Digital Imaging and Communications in Medicine (DICOM)

Supplement 189: Functional MRI Blending Presentation State Storage

Prepared by:

DICOM Standards Committee, Working Group 16 (MR sub group Functional MRI)

1300 N. 17th Street, Suite 1752

Rosslyn, Virginia 22209 USA

VERSION: Draft, July 2015

Developed in accordance with: DICOM Workitem 2014-12-A

Table of Contents

DOCUMENT HISTORY

Document Version	Date	Content
01	17-Feb-2015	Initial Draft
04	05-May-2015	Updated with more definitions and first set of parameters with specific values.
06	21-July-2015	Cleanup accepted items.
07	15-Sept-2015	Version after F2F, updated name and got supplement number (189) from WG06
08	13-Oct-2015	Update for tcon, start to incorporate WG06 feedback
09	14-Oct-2015	Start of Blending object definition
10	19-Nov-2015	

Scope and Field

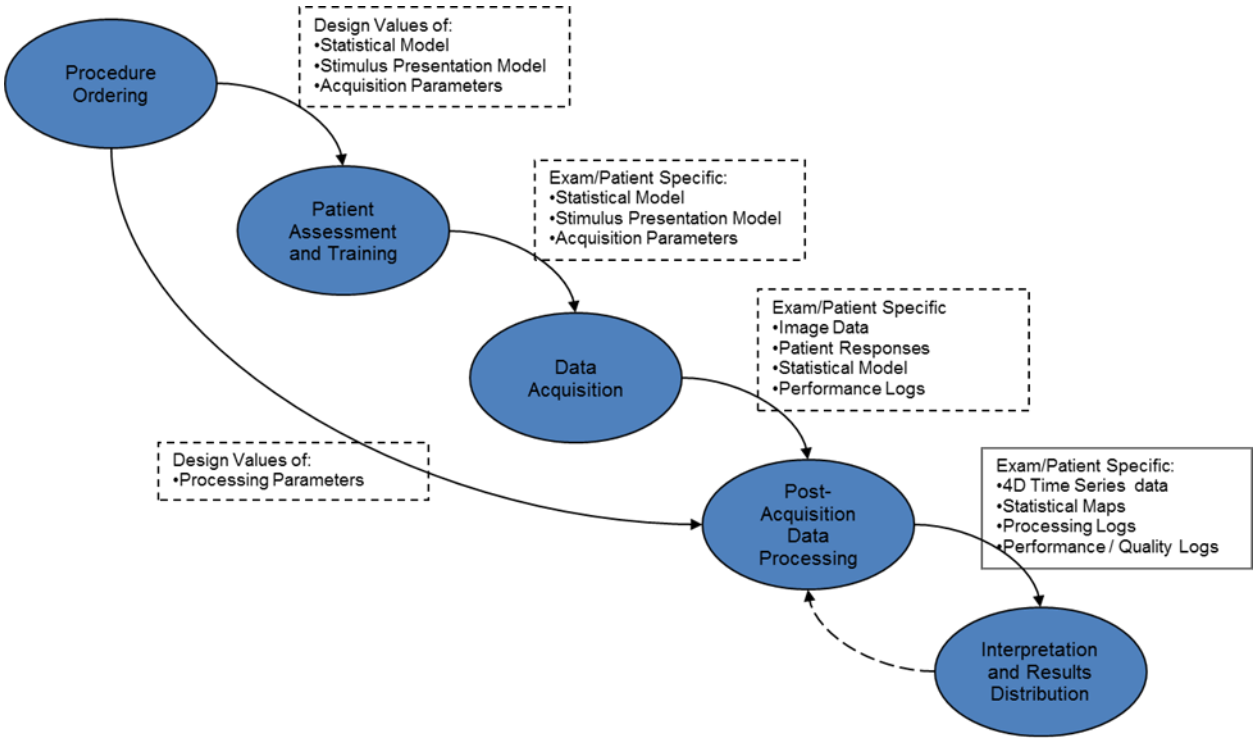
Since 2011 a Subcommittee of the QIBA-fMRI Technical Committee has been working on the description of the concepts surrounding task-based fMRI. These are generalized from the shared clinical and research experience of the QIBA-fMRI. This was done with the intend to be able to create the DICOM object and relationship definitions as well as procedure steps describing the workflow, inputs, and outputs of functional assessment with imaging. The current status is such that the adjustments to existing objects and the definition of new objects can start together with WG16.

The Paradigm is the set of stimuli that will be given to the patient combined with timing and other instructions needed for the correct execution. The type of stimuli will depend on the subject of the study (Motor, Hearing, Vision, Language, Cognitive, Memory, etc.) and can be images, sounds and all kind of tasks.
Limitations of Current Standard and Proposal

The current standard allows the storage of fMRI images in the Enhanced MR image object. The fMRI workflow however consists of multiple steps surrounding the actual imaging component, involving roles of patient, trainer, tester, processor and clinical user.
The proposal is to extend the DICOM framework to next to the imaging data also capture the workflow and data items like paradigms used during the functional assessment.

This supplement will is focusing on the correct storage of the fMRI image set. It is expected that CP 1476 defines the currently missing information in the Enhanced MR objects. The supplement will focus on the description of the usage of the Enhanced MR objects through describing the content for one or more use cases.

The fMRI workflow consists of the following steps, Procedure Ordering, Patient Assessment and Training, Data Acquisition, Post-Acquisition Data Processing and Interpretation and Results Distribution. The following figure gives the relation between these steps and the related data for the steps.



