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Digital Imaging and Communications in Medicine (DICOM)

Supplement 218: MR Protocol Storage

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Scope and Field of Application

This Supplement defines a pair of storage SOP Classes to distribute defined MR protocols and to record performed MR protocols.

The two storage SOP Classes are:

- 75 • **MR Defined Procedure Protocol Storage** SOP Class that describes desired values (and/or value ranges) for various parameters of an acquisition procedure. Defined Protocols are independent of a specific patient. Defined Protocols are typically specific to a certain scanner model and/or version (identified by device attributes in the protocol), but model-non-specific protocols are not prohibited.
- 80 • **MR Performed Procedure Protocol Storage** SOP Class that describes the values actually used in a performed acquisition. Performed protocols are patient-specific.

The SOP Classes address details including:

- patient preparation
- equipment characteristics
- acquisition technique.

85 Defined Procedure Protocol instances exist in the equipment hierarchy and can be accessed with the Defined Procedure Protocol query/retrieve service.

Performed Procedure Protocol instances exist in the traditional Patient-Study-Series hierarchy and can be accessed with the conventional query/retrieve service.

90 The primary goal is to set up the MR scanner, not to script the entire behavior of the department, or the scan suite.

It is also not the intent to serialize the internal state of the system. The Defined Procedure Protocol represents a starting point for setting up a MR scan for a given patient and the Performed Procedure Protocol represents the actual parameters when the initial MR scan is completed, but there is no record of the intermediate states between those.

95 It is expected that the vast majority of protocol objects will be specific to a certain model and version of the MR scanner. There is no requirement that a MR scanner be able to run a protocol from another MR scanner.

Open Issues

- 100 • C.34.8 Patient Positioning Module: do we need to extend CID 1010 for MR purpose?
Yes we need to add this and think about how we combine stacks.
- How we should proceed with Sup 164: Contrast Agent Administration Reporting?
We can park it for now or come with a proposal on how to make the connection. The control points in the protocol are still needed.
- 105 • How to get the proper contrast information for the Enhanced MR Images?
Might get intermediate reports from the injector.

Changes to NEMA Standards Publication PS 3.2**Digital Imaging and Communications in Medicine (DICOM)****Part 2: Conformance**110 **Add new SOP Classes in Table A.1-2****Table A.1-2
UID VALUES**

UID Value	UID NAME	Category
...		
<u>1.2.840.10008.5.1.4.1.1.200.x</u>	<u>MR Defined Procedure Protocol Storage</u>	<u>Transfer</u>
<u>1.2.840.10008.5.1.4.1.1.200.x</u>	<u>MR Performed Procedure Protocol Storage</u>	<u>Transfer</u>

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Changes to NEMA Standards Publication PS 3.3

Digital Imaging and Communications in Medicine (DICOM)

Part 3: Information Object Definitions

Add new IODs in Table A.1-1

IODs Modules	MR Performed Procedure Protocol	MR Defined Procedure Protocol
Patient	M	
Clinical Trial Subject	U	
General Study	M	
Patient Study	U	
Clinical Trial Study	U	
General Series	M	
Clinical Trial Series	U	
Enhanced Series	M	
MR Protocol Series	M	
Frame of Reference	M	
Synchronization	C	C
General Equipment	M	M
Enhanced General Equipment	M	M
SOP Common	M	M
Protocol Context	M	M
Clinical Trial Context		
Patient Protocol Context		
Patient Specification		
Equipment Specification	M	M
Instructions		
Defined MR Acquisition		
Performed MR Acquisition		
Defined MR Reconstruction		
Performed MR Reconstruction		
Defined Storage		
Performed Storage		

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Add section to Annex A**A.X PROCEDURE PROTOCOL INFORMATION OBJECT DEFINITIONS**

Procedure Protocol Information Object Definitions (IODs) encode the details of procedure protocols.

- 125 Separate IODs are defined for different types of Procedure Protocol, such as a MR image acquisition Procedure Protocol. A MR Performed Procedure Protocol IOD encodes the details of a procedure that has been performed, and a MR Defined Procedure Protocol IOD specifies details of a procedure that may be used for one or more Procedure Protocols to be performed in the future.

A.x.1 MR Performed Procedure Protocol Information Object Definition**130 A.x.1.1 MR Performed Procedure Protocol IOD Description**

The MR Performed Procedure Protocol IOD describes acquisition protocol parameter values used during a specific performed MR procedure.

A.x.1.2 MR Performed Procedure Protocol IOD Entity-Relationship Model

This IOD uses the E-R Model in Section A.1.2, with only the Procedure Protocol IE below the Series IE.

135 A.x.1.3 MR Performed Procedure Protocol IOD Module Table

**Table A.x.1.3-1
MR Performed Procedure Protocol IOD MODULES**

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
	Enhanced Series	C.7.3.3	M
	MR Protocol Series	C.34.x	M
Frame of Reference	Frame of Reference	C.7.4.1	M
	Synchronization	C.7.4.2	C – Required if time synchronization was applied
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Procedure Protocol	SOP Common	C.12.1	M
	Protocol Context	C.34.2	M
	Patient Protocol Context	C.34.3	U
	Instructions	C.34.7	U

Patient Positioning	C.34.8	U
Performed MR Acquisition	C.34.x5	U
Performed MR Reconstruction	C.34.x6	U
Performed Storage	C.34.14	U

A.x.2 MR Defined Procedure Protocol Information Object Definition

140 **A.x.2.1 MR Defined Procedure Protocol IOD Description**

The MR Defined Procedure Protocol IOD describes acquisition protocol parameters and related details for a defined MR procedure.

See PS3.17 Annex AAAA for explanatory information and examples.

A.x.2.2 MR Defined Procedure Protocol IOD Entity-Relationship Model

145 The Procedure Protocol in a MR Defined Procedure Protocol IOD is not associated with a specific patient, however it is associated with the equipment that created the instance.

