Digital Imaging and Communications in Medicine (DICOM)

Supplement 181: Tractography Results Storage SOP Class

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Table of Contents

Scope and Field

This Supplement to the DICOM Standard specifies a new DICOM Information Object for storing tractography results (tracks and measurements), which is referred to as Tractography Results IOD. Tractography results are usually calculated based on magnetic resonance diffusion tractography (MR DT). It also includes the corresponding Storage SOP Classes so that this IOD can be used for network and media storage exchanges.

A tracking algorithm produces tracks (i.e. fibers), which are collected into track sets. A track contains the set of x, y and z coordinates of each point making up the track. Depending upon the algorithm and software used, additional quantities like Fractional Anisotropy (FA) values or color etc. may be associated with the data, by track set, track or point, either to facilitate further filtering or for clinical use. Descriptive statistics of quantities like FA may be associated with the data by track set or track.

Examples of tractography applications include:

- Visualization of white matter tracks to aid in resection planning or to support image guided (neuro)surgery;
- Determination of proximity and/or displacement versus infiltration of white matter by tumor processes;
- Assessment of white matter health in neurodegenerative disorders, both axonal and myelin integrity, through sampling of derived diffusion parameters along the white matter tracks.

DICOM PS 3.2 Conformance

Item: Add SOP Class to Table A.1-2

Table A.1-2
UID VALUES

UID Value	UID NAME	Category
…		
1.2.840.10008.5.1.4.1.1.66.6	**Tractography Results Storage**	**Transfer**
…		

DICOM PS 3.3: Information Object Definitions

Item: Change Figure 7-1a. DICOM Model of the Real World:

Add “Tractography Results” to be contained in the Series.

Item: Change Figure A.1-1 DICOM Composite Instance IOD Information Model:

Add “Tractography Results” to the same level as Surface.

Item: Add the following new Section in A.1.2

A.1.2.X Tractography Results IE

The Tractography Results IE defines the attributes that describe the results of a tractography application.

Note: The term tractogram is not used because it does not include all types of tractography results.

Item: Add in Section A.1.4, rows and column to Table A.1-2

A.1.4 Overview of the Composite IOD Module Content

IODs Modules	**Tract Res**
Patient	**M**
Specimen	**U**
Clinical Trial Subject	**U**
General Study	**M**
Patient Study	**U**
Clinical Trial Study	**U**
General Series	M
Tractography Results Series	**M**
Clinical Trial Series	**U**
Frame of Reference	**M**
Tractography Results	**M**
General Equipment	**M**
Enhanced General Equipment	**M**
Common Instance Reference	**M**
SOP Common	**M**

Item: Add in the following new section in Annex A

A.X TRACTOGRAPHY RESULTS IOD

A.X.1 Tractography Results IOD Description

The Tractography Results IOD encodes tractography results into a collection of track sets. A track set collects a set of tracks containing the set of x, y and z coordinates of each point making up the track. Additional quantities like Fractional Anisotropy values, color, descriptive statistical values, etc. may be associated with track set, track or point.

A.X.2 Tractography Results IOD Entity-Relationship Model

The E-R Model in Section A.1.2 depicts those components of the DICOM Information Model that directly reference the Tractography Results IOD.

A.X.3 Tractography Results IOD Module Table

Table A.X-1. Tractography Results IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Specimen	C.7.1.2	U
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Tractography Results Series	C.8.X.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Tractography Results	Tractography Results	C.8.X.2	M
	Common Instance Reference	C.12.2	M
	SOP Common	C.12.1	M

Item: Add in the following new sections in C

C.8.X Tractography Results Modules

This Section describes Tractography Results Modules.

C.8.X.1 Tractography Results Series Module

Table C.8.X-1 specifies the Attributes that identify and describe general information about a Tractography Results Series.

Table C.8.X-1
TRACTOGRAPHY RESULTS SERIES MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of equipment that originally acquired the data used to create the instances in this Series. Enumerated Values: **MR** See Section C.7.3.1.1.1 for further explanation.
Series Number	(0020,0011)	1	A number that identifies this Series.
Referenced Performed Procedure Step Sequence	(0008,1111)	1C	Uniquely identifies the Performed Procedure Step SOP Instance to which the Series is related. Only a single Item shall be included in this Sequence. Required if a Performed Procedure Step SOP Class was involved in the creation of this Series.
>Include Table 10-11 “SOP Instance Reference Macro Attributes”			

C.8.X.2 Tractography Results Module

Table C.8.X-2 specifies the Attributes that describe the tracks and measurements in the tractography results.

Table C.8.X-2
TRACTOGRAPHY RESULTS MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Include Table 10-12 “Content Identification Macro Attributes”			
Content Date	(0008,0023)	1	The date the content creation started.
Content Time	(0008,0033)	1	The time the content creation started.
Track Set Sequence	(0066,0101)	1	Describes the track sets that are contained within the data. One or more Items shall be included in this sequence.
>Track Set Number	(0066,0105)	1	Identification number of the Track Set. Uniquely identifies a track set within this SOP instance. Shall start at a value of 1, and increase monotonically by 1.

>Track Set Label	(0066,0106)	1	User-defined label identifying this Track Set. This may be the same as Code Meaning (0008,0104) of Track Set Anatomical Type Code Sequence (0066,0108).
>Track Set Description	(0066,0107)	3	User-defined description for this Track Set.
>Track Set Anatomical Type Code Sequence	(0066,0108)	1	Sequence defining the specific property type of this Track Set. Only a single item shall be included in this sequence.
>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*Baseline CID 7710 “Tractography Anatomic Sites”.*
>> Modifier Code Sequence	(0040,A195)	3	A sequence of items modifying or specializing the Track Set Anatomical Type Code Sequence. One or more Items shall be included in this sequence.
>>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*Baseline CID 244 “Laterality”.*
>Track Sequence	(0066,0102)	1	Describes individual tracks part of the track set. One or more Items shall be included in this sequence.
>>Point Coordinates Data	(0066,0016)	1	Contains two or more point coordinates that define the track, encoded in x-y-z order, in mm in the patient-based coordinate system associated with the Frame of Reference. The order of the encoded points is from the first point to the last point of the track. When referencing points in Point Coordinates Data (0066,0016) the index of the first point x,y,z triplet is 1 See section C.27.2.1.1.
>>Recommended Display CIELab Value List	(0066,0103)	1C	Default triplet values in which it is recommended that the point shall be rendered. The units are specified in PCS-Values and the value is encoded as CIELab. See Section C.10.7.1.1. The number of triplets shall match the number of points stored in Point Coordinates Data (0066, 0016), and be encoded in the same order so as to correspond. Required if Recommended Display CIELab Value (0062, 000D) is not present in this Sequence Item nor in the containing Track Set Sequence (0066,0101) Item.

>>Recommended Display CIELab Value	(0062,000D)	1C	Default triplet value in which it is recommended that the track shall be rendered. The units are specified in PCS-Values and the value is encoded as CIELab. See Section C.10.7.1.1. Required if Recommended Display CIELab Value List (0066,0103) is not present in this Sequence Item and Recommended Display CIELab Value (0062, 000D) is not present in the containing Track Set Sequence (0066,0101) Item.
>Recommended Display CIELab Value	(0062,000D)	1C	Default triplet value in which it is recommended that the track set be rendered. The units are specified in PCS-Values, and the value is encoded as CIELab. See Section C.10.7.1.1. Required if neither Recommended Display CIELab Value (0062, 000D) nor Recommended Display CIELab Value List (0066,0103) are present in every Item of the Track Sequence (0066,0102).
>Recommended Line Thickness	(0066,0038)	3	Specifies the thickness of each track in the track set with which it is recommended to be rendered. The units shall be the same as the units of the coordinate system in which the point coordinates are specified.
>Measurements Sequence	(0066,0121)	3	Measurements for some or all points along the tracks. Each Item describes one type of measurement. See section C.8.X.2.1 for more details. One or more Items shall be included in this sequence.
>>Concept Name Code Sequence	(0040,A043)	1	Defines the type of measurement stored in this Item. Only a single item shall be included in this sequence.
>>>Include Table 8.8-1 "Code Sequence Macro Attributes"			*Defined CID 7263 "Diffusion Tractography Measurement Types"*
>>Measurement Units Code Sequence	(0040,08EA)	1	Units of measurement for the value in this item. Only a single item shall be included in this sequence.
>>>Include Table 8.8-1 "Code Sequence Macro Attributes"			*Defined CID 82 "Units of Measurement".*
>>Measurement Values Sequence	(0066,0132)	1	The measurement values for each track. The number and order of items shall equal the items in Track Sequence (0066,0102).

>>>Floating Point Values	(0066,0125)	1	Measurement values for points stored in Point Coordinates Data (0066, 0016) of the corresponding track in Track Sequence (0066,0102). If Track Point Index List (0066,0129) is absent, measurement values are stored for every point in Point Coordinates Data (0066,0016) and the number of values shall match the number and order of points stored in Point Coordinates Data (0066, 0016). If Track Point Index List (0066,0129) is present, measurement values are stored for a subset of points in Point Coordinates Data (0066, 0016) and the number of values shall match the number and order of point indices in Track Point Index List (0066,0129). See section C.8.X.2.1
>>>Track Point Index List	(0066,0129)	1C	List of indices referencing points stored in Point Coordinates Data (0066,0016) within the corresponding track for which measurement values shall be stored. Required if Measurement Values stored in Floating Point Values (0066,0125) shall be associated to only a subset of points in Point Coordinates Data (0066,0016). See section C.8.X.2.1
>Track Statistics Sequence	(0066,0130)	3	One statistic for one data value per track in the Track Sequence (0066,0102). See section C.8.X.2.1 for more details. One or more Items shall be included in this sequence.
>>Concept Name Code Sequence	(0040,A043)	1	The value (quantity) for which the statistic is a summary. Only a single item shall be included in this sequence.
>>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*Defined CID 7263 ”Diffusion Tractography Measurement Types”*
>>Modifier Code Sequence	(0040,A195)	1	Specified the statistic and modifies the Concept Name Code Sequence (0040,A0143) of this Sequence Item. Only a single item shall be included in this sequence.
>>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*Defined CID 7464 “General Region of Interest Measurement Modifiers”*
>>Measurement Units Code Sequence	(0040,08EA)	1	Units of measurement for the statistic. Only a single item shall be included in this sequence.
>>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*Defined CID 82 “Units of Measurement”.*