This supplement will focus on two items in the last step:

- 4D Time Series data
- Statistical Maps

It is expected that with the use of the Enhanced MR Image object and the Parametric Map object the data can be described in the right way. The usage of these will be described in a new chapter in PS 17 as Informative Annex. When needed extra information will be defined and added.

Patient Encounter for Pre-surgical Brain Mapping including fMRI

Step	*Actor*	*Action*	*Record*
		Procedure Ordering	
New Patient Encounter	Primary Treatment Provider	Shall evaluate the need for therapeutic intervention (e.g. surgery) in neurological disorder (e.g. brain tumor, epilepsy).	(HL7: RIS or EHR)
Mapping Order	Primary Treatment Provider	Shall create order for brain mapping (incl. preliminary timetable for intervention?)	(HL7: RIS or EHR)
		Patient Assessment and Training	

Step	*Actor*	*Action*	*Record*
New Patient Review	*Neuroradiologist*	*Shall review existing neuroimaging, symptoms; confirm need for brain mapping; set goals of brain mapping (e.g. motor strip, laterality, proximity of functional areas to resection, etc.); and select imaging methods to be employed (e.g. fMRI, diffusion MRI, perfusion MRI, PET, etc.)* Includes noting patient ability to understand the purpose of the imaging procedures, what is expected of them, and any risks.	(HL7: RIS or EHR)
Patient Assessment record (fMRI)	Neuroradiologist, Neuropsych.	Shall assess general ability of patient to understand and perform task-based fMRI procedures, by observing motor coordination, visual acuity, hearing, cooperation, etc.	(HL7: RIS or EHR)
Patient Training record (fMRI)	Neuroradiologist, Neuropsych., Technologist	*Per fMRI procedure:* *Shall explain purpose, procedure phases and patient role, interaction (response) if any, etc.* *Shall observe patient performance of procedure and evaluate results, correct patient behavior, adjust or replace procedure (e.g. speed, duration), and repeat as needed. Shall record final procedure choice and patient performance.*	Future WG-16 to-do
	Patient	*Per fMRI procedure:* *Shall perform procedure or facsimile under direction and observation of trainer.*	
Imaging Order	Neuroradiologist	*Shall order imaging studies required to meet the brain mapping goals, informed by the Patient Assessment and Patient Training (fMRI) results.*	(HL7: RIS or EHR)
Data Acquisition			
Scan session (fMRI)	Technologist	*Shall prepare patient for scanning (clothing, safety check, bathroom visit, etc.), and place patient in MRI scanner*	(HL7: RIS or EHR)

Step	*Actor*	*Action*	*Record*
Imaging Procedure (fMRI)	Neuroradiologist, Neuropsych., Technologist	*Per fMRI procedure:* *Shall review procedure with patient, and initiate procedure delivery system and MRI scanner acquisition.* *Shall observe patient performance of procedure and evaluate results, correct patient behavior, adjust or replace procedure (e.g. speed, duration), and repeat as needed. Shall record final procedure choice and patient performance.*	Future WG-16 to-do
	Stimulus Delivery & Patient Response system	*Per fMRI procedure:* *Shall present fMRI stimuli to patient (audio, visual, etc.) and capture patient interaction and other information (e.g. vital signs, eye tracking, etc.) as well as any operator comments.*	Future WG-16 to-do
	MRI Scanner	*Per fMRI procedure:* *Shall create 3D image series following suitable scan protocol (e.g. EPI).* *Shall record synchronization time stamp, discarded acquisitions, etc. in DICOM header.*	Enhanced MR object, incl. WG-16 fMRI additions
	Patient	*Per fMRI procedure:* *Shall perform procedure in scanner under direction and observation of trainer.*	
	Technologist	*Shall monitor imaging quality at MRI scanner console, correct patient behavior and/or scanner operation, and record any image quality observations.*	
Scan session results	MRI Scanner / Stimulus Delivery & Patient Response Systems	*Shall integrate and transmit scan results with fMRI procedure results to Post-processing Device.*	Enhanced MR object, incl. WG-16 fMRI additions
Post-Acquisition Data Processing			
Post-processing (fMRI)	*Post-Processing Device*	*Shall perform initial QA on received Scan Session results (e.g. all series received, correct # images per series, correct scan protocol and parameters, etc.)*	Enhanced MR object, incl. WG-16 fMRI additions

Step	*Actor*	*Action*	*Record*
	fMRI Procedure Definition	*Per fMRI procedure:* Shall be available as part of the fMRI procedure definition: statistical model (conditions, timing/waveforms); motion outlier rejection threshold; spatial and temporal smoothing controls; activation map parameter(s) (e.g. T, r); clustering control	Future WG-16 to-do
	Post-Processing Device	*Per fMRI procedure:* Shall compute a quantitative statistical map of activation based upon BOLD signal variation versus the indicated statistical model, stored as a derived image series. The map shall include a default suggested color map and statistical threshold (+/-). Shall also create 4D time series of activation; record extracted motion signals; record extracted nuisance regressors; etc. in separate DICOM objects or tags in the derived image series.	Real World Value Parameteric Map IOD; Future WG-16 to-do
	Technologist; Physicist; Neuroradiologist	*Shall direct fMRI post-processing activity and perform quality assurance, and record any relevant observations.*	Future WG-16 to-do
	Post-Processing Device	*Shall transmit all post-processed results to archival storage (e.g. PACS).*	Real World Value Parameteric Map IOD; Future WG-16 to-do
Interpretation and Results Distribution			
Visualization and Review (fMRI)	Review Device	*Shall display thresholded, color-mapped quantitative activation map. All fMRI procedure results and secondary fMRI post-processing results shall be available for reference.*	Real World Value Parameteric Map IOD; Future WG-16 to-do
	Neuroradiologist	*Shall evaluate fMRI activation map quality, adjust threshold and color map as needed.* *Shall review fMRI in context of anatomical underlay(s) and other imaging results, including other fMRI maps, diffusion MRI (e.g. color-coded DTI, tractography), perfusion MRI, PET, etc.*	Real World Value Parameteric Map IOD; Future WG-16 to-do