The E-R model for the MR Defined Procedure Protocol IOD is shown in Figure A.82.2.2-1.



Figure A.x.2.2-1 MR DEFINED PROCEDURE PROTOCOL IOD E-R MODEL

150 **A.x.2.3 MR Defined Procedure Protocol IOD Module Table**

**Table A.x.2.3-1
MR Defined Procedure Protocol IOD MODULES**

IE	Module	Reference	Usage
Frame of Reference	Synchronization	C.7.4.2	C – Required if time synchronization is needed
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Procedure Protocol	SOP Common	C.12.1	M
	Protocol Context	C.34.2	M
	Clinical Trial Context	C.34.4	U
	Patient Specification	C.34.5	U
	Equipment Specification	C.34.6	M
	Instructions	C.34.7	U
	Patient Positioning	C.34.8	U
	Defined MR Acquisition	C.34.x2	U

Defined MR Reconstruction	C.34.x4	U
Defined Storage	C.34.13	U

A.x.2.3.1 MR Defined Procedure Protocol IOD Content Constraints

155 **A.x.2.3.1.1 Equipment Modality Attribute**

The value of Equipment Modality (0008,0221) shall be MR.

Note: An application can query for Protocols by matching on the modality-specific Defined Protocol SOP Class.

160 **Modify C.7.3.1.1.1 to add MRPROTOCOL to the list of Modality Terms**

C.7.3.1.1.1 Modality

...

Defined Terms:

MRPROTOCOL **MR Protocol (Performed)**

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Add new protocol module sections

C.34 PROCEDURE PROTOCOL MODULES

170 This section describes modules specific to the family of Defined and Performed Procedure Protocol IODs.

C.34.x.1 MR Protocol Series

The MR Protocol IODs use the General Series module described in Section C.7.3.1, specialized by the MR Protocol Series Module, to describe the DICOM Series Entity described in Section A.1.2.3, and to define what constitutes a Series for the context of a Protocol.

175 Table C.x.1-1 specifies the Attributes that describe a MR Protocol series.

Table C.x.1-1. MR Protocol Series Module Attributes

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of data in this Series. Enumerated Values: MRPROTOCOL See Section C.7.3.1.1.1 for further explanation.

C.34.x.2 Defined MR Acquisition

180 Table C.35.2-1 contains a specification of acceptable values and ranges of acquisition parameters for an imaging procedure.

**Table C.x.2-1
DEFINED MR ACQUISITION MODULE ATTRIBUTES**

Attribute Name	Tag	Type	Attribute Description
Acquisition Protocol Element Specification Sequence	(0018,991F)	1	Specification of the acquisition parameters for acquisition protocol elements in an imaging procedure. There shall be one item in this sequence for each Acquisition Protocol Element in the Protocol. See C.34.9.1. One or more Items shall be included in this Sequence.
>Protocol Element Number	(0018,9921)	1	The Protocol Element Number of the Acquisition Protocol Element being specified in this item.
>Parameters Specification Sequence	(0018,9913)	3	Constraints on one or more acquisition parameters. One or more Items are permitted in this Sequence.
>>Include 'Attribute Value Constraint Macro' Table 10.25-1			Only Attributes defined in Table C.34.x.3-1 (i.e. in the Acquisition Protocol Element Sequence (0018,9920) in the Performed MR Acquisition Module) and private Data Elements associated with this acquisition protocol element may be specified as Selector Attributes. The semantics of values of Constraint Violation Significance (0082,0036) in the macro are assigned in C.34.9.3. The same Attribute shall not appear in more than one item in the sequence with the same values for Selector Sequence Pointer (0072,0052) and Selector Sequence Pointer Items (0074,1057).
>>Modifiable Constraint Flag	(0082,0038)	1C	Specifies whether this constraint may be encoded in a derived instance with a different value. See C.34.9.4. Enumerated Values: YES – the constraint may be modified. NO – the constraint may not be modified. Required if the constraint may not be modified, may be present otherwise.

185 **C.34.x.3 Acquisition Protocol Elements**

A MR Protocol usually includes more than one Acquisition Protocol Elements. The example below illustrates the localizer and a neuro element of a protocol definition.

Table C.34.x.3-1. Example Usage of Selector Macro Attributes for Acquisition Constraints

Example	Selector Attribute (0072,0026)	Selector Value Number (0072,0028)	Selector Sequence Pointer (0072,0052)	Selector Sequence Pointer Items (0074,1057)	Example Constraint
Constrain the value of Element Name (0018,9922) of the first item in the Acquisition Protocol Element Sequence (0018,9920)	(0018,9922)	1	(0018,9920)	1	EQUAL "Localizer"
Constrain the value of the Pulse Sequence Name (0018,9005) of the first item in the Acquisition Protocol Element Sequence (0018,9920)	(0018,9005)	1	(0018,9920)	1	EQUAL "loc2d"
Constrain the value of the MR Acquisition Type (0018,0023) of the first item in the Acquisition Protocol Element Sequence (0018,9920)	(0018,0023)	1	(0018,9920)	1	EQUAL "2D"
Constrain the value of the Echo Pulse Sequence (0018,9008) of the first item in the Acquisition Protocol Element Sequence (0018,9920)	(0018,9008)	1	(0018,9920)	1	EQUAL "GRADIENT"
...
Constrain the value of Element Name (0018,9922) of the second item in the Acquisition Protocol Element Sequence (0018,9920)	(0018,9922)	1	(0018,9920)	2	EQUAL "NeuroBold"
Constrain the value of the Pulse Sequence Name (0018,9005) of the first item in the Acquisition Protocol Element Sequence (0018,9920)	(0018,9005)	1	(0018,9920)	2	EQUAL "bold3d"
Constrain the value of the MR Acquisition Type (0018,0023) of the second item in the Acquisition Protocol Element Sequence (0018,9920)	(0018,0023)	1	(0018,9920)	2	EQUAL "3D"
Constrain the value of the Echo Pulse Sequence (0018,9008) of the second item in the Acquisition Protocol Element Sequence (0018,9920)	(0018,9008)	1	(0018,9920)	2	EQUAL "GRADIENT"
...

