DICOM Correction Proposal

STATUS	Letter Ballot
Date of Last Update	2024/08/24
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Submission Date	2023/10/31

Correction Number	CP-2393
Log Summary: Update CT Scanning Length Definition	
Name of Standard PS3.16	

Rationale for Correction:

TID 10014 Scanning Length is a TID included as part of the CT RDSR (root TID 10011). It is called as part of the CT Irradiation Event details and is encoded with, at a minimum, the “length” of radiation along a line orthogonal to the plane of rotation and intersecting the isocenter.

At issue is that the DICOM standard provides conflicting information on how to populate this value, resulting in a discrepancy in encodings across a survey of vendors.

The content item description for Row 1 of TID 10014 (113825, DCM, “Scanning Length”) provides three scanning scenarios (helical, sequential, stationary/free) and some normative text for how to encode the value for each. Of note for this CP is for spiral scanning: “the scanning length is normally the table travel in mm during the tube loading (see Figure A-16).”

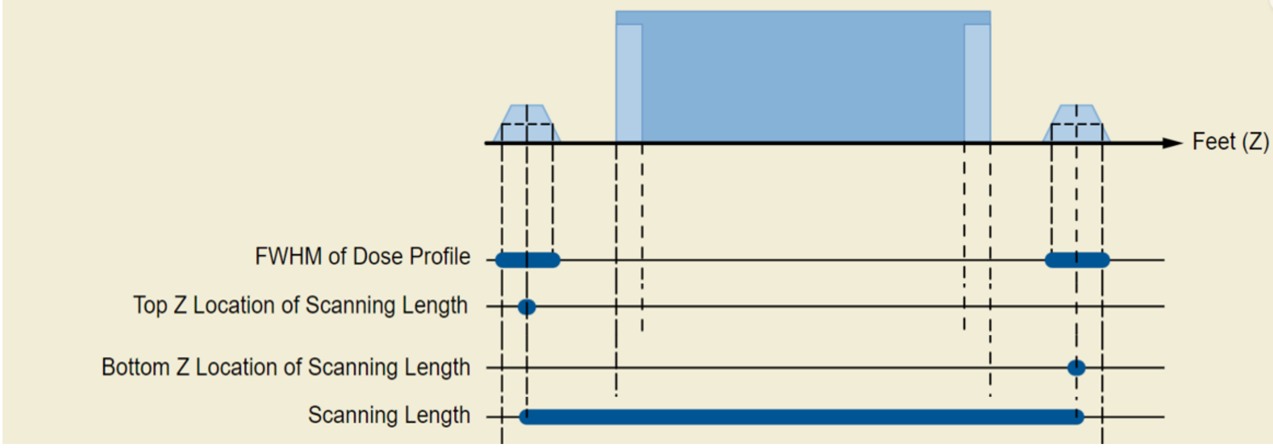
In another location (Table D-1), the definition for Scanning Length simply states:

“Length of the table travel during the entire tube loading, according to IEC 60601-2-44

> ***Note*** *Scanning Length might be longer than the programmed acquisition length (Length of Reconstructable Volume)*”

Note that for sequential and stationary/free scanning, there is no discussion of tube loading in the content item description in Row 1 of TID 10014. Nor is there a mention of how Scanning Length is defined in Table D-1 in these CT scanning modes. For sequential and stationary/free scanning modes, the normative text in the content item description for Row 1 of TID 10014 is mathematically equivalent to the definition of “L” in DLP according to the IEC.

Lastly, in the case of spiral scanning, the reader of the standard is referred to Figure A-16, where the Scanning Length appears to be described by the distance between the center of the leading dose profile to the center of the trailing dose profile along the Z-axis in the figure. Here is a trimmed version of the figure to show only the values of interest:



The different interpretations of how to encode this value amongst the vendors appears to be the result of a change in how the IEC has defined the "L" of DLP. More specifically, the latest version of IEC 60601-2-44 (Ed 3.2 2016-03) includes an additional information on "L" in the section describing DLP for helical scanning in 60601-2-44 201.3.214(b) (underlining added): "…where *L* is the table travel during the entire LOADING, adjusted for dynamic collimation modes if applicable." This adjustment for dynamic collimation causes the tube loading length to potentially be greater than the "L" of DLP.