>>Floating Point Values	(0066,0125)	1	A value per track in the Track Sequence (0066,0102). The number and order of values shall equal the items in the Track Sequence (0066,0102).
>Track Set Statistics Sequence	(0066,0124)	3	Statistics derived from the values for this Track Set. One or more Items shall be included in this sequence.
>>Include Table C8.X-2 “Summary Statistics Macro Attributes”			*Defined CID for Concept Name Code Sequence (0040,A043) is CID 7263 ”Diffusion Tractography Measurement Types”*
>Diffusion Acquisition Code Sequence	(0066,0133)	3	The diffusion acquisition (including post-processing) used to derive this track set. See section C.8.X.2.2 for more details. Only a single item shall be included in this sequence.
>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*Defined CID 7260 ”Diffusion Acquisition Value Types”*
>Diffusion Model Code Sequence	(0066,0134)	1	The diffusion model used to derive this track set. See section C.8.X.2.2 for more details. Only a single item shall be included in this sequence.
>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*Defined CID 7261 ”Diffusion Model Value Types”*
>Tracking Algorithm Identification Sequence	(0066,0104)	1	The tractography algorithms used to derive this track set. See section C.8.X.2.2 for more details. One or more items shall be included in this sequence.
>>Include Table 10-19 “Algorithm Identification Macro Attributes”			*For Algorithm Family Code Sequence (0066,002F) Defined CID 7262 “Diffusion Tractography Algorithm Families”.*
Referenced Instance Sequence	(0008,114A)	1	The set of images used for tractography for all Track Sets within this Instance. One or more items shall be included in this Sequence.
>Include Table 10-3 “Image SOP Instance Reference Macro Attributes”			

C.8.X.2.1 Tractography Results Module Attributes

This module encodes one or more Track Sets, each of which consists of one or more Tracks, each of which is defined by one or more points. For each Track, optionally one or more measurements may be defined, either for every point or a subset of points. Measurements are described by coded type and unit. For each Track and/or Track Set, summary statistics derived from measurements may be included (whether or not the actual measurements are encoded).

When a measurement (i.e. a sequence item of Measurements Sequence (0066,0121)) is encoded for every point in a track, then Floating Point Values (0066,0125) contains the corresponding values for every point. When a measurement is encoded for a subset of points, then Floating Point Values (0066,0125) contains measurement values for the points in Point Coordinates Data (0066,0016) which are referenced in Track Point Index List (0066,0129).

More than one Measurements Sequence (0066,0121) Item may be used, for example to encode different types of measurements, such as Fractional Anisotropy (FA) and Apparent Diffusion Coefficient (ADC), or to encode different components of a measurement that is a tuple, e.g. a diffusion tensor. In the latter case, which component, and which tensor, will be identified by the fully pre-coordinated code in the Concept Name Code Sequence (0040,A043).

Within one Track Set the different types of measurements or statistics must be the same for all Tracks within that set (i.e. it is not allowed to store one track to a set that does not contain a measurement of a specific type in case all other tracks within that set do).

C.8.X.2.2 Acquisition, Model and Algorithm Attributes

The attributes Diffusion Acquisition Code Sequence (0066,0133), Diffusion Model Code Sequence (0066,0134) and Tracking Algorithm Identification Sequence (0066,0104) describe the main parameters influencing the tractography calculation. They are for documentation purposes. With these parameters, a receiver may infer an assessment of the reliability or quality of the tractography result.

C.8.X.3 Summary Statistics Macro

This Macro encodes summary statistics derived from a set of values.

Table Table C.8.X-3
Summary Statistics Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Concept Name Code Sequence	(0040,A043)	1	The value (quantity) for which the statistic is a summary. Only a single item shall be included in this sequence.
>Include Table 8.8-1 "Code Sequence Macro Attributes"			*CID defined by invocation*
Modifier Code Sequence	(0040,A195)	1	Specified the statistic and modifies the Concept Name Code Sequence (0040,A0143) of this macro. Only a single item shall be included in this sequence.
>Include Table 8.8-1 "Code Sequence Macro Attributes"			*Defined CID 7464 "General Region of Interest Measurement Modifiers"*
Measurement Units Code Sequence	(0040,08EA)	1	Units of measurement for the statistic. Only a single item shall be included in this sequence.
>Include Table 8.8-1 "Code Sequence Macro Attributes"			*Defined CID 82 "Units of Measurement".*
Floating Point Value	(0040,A161)	1	The value of the statistic.

Attribute Name	Tag	Type	Attribute Description
			Only a single value shall be present.

Amend DICOM PS 3.3 Annex F.3.2.2 Directory Information Module:

Table F.3-3. Directory Information Module Attributes

Attribute Name	Tag	Type	Attribute Description
…	…	…	…
>Directory Record Type	(0004,1430)	1	… Enumerated Values: … **TRACT** …

Amend DICOM PS 3.3 F.4 Basic Directory IOD Information Model as follows:

Table F.4-1. Relationship Between Directory Records

Directory Record Type	Section	Directory Record Types that may be included in the next lower-level directory Entity
(Root Directory Entity)		PATIENT, HANGING PROTOCOL, PALETTE, IMPLANT, IMPLANT ASSY, IMPLANT GROUP, PRIVATE
PATIENT	F.5.1	STUDY, HL7 STRUC DOC, PRIVATE
STUDY	F.5.2	SERIES, PRIVATE
SERIES	F.5.3	IMAGE, RT DOSE, RT STRUCTURE SET, RT PLAN, RT TREAT RECORD, PRESENTATION, WAVEFORM, SR DOCUMENT, KEY OBJECT DOC, SPECTROSCOPY, RAW DATA, REGISTRATION, FIDUCIAL, ENCAP DOC, VALUE MAP, STEREOMETRIC, PLAN, MEASUREMENT, SURFACE, **TRACT,** PRIVATE
…	…	…
SURFACE	F.5.42	PRIVATE
SURFACE SCAN	F.5.43	PRIVATE
TRACT	**F.5.XX**	**PRIVATE**

Directory Record Type	Section	Directory Record Types that may be included in the next lower-level directory Entity
…	…	…

Item: Change Figure F.4-1 Basic Directory IOD Information Model:

Add “Tractography DR” to the same level as Surface Scan.

Item: Add in the following new sections in F.5

F.5.XX Tractography Results Directory Record Definition

The Directory Record is based on the specification of Section F.3. It is identified by a Directory Record Type of Value "TRACT". Table F.5-42 lists the set of keys with their associated Types for such a Directory Record Type. The description of these keys may be found in the Modules related to the Tractography Results IE of the Tractography Results IOD. This Directory Record shall be used to reference a Tractography Results SOP Instance. This type of Directory Record may reference a Lower-Level Directory Entity that includes one or more Directory Records as defined in Table F.4-1.

Table F.5-42. Tractography Results Keys

Key	Tag	Type	Attribute Description
Specific Character Set	(0008,0005)	1C	Required if an extended or replacement character set is used in one of the keys.
Content Date	(0008,0023)	1	The date the content creation started.
Content Time	(0008,0033)	1	The time the content creation started.
Include Table 10-12 “Content Identification Macro Attributes”			
Any other Attribute of the Tractography Results IE Modules		3	

Note

Because (0004,1511) Referenced SOP Instance UID in File may be used as a "pseudo" Directory Record Key (see Table F.3-3), it is not duplicated in this list of keys.

DICOM PS3.4: Service Class Specifications

Amend DICOM PS 3.4 Annex B.5 Standard SOP Classes as follows:

Table B.5-1. Standard SOP Classes

SOP Class Name	SOP Class UID	IOD Specification (defined in PS3.3)
…	…	…
Surface Segmentation Storage	1.2.840.10008.5.1.4.1.1.66.5	Surface Segmentation IOD
Tractography Results Storage	**1.2.840.10008.5.1.4.1.1.66.6**	**Tractography Results IOD**
…	…	…

Amend DICOM PS 3.4 Annex I.4 Media Storage Standard SOP Classes as follows:

Table I.4-1. Media Storage Standard SOP Classes

SOP Class Name	SOP Class UID	IOD Specification (defined in PS3.3)
…	…	…
Surface Segmentation Storage	1.2.840.10008.5.1.4.1.1.66.5	Surface Segmentation IOD
Tractography Results Storage	**1.2.840.10008.5.1.4.1.1.66.6**	**Tractography Results IOD**
…	…	…

DICOM PS3.5: Data Structures and Encoding

Amend DICOM PS 3.5 – Section 6 – Value Encoding as follows:

6.2 Value Representation (VR)

...

All new VRs defined in future versions of DICOM shall be of the same Data Element Structure as defined in Section 7.1.2 (i.e., following the format for VRs such as OB**, OL**, OW, SQ and UN).

...

Table 6.2-1. DICOM Value Representations

VR Name	Definition	Character Repertoire	Length of Value
...	...	...	...
OB Other Byte ~~**String**~~	A string of bytes where the encoding of the contents is specified by the negotiated Transfer Syntax. OB is a VR that is insensitive to Little/Big Endian byte ordering (see Section 7.3). The string of bytes shall be padded with a single trailing NULL byte value (00H) when necessary to achieve even length.	not applicable	see Transfer Syntax definition
OD Other Double ~~**String**~~	A string of 64-bit IEEE 754:1985 floating point words. OD is a VR that requires byte swapping within each 64-bit word when changing between Little Endian and Big Endian byte ordering (see Section 7.3).	not applicable	2^{32}-8 bytes maximum
OF Other Float ~~**String**~~	A string of 32-bit IEEE 754:1985 floating point words. OF is a VR that requires byte swapping within each 32-bit word when changing between Little Endian and Big Endian byte ordering (see Section 7.3).	not applicable	2^{32}-4 bytes maximum
OL **Other Long**	**A string of 32-bit words where the encoding of the contents is specified by the negotiated Transfer Syntax. OL is a VR that requires byte swapping within each word when changing**	**not applicable**	**see Transfer Syntax definition**

VR Name	Definition	Character Repertoire	Length of Value
	between Little Endian and Big Endian byte ordering (see Section 7.3).		
OW Other Word ~~**String**~~	A string of 16-bit words where the encoding of the contents is specified by the negotiated Transfer Syntax. OW is a VR that requires byte swapping within each word when changing between Little Endian and Big Endian byte ordering (see Section 7.3).	not applicable	see Transfer Syntax definition
...	...	...	...
UL Unsigned Long	Unsigned binary integer 32 bits long. Represents an integer n in the range: $0 <= n < 2^{32}$.	not applicable	4 bytes fixed
...	...	...	...