Step	*Actor*	*Action*	*Record*
	Neuroradiologist	*Shall export image presentation(s) including fMRI used for diagnostic and treatment planning to PACS, along with reading report dictation. Image presentation of fMRI will incorporate final threshold, color map, opacity, and other visualization properties.*	Real World Value Parameteric Map IOD; Future WG-16 to-do
Treatment planning	Primary Treatment Provider; Neuroradiologist	*Shall formulate treatment plan informed by neuroimaging reports including fMRI activation maps.*	(HL7: RIS or EHR)
	Neuroradiologist	*Shall export image presentation(s) including fMRI for use in surgical navigation or other treatment delivery systems.*	Standard or Enhanced DICOM (possibly SC)
Treatment delivery	Primary Treatment Provider	*Shall employ image presentation(s) including fMRI during treatment delivery to assist in location of resection target(s) as well as avoidance of eloquent cortex.*	Standard or Enhanced DICOM (possibly SC)
Treatment Outcome		*Follow-up imaging …*	

OPEN ISSUES

1	Naming of supplement, should cover ASL and possible other parametric map usage.
2	The blending operation might also be used for other areas than the Functional MRI. Should we make it generic or focus on Functional MRI. The real world value mapping already makes it already generic in nature.

CLOSED ISSUES

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
…		
XXX	**Functional MRI Blending Presentation State Storage**	**Transfer**
…		

DICOM PS 3.3: Information Object Definitions

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	fMRI Blending
Patient	**M**
Specimen	**U**
Clinical Trial Subject	**U**
General Study	**M**
Patient Study	**U**
Clinical Trial Study	**U**
General Series	M
Clinical Trial Series	**U**
Presn. Series	**M**
Frame of Reference	**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 FUNCTIONAL MRI BLENDING PRESENTATION STATE IOD

A.X.1 Functional MRI Blending Presentation State IOD Description

…

A.X.2 Functional MRI Blending Presentation State 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 Functional MRI Blending Presentation State IOD.

A.X.3 Functional MRI Blending Presentation State IOD Module Table

Table A.X-1. Functional MRI Blending Presentation State 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
	Presentation Series	C.11.9	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
Presentation State	Presentation State Identification	C.11.10	M
	Functional MRI Blending Presentation State	C.11.x	M
	Displayed Area	C.10.4	U
	~~Multi Planar Reconstruction Geometry~~	~~C.11.x5~~	~~U~~
	Graphic Annotation	C.10.5	U
	Spatial Transformation	C.10.6	C - Required if rotation or flipping are to be applied
	Graphic Layer	C.10.7	C - Required if Graphic Annotation Module is present
	Graphic Group	C.10.11	U
	ICC Profile	C.11.15	M
	SOP Common	C.12.1	M

Item: Add the following new sections in PS 3.3 C

C.11.X1 Functional MRI Blending Presentation State Module

Table C.11.X1-1 contains Attributes that describe the identification of a set of grayscale images, one or more sets of parametric maps, optionally one or more sets of registration objects and the color and thresholds to be applied to them, for the purpose of blending.

155 **Table C.11.X1-1. Functional MRI Blending Presentation State Module Attributes**

Attribute Name	Tag	Type	Attribute Description
Functional MRI Blending Sequence	(0070,xxx1)	1	A Sequence of Items, one identifying ~~and describing transformations upon~~ a set of underlying ~~grayscale~~ images, and one or more identifying and describing transformations upon a set of superimposed parametric map images. At least two Items shall be included in this Sequence. If more than two items are present the order of the items is determining the order of blending where the last item will be blended last and as such appear on top of all others. The number of Items shall be the same as in the Referenced Series Sequence (0008,1115) See Section C.11.X1.1.1.
>Functional MRI Blending Input Number	(0070,xxx2)	1	Identification number of the input. Values shall be ordinal numbers starting from 1 and monotonically increasing by 1 within the Functional MRI Blending Presentation State instance.
>Study Instance UID	(0020,000D)	1	Unique identifier for the Study.
>Series Instance UID	(0020,000E)	1	Unique identifier of a Series that is part of the Study defined by the Study Instance UID (0020,000D)
>Referenced Image Sequence	(0008,1140)	1C	The set of images comprising this input series. One or more items shall be included in this sequence. Required if a subset of the series is used.
>>Include 'Image SOP Instance Reference Macro' Table 10-3			
>Include Table C.11-1b "Modality LUT Macro Attributes" if a Modality LUT is to be applied to referenced image(s).			
>Referenced Spatial Registration Sequence	(0070,0404)	1C	A reference to a Spatial Registration Instance that is used to register the referenced inputs. Only one item shall be included in this sequence. Required if the Frame of Reference