The result of all this is that vendors are either populating Scanning Length with the non-adjusted tube loading length *or* the "L" of DLP. This CP aims to clarify the definition/content item description so that the same physical concept is encoded across all vendors.

While there may be concern over backward compatibility of this change, the current DICOM standard is inconsistent depending on where one looks, resulting in the need for correction. The correction also removes the reference to the IEC standard (which does not explicitly define the term "Scanning Length") to create a DICOM-specific definition that doesn't run the risk of changing in the event of IEC standard changes. The change is based on the additional footnote within the IEC standard on how to obtain "L" for DLP during sprial scanning by using the dose profile and should be readily achievable by all vendors. It is also based on the interpretation of the DICOM standard that Scanning Length is intended to be equal to the "L" of DLP based on the original IEC wording and corresponding DICOM wording. This is supported by the definition of DLP in Table D-1 and elsewhere, which states: "For Spiral scanning, DLP = CTDIvol × Scanning Length."

Regarding invalidation of existing implementations, this CP will only affect implementations where dynamic collimation is used but not accounted for in the Scanning Length encoding. Implementations for scanners without dynamic collimation will not be affect, nor will those implementations which already account for dynamic collimation. A survey of implementations shows that the majority of implementations where dynamic collimation is used already account for it when encoding Scanning Length in the RDSR. To address existing implementations where the effects of dynamic collimation are not accounted for in the encoding of Scanning Length, an additional note is included in the content item description to refer to historical IEC definitions.

For completion, this CP also includes an additional scan scenario where Scanning Length may be populated: shuttle mode. In this mode of scanning, the CT scanner "shuttles" between two axial locations. It may be thought of like two simultaneous stationary acquistions separated by some distance (described as "R" in the IEC standard). The corresponding CTDIvol and DLP definitions and content item descriptions are similarly modified to incorporate this mode, as well as to clean up the language to better match the IEC definitions.

Lastly, the definition and content item descriptions for the DLP calculation for sequential (axial) scanning is corrected from DLP = CTDIvol × NT × Total Exposure Time / Exposure Time per Rotation to DLP = CTDIvol × Table Travel Between Consecutive Scans × Number of Scans. The previous definition is erroneous in that it does not correctly calculate DLP when Table Travel between Scans ≠ NT.

All other changes should not invalidate existing implementations because vendors are using the IEC definitions of CTDI, DLP, etc. to calculate the values which are eventually encoded into the DICOM RDSR.

Correction Wording:

Modify PS3.16 as follows:

TID 10013 CT Irradiation Event Data

This Template conveys the dose and equipment parameters of a single irradiation event.

A CT irradiation event is the loading of X-Ray equipment caused by a single continuous actuation of the equipment's irradiation switch, from the start of the loading time of the first pulse until the loading time trailing edge of the final pulse. Any on-off switching of the radiation source during the event shall not be treated as separate events; rather the event includes the time between start and stop of radiation as triggered by the user, e.g., a single sequence of scanning comprised of multiple slices acquired with successive tube rotations and table increments shall be treated as a single irradiation event. Depending on the examination workflow and the anatomical target region the CT irradiation event data may split into multiple instances of this Template for better dose estimation. The irradiation event is the "smallest" information entity to be recorded in the realm of Radiation Dose reporting. Individual Irradiation Events are described by a set of accompanying physical parameters that are sufficient to understand the "quality" of irradiation that is being applied. This set of parameters may be different for the various types of equipment that are able to create irradiation events.