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C.34.x.4 Defined MR Reconstruction

Table C.34.x.3-1 contains specification of acceptable values and ranges of reconstruction parameters for an imaging procedure.

**Table C.34.x.4-1
DEFINED MR RECONSTRUCTION MODULE ATTRIBUTES**

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Attribute Name	Tag	Type	Attribute Description
Reconstruction Protocol Element Specification Sequence	(0018,9933)	1	Specification of the parameters for reconstruction of the acquired data of an imaging procedure. There shall be one item in this sequence for each reconstruction protocol element in the Protocol. See C.34.11.1. One or more Items shall be included in this Sequence.
>Protocol Element Number	(0018,9921)	1	The Protocol Element Number of the Reconstruction Protocol Element being specified in this item.
>Parameters Specification Sequence	(0018,9913)	3	Constraints on reconstruction parameters. One or more Items are permitted in this Sequence.
>>Include 'Attribute Value Constraint Macro' Table 10.25-1			Only Attributes defined in Table C.34.x.5-1 (i.e. in the Reconstruction Protocol Element Sequence (0018,9934) in the Performed MR Reconstruction Module) and private Data Elements associated with this reconstruction protocol element may be specified as Selector Attributes. The semantics of values of Constraint Violation Significance (0082,0036) in the macro are assigned in C.34.9.3. The same Attribute shall not appear in more than one item in the sequence with the same values for Selector Sequence Pointer (0072,0052) and Selector Sequence Pointer Items (0074,1057).
>>Modifiable Constraint Flag	(0082,0038)	1C	Whether this constraint may be encoded in a derived instance with a different value. See C.34.9.4. Required if the constraint may not be modified, may be present otherwise. Enumerated Values: YES – the constraint may be modified. NO – the constraint may not be modified.

C.34.x.5 Performed MR Acquisition

200 This Module contains acquisition parameter values for a performed MR imaging procedure on a MR scanner. The purpose of this module is to record all relevant parameters, not just to record the values that were constrained in the executed Defined Protocol.

The Module contains attributes to perform Enhanced MR Images and MR Spectroscopy Objects.

**Table C.34.x.5-1
PERFORMED MR ACQUISITION MODULE ATTRIBUTES**

Attribute Name	Tag	Type	Attribute Description
Acquisition Protocol Element Sequence	(0018,9920)	2	Parameter values for each Protocol Element in the acquisition protocol. Each item in the sequence describes one Element. Elements are performed in the order of their Protocol Element Number (0018,9921). See C.34.9.1. Zero or more Items shall be included in this Sequence.
>Include 'Protocol Element Identification Macro' Table 10.28-1			
>Included 'Enhanced Contrast/Bolus Module' Table C.7-12b			Attributes that describe the contrast/bolus used for the acquisition of Enhanced MR Images and MR Spectroscopy Objects
>>Contrast/Bolus Agent Sequence	(0018,0012)	2	Sequence that identifies one or more contrast agents administered prior to or during the acquisition. Zero or more Items shall be included in this Sequence.
>>>Include Table 8.8-1 "Code Sequence Macro Attributes"	Baseline CID 12 "Radiographic Contrast Agent".		
>>>Contrast/Bolus Agent Number	(0018,9337)	1	Identifying number, unique within this SOP Instance, of the agent administered. Used to reference this particular agent from the Contrast/Bolus Functional Group Macro. The number shall be 1 for the first Item and increase by 1 for each subsequent Item.
>>>Contrast/Bolus Administration Route Sequence	(0018,0014)	1	Sequence that identifies the route of administration of contrast agent. Only a single Item shall be included in this Sequence.
>>>>Include Table 8.8-1 "Code Sequence Macro Attributes"	Baseline CID 11 "Route of Administration".		
>>>Contrast/Bolus Ingredient Code Sequence	(0018,9338)	2	Active ingredient of agent. Zero or more Items shall be included in this Sequence.

Commented [SE1]: Do we need a reference to a contrast/bolus SR alternative ?

Commented [SE2]: Contrast agent definition on protocol level or acquisition level ?

>>>>Include Table 8.8-1 "Code Sequence Macro Attributes"	Baseline CID 13 "Radiographic Contrast Agent Ingredient".		
>>>Contrast/Bolus Volume	(0018,1041)	2	Total volume administered in milliliters of diluted contrast agent.
>>>Contrast/Bolus Ingredient Concentration	(0018,1049)	2	Milligrams of active ingredient per milliliter of agent.
>>>Contrast/Bolus Ingredient Percent by Volume	(0052,0001)	3	Percentage by volume of active ingredient in the total volume.
>>>Contrast/Bolus Ingredient Opaque	(0018,9425)	3	Absorption of the ingredient greater than the absorption of water (tissue). Enumerated Values: YES NO See Section C.7.6.4b.1.
>>>Contrast/Bolus T1 Relaxivity	(0018,0013)	3	T1 Relaxivity of the MR Contrast/Bolus used specified in s ⁻¹ mmol ⁻¹ specified at body temperature in human blood plasma.
>Included 'MR Pulse Sequence Module' Table C.8-87			Attributes that describe the pulse sequences for Enhanced MR Images
>>Pulse Sequence Name	(0018,9005)	1	Name of the pulse sequence for annotation purposes. Potentially vendor-specific name.
>>MR Acquisition Type	(0018,0023)	1	Identification of spatial data encoding scheme. Defined Terms: 1D 2D 3D
>>Echo Pulse Sequence	(0018,9008)	1	Echo category of pulse sequences. Enumerated Values: SPIN GRADIENT BOTH
>>Multiple Spin Echo	(0018,9011)	1C	Multiple Spin Echo category of pulse sequence used to collect different lines in k-space for a single frame. Enumerated Values: YES NO
>>Multi-planar Excitation	(0018,9012)	1	Technique that simultaneously excites several volumes.