Attribute Name	Tag	Type	Attribute Description
			UID (0020,0052) value of the Images referenced by the Referenced Image Sequence (0008,1140) of this item does not match the Frame of Reference UID (0020,0052) value of this Presentation State instance. May be present otherwise.
>>Include SOP Instance Reference Macro Table 10-11			
>Relative Opacity	(0070,0403)	1	A value from 0.0 to 1.0 indicating the relative opacity of the pixels of the superimposed image, where 1.0 means that pixels of the superimposed image completely replace the pixels of the underlying image, and 0.0 means that the pixels of the underlying image completely replace the pixels of the superimposed image. See PS3.4 for a detailed description of the blending operation.
>Threshold Sequence	(xxx1,yyy1)	1	Sequence describing the threshold applicable for this item. Threshold will determine which part of the color scale will be displayed. See section C.x.x.x.x
>Include Table C.17-3 "Hierarchical SOP Instance Reference Macro Attributes"			

Attribute Name	Tag	Type	Attribute Description
Pixel Presentation	(0008,9205)	1	Grayscale or color space of the Presentation State output. Enumerated Values: TRUE_COLOR Output consists of PCS-Values

Presentation State Classification Component Sequence	(0070,1801)	2C	Sequence of classification components in which the order of items is significant. Each classification component converts one ~~or two processed~~ inputs into a single RGB output. One or more items shall be included in this sequence. See C.11.x8.2. Required if Pixel Presentation (0008,9205) has a value of TRUE_COLOR.
>Functional MRI Blending Input Number	(0070,xxx2)	1	Identification number of the input series to which the Color information must be applied.
>*Include Tabel C.11.X2.1-1 'Threshold Sequence Macro Attributes'*			
>Component Type	(0070,1802)	1	Type of component. Enumerated values: ONE_TO_RGBA ~~TWO_TO_RGBA~~ See C.11.x8.2 for description of the components corresponding to each selection.
>RGB LUT Transfer Function	(0028,140F)	1	Specifies the mapping that takes place between the input value and RGB output. Enumerated values: EQUAL_RGB Output is R=G=B = input value TABLE Output is RGB LUT values See C.11.x8.1.

>Alpha LUT Transfer Function	(0028,1410)	1C	Specifies the transformation that is used to create the Alpha input a compositor component. Enumerated values: NONE Output = 1 (opaque) for all input values IDENTITY Output = input value TABLE Output = output of the Alpha LUT Required if the number of items in Presentation State Classification Component Sequence (0070,1801) is greater than 1. Note: When this condition is true, there will be one or more compositor components to follow this classification component.
>Red Palette Color Lookup Table Descriptor	(0028,1101)	1C	Specifies the format of the Red Palette Color Lookup Table Data (0028,1201). The second value (first stored pixel value mapped) shall be zero. See C.7.6.3.1.5. Required if RGB LUT Transfer Function (0028,140F) has a value of TABLE.
>Green Palette Color Lookup Table Descriptor	(0028,1102)	1C	Specifies the format of the Green Palette Color Lookup Table Data (0028,1202). The second value (first stored pixel value mapped) shall be zero. See C.7.6.3.1.5. Required if RGB LUT Transfer Function (0028,140F) has a value of TABLE.
>Blue Palette Color Lookup Table Descriptor	(0028,1103)	1C	Specifies the format of the Blue Palette Color Lookup Table Data (0028,1203). The second value (first stored pixel value mapped) shall be zero. See C.7.6.3.1.5. Required if RGB LUT Transfer Function (0028,140F) has a value of TABLE.
>Alpha Palette Color Lookup Table Descriptor	(0028,1104)	1C	Specifies the format of the Alpha Palette Color Lookup Table Data. The second value (first stored pixel value mapped) shall be zero. See C.7.6.3.1.5. Required if Alpha LUT Transfer Function (0028,1410) has a value of TABLE.

>Palette Color Lookup Table UID	(0028,1199)	3	Palette Color Lookup Table UID. See C.7.9.1. Note: Including the UID in Presentation States that comprise a presentation collection is helpful to the display application that is rendering several related presentations together. The palettes and UIDs do not need to be the same in such a case.
>Red Palette Color Lookup Table Data	(0028,1201)	1C	Red Palette Color Lookup Table Data. See C.7.6.3.1.5. Required if RGB LUT Transfer Function (0028,140F) has a value of TABLE and Segmented Red Palette Color Lookup Table Data (0028,1221) is not present.
>Green Palette Color Lookup Table Data	(0028,1202)	1C	Green Palette Color Lookup Table Data. See C.7.6.3.1.5. Required if Red Palette Color Lookup Table Data (0028,1201) is present.
>Blue Palette Color Lookup Table Data	(0028,1203)	1C	Blue Palette Color Lookup Table Data. See C.7.6.3.1.5. Required if Red Palette Color Lookup Table Data (0028,1201) is present.
>Alpha Palette Color Lookup Table Data	(0028,1204)	1C	Alpha LUT contains the blending values for the data frames. See C.7.6.3.1.5. Required if Alpha LUT Transfer Function (0028,1410) has a value of TABLE and Segmented Alpha Palette Color Lookup Table Data (0028,1224) is not present.
>Segmented Red Palette Color Lookup Table Data	(0028,1221)	1C	Segmented Red Palette Color Lookup Table Data. See C.11.x8.5. Required if RGB LUT Transfer Function (0028,140F) has a value of TABLE and Red Palette Color Lookup Table Data (0028,1201) is not present.
>Segmented Green Palette Color Lookup Table Data	(0028,1222)	1C	Segmented Green Palette Color Lookup Table Data. See C.11.x8.5 Required if Segmented Red Palette Color Lookup Table Data (0028,1221) is present.