...

6.4 Value Multiplicity (VM) and Delimitation

...

Data Elements with a VR of SQ, OF, OD, **OL,** OW, OB, UN or UR shall always have a Value Multiplicity of one.

...

Amend DICOM PS 3.5 – Section 7 – The Data Set as follows:

7.1.2 Data Element Structure with Explicit VR

When using the Explicit VR structures, the Data Element shall be constructed of four consecutive fields: Data Element Tag, VR, Value Length, and Value. Depending on the VR of the Data Element, the Data Element will be structured in one of two ways:

- for VRs of OB, OW, **OL,** OF, OD, SQ and UN the 16 bits following the two character VR Field are reserved for use by later versions of the DICOM Standard. These reserved bytes shall be set to 0000H and shall not be used or decoded (Table 7.1-1). The Value Length Field is a 32-bit unsigned integer. If the Value Field has an Explicit Length, then the Value Length Field shall contain a value equal to the length (in bytes) of the Value Field. Otherwise, the Value Field has an Undefined Length and a Sequence Delimitation Item marks the end of the Value Field.

- for VRs of UC, UR and UT the 16 bits following the two character VR Field are reserved for use by later versions of the DICOM Standard. These reserved bytes shall be set to 0000H and shall not be used or decoded. The Value Length Field is a 32-bit unsigned integer. The Value Field is required to have an Explicit Length, that is the Value Length Field shall contain a value equal to the length (in bytes) of the Value Field.

  Note

  VRs of UC, UR and UT may not have an Undefined Length, i.e. a Value Length of FFFFFFFFH.

- for all other VRs the Value Length Field is the 16-bit unsigned integer following the two character VR Field (Table 7.1-2). The value of the Value Length Field shall equal the length of the Value Field.

Table 7.1-1. Data Element with Explicit VR of OB, OL, OW, OF, OD, SQ, UC, UR, UT or UN

Tag		**VR**		**Value Length**	**Value**
Group Number (16-bit unsigned integer)	Element Number (16-bit unsigned integer)	VR (2 byte character string) of "OB", **"OL",** "OW", "OF", "OD", "SQ", "UC", "UR", "UT" or "UN"	Reserved (2 bytes) set to a value of 0000H	32-bit unsigned integer	Even number of bytes containing the Data Element Value(s) encoded according to the VR and negotiated Transfer Syntax. Delimited with Sequence Delimitation Item if of Undefined Length.
2 bytes	2 bytes	2 bytes	2 bytes	4 bytes	'Value Length' bytes if of Explicit Length

...

7.3 Big Endian Versus Little Endian Byte Ordering

Another component of the encoding of a Data Set that shall be agreed upon by communicating Application Entities is the Byte Ordering.

Little Endian byte ordering is defined as follows:

- In a binary number consisting of multiple bytes (e.g., a 32-bit unsigned integer value, the Group Number, the Element Number, etc.), the least significant byte shall be encoded first; with the remaining bytes encoded in increasing order of significance.
- In a character string consisting of multiple 8-bit single byte codes, the characters will be encoded in the order of occurrence in the string (left to right).

Big Endian byte ordering is defined as follows:

- In a binary number consisting of multiple bytes, the most significant byte shall be encoded first; with the remaining bytes encoded in decreasing order of significance.
- In a character string consisting of multiple 8-bit single byte codes, the characters will be encoded in the order of occurrence in the string (left to right).

Note

The packing of bits within values of OB**, OL** or OW Value representation for Pixel Data and Overlay Data is described in Section 8.

Byte ordering is a component of an agreed upon Transfer Syntax (see Section 10). The default DICOM Transfer Syntax, which shall be supported by all AEs, uses Little Endian encoding and is specified in Section A.1. Alternate Transfer Syntaxes, some of which use Big Endian encoding, are also specified in Annex A.

Note

The Command Set structure as specified in PS3.7 is encoded using the Little Endian Implicit VR Transfer Syntax.

In the default case of Little Endian encoding, Big Endian Machines interpreting Data Sets shall do 'byte swapping' before interpreting or operating on certain Data Elements. The Data Elements affected are all those having VRs that are multiple byte Values and that are not a character string of 8-bit single byte codes. VRs constructed of a string of characters of 8-bit single byte codes are really constructed of a string of individual bytes, and are therefore not affected by byte ordering. The VRs that are not a string of characters and consist of multiple bytes are:

- 2-byte US, SS, OW and each component of AT
- 4-byte OF**, OL**, UL, SL, and FL
- 8 byte OD, FD

Note

For the above VRs, the multiple bytes are presented in increasing order of significance when in Little Endian format. For example, an 8-byte Data Element with VR of FD, might be written in hexadecimal as 68AF4B2CH, but encoded in Little Endian would be 2C4BAF68H.

...

Amend DICOM PS 3.6 – Appendix A – Transfer Syntax Specifications (Normative) as follows:

A.1 DICOM Implicit VR Little Endian Transfer Syntax

This Transfer Syntax applies to the encoding of the entire DICOM Data Set. This implies that when a DICOM Data Set is being encoded with the DICOM Implicit VR Little Endian Transfer Syntax the following requirements shall be met:

a. The Data Elements contained in the Data Set structure shall be encoded with Implicit VR (without a VR Field) as specified in Section 7.1.3.

b. The encoding of the overall Data Set structure (Data Element Tags, Value Length, and Value) shall be in Little Endian as specified in Section 7.3.

c. The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

- For all Value Representations defined in this part, except for the Value Representations OB**, OL** and OW, the encoding shall be in Little Endian as specified in Section 7.3.
- For the Value Representations OB**, OL** and OW, the encoding shall meet the following specification depending on the Data Element Tag:
  - Data Element (7FE0,0010) Pixel Data has the Value Representation OW and shall be encoded in Little Endian.

  Note: The OL Value Representation is not used for Pixel Data, even if it has a Bits Allocated (0028,0100) of 32, since OL was added to the standard after the encoding of Pixel Data had been established.

  - Data Element (60xx,3000) Overlay Data has the Value Representation OW and shall be encoded in Little Endian.
  - Data Element (5400,1010) Waveform Data shall have Value Representation OW and shall be encoded in Little Endian.
  - Data Elements (0028,1201), (0028,1202), (0028,1203), (0028,1204) Red, Green, Blue, Alpha Palette Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.

    Note

    Previous versions of the Standard either did not specify the encoding of Data Elements (0028,1201), (0028,1202), (0028,1203) in this Part, but specified a VR of US or SS in PS3.6-1993, or specified OW in this Part but a VR of US, SS or OW in PS3.6-1996. The actual encoding of the values and their byte order would be identical in each case.

- Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette Lookup Table Descriptor have the Value Representation SS or US (depending on rules specified in the IOD in PS3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
- Data Elements (0028,1221),(0028,1222),(0028,1223) Segmented Red, Green, Blue Palette Color Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.
- Data Element (0028,3006) LUT Data has the Value Representation US or OW and shall be encoded in Little Endian.

  Note

  Previous versions of the Standard did not specify the encoding of these Data Elements in this Part, but specified a VR of US or SS in PS3.6-1998. A VR of OW has been added to support explicit VR transfer syntaxes. Moreover this element is always unsigned, therefore the VR of SS has been removed. The actual encoding of the values and their byte order would be identical in each case.

- Data Element (0028,3002) LUT Descriptor has the Value Representation SS or US (depending on rules specified in the IOD in PS3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.

- Data Element (0028,1408) Blending Lookup Table Data has the Value Representation OW and shall be encoded in Little Endian.

- Data Elements (0066,0025) Vertex Point Index List, (0066,0024) Edge Point Index List, (0066,0023) Triangle Point Index List and (0066,0029) Primitive Point Index List have the Value Representation OW and shall be encoded in Little Endian and are always interpreted as unsigned.

- **Data Element (0066,0129) Track Point Index List has the Value Representation OL and shall be encoded in Little Endian and is always interpreted as unsigned.**

Note

Encoding of Curve Data and Audio Sample Data was previously defined but has been retired. See PS3.5-2004.

This DICOM Implicit VR Little Endian Transfer Syntax shall be identified by a UID of Value "1.2.840.10008.1.2".

A.2 DICOM Little Endian Transfer Syntax (Explicit VR)

This Transfer Syntax applies to the encoding of the entire DICOM Data Set. This implies that when a DICOM Data Set is being encoded with the DICOM Little Endian Transfer Syntax the following requirements shall be met:

a. The Data Elements contained in the Data Set structure shall be encoded with Explicit VR (with a VR Field) as specified in Section 7.1.2.

b. The encoding of the overall Data Set structure (Data Element Tags, Value Length, and Value) shall be in Little Endian as specified in Section 7.3.

c. The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

- For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.

- For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:

  - Data Element (7FE0,0010) Pixel Data

    - where Bits Allocated (0028,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Little Endian;

    - where Bits Allocated (0028,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Little Endian.

    Note: The OL Value Representation is not used for Pixel Data, even if it has a Bits Allocated (0028,0100) of 32, since OL was added to the standard after the encoding of Pixel Data had been established.

  - Data Element (60xx,3000) Overlay Data

    - shall have the Value Representation OB or OW and shall be encoded in Little Endian.

> Note
>
> Previous versions of the Standard specified that the choice of OB or OW VR was based on whether or not Overlay Bits Allocated (60xx,0100) was greater than, or less than or equal to, 8. However, since only one bit plane can be encoded in each Overlay Data Element (60xx,3000), no value of Overlay Bits Allocated other than 1 makes sense. Such a restriction is now present in PS3.3.

- Data Element (5400,1010) Waveform Data has the Value Representation specified in its Explicit VR Field. The component points shall be encoded in Little Endian.
- Data Elements (0028,1201), (0028,1202), (0028,1203), (0028,1204) Red, Green, Blue, Alpha Palette Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.

> Note
>
> Previous versions of the Standard either did not specify the encoding of Data Elements (0028,1201), (0028,1202), (0028,1203) in this Part, but specified a VR of US or SS in PS3.6-1993, or specified OW in this Part but a VR of US, SS or OW in PS3.6-1996. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits.

- Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette Lookup Table Descriptor have the Value Representation SS or US (depending on rules specified in the IOD in PS3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
- Data Elements (0028,1221), (0028,1222), (0028,1223) Segmented Red, Green, Blue Palette Color Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.
- Data Element (0028,3006) LUT Data has the Value Representation US or OW and shall be encoded in Little Endian.

> Note
>
> Previous versions of the Standard did not specify the encoding of these Data Elements in this Part, but specified a VR of US or SS in PS3.6-1998. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits. Hence a VR of OW has been added. Moreover this element is always unsigned, therefore the VR of SS has been removed. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different.

- Data Element (0028,3002) LUT Descriptor has the Value Representation SS or US (depending on rules specified in the IOD in PS3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
- Data Element (0028,1408) Blending Lookup Table Data has the Value Representation OW and shall be encoded in Little Endian.
- Data Elements (0066,0025) Vertex Point Index List, (0066,0024) Edge Point Index List, (0066,0023) Triangle Point Index List and (0066,0029) Primitive Point Index List have the Value Representation OW and shall be encoded in Little Endian and are always interpreted as unsigned.
- **Data Element (0066,0129) Track Point Index List has the Value Representation OL and shall be encoded in Little Endian and is always interpreted as unsigned.**

Note

1. For Data encoded with the Value Representation OB, the Data encoding is unaffected by Little Endian or Big Endian byte ordering.
2. Encoding of Curve Data and Audio Sample Data was previously defined but has been retired. See PS3.5-2004.

This DICOM Explicit VR Little Endian Transfer Syntax shall be identified by a UID of Value "1.2.840.10008.1.2.1".

A.3 DICOM Big Endian Transfer Syntax (Explicit VR)

This Transfer Syntax applies to the encoding of the entire DICOM Data Set. This implies that when a DICOM Data Set is being encoded with the DICOM Big Endian Transfer Syntax the following requirements shall be met:

a. The Data Elements contained in the Data Set structure shall be encoded with Explicit VR (with a VR Field) as specified in Section 7.1.2.

b. The encoding of the overall Data Set structure (Data Element Tags, Value Length, and Value) shall be in Big Endian as specified in Section 7.3.

c. The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

- For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Big Endian as specified in Section 7.3.
- For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:
  - Data Element (7FE0,0010) Pixel Data
    - where Bits Allocated (0028,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Big Endian;
    - where Bits Allocated (0028,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Big Endian.

    Note: The OL Value Representation is not used for Pixel Data, even if it has a Bits Allocated (0028,0100) of 32, since OL was added to the standard after the encoding of Pixel Data had been established.
  - Data Element (60xx,3000) Overlay Data
    - shall have the Value Representation OB or OW and shall be encoded in Big Endian.

      Note

      Previous versions of the Standard specified that the choice of OB or OW VR was based on whether or not Overlay Bits Allocated (60xx,0100) was greater than, or less than or equal to, 8. However, since only one bit plane can be encoded in each Overlay Data Element (60xx,3000), no value of Overlay Bits Allocated other than 1 makes sense. Such a restriction is now present in PS3.3.
  - Data Element (5400,1010) Waveform Data has the Value Representation specified in its Explicit VR Field. The component points shall be encoded in Big Endian.
  - Data Elements (0028,1201), (0028,1202), (0028,1203), (0028,1204) Red, Green, Blue, Alpha Palette Lookup Table Data have the Value Representation OW and shall be encoded in Big Endian.

> Note
>
> Previous versions of the Standard either did not specify the encoding of Data Elements (0028,1201), (0028,1202), (0028,1203) in this Part, but specified a VR of US or SS in PS3.6-1993, or specified OW in this Part but a VR of US, SS or OW in PS3.6-1996. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits.

- Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette Lookup Table Descriptor have the Value Representation SS or US (depending on rules specified in the IOD in PS3.3), and shall be encoded in Big Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
- Data Elements (0028,1221), (0028,1222), (0028,1223) Segmented Red, Green, Blue Palette Color Lookup Table Data have the Value Representation OW and shall be encoded in Big Endian.
- Data Element (0028,3006) LUT Data has the Value Representation US or OW and shall be encoded in Big Endian.

> Note
>
> Previous versions of the Standard did not specify the encoding of these Data Elements in this Part, but specified a VR of US or SS in PS3.6-1998. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits. Hence a VR of OW has been added. Moreover this element is always unsigned, therefore the VR of SS has been removed. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different.

- Data Element (0028,3002) LUT Descriptor has the Value Representation SS or US (depending on rules specified in the IOD in PS3.3), and shall be encoded in Big Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
- Data Element (0028,1408) Blending Lookup Table Data has the Value Representation OW and shall be encoded in Big Endian.
- Data Elements (0066,0025) Vertex Point Index List, (0066,0024) Edge Point Index List, (0066,0023) Triangle Point Index List and (0066,0029) Primitive Point Index List have the Value Representation OW and shall be encoded in ~~Little~~ **Big** Endian and are always interpreted as unsigned.
- **Data Element (0066,0129) Track Point Index List has the Value Representation OL and shall be encoded in Big Endian and is always interpreted as unsigned**

Note

1. For Data encoded with the Value Representation OB, the Data encoding is unaffected by Little Endian or Big Endian byte ordering.
2. Encoding of Curve Data and Audio Sample Data was previously defined but has been retired. See PS3.5-2004.

This DICOM Explicit VR Big Endian Transfer Syntax shall be identified by a UID of Value "1.2.840.10008.1.2.2".

A.4 Transfer Syntaxes For Encapsulation of Encoded Pixel Data

These Transfer Syntaxes apply to the encoding of the entire DICOM Data Set, even though the image Pixel Data (7FE0,0010) portion of the DICOM Data Set is the only portion that is encoded by an encapsulated format. These Transfer Syntaxes shall only be used when Pixel Data (7FE0,0010) is present in the top level Data Set, and hence shall not be used when Float Pixel Data (7FE0,0008) or Double Float Pixel Data (7FE0,0009) are present. This implies that when a DICOM Message is being encoded according to an encapsulation Transfer Syntax the following requirements shall be met:

1. The Data Elements contained in the Data Set structure shall be encoded with Explicit VR (with a VR Field) as specified in Section 7.1.2.

2. The encoding of the overall Data Set structure (Data Element Tags, Value Length, etc.) shall be in Little Endian as specified in Section 7.3.

3. The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

   - For all Value Representations defined in this part of the DICOM Standard, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.

   - For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:

     - Data Element (7FE0,0010) Pixel Data may be encapsulated or native.

       It shall be encapsulated if present in the top-level Data Set (i.e., not nested within a Sequence Data Element).

       Note

       The distinction between fixed value length (native) and undefined value length (encapsulated) is present so that the top level Data Set Pixel Data can be compressed (and hence encapsulated), but the Pixel Data within an Icon Image Sequence may or may not be compressed.

       If native, it shall have a defined Value Length, and be encoded as follows:

       - where Bits Allocated (0028,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Little Endian;

       - where Bits Allocated (0028,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Little Endian.

       Note

       1. That is, as if the transfer syntax were Explicit VR Little Endian.

       2. The OL Value Representation is not used for Pixel Data, even if it has a Bits Allocated (0028,0100) of 32, since OL was added to the standard after the encoding of Pixel Data had been established.

       If encapsulated, it has the Value Representation OB and is a sequence of bytes resulting from one of the encoding processes. It contains the encoded pixel data stream fragmented into one or more Item(s). This Pixel Data Stream may represent a Single or Multi-frame Image. See Table A.4-1 and Table A.4-2.

       - The Length of the Data Element (7FE0,0010) shall be set to the Value for Undefined Length (FFFFFFFFH).

       - Each Data Stream Fragment encoded according to the specific encoding process shall be encapsulated as a DICOM Item with a specific Data Element Tag of Value (FFFE,E000). The Item Tag is followed by a 4 byte Item Length field encoding the explicit number of bytes of the Item.

         Note

         Whether more than one fragment per frame is permitted or not is defined per Transfer Syntax.

  - All items containing an encoded fragment shall be made of an even number of bytes greater or equal to two. The last fragment of a frame may be padded, if necessary, to meet the sequence item format requirements of the DICOM Standard.

    Note

    1. Any necessary padding may be added in the JPEG or JPEG-LS compressed data stream as per ISO 10918-1 and ISO 14495-1 such that the End of Image (EOI) marker ends on an even byte boundary, or may be appended after the EOI marker, depending on the implementation.
    2. ISO 10918-1 and ISO 14495-1 define the ability to add any number of padding bytes FFH before any marker (all of which also begin with FFH). It is strongly recommended that FFH padding bytes not be added before the Start of Image (SOI) marker.

  - The first Item in the Sequence of Items before the encoded Pixel Data Stream shall be a Basic Offset Table item. The Basic Offset Table Item Value, however, is not required to be present:
    - When the Item Value is not present, the Item Length shall be zero (00000000H) (see Table A.4-1).
    - When the Item Value is present, the Basic Offset Table Item Value shall contain concatenated 32-bit unsigned integer values that are byte offsets to the first byte of the Item Tag of the first fragment for each frame in the Sequence of Items. These offsets are measured from the first byte of the first Item Tag following the Basic Offset Table item (see Table A.4-2).

      Note

      1. For a Multi-Frame Image containing only one frame or a Single Frame Image, the Basic Offset Table Item Value may be present or not. If present it will contain a single 00000000H value.
      2. Decoders of encapsulated pixel data, whether Single Frame or Multi-Frame, need to accept both an empty Basic Offset Table (zero length) and a Basic Offset Table filled with 32 bit offset values.

  - This Sequence of Items is terminated by a Sequence Delimiter Item with the Tag (FFFE,E0DD) and an Item Length Field of Value (00000000H) (i.e., no Value Field shall be present).

- Data Element (60xx,3000) Overlay Data
  - shall have the Value Representation OB or OW and shall be encoded in Little Endian.
- Data Element (5400,1010) Waveform Data has the Value Representation specified in its Explicit VR Field. The component points shall be encoded in Little Endian.
- Data Elements (0028,1201), (0028,1202), (0028,1203), (0028,1204) Red, Green, Blue, Alpha Palette Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.