			Enumerated Values: YES NO
>>Phase Contrast	(0018,9014)	1	Phase contrast pulse sequence is a pulse sequence in which the flowing spins are velocity encoded in phase. Enumerated Values: YES NO
>>Velocity Encoding Acquisition Sequence	(0018,9092)	1C	Velocity encoding directions used for acquisition. Required if Phase Contrast (0018,9014) equals YES. One or more Items shall be included in this Sequence.
>>>Velocity Encoding Direction	(0018,9090)	1	The direction cosines of the velocity encoding vector with respect to the patient. See Section C.7.6.2.1.1 for further explanation.
>>Time of Flight Contrast	(0018,9015)	1	Time of Flight contrast is created by the inflow of blood in the saturated plane. Enumerated Values: YES NO
>>Arterial Spin Labeling Contrast	(0018,9250)	1C	Arterial Spin Labeling contrast technique. Enumerated Values: CONTINUOUS a single long low powered RF pulse PSEUDOCONTINUOUS multiple short low powered RF pulses PULSED a single short high powered RF pulse Required if the acquisition is ASL. May be present otherwise.
>>Steady State Pulse Sequence	(0018,9017)	1	Steady State Sequence. Defined Terms: FREE_PRECESSION TRANSVERSE TIME_REVERSED LONGITUDINAL NONE
>>Echo Planar Pulse Sequence	(0018,9018)	1	Echo Planar category of Pulse Sequences. Enumerated Values: YES NO

Commented [SE3]: Consistent to the Enhanced MR IOD.

>>Saturation Recovery	(0018,9024)	1	Saturation recovery pulse sequence. Enumerated Values: YES NO
>>Spectrally Selected Suppression	(0018,9025)	1	Spectrally Selected Suppression. Defined Terms: FAT WATER FAT_AND_WATER SILICON_GEL NONE
>>Oversampling Phase	(0018,9029)	1	Oversampling Phase. Enumerated Values: 2D phase direction 3D out of plane direction 2D_3D both NONE
>>Geometry of k-Space Traversal	(0018,9032)	1	Geometry category of k-Space traversal. Defined Terms: RECTILINEAR RADIAL SPIRAL
>>Rectilinear Phase Encode Reordering	(0018,9034)	1C	Rectilinear phase encode reordering. Defined Terms: LINEAR CENTRIC SEGMENTED REVERSE_LINEAR REVERSE_CENTRIC Required if Geometry of k-Space Traversal (0018,9032) equals RECTILINEAR.
>>Segmented k-Space Traversal	(0018,9033)	1	Segmented k-Space traversal. If Geometry of k-Space Traversal is rectilinear, multiple lines can be acquired at one time. If Geometry of k-Space Traversal is spiral or radial, paths can be interleaved and acquired at one time. Enumerated Values: SINGLE successive single echo coverage PARTIAL segmented coverage FULL single shot full coverage
>>Coverage of k-Space	(0018,9094)	1C	Coverage of k-Space in the ky-kz plane. Defined Terms: FULL CYLINDRICAL

			ELLIPSOIDAL WEIGHTED Required if MR Acquisition Type (0018,0023) equals 3D.
>>Number of k-Space Trajectories	(0018,9093)	1	Number of interleaves or shots.
>>Included 'Enhanced MR Image Functional Group Macros' Table A.36-2			Attributes that describe the Functional Group Macros for Enhanced MR Images
>>Include 'Pixel Measures' Section C.7.6.16.2.1			M
>>Include 'Frame Content' Section C.7.6.16.2.2			M
>>Include 'Cardiac Synchronization' Section C.7.6.16.2.7			C - Required if Cardiac Synchronization Technique (0018,9037) equals other than NONE and if Image Type (0008,0008) Value 1 is ORIGINAL or MIXED. May be present otherwise.
>>Include 'Frame Anatomy' Section C.7.6.16.2.8			M
>>Include 'Pixel Value Transformation' Section C.7.6.16.2.9			C - Required if Photometric Interpretation (0028,0004) is MONOCHROME2
>>Include 'Contrast/Bolus Usage' Section C.7.6.16.2.12			C - Required if Contrast/Bolus Agent Sequence (0018,0012) is used.
>>Include 'Respiratory Synchronization' Section C.7.6.16.2.17			C - Required if Respiratory Motion Compensation Technique (0018,9170) equals other than NONE, REALTIME or BREATH_HOLD and if Image Type (0008,0008) Value 1 is ORIGINAL or MIXED. May be present otherwise.
>>Include 'MR Image Frame Type' Section C.8.13.5.1			M
>>Include 'MR Timing and Related Parameters' Section C.8.13.5.2			M
>>Include 'MR FOV/Geometry' Section C.8.13.5.3			M
>>Include 'MR Echo' Section C.8.13.5.4			M
>>Include 'MR Modifier' Section C.8.13.5.5			M
>>Include 'MR Imaging Modifier' Section C.8.13.5.6			M
>>Include 'MR Receive Coil' Section C.8.13.5.7			M
>>Include 'MR Transmit Coil' Section C.8.13.5.8			M
>>Include 'MR Diffusion' Section C.8.13.5.9			C - Required if Acquisition Contrast (0008,9209) in any MR Image Frame Type Functional Group in the SOP Instance equals DIFFUSION and Image Type (0008,0008) Value 1 is ORIGINAL or MIXED. May be present otherwise.
>>Include 'MR Averages' Section C.8.13.5.10			M
>>Include 'MR Spatial Saturation' Section C.8.13.5.11			C - Required if Spatial Pre-saturation (0018,9027) equals SLAB for any frame in the SOP Instance and Image Type (0008,0008) Value 1 is ORIGINAL or MIXED. May be present otherwise.
>>Include 'MR Metabolite Map' Section C.8.13.5.12			C - Required if Image Type (0008,0008) Value 3 equals METABOLITE_MAP. May be present otherwise.
>>Include 'MR Velocity Encoding' Section C.8.13.5.13			C - Required if Phase Contrast (0018,9014) equals YES and Image Type (0008,0008) Value