>Segmented Blue Palette Color Lookup Table Data	(0028,1223)	1C	Segmented Blue Palette Color Lookup Table Data. See C.11.x8.5 Required if Segmented Red Palette Color Lookup Table Data (0028,1221) is present.
>Segmented Alpha Palette Color Lookup Table Data	(0028,1224)	1C	Segmented Alpha Palette Color Lookup Table Data. See C.11.x8.5 Required if Alpha LUT Transfer Function (0028,1410) has a value of TABLE and Alpha Palette Color Lookup Table Data (0028,1204) is not present.
Presentation State Compositor Component Sequence	(0070,1805)	2C	Sequence of RGB Compositor components in which the order of items is significant. Each RGB Compositor component combines together pairs of RGB values to produce a single RGB value. If there is more than one compositor component, the components are chained such that the output of one compositor component is an input to the next compositor component. The number of items in this sequence shall be the number of items in Presentation State Classification Component Sequence (0070,1801) minus one. See C.11.x8.3. Required if Pixel Presentation (0008,9205) has a value of TRUE_COLOR.
>Weighting Transfer Function Sequence	(0070,1806)	1	Transfer functions each represented by the formula $f(Alpha_1, Alpha_2) = WeightingFactor$ used to derive the weighting factors for each of the two RGB inputs from both input Alphas. The function is specified in the form of a table. Two items shall be included in this sequence to produce weighting factors for RBG1 and RGB2 inputs, respectively. See C.11.x8.4.

>>LUT Descriptor	(0028,3002)	1	Specifies the format of the LUT Data (0028,3006) in this Sequence. The first value (number of entries in the LUT) shall be an even power of two or zero indicating 2^{16}, so that there are an even number of bits in the LUT input. The third value (number of bits in the LUT Data) shall be 8. See C.11.1.1.
>>LUT Data	(0028,3006)	1	LUT Data in this Sequence.
~~Presentation LUT Shape~~	~~(2050,0020)~~	~~1C~~	~~Presentation LUT transformation.~~ ~~Enumerated Values:~~ ~~IDENTITY~~ ~~No further translation necessary; input values are P-Values;~~ ~~INVERSE~~ ~~Output values after inversion are P-Values~~ ~~See C.11.6.1.2.~~ ~~Required if Pixel Presentation (0008,9205) has a value of MONOCHROME.~~
ICC Profile	(0028,2000)	1C	An ICC Profile encoding the transformation of device-dependent color stored pixel values into PCS-Values. When present, defines the color space of the output of the Volumetric Presentation State. See C.11.15.1.1 Required if Pixel Presentation (0008,9205) has a value of TRUE_COLOR.

C.11.X1.1 Color mapping for Floating point values

Description of how to transfer the floating point values of the parametric maps to color information. The data will be mapped according the following mechanism

The floating point values of the Parametric map shall be mapped to RGB values using the following transformation.

MinRWV (0028,yyy1): the minimum value for the type of analysis, this is not the minimum value present in the data.

MaxRWV (0028,yyy2): the maximum value for the type of analysis, this is not the maximum value present in the data.

Pixel: pixel value

nLUT: number of entries in the LUT (derived from first value in LUT descriptor (0028,3006))

LUTindex = MAX(1, MIN(nLUT, (1 + (nLUT-1) * (Pixel – MinRWV) / (MaxRWV – MinRWV))))

x = Trunc (LUTindex), being the largest integer smaller than LUTindex

y = Fraction (LUTindex), being LUTindex – x

With this the values for R, G and B are calculated as follows

[R,G,B](LUTindex) = [R(x)+y*(R(x+1)-R(x)), G(x)+y*(G(x+1)-G(x)), B(x)+y*(B(x+1)-B(x))]

If x equals nLUT then [R,G,B] = [R(nLUT), G(nLUT), B(nLUT)]

The RGB values need to be rounded to the nearest integer value.

Example:

For a percentage scale (0-100) with 256 LUT entries and pixel value of 8.25 this would be

LUTindex = MAX(1, MIN(256, (1 + (256 - 1) * (8.25 - 0) / (100 - 0))))

= MAX(1, MIN(256, 22.0375)) = 22.0375

[R,G,B] = [R(22)+0.0375*(R(23)-R(22)), G(22)+0.0375*(G(23)-G(22)), B(22)+0.0375*(B(23)-B(22))]

C.11.X2 Threshold Sequence Macro

The threshold is defining the values of the image that are used versus ignored.

Table C.11.X2.1-1
THRESHOLD SEQUENCE MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Threshold Sequence	(xxx1yyy1)	1	Threshold specification for the image One or more Items are permitted in this Sequence.
>Threshold	(xxx1,yyy2)	1	Value(s) used as boundary for the threshold

>Threshold Type	(xxx1,yyy3)		Describes how the value(s) specified by the Threshold (xxxx,yyy2) shall be used to determine the presence of the pixel value See C.11.X2.1. Enumerated Values: RANGE_INCL RANGE_EXCL GREATER_OR_EQUAL LESS_OR_EQUAL GREATER_THAN LESS_THAN EQUAL

C.11.X2.1 Threshold

The Threshold Type is defining the pixel values that shall be shown versus the ones that are ignored. Values that are not conform the specified Threshold are dropped for the blending operation.