  Note

  Previous versions of the Standard either did not specify the encoding of Data Elements 0028,1201), (0028,1202), (0028,1203) in this Part, but specified a VR of US or SS in PS3.6-1993, or specified OW in this Part but a VR of US, SS or OW in PS3.6-1996. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits.

- Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette Lookup Table Descriptor have the Value Representation SS or US (depending on rules specified in the IOD in PS3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.

- Data Elements (0028,1221), (0028,1222), (0028,1223) Segmented Red, Green, Blue Palette Color Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.
- Data Element (0028,3006) LUT Data has the Value Representation US or OW and shall be encoded in Little Endian.

  Note

  Previous versions of the Standard did not specify the encoding of these Data Elements in this Part, but specified a VR of US or SS in PS3.6-1998. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits. Hence a VR of OW has been added. Moreover this element is always unsigned, therefore the VR of SS has been removed. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different.

- Data Element (0028,3002) LUT Descriptor has the Value Representation SS or US (depending on rules specified in the IOD in PS3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
- Data Element (0028,1408) Blending Lookup Table Data has the Value Representation OW and shall be encoded in Little Endian.
- Data Elements (0066,0025) Vertex Point Index List, (0066,0024) Edge Point Index List, (0066,0023) Triangle Point Index List and (0066,0029) Primitive Point Index List have the Value Representation OW and shall be encoded in Little Endian and are always interpreted as unsigned.
- **Data Element (0066,0129) Track Point Index List has the Value Representation OL and shall be encoded in Little Endian and is always interpreted as unsigned.**

Note

1. For Data encoded with the Value Representation OB, the Data encoding is unaffected by Little Endian or Big Endian byte ordering.
2. Encoding of Curve Data and Audio Sample Data was previously defined but has been retired. See PS3.5-2004.

DICOM PS 3.6: Data Dictionary

Amend DICOM PS 3.6 – Data Dictionary – Section 6 Registry of DICOM Data Elements as follows:

Table 6-1. Registry of DICOM Data Elements

Tag	Name	Keyword	VR	VM	
...	...	...	...	...	
(0066,0101)	Track Set Sequence	TrackSetSequence	SQ	1	
(0066,0102)	Track Sequence	TrackSequence	SQ	1	
(0066,0103)	Recommended Display CIELab Value List	RecommendedDisplayCIELabValueList	OW	1	
(0066,0104)	Tracking Algorithm Identification Sequence	TrackingAlgorithmIdentificationSequence	SQ	1	
(0066,0105)	Track Set Number	TrackSetNumber	UL	1	
(0066,0106)	Track Set Label	TrackSetLabel	LO	1	
(0066,0107)	Track Set Description	TrackSetDescription	UT	1	
(0066,0108)	Track Set Anatomical Type Code Sequence	TrackSetAnatomicalTypeCodeSequence	SQ	1	
(0066,0121)	Measurements Sequence	MeasurementsSequence	SQ	1	
(0066,0124)	Track Set Statistics Sequence	TrackSetStatisticsSequence	SQ	1	
(0066,0125)	Floating Point Values	FloatingPointValues	OF	1	
(0066,0129)	Track Point Index List	TrackPointIndexList	OL	1	
(0066,0130)	Track Statistics Sequence	TrackStatisticsSequence	SQ	1	
(0066,0132)	Measurement Values Sequence	MeasurementValuesSequence	SQ	1	
(0066,0133)	Diffusion Acquisition Code Sequence	DiffusionAcquisitionCodeSequence	SQ	1	
(0066,0134)	Diffusion Model Code Sequence	DiffusionModelCodeSequence	SQ	1	
...	...	...	...	...	

Amend DICOM PS 3.6 - Data Dictionary - Annex A - Registry of DICOM Unique Identifiers (UIDs) as follows:

Table A-1. UID Values

UID Value	UID Name	UID Type	Part
…	…	…	…
1.2.840.10008.5.1.4.1.1.66.6	**Tractography Results**	**SOP Class**	**PS 3.3**
…	…	…	…

Table A-3. Context Group UID Values

Context UID	Context Identifier	Context Group Name
…	…	…
1.2.840.10008.6.1.1059	**CID 7260**	**Diffusion Acquisition Value Types**
1.2.840.10008.6.1.1060	**CID 7261**	**Diffusion Model Value Types**
1.2.840.10008.6.1.1061	**CID 7262**	**Diffusion Tractography Algorithm Families**
1.2.840.10008.6.1.1062	**CID 7263**	**Diffusion Tractography Measurement Types**
…	…	…

DICOM PS 3.15: Security and System Management Profiles

Amend: C.2 Creator RSA Digital Signature Profile:

…

aa. any attributes of the Enhanced Mammography Image module that are present

xx. any attributes of the Tractography Results module that are present

…

DICOM PS 3.16: Content Mapping Resource

Item: Add in Section B DCMR Context Groups (Normative)

CID 7260 Diffusion Acquisition Value Types

Type: **Extensible**
Version: **20150918**

Table CID 7260. Diffusion Acquisition Value Types

Coding Scheme Designator	Code Value	Code Meaning
DCM	113221	HARDI
DCM	113222	DKI
DCM	113223	DTI
DCM	113224	DSI
DCM	113225	LSDI
DCM	113226	Single Shot EPI
DCM	113227	Multiple Shot EPI
DCM	113228	Parallel Imaging

CID 7261 Diffusion Model Value Types

Type: **Extensible**
Version: **20150918**

Table CID 7261. Diffusion Model Value Types

Coding Scheme Designator	Code Value	Code Meaning
DCM	113231	Single Tensor
DCM	113232	Multi Tensor

Coding Scheme Designator	Code Value	Code Meaning
DCM	113233	Model Free
DCM	113234	CHARMED
DCM	113224	DSI
DCM	113236	DOT
DCM	113237	PAS
DCM	113238	Spherical Deconvolution

CID 7262 Diffusion Tractography Algorithm Families

Type: **Extensible**
Version: **20150918**

Table CID 7262. Diffusion Tractography Algorithm Families

Coding Scheme Designator	Code Value	Code Meaning
DCM	113211	Deterministic
DCM	113212	Probabilistic
DCM	113213	Global
DCM	113214	FACT
DCM	113215	Streamline
DCM	113216	TEND
DCM	113217	Bootstrap
DCM	113218	Euler
DCM	113219	Runge-Kutta

CID 7263 Diffusion Tractography Measurement Types

Type: **Extensible**
Version: **20150918**

Table CID 7263. Diffusion Tractography Measurement Types

Coding Scheme Designator	Code Value	Code Meaning
DCM	113201	Trace
DCM	113202	Mean Diffusivity

Coding Scheme Designator	Code Value	Code Meaning
DCM	113041	Apparent Diffusion Coefficient
DCM	110808	Fractional Anisotropy
DCM	110809	Relative Anisotropy
DCM	113203	Radial Diffusivity
DCM	113204	Axial Diffusivity
DCM	113205	Mean Kurtosis
DCM	113206	Apparent Kurtosis Coefficient
DCM	113207	Radial Kurtosis
DCM	113208	Axial Kurtosis
DCM	113209	Fractional Kurtosis Anisotropy
DCM	110810	Volumetric Diffusion Dxx Component
DCM	110811	Volumetric Diffusion Dxy Component
DCM	110812	Volumetric Diffusion Dxz Component
DCM	110813	Volumetric Diffusion Dyy Component
DCM	110814	Volumetric Diffusion Dyz Component
DCM	110815	Volumetric Diffusion Dzz Component

608 **Item: Add +/- update definitions in Annex D**

Code Value	Code Meaning	Definition	Notes
110808	Fractional Anisotropy	Coefficient reflecting the Fractional Anisotropy of the tissues, derived from a diffusion weighted MR image. Fractional Anisotropy is proportional to the square root of the variance of the Eigen values divided by the square root of the sum of the squares of the Eigen values.	
110809	Relative Anisotropy	Coefficient reflecting the relative anisotropy of the tissues, derived from a diffusion weighted MR image.	
110810	Volumetric Diffusion Dxx Component	Dxx Component of the diffusion tensor, quantifying the molecular mobility along the X axis.	

110811	Volumetric Diffusion Dxy Component	Dxy Component of the diffusion tensor, quantifying the correlation of molecular displacements in the X and Y directions.	
110812	Volumetric Diffusion Dxz Component	Dxz Component of the diffusion tensor, quantifying the correlation of molecular displacements in the X and Z directions.	
110813	Volumetric Diffusion Dyy Component	Dyy Component of the diffusion tensor, quantifying the molecular mobility along the Y axis.	
110814	Volumetric Diffusion Dyz Component	Dyz Component of the diffusion tensor, quantifying the correlation of molecular displacements in the Y and Z directions.	
110815	Volumetric Diffusion Dzz Component	Dzz Component of the diffusion tensor, quantifying the molecular mobility along the Z axis.	
113041	Apparent Diffusion Coefficient	Values are derived by calculation of the apparent diffusion coefficient.	
…	…	…	…
113201	**Trace**	**Sum of the diffusion tensor eigenvalues.** **I.e.: Tr = $\lambda 1 + \lambda 2 + \lambda 3$, where $\lambda 1 \geq \lambda 2 \geq \lambda 3$.**	**Winston GP. The physical and biological basis of quantitative parameters derived from diffusion MRI. *Quantitative Imaging in Medicine and Surgery*. 2012;2(4):254-265. doi:10.3978/j.issn.2223-4292.2012.12.05. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3533595/)**
113202	**Mean Diffusivity**	**Average of the diffusion tensor eigenvalues in all directions.** **I.e.: MD = $(\lambda 1 + \lambda 2 + \lambda 3)/3$**	**Winston GP. The physical and biological basis of quantitative parameters derived from diffusion MRI. *Quantitative Imaging in Medicine and Surgery*. 2012;2(4):254-265.**

			doi:10.3978/j.issn.2223-4292.2012.12.05. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3533595/)
113203	**Radial Diffusivity**	**Average of the two non-principal (i.e. perpendicular) diffusion tensor eigenvalues (also known as transverse diffusivity, perpendicular diffusivity).** **I.e.: DR= (λ2+ λ3)/2**	**Winston GP. The physical and biological basis of quantitative parameters derived from diffusion MRI. *Quantitative Imaging in Medicine and Surgery*. 2012;2(4):254-265. doi:10.3978/j.issn.2223-4292.2012.12.05. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3533595/)**
113204	**Axial Diffusivity**	**Diffusion tensor eigenvalue of the principal axis (also known as longitudinal diffusivity, parallel diffusivity).** **I.e.: DA = λ1**	**Winston GP. The physical and biological basis of quantitative parameters derived from diffusion MRI. *Quantitative Imaging in Medicine and Surgery*. 2012;2(4):254-265. doi:10.3978/j.issn.2223-4292.2012.12.05. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3533595/)**
113205	**Mean Kurtosis**	**MK = diffusional kurtosis averaged over all gradient directions**	**Tabesh A, Jensen JH, Ardekani BA, Helpern JA. Estimation of Tensors and Tensor-Derived Measures in Diffusional Kurtosis Imaging. *Magnetic Resonance in Medicine*. 2011;65(3):823-836. doi:10.1002/mrm.22655. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3042509/)** **Liu C, Mang SC, Moseley ME. *In Vivo* Generalized Diffusion Tensor Imaging (GDTI) Using Higher-Order Tensors (HOT). *Magnetic resonance in medicine : official journal of the***