	1 is ORIGINAL or MIXED. May be present otherwise.
>>Include MR Arterial Spin Labeling' Section C.8.13.5.14	C - Required if Image Type (0008,0008) Value 3 is ASL. May be present otherwise.
>>Include Functional MR' Section C.8.13.5.15	U
>Include 'MR Spectroscopy Module' Table C.8-102	Attributes that describe the Spectroscopy Module for MR Spectroscopy Objects
>Include 'MR Spectroscopy Pulse Sequence Module' Table C.8-103	Attributes that describe the pulse sequences for MR Spectroscopy Objects
>Include 'MR Spectroscopy Functional Group Macros' Table A.36-4	Attributes that describe the Functional Group Macros for MR Spectroscopy Objects
>Include 'MR Spectroscopy Data Module Attributes' Table C.8-106	Attributes that describe the Spectroscopy Data for MR Spectroscopy Objects. The Spectroscopy Data attribute (5600,0020) must be excluded

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C.34.x.6 Performed MR Reconstruction

This Module contains reconstruction parameter values for a performed MR imaging procedure.

This Module contains Attributes that affect machine behavior but not those that are merely descriptive. The latter may be found in the performed images.

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**Table C.34.x.6-1
PERFORMED MR RECONSTRUCTION MODULE ATTRIBUTES**

Attribute Name	Tag	Type	Attribute Description
Reconstruction Protocol Element Sequence	(0018,9934)	1	Parameter values for each reconstruction protocol element in the Protocol. Elements are performed in the order of their Protocol Element Number (0018,9921). One or more Items shall be included in this Sequence.
>Include Protocol Element Identification Macro Table 10.28-1			
>Included 'Enhanced MR Image Module' Table C.8-79			
>>Image Type	(0008,0008)	1	Image characteristics. See Section C.8.16.1 and Section C.8.13.1.1.1.
>>Pixel Presentation	(0008,9205)	1	Indication of the presence or absence of color information that may be used during rendering. See Section C.8.16.2.1.1 for a description and Enumerated Values.
>>Volumetric Properties	(0008,9206)	1	Indication if geometric manipulations are possible with frames in the SOP Instance. See Section C.8.16.2.1.2 for a description and Enumerated Values.

>>Volume Based Calculation Technique	(0008,9207)	1	Method used for volume calculations with frames in the SOP Instance. See Section C.8.16.2.1.3 for a description and Defined Terms.
>>Complex Image Component	(0008,9208)	1C	Representation of complex data of frames in the SOP Instance. See Section C.8.13.3.1.1 for a description and Defined Terms. Required if SOP Class UID is not "1.2.840.10008.5.1.4.1.1.4.4" (Legacy Converted). May be present otherwise.
>>Acquisition Contrast	(0008,9209)	1C	Indication of acquisition contrast used with frames in the SOP Instance. See Section C.8.13.3.1.2 for a description and Defined Terms. Required if SOP Class UID is not "1.2.840.10008.5.1.4.1.1.4.4" (Legacy Converted). May be present otherwise.
>>Functional Settling Phase Frames Present	(0018,9622)	3	Specifies if the acquisition used and stored settling phases. Enumerated Values: YES NO
>>Samples per Pixel	(0028,0002)	1	Number of samples (planes) in this image. For Enumerated Values See Section C.8.13.1.1.2.
>>Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. Enumerated Values are specified in the IOD that invokes this Module. See Section C.7.6.3.1.2 for definition of this term.
>>Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Each sample shall have the same number of bits allocated. For Enumerated Values See Section C.8.13.1.1.2.
>>Bits Stored	(0028,0101)	1	Number of bits stored for each pixel sample. Each sample shall have the same number of bits stored. For Enumerated Values See Section C.8.13.1.1.2.
>>High Bit	(0028,0102)	1	Most significant bit for pixel sample data. Each sample shall have the same high bit. Shall be one less than the value in Bits Stored (0028,0101).
>>Pixel Representation	(0028,0103)	1	Data representation of the pixel samples. Each sample shall have the same pixel representation. For Enumerated Values See Section C.8.13.1.1.2

>>Planar Configuration	(0028,0006)	1C	Indicates whether the pixel data are encoded color-by-plane or color-by-pixel. Required if Samples per Pixel (0028,0002) has a value greater than 1. See Section C.7.6.3.1.3 and Section C.8.13.1.1.2 for further explanation.
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Changes to NEMA Standards Publication PS 3.4

Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

215

Add SOP Classes to Table B.5-1

B.5 STANDARD SOP CLASSES

**Table B.5-1
Standard SOP Classes**

SOP Class Name	SOP Class UID	IOD Specification (defined in PS 3.3)
...		
<u>MR Performed Procedure Protocol Storage</u>	<u>1.2.840.10008.5.1.4.1.1.200.x</u>	<u>MR Performed Procedure Protocol IOD</u>
...		

220

Add new section to describe SCP requirements for MR Performed Procedure Protocol Storage

B.5.x MR Performed Procedure Protocol Storage SOP Class

The MR Performed Procedure Protocol Storage SOP Class encodes the acquisition protocol parameter values used during a specific performed MR procedure and related details.

225 For a device that is both a SCU and a SCP of the MR Performed Procedure Protocol Storage SOP Class, in addition to the behavior for the Storage Service Class specified in Section B.2.2, the following additional requirements are specified for MR Performed Procedure Protocol Storage SOP Classes:

- A SCP of this SOP Class shall support Level 2 Conformance as defined in Section B.4.1.

230 Note: This requirement means that all Type 1, Type 2, and Type 3 Attributes defined in the Information Object Definition and Private Attributes associated with the SOP Class will be stored and may be accessed.

