated volumes (or areas) V_n in Dose Histogram Spatial Units (3004,0054) in the order D_1V_1, D_2V_2, ... D_nV_n.
>Dose Statistics Sequence	(30xx,1211)	3	Dose statistics information. One or more Items are permitted in this sequence.
>>Include 'Content Item Macro' Table 10-2			*Defined CID of Concept Name Code Sequence is CID SUP147026.* *The Content Item shall have a Value Type (0040,A040) of NUMERIC.* *Content items shall use UCUM units of Gy where applicable.*
Source Image Sequence	(0008,2112)	2	Reference to RT Dose Image SOP instances from which the dose histogram has been calculated. Zero or more Items shall be included in this sequence.
>Include 'SOP Instance Reference Macro' Table 10-11			

C.AA.M4.1 RT Dose Histogram Attribute Description

C.AA.M4.1.1 Referenced Segmentation Properties Sequence

The Conceptual Volume Macro in the Dose Histogram Referenced Segment Sequence (30xx,1203) is used to specify the segments, or combinations of segments, used to compute Dose Histograms. Segments are defined in the RT Segment Annotation SOP Instance referenced by the Referenced RT Segment Annotation Sequence (30xx,0874) and are identified using their Conceptual Volume UID.

The geometry of segments represented in the referenced RT Segment Annotation SOP Instance may be defined in an RT Structure Set, Segmentation, or Surface Segmentation SOP Instance. Segments defined by an RT Structure Set SOP Instance shall contain only contours with a Contour Geometric Type (3006,0042) of CLOSED_PLANAR.

C.AA.M4.1.2 Dose Histogram Data

The RT Dose Histogram Module differs from the earlier RT DVH module in that the attribute Dose Histogram Data (30xx,1204) is encoded with VR of OF. In the earlier DVH Module, the corresponding DVH Data (3004,0058) was encoded with VR of DS, leading to attribute value length limitations when the dataset was encoded with ELE transfer syntax and there were many histogram bins.

The RT Dose Histogram Module differs from the earlier RT DVH module in that Dose Histogram Data (30xx,1204) attribute represents DIFFERENTIAL dose-volume or dose-area histograms, i.e., in the sequence of pairs, D_1V_1, D_2V_2, ... D_nV_n the Values V_i represent the volume (or area) of the referenced segment(s) receiving dose $< D_i$ and $\geq D_{i-1}$ for i>1 and dose ≥ 0 for i=1.

C.AA.M4.1.3 Dose Histogram Referenced Segment Sequence

The Dose Histogram Referenced Segment Sequence (30xx,1203) identifies Conceptual Volumes used to define the volume for calculation of the dose histograms. In this context, the Conceptual Volume shall be well-defined and point to the appropriate segment as identified by the Referenced Segment Annotation Index (30xx,0151) in the Conceptual Volume Segmentation Reference and Combination Macro (see section C.AA.2.6).

C.AA.M5 Dose Samples Module

The Dose Samples module provides for the inclusion of a list of spatial dose sample data.

Table C.AA.M5-1
DOSE SAMPLES MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Number of Dose Samples	(30xx,1250)	1	Number of sample values used to store Dose Samples Data (3004,1251).
Dose Samples Data	(30xx,1251)	1	A data stream describing locations of the dose samples X, Y, Z and associated dose values in the order $X_1Y_1Z_1D_1$, $X_2Y_2Z_2D_2$,, ... $X_nY_nZ_nD_n$.
Dose Samples Dose Unit Code Sequence	(30xx,1253)	1	Units of measurement for the dose dimension of the dose samples. Only a single Item shall be included in this sequence. See C.7.6.16.2.11.1 for further explanation.
>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID SUP147065.*
Source Image Sequence	(0008,2112)	1C	Reference to images from which the dose has been calculated. Required if Dose Data Source (30xx,1138) in the Enhanced RT Dose Module is PLANNED or RECORD. May be present otherwise. One or more Items shall be included in this sequence.
>Include 'Image SOP Instance Reference Macro' Table 10-3			

C.AA.M5.1 RT Dose Samples Attribute Description

C.AA.M5.1.1 Dose Samples Data

Dose Samples Module encodes a list of (x, y, z, dose) values with VR of OF. This VR avoids limitations in the VL specified using an Explicit-VR transfer syntax.