Type: Extensible
Order: Significant
Root: No

Table TID 10013. CT Irradiation Event Data

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			CONTAINER	EV (113819, DCM, "CT Acquisition")	1	M		
…								
21	>	CONTAINS	CONTAINER	EV (113829, DCM, "CT Dose")	1	MC	IF Row 4 does not equal (113805, DCM, "Constant Angle Acquisition")	
22	>>	CONTAINS	NUM	EV (113830, DCM, "Mean CTDIvol")	1	M		UNITS = EV (mGy, UCUM, "mGy")
23	>>	CONTAINS	CODE	EV (113835, DCM, "CTDIw Phantom Type")	1	M		DCID 4052 “Phantom Device”
24	>>	CONTAINS	NUM	EV (113836, DCM, "CTDIfreeair Calculation Factor")	1	U		UNITS = EV (mGy/mA.s, UCUM, "mGy/mA.s")
25	>>	CONTAINS	NUM	EV (113837, DCM, "Mean CTDIfreeair")	1	U		UNITS = EV (mGy, UCUM, "mGy")
26	>>	CONTAINS	NUM	EV (113838, DCM, "DLP")	1	M		UNITS = EV (mGy.cm, UCUM, "mGy.cm")
…								

Content Item Descriptions

…	
Row 21	CT Dose for one acquisition

Row 22	"Mean $CTDI_{vol}$" refers to the average value of the $CTDI_{vol}$ applied within this acquisition. $CTDI_{vol}$ is the volume $CTDI_{w}$, where $CTDI_{w}$ is the weighted computed tomography dose index 100 as defined in IEC 60601-2-44. For Sequenced and Spiral scanning, $CTDI_{vol}$ = $CTDI_{w}$ / Pitch Factor. For Stationary and Free scanning, $CTDI_{vol}$ = $CTDI_{w}$ × ~~**Cumulative Exposure Time/ Exposure Time Per Rotation**~~**Number of Rotations**. **For Shuttle Mode scanning, $CTDI_{vol}$ = $CTDI_{w}$ × Number of Rotations for Entire Scan Series × Nominal Total Collimation Width / (Nominal Total Collimation Width + Distance Between the Two Scan Positions)** According to IEC 60601-2-44 Ed 3 for Constant Angle Acquisition may be calculated as CTDIvol = (CTDIw / Current Time Product (mAs)) × X-Ray Tube Current (mA) x (Nominal Total Collimation Width (mm) / Table Speed (mm/s)). Note The ratio CTDIw / Current Time Product is evaluated independently of the Constant Angle Acquisition but with the same settings of tube voltage and Total Collimation Width as those of the Constant Angle Acquisition. See also CTDIvol (0018,9345) and Spiral Pitch Factor (0018,9311) in the "Enhanced CT Image IODs" in PS3.3.
Row 23	The type of phantom used for CTDI measurement according to IEC 60601-2-44(e.g., Head 16 cm diameter PMMA, Body 32 cm diameter PMMA).
Row 24	The $CTDI_{free\ air}$ Calculation Factor is the $CTDI_{free\ air}$ per mAs, expressed in units of mGy/mAs. The $CTDI_{free\ air}$ Calculation Factor may be used in one method calculating Dose. For example, for this acquisition, Effective Dose = Mean X-Ray Tube Current × Cumulative Exposure Time × $CTDI_{free\ air}$ Calculation Factor × (Effective Dose/ $CTDI_{free\ air}$).
Row 25	$MeanCTDI_{free\ air}$ is the mean CTDI for this acquisition, evaluated free-in-air according to IEC 60601-2-44. $MeanCTDI_{free\ air}$ = Mean X-Ray Tube Current × Cumulative Exposure Time × $CTDI_{free\ air}$ Calculation Factor. The $CTDI_{free\ air}$ may be used in one method of calculating Effective Dose.
Row 26	For Spiral scanning, DLP = $CTDI_{vol}$ × Scanning Length. For Sequenced scanning, DLP = $CTDI_{vol}$ × ~~**Nominal Total Collimation Width × Cumulative Exposure Time / Exposure Time per Rotation**~~ **Table Travel Between Consecutive Scans × Number of Scans**. For Stationary and Free scanning, DLP = $CTDI_{vol}$ × Nominal Total Collimation Width**. For Shuttle Mode scanning, DLP = $CTDI_{vol}$ × (Nominal Total Collimation Width + Distance Between the Two Scan Positions)** (according to IEC 60601-2-44).
…	