235

Add Defined Protocol SOP to GG.3

GG.3 SOP Classes

240 The application-level services addressed by the Non-Patient Object Storage Service Class definition are specified in the SOP Classes specified in Table GG.3-1.

Table GG.3-1. Standard SOP Classes

SOP Class Name	SOP Class UID	IOD Specification (defined in PS3.3)
<u>MR Defined Procedure Protocol Storage</u>	<u>1.2.840.10008.5.1.4.1.1.200.x</u>	<u>MR Defined Procedure Protocol IOD</u>

Add GG.6.4 with SOP-specific details

GG.6.4 MR Defined Procedure Protocol Storage SOP Class

245 An implementation that conforms to the MR Defined Procedure Protocol Storage SOP Class as an SCP shall not modify constraints for which the value of the Modifiable Constraint Flag (0082,0038) is NO.

Modifying protocol constraints changes the semantics of a MR Defined Procedure Protocol Storage SOP Instance.

250

Changes to NEMA Standards Publication PS 3.6

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

Add the following rows to Section 6

255

Tag	Name	Keyword	VR	VM
-----	------	---------	----	----

Add the following rows to Table A-1

**Table A-1
UID Values**

UID Value	UID Name	UID Type	Part
...			
<u>1.2.840.10008.5.1.4.1.1.200.x</u>	<u>MR Defined Procedure Protocol Storage</u>	<u>SOP Class</u>	<u>PS 3.4</u>
<u>1.2.840.10008.5.1.4.1.1.200.x</u>	<u>MR Performed Procedure Protocol Storage</u>	<u>SOP Class</u>	<u>PS 3.4</u>
...			

260

Changes to NEMA Standards Publication PS 3.16

Digital Imaging and Communications in Medicine (DICOM)

Part 16: Content Mapping Resource

265

Changes to NEMA Standards Publication PS 3.17**Digital Imaging and Communications in Medicine (DICOM)****Part 17: Explanatory Information**270 **Add the following New Annex to PS3.17****Annex JJJJ Procedure Protocol Storage Examples and Concepts
(Informative)**

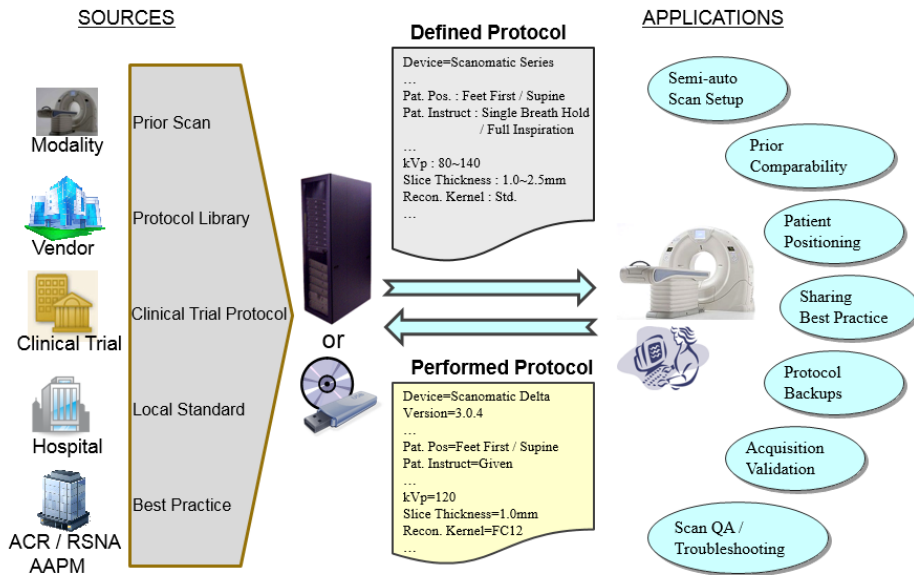
The following examples are provided to illustrate the usage of the MR Defined and Performed Procedure Protocol IODs. They do NOT represent recommended MR scanning practice.

275 **JJJJ.1 PROCEDURE PROTOCOL STORAGE CONCEPTS****JJJJ.1.1 Use Cases**

The primary applications (use cases) considered during the development of the MR Procedure Protocol Storage IODs were the following:

- 280 • Managing protocols within a site for consistency
(Using Defined Protocols)
- Recording protocol details for a performed study so the same or similar values can be used when performing follow-up or repeat studies
(Using Performed Protocols)
- 285 • Vendor troubleshooting image quality issues that may be due to poor protocol/technique
(Using Performed Protocols, Defined Protocols)
- Distributing departmental, "best practice" or reference protocols to modality systems
(Using Defined Protocols)
- 290 • Backing up protocols from a modality to PACS or removable media (e.g., during system upgrades or replacement). Most vendors have a proprietary method for doing this which would essentially become redundant when Protocol Management is implemented.
(Using Defined Protocols)
- 295 • Making more detailed protocol information available to rendering or processing applications that would allow them to select processing that corresponds to the acquisition protocol, to select parameters appropriate to the acquisition characteristics, and to select the right series to process/display.
(Using Performed Protocols)
- Improving imaging consistency in terms of repeatable technique, performance, quality and image characteristics. Would benefit from associated image quality metrics and other physics work.
(Using Defined Protocols and Performed Protocols)

- 300 • Distributing clinical trial protocols (general purpose or MR scanner model specific) to participating sites
(Using Defined Protocols)
- Recording protocol details for a performed study to submit with clinical trial images for technique validation
305 (Using Performed Protocols)
- Tracking/extracting details of Performed Protocol such as timestamps, execution sequence and technique for QA, data mining, etc.
(Using Performed Protocols)
- 310 • Making more detailed protocol information available to radiologists reviewing a study and priors, or comparing similar studies of different patients.
(Using Performed Protocols)



JJJ.1.2 Workflow

315 Usually the MR scanner uses any protocol details in the Modality Worklist item to present to the technologist a list of matching Defined Protocols for this MR scanner and the requested acquisition.