The Dose Samples Module represents N dose samples as a sequence of 4-tuples: $X_1Y_1Z_1D_1$, $X_2Y_2Z_2D_2$,, ... $X_NY_NZ_ND_N$. The Values X_i, Y_i, Z_i represent the location in patient coordinates of dose sample D_i, expressed in units specified by Dose Samples Dose Unit Code Sequence(30xx,1253).

Change the following in PS3.3, section C.7.5.1 General Equipment Module

C.7.5.1 General Equipment Module

…

Attribute Name	Tag	Type	Attribute Description
Pixel Padding Value	(0028,0120)	1C	Single pixel value or one limit (inclusive) of a range of pixel values used in an image to pad to rectangular format or to signal background that may be suppressed. See C.7.5.1.1.2 for further explanation. Required if Pixel Padding Range Limit (0028,0121) is present and either Pixel Data (7FE0,0010) or Pixel Data Provider URL (0028,7FE0) is present **and Bits Stored (0028,0101) is less or equal 16**. May be present otherwise only if Pixel Data (7FE0,0010) or Pixel Data Provider URL (0028,7FE0) is present. Notes: 1. The Value Representation of this Attribute is determined by the value of Pixel Representation (0028,0103). 2. This Attribute is not used in Presentation State Instances; there is no means in a Presentation State to "override" any Pixel Padding Value specified in the referenced images. 3. This Attribute does apply to RT Dose and Segmentation instances, since they include Pixel Data.

Long Pixel Padding Value	**(0028,xxxx)**	**1C**	**Pixel Padding Value, which shall be used instead of Pixel Padding Value (0028,0120), when this attribute ir present.** **Required, when the rules of Pixel Padding Value (0028,0120) apply and Bits Stored (0028,0101) is greater than 16.** **Otherwise, all specifications of Pixel Padding Value (0028,0120) apply.**

2 **Change the following in PS3.3, section C.7.6.3 Image Pixel Module**

C.7.6.3 Image Pixel Module

4

Attribute Name	Tag	Type	Attribute Description
Pixel Padding Range Limit	(0028,0121)	1C	Pixel value that represents one limit (inclusive) of a range of padding values used together with Pixel Padding Value (0028,0120) as defined in the General Equipment Module. See C.7.5.1.1.2 for further explanation. Required if pixel padding is to be defined as a range rather than a single value **and Bits Stored (0028,0101) is less or equal 16.** Notes: 1. The Value Representation of this Attribute is determined by the value of Pixel Representation (0028,0103). 2. Pixel Padding Value (0028,0120) is also required when this Attribute is present.

Long Pixel Padding Range Limit	**(0028,yyyy)**	**1C**	**Pixel Padding Value, which shall be used instead of Pixel Padding Value Range Limit (0028,0121), when this attribute ir present.** **Required, when the rules of Pixel Padding Value Range Limit (0028,0121) apply and Bits Stored (0028,0101) is greater than 16.** **Otherwise, all specifications of Pixel Padding Range Limit (0028,0121) apply.**

2

Part 4 Addendum

Add the following to PS3.4, Appendix B.5, Table B.5-1

SOP Class Name	SOP Class UID	IOD Spec (defined in PS 3.3)
RT Dose Image Storage	1.2.840.10008.5.1.4.1.1.481.XN.7.1	
RT Dose Histogram Storage	1.2.840.10008.5.1.4.1.1.481.XN.7.2	
RT Dose Samples Storage	1.2.840.10008.5.1.4.1.1.481.XN.7.3	

Add the following to PS3.4, Table I.4-1

2

Table I.4-1 Media Storage Standard SOP Classes

SOP Class Name	SOP Class UID	IOD Specification
RT Dose Image Storage	1.2.840.10008.5.1.4.1.1.481.XN.7.1	RT Dose Image
RT Dose Histogram Storage	1.2.840.10008.5.1.4.1.1.481.XN.7.2	RT Dose Histogram
RT Dose Samples Storage	1.2.840.10008.5.1.4.1.1.481.XN.7.3	RT Dose Samples

4

Add the following to PS3.4, Appendix Z.1.3, Table Z.1-1

Table Z.1-1

Attributes not to be Included in Instances Sent

Attribute	Tag
Dose Samples Data	(30xx,1251)
Dose Histogram Data	(30xx,1204)

Part 6 Addendum

Add the following data elements to PS3.6:

6 REGISTRY OF DICOM DATA ELEMENTS

[Editorial Note: The content of this chapter is currently only part of Supplement 147, rev. 43, where the table of attributes is already separted between those attributes that will be part of Supplement 147 and those that will be moved over to this document, once Supplement 147 is ready for Public comment.]