TID 10014 Scanning Length

Type: Extensible
Order: Significant
Root: No

Table TID 10014. Scanning Length

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			NUM	EV (113825, DCM, "Scanning Length")	1	M		UNITS = EV (mm, UCUM, "mm")

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
2			NUM	EV (113893, DCM, "Length of Reconstructable Volume")	1	U		UNITS = EV (mm, UCUM, "mm")
3			NUM	EV (113899, DCM, "Exposed Range")	1	UC	IFF TID 10013 “CT Irradiation Event Data” Row 4 CT Acquisition Type equals (116152004, SCT, "Spiral Acquisition")	UNITS = EV (mm, UCUM, "mm")
4			NUM	EV (113895, DCM, "Top Z Location of Reconstructable Volume")	1	U		UNITS = EV (mm, UCUM, "mm")
5			NUM	EV (113896, DCM, "Bottom Z Location of Reconstructable Volume")	1	U		UNITS = EV (mm, UCUM, "mm")
6			NUM	EV (113897, DCM, "Top Z Location of Scanning Length")	1	U		UNITS = EV (mm, UCUM, "mm")
7			NUM	EV (113898, DCM, "Bottom Z Location of Scanning Length")	1	U		UNITS = EV (mm, UCUM, "mm")
8			UIDREF	EV (112227, DCM, "Frame of Reference UID")	1	MC	IF any of Rows 4 through 7 or Row 34e of TID 10013 are present.	If present, shall be the same UID as in the images reconstructed from this irradiation event.

Content Item Descriptions

Row 1	For Spiral scanning, the scanning length is ~~normally~~ the table travel in mm during the tube loading**, adjusted for dynamic collimation if applicable** (see Figure A-16). **In the case of Spiral scanning with dynamic collimation, one may approximate the scanning length as the FWHM along a line perpendicular to the tomographic plane at isocenter of the free-in-air dose profile for the entire scan.** **Note** **IEC 60601-2-44 (Ed 3.2 2016-03) includes an adjustment for dynamic collimation when determining scanning length for DLP calculation in Spiral scanning. Previous versions of this IEC standard do not include this adjustment. For those scanners using dynamic collation which used previous versions of the IEC standard, the reported Scanning Length may not be adjusted for dynamic collimation.** For Sequenced scanning, the scanning length is the table travel between consecutive scans times the number of scans. For Stationary and Free scanning, the scanning length is the nominal width of the total collimation. **For Shuttle Mode scanning, the scanning length is the nominal width of the total collimation plus the distance between the two scan positions.**
Row 2	The length of the reconstructable volume is the maximum z-range between the outermost edges of the top and bottom slices that can be reconstructed from the acquisition. For Spiral scanning, the length of reconstructable volume is the z-range between the outermost beginning of the first reconstructable slice and the outermost end of the last reconstructable slice (see Figure A-16).