To describe a thresholding that consists of more than one range, multiple elements in the Threshold sequence need to be specified.

When more than one item is specified in the Threshold Sequence (xxxx,yyy1) the union of the different ranges shall be used to determine the presence of a pixel.

The number of values in the Threshold (xxxx,yyy2) is depending on the Threshold Type (xxxx,yyy3).

The use of the specified value(s) in the Threshold (xxxx,yyy2) shall depend on the value of the Threshold Type (xxxx,yyy3) as follows:

RANGE_INCL	the pixel value shall be used when the value lies between the specified values, or be equal to one of the specified values. Two values shall be present in the Threshold (xxxx,yyy2)
RANGE_EXCL	the pixel value shall be used when the value lies outside (i.e. not between) the specified values. Two values shall be present in the Threshold (xxxx,yyy2)
GREATER_OR_EQUAL	the pixel value shall be used when the value is greater than or equal to the specified value. One value shall be present in the Threshold (xxxx,yyy2).
LESS_OR_EQUAL	the pixel value shall be used when the value is less than or equal to the specified value. One value shall be present in the Threshold (xxxx,yyy2).
GREATER_THAN	the pixel value shall be used when the value is greater than the specified value. One value shall be present in the Threshold (xxxx,yyy2).
LESS_THAN	the pixel value shall be used when the value is less than the specified value. One value shall be present in the Threshold (xxxx,yyy2).
EQUAL	the pixel value shall be used when the value is equal to the specified value. One value shall be present in the Threshold (xxxx,yyy2).

220

C.11.x1.1 Functional MRI Blending Sequence

225 Blending Sequence (0070,0402) is used to identify two sets of images, one to be superimposed upon the other.

The sets of images and any subset of the frames therein in the case of multi-frame images are identified by Study, Series, SOP Instance and Frame Number. In the case of a Segmentation image, the subset of segments is identified by the attribute Referenced Segment Number (0062,000B) in the Referenced Image Sequence (0008,1140) invoked in the Presentation State Relationship Macro.

230 This module specifies no explicit relationship (such as pairing or ordering) between the sets of images and frames defined in the first item for the underlying images, and the second item for the superimposed images. This module does not define how the images are spatially related, and what re-sampling, if any, needs to be performed before the images are blended for rendering.

Note

235 1. The images in the two sets may share the same Frame of Reference, in which case the rendering application can spatially relate the two sets of images based on their Image Position (Patient) (0020,0032) and Image Orientation (Patient) (0020,0037) Attributes.

   Alternatively, a Spatial Registration SOP Instance may exist that relates either two different Frames of Reference, or two sets of images identified by UID and frame.

240 Whilst the two sets of images may already be spatially co-registered and oriented in the same plane, or even be sampled at the same in-plane and between-plane resolution, this will frequently not be the case.

   See PS3.4 for behavioral requirements that apply to Storage SOP Classes using this Module.

2. The underlying image for a superimposed Segmentation image need not be the source image for the segmentation.

245 This Section describes Functional MRI Blending Presentation State Module.

C.11.X1.1 Functional MRI Blending Presentation State Module

Table C.11.X-1 specifies the Attributes that identify and describe general information about a Functional MRI Blending Presentation State.

250

We need to describe:

Involved series, anatomical, parametric map,(incl. real world value information) and optional registration objects

255 - Blending information for the different series, including threshold information of the parametric maps, use as starting point the volumetric MPR PS work
- Use special functions to translate functional values to colors, check volumetric ps. (new or has volumetric ps defined this)

260

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)
…	…	…
XA/XRF Grayscale Softcopy Presentation State Storage	1.2.840.10008.5.1.4.1.1.11.5	XA/XRF Grayscale Softcopy Presentation State IOD
Functional MRI Blending Presentation State Storage	**1.2.840.10008.5.1.4.1.1.11.x**	**Functional MRI Blending Presentation State 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)
…	…	…
XA/XRF Grayscale Softcopy Presentation State Storage	1.2.840.10008.5.1.4.1.1.11.5	XA/XRF Grayscale Softcopy Presentation State IOD
Functional MRI Blending Presentation State Storage	**1.2.840.10008.5.1.4.1.1.11.x**	**Functional MRI Blending Presentation State IOD**
…	…	…

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	
(0070,xxx1)	Functional MRI Blending Sequence	FunctionalMRIBlendingSequence	SQ	1	
(0070,xxx2)	Functional MRI Blending Input Number	FunctionalMRIBlendingInputNumber	IS	1	
(xxx1,yyy1)	Threshold Sequence	ThresholdSequence	SQ	1	
(xxx1,yyy2)	Threshold	Threshold	FD	1-2	
(xxx1,yyy3)	Threshold Type	ThresholdType	CS	1	

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

might need to add row here

DICOM PS 3.16: Content Mapping Resource

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

DICOM PS 3.17: Explanatory Information

Item: Add the following Section

XX Functional MRI Storage Encoding Example (Informative)

This section illustrates the usage of the Enhanced MR Image Object in combination with the Parametric Map Object to store the results of the Post Acquisition Data Processing in order to enable Interpretation and Results Distribution.

A task based Functional MRI study is used to correlate specific activities to area's in the brain that are used during the specific activity.

A full Functional MRI (fMRI) study consists of several steps. The full workflow is shown in fig XX.1-1.