			Society of Magnetic Resonance in Medicine / Society of Magnetic Resonance in Medicine. **2010;63(1):243-252. doi:10.1002/mrm.22192. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2824337/)**
113206	**Apparent Kurtosis Coefficient**	**AKC = diffusional kurtosis in a given direction**	**Liu C, Mang SC, Moseley ME. *In Vivo* Generalized Diffusion Tensor Imaging (GDTI) Using Higher-Order Tensors (HOT). *Magnetic resonance in medicine : official journal of the Society of Magnetic Resonance in Medicine / Society of Magnetic Resonance in Medicine*. 2010;63(1):243-252. doi:10.1002/mrm.22192. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2824337/)**
113209	**Fractional Kurtosis Anisotropy**	**FKA = fractional kurtosis of diffusion in tissues**	**Liu C, Mang SC, Moseley ME. *In Vivo* Generalized Diffusion Tensor Imaging (GDTI) Using Higher-Order Tensors (HOT). *Magnetic resonance in medicine : official journal of the Society of Magnetic Resonance in Medicine / Society of Magnetic Resonance in Medicine*. 2010;63(1):243-252. doi:10.1002/mrm.22192. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2824337/)**
113208	**Axial Kurtosis**	**KA = diffusional kurtosis in the direction of the highest diffusion (also known as longitudinal kurtosis, parallel kurtosis)**	**Tabesh A, Jensen JH, Ardekani BA, Helpern JA. Estimation of Tensors and Tensor-Derived Measures in Diffusional Kurtosis Imaging. *Magnetic Resonance in Medicine*. 2011;65(3):823-836. doi:10.1002/mrm.22655.**

			(http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3042509/)
113207	Radial Kurtosis	KR = diffusional kurtosis perpendicular to the direction of the highest diffusion (also known as transverse kurtosis, perpendicular kurtosis)	Tabesh A, Jensen JH, Ardekani BA, Helpern JA. Estimation of Tensors and Tensor-Derived Measures in Diffusional Kurtosis Imaging. *Magnetic Resonance in Medicine.* 2011;65(3):823-836. doi:10.1002/mrm.22655. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3042509/)
…	…	…	…
113211	Deterministic Tracking Algorithm	Tracking based on local directionality	Descoteaux M, Deriche R, Knösche TR, Anwander A. Deterministic and probabilistic tractography based on complex fibre orientation distributions. *IEEE Trans Med Imaging.* 2009; 28(2):269-86 (http://www.ncbi.nlm.nih.gov/pubmed/19188114)
113212	Probabilistic Tracking Algorithm	Tracking using local fiber orientation likelihood derive global connectivity likelihood	Descoteaux M, Deriche R, Knösche TR, Anwander A. Deterministic and probabilistic tractography based on complex fibre orientation distributions. *IEEE Trans Med Imaging.* 2009; 28(2):269-86 (http://www.ncbi.nlm.nih.gov/pubmed/19188114)
113213	Global Tracking Algorithm	Tracking all fibers simultaneously, searching for a global optimum.	Reisert M, Mader I, Anastasopoulos C, Weigel M, Schnell S, Kiselev V. Global fiber reconstruction becomes practical. NeuroImage. 2011 Jan

			15;54(2):955–62. (http://www.ncbi.nlm.nih.gov/pubmed/20854913)
113214	**FACT**	**Fiber Assessment by Continuous Tracking**	**Mori S, Crain BJ, Chacko VP, van Zijl PC. Three-dimensional tracking of axonal projections in the brain by magnetic resonance imaging. *Ann Neurol*. 1999 Feb;45(2):265-9 (http://www.ncbi.nlm.nih.gov/pubmed/9989633)** **Descoteaux M, Deriche R, Knösche TR, Anwander A. Deterministic and probabilistic tractography based on complex fibre orientation distributions. *IEEE Trans Med Imaging.* 2009; 28(2):269-86 (http://www.ncbi.nlm.nih.gov/pubmed/19188114)**
113215	**Streamline**	**Streamline tracking techniques (STT)**	**Basser PJ, Pajevic S, Pierpaoli C, Duda J, Aldroubi A. In vivo fiber tractography using DT-MRI data. *Magn Reson Med*. 2000 Oct;44(4):625-32 (http://www.ncbi.nlm.nih.gov/pubmed/11025519)**
113216	**TEND**	**Tensor Deflection**	**Lazar M, Weinstein DM, Tsuruda JS, Hasan KM, Arfanakis K, Meyerand ME, Badie B, Rowley HA, Haughton V, Field A, Alexander AL. White matter tractography using diffusion tensor deflection. *Hum Brain Mapp.* 2003 Apr;18(4):306-21. (http://www.ncbi.nlm.nih.gov/pubmed/12632468)**

113217	Bootstrap Tracking Algorithm	Non-parametric estimation of fiber tracking dispersion	Lazar M, Alexander AL. Bootstrap white matter tractography (BOOT-TRAC). *Neuroimage.* 2005 Jan 15;24(2):524-32. Epub 2004 Nov 24. (http://www.ncbi.nlm.nih.gov/pubmed/15627594) Jones DK, Pierpaoli C. Confidence mapping in diffusion tensor magnetic resonance imaging tractography using a bootstrap approach. *Magn Reson Med.* 2005 May;53(5):1143-9. (http://www.ncbi.nlm.nih.gov/pubmed/15844149)
113218	Euler	Integration method, 1st order	Basser PJ, Pajevic S, Pierpaoli C, Duda J, Aldroubi A. In vivo fiber tractography using DT-MRI data. *Magn Reson Med.* 2000 Oct;44(4):625-32 (http://www.ncbi.nlm.nih.gov/pubmed/11025519) Descoteaux M, Deriche R, Knösche TR, Anwander A. Deterministic and probabilistic tractography based on complex fibre orientation distributions. *IEEE Trans Med Imaging.* 2009; 28(2):269-86 (http://www.ncbi.nlm.nih.gov/pubmed/19188114)
113219	Runge-Kutta	Integration method, 2nd or 4th order	Basser PJ, Pajevic S, Pierpaoli C, Duda J, Aldroubi A. In vivo fiber tractography using DT-MRI data. *Magn Reson Med.* 2000 Oct;44(4):625-32 (http://www.ncbi.nlm.nih.gov/pubmed/1102551

			9)
…	…	…	…
113221	HARDI	High Angular Resolution Diffusion Imaging	Tuch DS, Reese TG, Wiegell MR, Makris N, Belliveau JW, Wedeen VJ. High angular resolution diffusion imaging reveals intravoxel white matter fiber heterogeneity. *Magn Reson Med.* 2002 Oct;48(4):577-82. (http://www.ncbi.nlm.nih.gov/pubmed/12353272) Descoteaux M, Deriche R, Knösche TR, Anwander A. Deterministic and probabilistic tractography based on complex fibre orientation distributions. *IEEE Trans Med Imaging.* 2009; 28(2):269-86 (http://www.ncbi.nlm.nih.gov/pubmed/19188114)
113222	DKI	Diffusion(al) Kurtosis Imaging	Jensen JH, Helpern JA, Ramani A, Lu H, Kaczynski K. Diffusional kurtosis imaging: the quantification of non-gaussian water diffusion by means of magnetic resonance imaging. *Magn Reson Med. 2005* Jun;53(6):1432-40. (http://www.ncbi.nlm.nih.gov/pubmed/15906300)
113223	DTI	Diffusion Tensor Imaging	Winston GP. The physical and biological basis of quantitative parameters derived from diffusion MRI. Quantitative Imaging in Medicine and Surgery. 2012;2(4):254-265. doi:10.3978/j.issn.2223-

			4292.2012.12.05. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3533595/)
113224	DSI	Diffusion Spectrum Imaging	Wedeen VJ, Wang RP, Schmahmann JD, Benner T, Tseng WY, Dai G, Pandya DN, Hagmann P, D'Arceuil H, de Crespigny AJ. Diffusion spectrum magnetic resonance imaging (DSI) tractography of crossing fibers. *Neuroimage.* 2008 Jul 15;41(4):1267-77. doi: 10.1016/j.neuroimage.2008.03.036. (http://www.ncbi.nlm.nih.gov/pubmed/18495497) Hagmann P, Jonasson L, Maeder P, Thiran JP, Wedeen VJ, Meuli R. Understanding diffusion MR imaging techniques: from scalar diffusion-weighted imaging to diffusion tensor imaging and beyond. *Radiographics.* 2006 Oct;26 Suppl 1:S205-23. (http://www.ncbi.nlm.nih.gov/pubmed/17050517)
113225	LSDI	Line Scan Diffusion Imaging sequence	Gudbjartsson H, Maier SE, Mulkern RV, Mórocz IA, Patz S, Jolesz FA. Line scan diffusion imaging. *Magn Reson Med.* 1996 Oct;36(4):509-19. (http://www.ncbi.nlm.nih.gov/pubmed/8892201)
113226	Single Shot EPI	An Echo Planar Imaging sequence in which the entire range of phase encoding steps is acquired in one repetition.	Turner R, Le Bihan D, Chesnick AS. Echo-planar imaging of diffusion and perfusion. *Magn Reson Med.* 1991 Jun;19(2):247-53. (http://www.ncbi.nlm.nih.gov/pubmed/1881311)
113227	Multi Shot EPI	An Echo Planar Imaging sequence in which separate parts of the range of phase encoding	Robson MD, Anderson AW, Gore JC. Diffusion-