	For Sequenced scanning, the length of reconstructable volume is the z-range between the outermost beginning of the first slice and the outermost end of the last slice (i.e., including any skip). For Stationary and Free scanning, the length of reconstructable volume is the ~~nominal width of the total collimation~~ **<u>z-range between the outermost beginning of the first reconstructable slice and the outermost end of the last reconstructable slice</u>**.
Row 3	For Spiral scanning, the exposed range is as defined in IEC 60601-2-44 (Ed. 3) 302.115(b) (see Figure A-16). Exposed range is not defined for other modes of scanning.
Rows 4, 5	The Top and Bottom Z Locations of the Reconstructable Volume are independent of the slice width of any actual reconstructed slices. They are measured from the edges of the volume, and hence are not equal to the Z locations encoded in the images of any actual reconstructed slices, which are recorded as the center of the slice.
Rows 4-7	These locations are patient (not table or gantry) relative, to allow them to be defined in the Patient Coordinate System and hence related to the Image Position (Patient) in the reconstructed images. They are also defined in terms of the top (towards the patient's head), and bottom (towards the patient's feet) of the corresponding ranges, in order to make them independent of whether the scan starts at the top or the bottom or shuttles back and forth in between (see Figure A-16).

Modify PS3.16 as follows:

TID 10042 Irradiation Event Summary Data

This template documents irradiation event-level summary data.

Type: **Extensible**
Order: **Non-Significant**
Root: **No**

Table TID 10042. Irradiation Event Summary Data

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			CONTAINER	EV (130501, DCM, "Irradiation Event Summary Data")	1	M		
…								
27	>	CONTAINS	CONTAINER	EV (113829, DCM, "CT Dose")	1	U		
28	>>	CONTAINS	NUM	EV (113830, DCM, "Mean CTDIvol")	1	M		UNITS = EV (mGy, UCUM, "mGy")
29	>>	CONTAINS	CODE	EV (113835, DCM, "CTDIw Phantom Type")	1	M		DCID 4052 “Phantom Device”
30	>>	CONTAINS	NUM	EV (113836, DCM, "CTDIfreeair Calculation Factor")	1	U		UNITS = EV (mGy/mA.s, UCUM, "mGy/mA.s")
31	>>	CONTAINS	NUM	EV (113837, DCM, "Mean CTDIfreeair")	1	U		UNITS = EV (mGy, UCUM, "mGy")

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
32	>>	CONTAINS	NUM	EV (113838, DCM, "DLP")	1	M		UNITS = EV (mGy.cm, UCUM, "mGy.cm")
…								

Content Item Descriptions

…	
Row 27	CT Dose for one acquisition.
Row 28	"Mean $CTDI_{vol}$" refers to the average value of the $CTDI_{vol}$ applied within this acquisition. $CTDI_{vol}$ is the volume $CTDI_{w}$, where $CTDI_{w}$ is the weighted computed tomography dose index 100 as defined in IEC 60601-2-44. For Sequenced and Spiral scanning, $CTDI_{vol}$ = $CTDI_{w}$ / Pitch Factor. For Stationary and Free scanning, $CTDI_{vol}$ = $CTDI_{w}$ × ~~**Cumulative Exposure Time/ Exposure Time Per Rotation**~~**Number of Rotations**. **For Shuttle Mode scanning, $CTDI_{vol}$ = $CTDI_{w}$ × Number of Rotations for Entire Scan Series × Nominal Total Collimation Width / (Nominal Total Collimation Width + Distance Between the Two Scan Positions)** According to IEC 60601-2-44 Ed 3 for Constant Angle Acquisition may be calculated as CTDIvol = (CTDIw / Current Time Product (mAs)) × X-Ray Tube Current (mA) x (Nominal Total Collimation Width (mm) / Table Speed (mm/s)). Note The ratio CTDIw / Current Time Product is evaluated independently of the Constant Angle Acquisition but with the same settings of tube voltage and Total Collimation Width as those of the Constant Angle Acquisition. See also CTDIvol (0018,9345) and Spiral Pitch Factor (0018,9311) in the “Enhanced CT Image IODs” in PS3.3.
Row 29	The type of phantom used for CTDI measurement according to IEC 60601-2-44 (e.g., Head 16 cm diameter PMMA, Body 32 cm diameter PMMA).
Row 30	The $CTDI_{free}air$ Calculation Factor is the $CTDI_{free}air$ per mAs, expressed in units of mGy/mAs. The $CTDI_{free}air$ Calculation Factor may be used in one method calculating Dose. For example, for this acquisition, Effective Dose = Mean X-Ray Tube Current × Cumulative Exposure Time × $CTDI_{free}air$ Calculation Factor × (Effective Dose/ $CTDI_{free}air$).
Row 31	$MeanCTDI_{free}air$ is the mean CTDI for this acquisition, evaluated free-in-air according to IEC 60601-2-44. $MeanCTDI_{free}air$ = Mean X-Ray Tube Current × Cumulative Exposure Time × $CTDI_{free}air$ Calculation Factor. The $CTDI_{free}air$ may be used in one method of calculating Effective Dose.
Row 32	For Spiral scanning, DLP = $CTDI_{vol}$ × Scanning Length. For Sequenced scanning, DLP = $CTDI_{vol}$ × ~~**Nominal Total Collimation Width × Cumulative Exposure Time / Exposure Time per Rotation**~~ **Table Travel Between Consecutive Scans × Number of Scans**. For Stationary and Free scanning, DLP = $CTDI_{vol}$ × Nominal Total Collimation Width**. For Shuttle Mode scanning, DLP = $CTDI_{vol}$ × (Nominal Total Collimation Width + Distance Between the Two Scan Positions)** (according to IEC 60601-2-44).
…	