Add the following to PS3.6 Annex A:

ANNEX A REGISTRY OF DICOM UNIQUE IDENTIFIERS (UID) (NORMATIVE)

Table A-1
UID VALUES

UID Value	UID NAME	UID TYPE	Part
1.2.840.10008.5.1.4.1.1.481.XN.7.1	RT Dose Image Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.481.XN.7.2	RT Dose Histogram Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.481.XN.7.3	RT Dose Samples Storage	SOP Class	PS 3.4

Add the following data elements to PS3.6, Annex A:

Table A-3
CONTEXT GROUP UID VALUES

Context UID	Context Identifier	Context Group Name
1.2.840.10008.6.1.FFF.10	SUP147010	Beam Limiting Device Types
1.2.840.10008.6.1.FFF.11	SUP147011	Radiotherapy Robotic Paths
1.2.840.10008.6.1.FFF.14	SUP147014	Treatment RT Radiation Set Alteration Types
1.2.840.10008.6.1.FFF.15	SUP147015	Treatment Termination Reasons
1.2.840.10008.6.1.FFF.16	SUP147016	Compensator Device Types
1.2.840.10008.6.1.FFF.17	SUP147017	Radiotherapy Treatment Machine Modes
1.2.840.10008.6.1.FFF.18	SUP147018	Pre-Treatment RT Radiation Set Purpose
1.2.840.10008.6.1.FFF.20	SUP147020	Instance Reference Purposes
1.2.840.10008.6.1.FFF.21	SUP147021	Patient Setup Techniques
1.2.840.10008.6.1.FFF.23	SUP147023	Shielding Device Types
1.2.840.10008.6.1.FFF.24	SUP147024	Setup Devices
1.2.840.10008.6.1.FFF.26	SUP147026	Dose Statistics
1.2.840.10008.6.1.FFF.27	SUP147027	Fixed Beam Limiting Device Types
1.2.840.10008.6.1.FFF.28	SUP147028	Radiotherapy Wedge Types
1.2.840.10008.6.1.FFF.30	SUP147030	General Accessory Device Types
1.2.840.10008.6.1.FFF.35	SUP147035	Effective Dose Method Code Definition
1.2.840.10008.6.1.FFF.36	SUP147036	Purpose of Referenced Dose Calculation Annotation Object
1.2.840.10008.6.1.FFF.37	SUP147037	Dose Data Source Measurement Definition

1.2.840.10008.6.1.FFF.39	SUP147039	Dose Histogram Spatial Unit Definition
1.2.840.10008.6.1.FFF.41	SUP147041	Dose Algorithm Class
1.2.840.10008.6.1.FFF.43	SUP147043	RT Item States
1.2.840.10008.6.1.FFF.44	SUP147044	RT Operation States
1.2.840.10008.6.1.FFF.48	SUP147048	Revised value
1.2.840.10008.6.1.FFF.49	SUP147049	Radiotherapy General Workitem Definition
1.2.840.10008.6.1.FFF.50	SUP147050	Beam Mode Type Definition
1.2.840.10008.6.1.FFF.51	SUP147051	Delivery Rate Unit Definition
1.2.840.10008.6.1.FFF.54	SUP147054	Treatment Delivery Device Type
1.2.840.10008.6.1.FFF.55	SUP147055	Dosimeter Unit Definition
1.2.840.10008.6.1.FFF.56	SUP147056	Treatment Session Sign-Off
1.2.840.10008.6.1.FFF.65	SUP147065	Radiotherapy Dose Real World Units

2

Part 16 Addendum

2

Add the following new CIDs to PS3.16, Annex B:

[Editorial Note: The content of this chapter is currently only part of Supplement 147, rev. 43, where the CID tables are already separted between those that will be part of Supplement 147 and those that will be moved over to this document, once Supplement 147 is ready for Public comment.]

2

Add the following to the table in PS3.16, Annex D:

ANNEX D DICOM CONTROLLED TERMINOLOGY DEFINITIONS (NORMATIVE)

[Editorial Note: The content of this chapter is currently only part of Supplement 147, rev. 43, where the definitions are already separted between those that will be part of Supplement 147 and those that will be moved over to this document, once Supplement 147 is ready for Public comment.]