Preparing and performing Defined Protocols

Radiologist at the RIS:

- Selects a imaging procedure for the Modality Worklist request
 - Adds notes for the technologist to the appropriate Modality Worklist entry (e.g., "Use Defined Protocol X; Decrease parameter Y...")
- 320

Technologist at the Modality:

- Selects the requested imaging procedure of the Modality Worklist
- Reads the tech notes in the Modality Worklist entry
- 325 • Selects the identified Defined Protocol and adjusts the parameter or modifies the protocol
- Performs acquisition procedure
- Optionally reviews the Performed Protocols
- Sends the study which includes the MR Protocol Series to the PACS system.

330 JJJJ.2 FMRI PROTOCOL

The examples in this Annex are intended to illustrate the encoding mechanisms of the DICOM MR Protocol Storage IODs, not to suggest particular values for clinical use. Further, this example do not contain the many detailed attributes one would expect from a fully executable defined protocol generated by a MR scanner, but it demonstrates the usage of many common attributes.

- 335 This section includes a Defined Protocol example of a fMRI protocol for several different scanner models. The protocol is presented as adjusted by a fictitious Mercy Hospital from a reference protocol referenced in the Predecessor Protocol Sequence.

JJJJ.2.1 Common Context

- 340 Table JJJJ.2-1 is basically the same for each MR scanner model. Table JJJJ.2-2 is specific for each MR scanner model.

Table JJJJ.2-1 fMRI - Context

Attribute	Tag	Value
Equipment Modality	(0008,0221)	MR
Custodial Organization Sequence	(0040,A07C)	
>Institution Name	(0008,0800)	Mercy Hospital
>Institution Code Sequence	(0008,0082)	
Responsible Group Code Sequence	(0008,0220)	(C2183225,UMLS, "Neuroradiology")
Protocol Name	(0018,1030)	2d_bold
Potential Scheduled Protocol Code Sequence	(0018,9906)	(24590-2, LN, "Brain MRI") ...
Potential Reasons for Procedure	(0018,9908)	Acute neurologic deficits\ Headache\ Suspected mass or tumor
Potential Diagnostic Tasks	(0018,990A)	Identify brain masses\ Detect brain edema or ischemia\ Identify shift in the normal locations of the brain structures
Predecessor Protocol Sequence	(0018,990E)	
Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.200.X

Referenced SOP Instance UID	(0008,1155)	9.8.7.6.5.12345.2
Content Creator's Name	(0070,0084)	Braindoc^Barry^^MD
Protocol Design Rationale	(0018,9910)	This protocol example demonstrates the usage of many common attributes.
Protocol Planning Information	(0018,990F)	Contrast use as indicated by radiologist
Instance Creation Date	(0008,0012)	20180718
Instance Creation Time	(0008,0013)	124200
Instruction Sequence	(0018,9914)	
>Instruction Index	(0018,9915)	1
>Instruction Text	(0018,9916)	"Contrast, if directed. See Instruction Description."
>Instruction Description	(0018,9917)	"Some indications require injection of intravenous or intrathecal contrast media during imaging of the brain. Intravenous contrast administration should be performed as directed by the supervising radiologist using appropriate injection protocols. A typical amount would be 100 cc at 300 mg/cc strength, injected at 1 cc/sec. A delay of 4 minutes between contrast injection and the start of scanning is typical."

JJJJ.2.2 MR Scantech Industries

345 The first part of this example is shown above in Table AAAA.2-1.

Table JJJJ.2-2 fMRI BOLD – Acquisition

Attribute	Tag	Value
Model Specification Sequence	(0018,9912)	
>Manufacturer	(0008,0070)	MR Scantech
>Manufacturer's Related Model Group	(0008,0222)	MR Scanomatic
>Software Versions	(0018,1020)	VMR33
Patient Specification Sequence	(0018,9911)	
<i>>See Table JJJJ.2-2a Patient Specification</i>		
Acquisition Protocol Element Specification Sequence	(0018,991F)	
>Protocol Element Number	(0018,9921)	1
>Parameters Specification Sequence	(0018,9913)	
<i>>>See Table JJJJ.2-2b First Acquisition Protocol Element Specification - Localizer</i>		
>Protocol Element Number	(0018,9921)	2
>Parameters Specification Sequence	(0018,9913)	
<i>>>See Table JJJJ.2-2c Second Acquisition Protocol Element Specification - fMRI</i>		
Private Data Element Characteristics Sequence	(0008,0300)	

>Private Group Reference	(0008,0301)	0x0021
>Private Creator Reference	(0008,0302)	"SCANTECH PRIVATE MR ELEMENTS"
>Private Data Element Definition Sequence	(0008,0310)	
>>Private Data Element	(0008,0308)	xx33
>>Private Data Element Value Multiplicity	(0008,0309)	1
>>Private Data Element Value Representation	(0008,030A)	IS
>>Private Data Element Keyword	(0008,030D)	fMRI Stimulus Info
>>Private Data Element Name	(0008,030C)	fMRI Stimulus Info
>>Private Data Element Description	(0008,030E)	Stimulus info about the assigned paradigm
>Block Identifying Information Status	(0008,0303)	SAFE

350 The following tables reflect the semantic contents of constraint sequences but not the actual structure of the IOD. The centered rows in italics clarify the context of the constrained attributes that follow by indicating which sequence in the performed module contains the constrained attribute (as specified in the Selector Sequence Pointer).