Modify PS3.16 as follows:

D DICOM Controlled Terminology Definitions (Normative)

This Annex specifies the meanings of codes defined in DICOM, either explicitly or by reference to another part of DICOM or an external reference document or standard.

The contents of this table are available in OWL, XRDF and CSV format at ftp://medical.nema.org/medical/dicom/resources/ontology/dcm/dcm.owl and in Bioportal.

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

Code Value	Code Meaning	Definition	Notes
…	…	…	…
113825	Scanning Length	~~**Length of the table travel during the entire tube loading, according to IEC 60601-2-44**~~ **For Spiral scanning, the scanning length is the table travel in mm during the tube loading, adjusted for dynamic collimation if applicable. In the case of Spiral scanning with dynamic collimation, one may approximate scanning length as the FWHM along a line perpendicular to the tomographic plane at isocenter of the free-in-air dose profile for the entire scan.** **For Sequenced scanning, the scanning length is the table travel between consecutive scans times the number of scans.** **For Stationary and Free scanning, the scanning length is the nominal width of the total collimation.** **For Shuttle Mode scanning, the scanning length is the nominal width of the total collimation plus the distance between the two scanning positions.** Note Scanning Length might be longer than the programmed acquisition length (Length of Reconstructable	

Code Value	Code Meaning	Definition	Notes
		Volume)	
…	…	…	…
113838	DLP	Dose Length Product (DLP), expressed in mGy-cm, is an index characterizing the product of the CTDIvol and the length scanned. For Spiral scanning, DLP = CTDIvol × Scanning Length. For Sequenced scanning, DLP = $CTDI_{vol}$ × ~~**Nominal Total Collimation Width × Cumulative Exposure Time / Exposure Time per Rotation**~~ **Table Travel Between Consecutive Scans × Number of Scans**. For Stationary and Free scanning, DLP = CTDIvol × Nominal Total Collimation Width. **For Shuttle Mode scanning, DLP = CTDIvol × (Nominal Total Collimation Width + Distance Between the Two Scan Positions)**	
…	…	…	…
113893	Length of Reconstructable Volume	The length from which images may be reconstructed (i.e., excluding any overranging performed in a spiral acquisition that is required for data interpolation). Value is distinct from (1113825, DCM, "Scanning Length"), which **includes any overranging and any effects from dynamic collimation.**~~**is the actual length of the table travel during the entire tube loading, according to IEC 60601-2-44, and includes overranging.**~~ Also distinct from any actual Reconstructed Volume, which may depend on the slice thickness chosen for a particular reconstruction.	