		steps are acquired in multiple repetitions.	weighted multiple shot echo planar imaging of humans without navigation. *Magn Reson Med.* 1997 Jul;38(1):82-8. (http://www.ncbi.nlm.nih.gov/pubmed/9211383)
113228	Parallel Imaging	A imaging sequence that uses a subset of k-space data from an array of receiver coils, e.g. Sensitivity Encoding.	Pruessmann KP, Weiger M, Scheidegger MB, Boesiger P. SENSE: sensitivity encoding for fast MRI. *Magn Reson Med.* 1999 Nov;42(5):952-62. (http://www.ncbi.nlm.nih.gov/pubmed/10542355) Deshmane A, Gulani V, Griswold MA, Seiberlich N. Parallel MR imaging. *J Magn Reson Imaging*. 2012 Jul;36(1):55-72. (http://www.ncbi.nlm.nih.gov/pubmed/22696125)
…	…	…	…
113231	Single Tensor	Modeling anisotropic diffusion in a volume with a tensor following a Gaussian distribution (six degrees of freedom)	Basser PJ, Mattiello J, LeBihan D. Estimation of the effective self-diffusion tensor from the NMR spin echo. *J Magn Reson B.* 1994 Mar;103(3):247-54. (http://www.ncbi.nlm.nih.gov/pubmed/8019776) Hagmann P1, Jonasson L, Maeder P, Thiran JP, Wedeen VJ, Meuli R. Understanding diffusion MR imaging techniques: from scalar diffusion-weighted imaging to diffusion tensor imaging and beyond. *Radiographics.* 2006 Oct;26 Suppl 1:S205-23. (http://www.ncbi.nlm.nih.gov/pubmed/17050517)
113232	Multi Tensor	Modeling anisotropic diffusion in a volume by fitting of multiple tensors	Ozarslan E, Mareci TH. Generalized diffusion tensor imaging and analytical relationships between diffusion

			tensor imaging and high angular resolution diffusion imaging. *Magn Reson Med.* 2003 Nov;50(5):955-65. (http://www.ncbi.nlm.nih.gov/pubmed/14587006) Pasternak O, Assaf Y, Intrator N, Sochen N. Variational multiple-tensor fitting of fiber-ambiguous diffusion-weighted magnetic resonance imaging voxels. *Magn Reson Imaging.* 2008 Oct;26(8):1133-44. doi: 10.1016/j.mri.2008.01.006. (http://www.ncbi.nlm.nih.gov/pubmed/18524529)
113233	Model Free	Reconstruction of anisotropic diffusion in a volume without imposing an underlying statistical model (data-driven approach)	Wedeen VJ, Hagmann P, Tseng WY, Reese TG, Weisskoff RM. Mapping complex tissue architecture with diffusion spectrum magnetic resonance imaging. *Magn Reson Med.* 2005 Dec;54(6):1377-86. (http://www.ncbi.nlm.nih.gov/pubmed/16247738) Hagmann P, Jonasson L, Maeder P, Thiran JP, Wedeen VJ, Meuli R. Understanding diffusion MR imaging techniques: from scalar diffusion-weighted imaging to diffusion tensor imaging and beyond. *Radiographics.* 2006 Oct;26 Suppl 1:S205-23. (http://www.ncbi.nlm.nih.gov/pubmed/17050517)
113234	CHARMED	Composite Hindered and Restricted Model of Diffusion	Assaf Y, Basser PJ. Composite hindered and restricted model of diffusion (CHARMED) MR imaging of the human brain. *Neuroimage.* 2005 Aug

			1;27(1):48-58. (http://www.ncbi.nlm.nih.gov/pubmed/17050517)
113236	DOT	Diffusion Orientation Transform	Ozarslan E, Shepherd TM, Vemuri BC, Blackband SJ, Mareci TH. Resolution of complex tissue microarchitecture using the diffusion orientation transform (DOT). *Neuroimage.* 2006 Jul 1;31(3):1086-103. Epub 2006 Mar 20. (http://www.ncbi.nlm.nih.gov/pubmed/16546404)
113237	PAS	Persistent Angular Structure	Jansons KM, Alexander DC. Persistent Angular Structure: new insights from diffusion MRI data. Dummy version. *Inf Process Med Imaging.* 2003 Jul;18:672-83. (http://www.ncbi.nlm.nih.gov/pubmed/15344497)
113238	Spherical Deconvolution	A method to estimate the distribution of fiber orientations by deconvolution of the diffusion-weighted signal attenuation measured over the surface of a sphere expressed as the convolution over the sphere of a response function.	Tournier JD, Calamante F, Gadian DG, Connelly A. Direct estimation of the fiber orientation density function from diffusion-weighted MRI data using spherical deconvolution. *NeuroImage.* 2004 Nov;23(3):1176–85. (http://www.ncbi.nlm.nih.gov/pubmed/15528117)
…	…	…	…

DICOM PS 3.17: Explanatory Information

Item: Add the following Section

XX Tractography Results

XX.1 Introduction

MRI diffusion imaging is able to quantify diffusion of water along certain directions. The diffusion tensor model is a simple model that is able to describe the statistical diffusion process accurately at most white matter positions. To calculate diffusion tensors, a base-line MRI without diffusion-weighting and at least six differently weighted diffusion MRIs have to be acquired. After some preprocessing of the data, at each grid point a diffusion tensor can be calculated. This gives rise to a tensor volume that is the basis for tracking. Refinements to the diffusion model and acquisition method such as HARDI, Q-Ball, diffusion spectrum imaging (DSI) and diffusion kurtosis imaging (DKI) are expanding the directionality information available beyond the simple tensor model, enhancing tracking through crossings, adjacent fibers, sharp turns, and other difficult scenarios.

A tracking algorithm produces tracks (i.e. fibers) which are collected into track sets. A track contains the set of x, y and z coordinates of each point making up the track. Depending upon the algorithm and software used, additional quantities such as Fractional Anisotropy (FA) values or color etc. may be associated with the data, by track set, track or point, either to facilitate further filtering or for clinical use. Descriptive statistics of quantities such as FA may be associated with the data by track set or track.

Examples of tractography applications include:

- Visualization of white matter tracks to aid in resection planning or to support image guided (neuro)surgery;
- Determination of proximity and/or displacement versus infiltration of white matter by tumor processes;
- Assessment of white matter health in neurodegenerative disorders, both axonal and myelin integrity, through sampling of derived diffusion parameters along the white matter tracks.

XX.2 Encoding Example (Informative)

This section illustrates the usage of the Tractography Results Module (PS 3.3 C.8.X.2) in the context of the Tractography Results IOD.

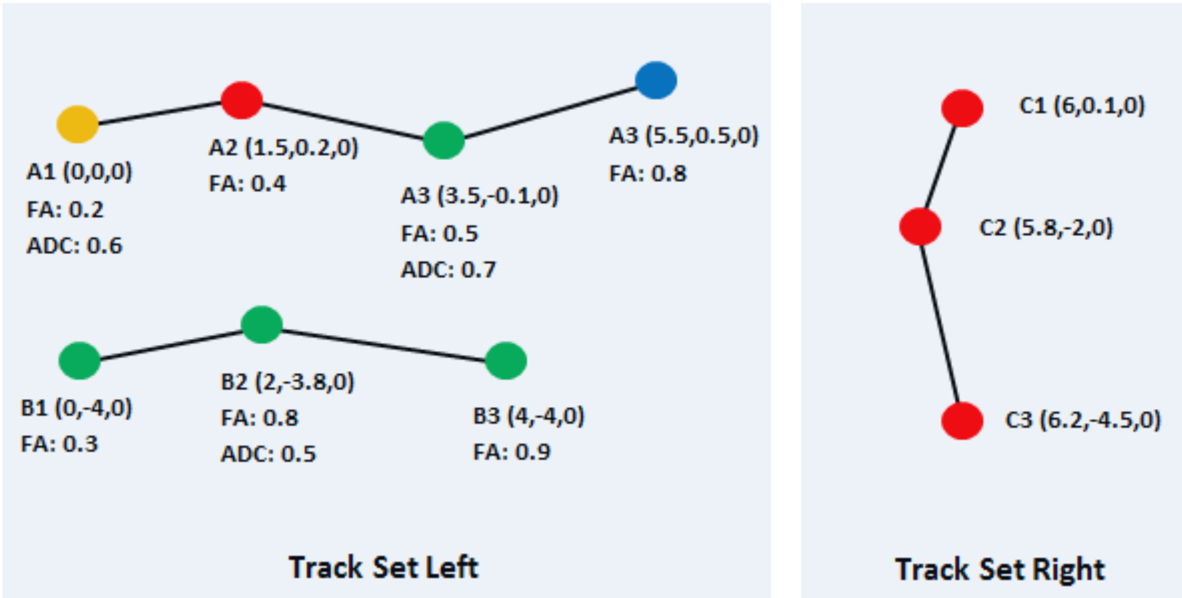

Figure XX-1. Two Example Track Sets. "Track Set Left" with two tracks, "Track Set Right" with one track.

Figure XX-1 shows two example track sets. The example consists of:

- Two track sets "Track Set Left" and "Track Set Right"
  - Track Set Sequence (0066,0101) => each item describes one track set.
- Track Set "Track Set Left" contains two tracks "A" and "B"
  - Track Sequence (0066,0102) => each item describes one track.
- Track "A" consists of:
  - 4 points
    - Point Coordinates Data (0066,0016) => describes the coordinates for all points in the track.
  - Different color for each point
    - Recommended Display CIELab Value List (0066,0103) => describes the colors for all points in the track.
  - Fractional Anisotropy for each point
    - On how the values are stored, see description in "Encoding of Measurement Values" below.
  - Apparent Diffusion Coefficient for point 1 and 3

        - On how the values are stored, see description in “Encoding of Measurement Values” below.