Table JJJ.2-2a Patient Specification

Attribute	Selector Attribute	Selector Value Number	Selector Sequence Pointer	Selector Sequence Pointer Items	Constraint Type	Constraint Value
Patient's Age	(0010,1010)	1	absent	absent	GREATER_THAN	"12Y"

Table JJJ.2-2b First Acquisition Protocol Element Specification - Localizer

Attribute	Selector Attribute	Selector Value Number	Selector Sequence Pointer	Selector Sequence Pointer Items	Constraint Type	Constraint Value
<i>Acquisition Protocol Element Sequence (0018,9920)</i>						
Protocol Element Name	(0018,9922)	1	(0018,9920)	1	EQUAL	Localizer
Content Qualification	(0018,9004)	1	(0018,9920)	1	EQUAL	PRODUCT
Resonant Nucleus	(0018,9100)	1	(0018,9920)	1	EQUAL	1H
Pixel Presentation	(0008,9205)	1	(0018,9920)	1	EQUAL	MONOCHROME
Volumetric Properties	(0008,9206)	1	(0018,9920)	1	EQUAL	VOLUME
Volume Based Calculation Technique	(0008,9207)	1	(0018,9920)	1	EQUAL	NONE
Image Type	(0008,0008)	3	(0018,9920)	1	EQUAL	LOCALIZER
Image Type	(0008,0008)	4	(0018,9920)	1	EQUAL	NONE
Complex Image Component	(0008,9208)	1	(0028,9920)	1	EQUAL	MAGNITUDE

Acquisition Contrast	(0008,9209)	1	(0028,9920)	1	EQUAL	UNKNOWN
Pulse Sequence Name	(0018,9005)	1	(0018,9920)	1	EQUAL	locpulse2d
MR Acquisition Type	(0018,0023)	1	(0018,9920)	1	EQUAL	2D
Echo Pulse Sequence	(0018,9008)	1	(0018,9920)	1	EQUAL	GRADIENT
Multiple Spin Echo	(0018,9011)	1	(0018,9920)	1	EQUAL	NO
Multi-planar Excitation	(0018,9012)	1	(0018,9920)	1	EQUAL	NO
Phase Contrast	(0018,9014)	1	(0018,9920)	1	EQUAL	NO
Time of Flight Contrast	(0018,9015)	1	(0018,9920)	1	EQUAL	NO
Steady State Pulse Sequence	(0018,9017)	1	(0018,9920)	1	EQUAL	NONE
Echo Planar Pulse Sequence	(0018,9018)	1	(0018,9920)	1	EQUAL	NO
Saturation Recovery	(0018,9024)	1	(0018,9920)	1	EQUAL	YES
Spectrally Selected Suppression	(0018,9025)	1	(0018,9920)	1	EQUAL	NONE
Oversampling Phase	(0018,9029)	1	(0018,9920)	2	EQUAL	NONE
Geometry of k-Space Traversal	(0018,9032)	1	(0018,9920)	1	EQUAL	RECTLINEAR
Rectilinear Phase Encode Reordering	(0018,9034)	1	(0018,9920)	1	EQUAL	LINEAR
Segmented k-Space Traversal	(0018,9033)	1	(0018,9920)	1	EQUAL	SINGLE
Number of k-Space Trajectories	(0018,9093)	1	(0018,9920)	1	EQUAL	1

355

Table JJJJ.2-2c Second Acquisition Protocol Element Specification - fMRI

Attribute	Selector Attribute	Selector Value Number	Selector Sequence Pointer	Selector Sequence Pointer Items	Constraint Type	Constraint Value
<i>Acquisition Protocol Element Sequence (0018,9920)</i>						
Protocol Element Name	(0018,9922)	1	(0018,9920)	2	EQUAL	fMRI
Content Qualification	(0018,9004)	1	(0018,9920)	2	EQUAL	PRODUCT
Resonant Nucleus	(0018,9100)	1	(0018,9920)	2	EQUAL	1H
Pixel Presentation	(0008,9205)	1	(0018,9920)	2	EQUAL	MONOCHROME
Volumetric Properties	(0008,9206)	1	(0018,9920)	2	EQUAL	VOLUME
Volume Based Calculation Technique	(0008,9207)	1	(0018,9920)	2	EQUAL	NONE
Image Type	(0008,0008)	3	(0018,9920)	2	EQUAL	FMRI
Image Type	(0008,0008)	4	(0018,9920)	2	EQUAL	NONE

Complex Image Component	(0008,9208)	1	(0028,9920)	2	EQUAL	MAGNITUDE
Acquisition Contrast	(0008,9209)	1	(0028,9920)	2	EQUAL	T1
Functional Settling Phase Frames Present	(0018,9622)	1	(0028,9920)	2	EQUAL	YES
Pulse Sequence Name	(0018,9005)	1	(0018,9920)	2	EQUAL	fmri2d
MR Acquisition Type	(0018,0023)	1	(0018,9920)	2	EQUAL	2D
Echo Pulse Sequence	(0018,9008)	1	(0018,9920)	2	EQUAL	GRADIENT
Multiple Spin Echo	(0018,9011)	1	(0018,9920)	2	EQUAL	NO
Multi-planar Excitation	(0018,9012)	1	(0018,9920)	2	EQUAL	NO
Phase Contrast	(0018,9014)	1	(0018,9920)	2	EQUAL	NO
Time of Flight Contrast	(0018,9015)	1	(0018,9920)	2	EQUAL	NO
Steady State Pulse Sequence	(0018,9017)	1	(0018,9920)	2	EQUAL	NONE
Echo Planar Pulse Sequence	(0018,9018)	1	(0018,9920)	2	EQUAL	YES
Saturation Recovery	(0018,9024)	1	(0018,9920)	2	EQUAL	YES
Spectrally Selected Suppression	(0018,9025)	1	(0018,9920)	2	EQUAL	NONE
Oversampling Phase	(0018,9029)	1	(0018,9920)	2	EQUAL	NONE
Geometry of k-Space Traversal	(0018,9032)	1	(0018,9920)	2	EQUAL	RECTLINEAR
Rectilinear Phase Encode Reordering	(0018,9034)	1	(0018,9920)	2	EQUAL	LINEAR
Segmented k-Space Traversal	(0018,9033)	1	(0018,9920)	2	EQUAL	SINGLE
Number of k-Space Trajectories	(0018,9093)	1	(0018,9920)	2	EQUAL	1