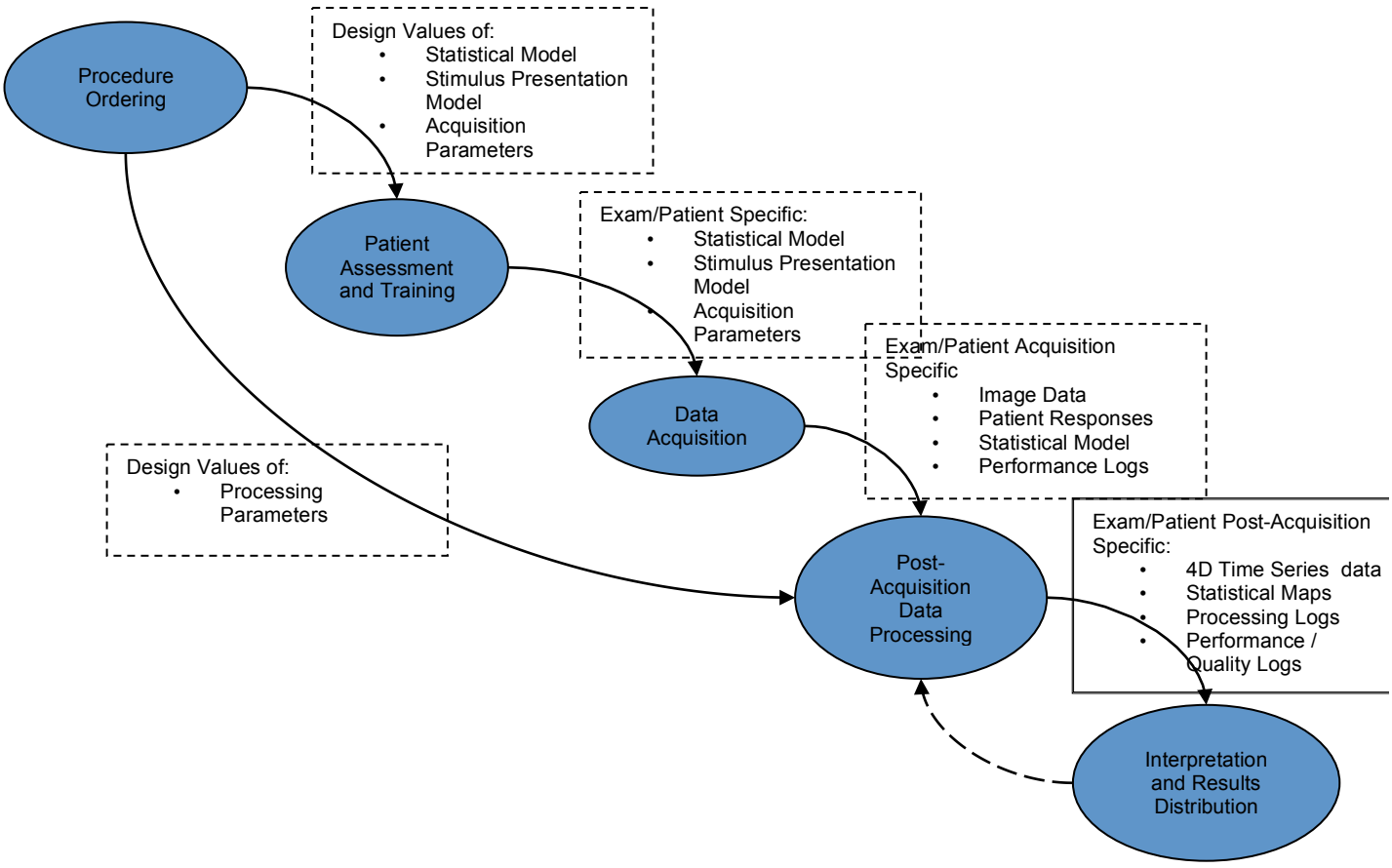


Figure XX.1-1. Workflow overview of typical fMRI study

Procedure Ordering will describe the goals of the study (e.g, identify motor strip, determine language laterality, etc.), which in turn dictates the anatomical, functional and physiological procedures to be performed on the patient.

Patient Assessment and Training is to determine the specific fMRI paradigms which will accomplish the requested clinical goals given the patient's mental and physical capabilities.

Data Acquisition is the execution of paradigms during MR scanning, with collection of (time) series image data, given paradigm as well as patient response data and other free-form information.

Post-Acquisition Data Processing is processing the acquired fMRI time series in combination with the paradigm data and derives clinically useful series of images for example activation maps and other information.

Interpretation and Results Distribution is the final adjustments of thresholds for clinical decision-making based upon functional assessment results and other case information, resulting in diagnosis and treatment planning.

Definitions used:

(fMRI) Paradigm is a collection of four components that together describe a complete fMRI experimental design. The four components are the statistical model, the stimulus presentation model, the acquisition parameters and the processing parameters.

Statistical Model represents the underlying statistical hypothesis. It consists of: (a) one or more statistical conditions of interest that model "active" mental states (i.e., the neuronal activities of interest) and "baseline" mental states; and (b), zero or more statistical conditions of no interest that model statistical confounds, such as DC bias, linear signal drift over time, low-frequency noise, etc. In a well-designed fMRI experiment, each condition of interest models the onset and duration of one specific type of neuronal activity throughout the course of the experiment. From a mathematical perspective, each statistical condition, whether it is a condition of interest or a condition of no interest, is used to generate a regressor, which is a quantity employed in the multiple regression analysis. It should be noted that regressors of interest (those that are expected to invoke a BOLD effect) are usually convolved with an HRF (hemodynamic response function).