- Track “B” consists of:
    - 3 points
        - Point Coordinates Data (0066,0016) => describes the coordinates for all points in the track.
    - Same color for each point
        - Recommended Display CIELab Value (0062,000D) => describes the color for all points in the track.
    - Fractional Anisotropy for each point
        - On how the values are stored, see description in “Encoding of Measurement Values” below.
    - Apparent Diffusion Coefficient for point 2
        - On how the values are stored, see description in “Encoding of Measurement Values” below.
- Encoding of Measurement Values for Tracks “A” and “B”
    - For storing measurement values like Fractional Anisotropy or Apparent Diffusion Coefficient values on specific points on a track the overall view over all tracks of a given track set is needed. Only tracks shall be grouped in track sets that share a specific type of measurement value.
    - Measurements Sequence (0066,0121) => each item describes one value type of all tracks in the track set (here: “Track Set Left” contains two value types: Fractional Anisotropy and Apparent Diffusion Coefficient).
    - Measurement Values Sequence (0066,0132) => one item for each track of a track set.
        - When used to store Fractional Anisotropy values:
          Since a Fractional Anisotropy value is stored for each point in both tracks of “Track Set Left”, Floating Point Values (0066,0125) contains an array of Fractional Anisotropy values for tracks “A” and “B” respectively. Track Point Index List (0066,0129) is absent since there is a Fractional Anisotropy value associated with every point in Point Coordinates Data (0066,0016).
        - When used to store Apparent Diffusion Coefficient values:
          Since an Apparent Diffusion Coefficient value is stored only for a subset of points in both tracks of “Track Set Left”, Track Point Index List (0066,0129) contains indices to the track points in Point Coordinates Data (0066,0016) and Floating Point Values (0066,0125) contains a measurement value for every track point referenced in Track Point Index List (0066,0129).

- Track Set “Track Set Right” contains one track “C”
- Track “C” consists of:
  - 3 points
    - Point Coordinates Data (0066,0016) => describes the coordinates for all points in the track.
  - Same color for all points
    - Recommended Display CIELab Value (0062,000D) => describes the color for all points in the track set (Note: In this example this attribute is stored on Track Set level).
  - No measurement values

The table XX-1 shows the encoding of the Tractography Results module for the example above. In addition to the two example track sets the table XX-1 also encodes the following information:

- Within “Track Set Left” the mean Fractional Anisotropy values for track “A” (0.475) and “B” (0.667).
- For “Track Set Left” the maximum Fractional Anisotropy value (0.9).
- Diffusion acquisition, model and tracking algorithm information.
- Image instance references used to define the Tractography Results instance.

Table XX-1. Example of the Tractography Results Module

Name	Tag	Value	Comment
Instance Number	(0020,0013)	1	
Content Label	(0070,0080)	Left and Right	
Content Description	(0070,0081)	Two Sample Tracksets	
Content Creator’s Name	(0070,0084)	<empty>	*Type 2 Attribute*
Content Date	(0008,0023)	20150529	
Content Time	(0008,0033)	121933.000000	
Track Set Sequence	(0066,0101)		
Item 1 (First Track Set “Track Set Left”)			
>Track Set Number	(0066,0105)	1	
>Track Set Label	(0066,0106)	Track Set Left	
>Track Set Anatomical Type Code Sequence	(0066,0108)		
>>Code Sequence Macro Values	(0008,0100) (0008,0102) (0008,0104)	(T-A0095, SRT, “White matter of brain and spinal cord”)	*CID 7710*

	>>Modifier Code Sequence	(0040,A195)		
	Item 1			
	>>>Code Sequence Macro Values	…	(G-A101, SRT, “Left”)	*CID 244*
	>Track Sequence	(0066,0102)		
	Item 1 (First Track “A”)			
	>>Point Coordinates Data	(0066,0016)	**0, 0, 0** **1.5, 0.2, 0** **3.5, -0.1, 0** **5.5, 0.5, 0**	Coordinates of A1, A2, A3, A4
	>>Recommended Display CIELab Value List	(0066,0103)	**47270/40385/52501/** **34751/53214/49924/** **57318/11632/54042** **22077/53113/5901/**	Colors of A1, A2, A3, A4
	Item 2 (Second Track “B”)			
	>>Point Coordinates Data	(0066,0016)	**0, -4, 0** **2,-3.8, 0** **4,-4, 0**	Coordinates of B1, B2, B3
	>>Recommended Display CIELab Value	(0062,000D)	**57318/11632/54042**	Color of B1, B2, B3
	>Measurements Sequence	(0066,0121)		
	Item 1 (Fractional Anisotropy (FA) values stored on each Track)			
	>>Concept Name Code Sequence	(0040,A043)		
	>>>Code Sequence Macro Values	…	(110808, DCM, “Fractional Anisotropy”)	*CID 7263*
	>>Measurement Units Code Sequence	(0040,08EA)		
	>>>Code Sequence Macro Values	…	(1, UCUM, “no units”)	*CID 82*
	>>Measurement Values Sequence	(0066,0132)		
	Item 1 (FA Values for each point on first Track “A”)			
	>>>Floating Point Values	(0066,0125)	**0.2, 0.4, 0.5, 0.8**	FA values of A1, A2, A3, A4
	Item 2 (FA Values for each point on second Track “B”)			
	>>>Floating Point Values	(0066,0125)	**0.3, 0.8, 0.9**	FA values of B1, B2, B3
	Item 2 (Apparent Diffusion Coefficient (ADC) values stored on each Track)			

		>>Concept Name Code Sequence	(0040,A043)		
		>>>Code Sequence Macro Values	…	(113041, DCM, "Apparent Diffusion Coefficient")	*CID 7263*
		>>Measurement Units Code Sequence	(0040,08EA)		
		>>>Code Sequence Macro Values	…	(1, UCUM, "no units")	*CID 82*
		>>Measurement Values Sequence	(0066,0132)		
		Item 1 (ADC Values stored on 1st and 3rd point of first Track "A")			
		>>>Floating Point Values	(0066,0125)	**0.6, 0.7**	ADC values of A1 and A3
		>>>Track Point Index List	(0066,0129)	1, 3	
		Item 2 (ADC Values stored on 2nd point of second Track "B")			
		>>>Floating Point Values	(0066,0125)	**0.5**	ADC value of B2
		>>>Track Point Index List	(0066,0129)	2	
	>Track Statistics Sequence		(0066,0130)		*Statistical values derived from each Track*
		Item 1 (Mean FA values for Tracks "A" and "B")			
		>>Concept Name Code Sequence	(0040,A043)		
		>>>Code Sequence Macro Values	…	(110808, DCM, "Fractional Anisotropy")	*CID 7263*
		>>Modifier Code Sequence	(0040,A195)		
		>>>Code Sequence Macro Values	…	(R-00317, SRT, "Mean")	*CID 3488 (part of CID 7464)*
		>>Measurement Units Code Sequence	(0040,08EA)		
		>>>Code Sequence Macro Values	…	(1, UCUM, "no units")	*CID 82*
		>>Floating Point Values	(0066,0125)	0.475, 0.667	
	>Track Set Statistics Sequence		(0066,0124)		*Statistical values derived from whole track set*
		Item 1 (Maximum FA value of whole Track Set "Track Set Left")			

>>Concept Name Code Sequence	(0040,A043)		
>>>Code Sequence Macro Values	…	(110808, DCM, “Fractional Anisotropy”)	*CID 7263*
>>Modifier Code Sequence	(0040,A195)		
>>>Code Sequence Macro Values	…	(G-A437, SRT, “Maximum”)	*CID 3488 (part of CID 7464)*
>>Measurement Units Code Sequence	(0040,08EA)		
>>>Code Sequence Macro Values	…	(1, UCUM, “no units”)	*CID 82*
>>Floating Point Value	(0040,A161)	0.9	
>Diffusion Acquisition Code Sequence	(0066,0133)		
>>Code Sequence Macro Values	…	(113223, DCM, “DTI”)	*CID 7260*
>Diffusion Model Code Sequence	(0066,0134)		
>>Code Sequence Macro Values	…	(113231, DCM, “Single Tensor”)	*CID 7261*
>Tracking Algorithm Identification Sequence	(0066,0104)		
Item 1			
>>Algorithm Family Code Sequence	(0066,002F)		
>>>Code Sequence Macro Values	…	(113211, DCM, “Deterministic”)	*CID 7262*
>>Algorithm Name	(0066,0036)	Example	
>>Algorithm Version	(0066,0031)	1.0	
Item 2 (Second Track Set “Track Set Right”)			
>Track Set Number	(0066,0105)	2	
>Track Set Label	(0066,0106)	Track Set Right	
>Track Set Anatomical Type Code Sequence	(0066,0108)		
>>Code Sequence Macro Values	(0008,0102) (0008,0100) (0008,0104)	(T-A0095, SRT, “White matter of brain and spinal cord”)	*CID 7710*
>>Modifier Code Sequence	(0040,A195)		
Item 1			
>>>Code Sequence Macro Values	…	(G-A100, SRT, “Right”)	*CID 244*
>Track Sequence	(0066,0102)		
Item 1 (Single Track “C”)			

>>Point Coordinates Data	(0066,0016)	**6, 0.1, 0** **5.8, -2, 0** **6.2, -4.5, 0**	Coordinates of C1, C2, C3
>Recommended Display CIELab Value	(0062,000D)	**34751/53214/49924/**	Color of C1, C2, C3
>Diffusion Acquisition Code Sequence	(0066,0133)		
>>Code Sequence Macro Values	…	(113223, DCM, “DTI”)	*CID 7260*
>Diffusion Model Code Sequence	(0066,0134)		
>>Code Sequence Macro Values	…	(113231, DCM, “Single Tensor”)	*CID 7261*
>Tracking Algorithm Identification Sequence	(0066,0104)		
Item 1			
>>Algorithm Family Code Sequence	(0066,002F)		
>>>Code Sequence Macro Values	…	(113211, DCM, “Deterministic”)	*CID 7262*
>>Algorithm Name	(0066,0036)	Example	
>>Algorithm Version	(0066,0031)	1.0	
Referenced Instance Sequence	(0008,114A)		
Item 1			
>Referenced SOP Class UID	…	1.2.840.10008.5.1.4.1.1.4	*MR Image Storage*
>Referenced SOP Instance UID	…	1.2.3.4.1	
Item 2			
>Referenced SOP Class UID	…	1.2.840.10008.5.1.4.1.1.4	*MR Image Storage*
>Referenced SOP Instance UID	…	1.2.3.4.2	
…			
Item n			
>Referenced SOP Class UID	…	1.2.840.10008.5.1.4.1.1.4	*MR Image Storage*
>Referenced SOP Instance UID	…	1.5.6.1	