A statistical model is thus represented by a list of statistical conditions, along with an associated flag for each that indicates whether it is a condition of interest, or a condition of no interest. In principle, there are three possible ways to represent the statistical conditions that form the statistical model of an fMRI experiment:

1. A statistical condition could be represented as a list of statistical events, with each event described by an onset time, duration, and statistical weight. This is the most logical, compact, and precise way to describe a condition of interest.
2. A statistical condition could be represented as a parameterized description of a function. This is the most compact and logical way of describing basis functions typically employed as conditions of no interest.
3. A statistical condition could also be represented as a periodically sampled waveform of some physiological process.

It is our opinion that a combination of options (1.) and (2.) would provide the most space-efficient solution for representing statistical conditions, while simultaneously providing the best possible precision. Option (3.) is only useful and relevant in the rare cases where physiological processes must be monitored during the experiment.

Stimulus presentation model represents the specific sequences of *external* sensory stimuli delivered to the patient during image acquisition.

Although frequently confused, and often used incorrectly in an interchangeable manner, the statistical model and the stimulus presentation model are two very different concepts, and convey different information. In some cases it is possible to derive a portion of the statistical model from the stimulus presentation model, but this does NOT generally hold true.

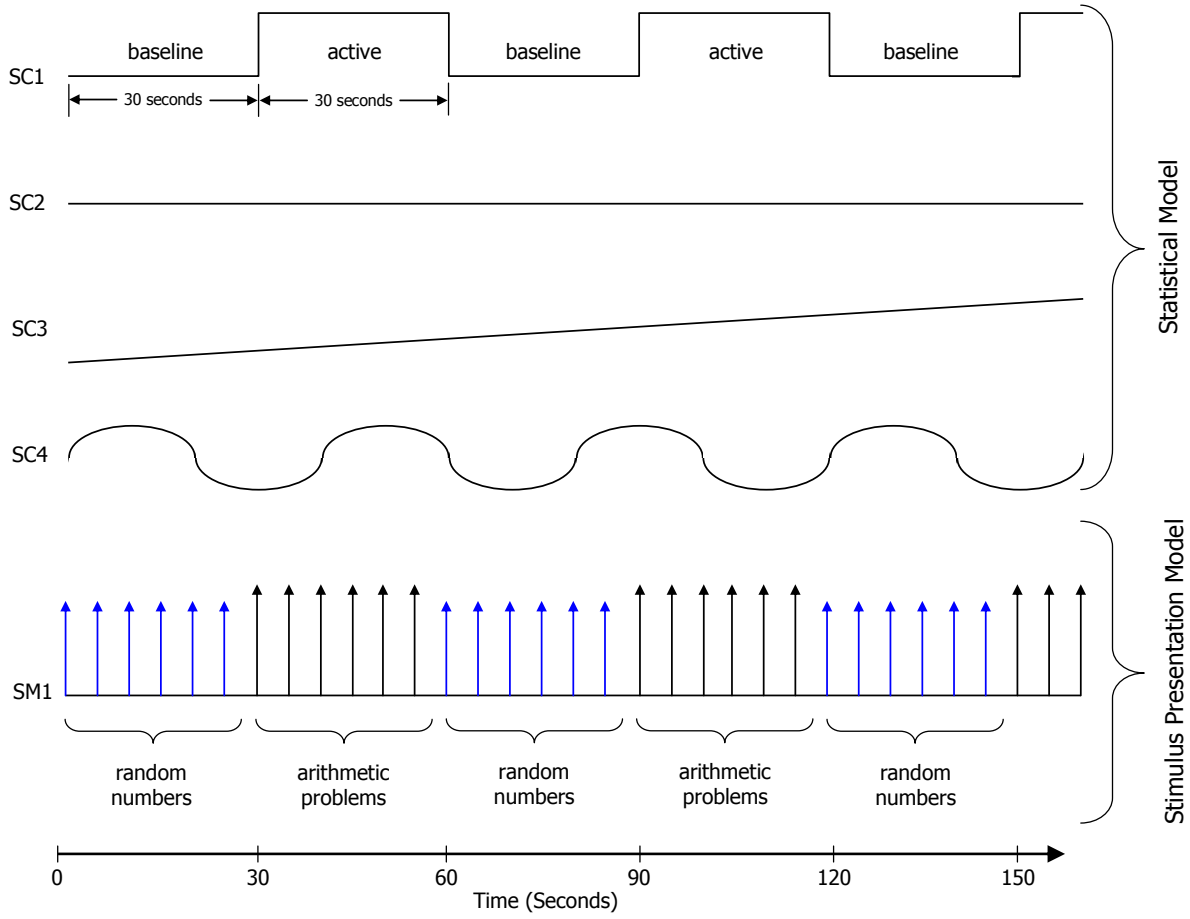
Stimulus Presentation Log is the log of stimulus presentation for a particular paradigm execution as a sequence of time-stamped events

Patient Response Log is the log of the patient responses for a particular paradigm execution as a sequence of time-stamped events.

Statistical Activation Map is a derived image series representing a volume with dimensions (r * c * s) corresponding to the acquired image volumes representing the statistical activation value for each voxel in the volume.

Physiological monitoring

Propose to put in all stages but give only limited information for the stages that we not cover by objects yet. In the end we want all stages being described here with an example with the relevant tags and structure of a typical study.



Example of Statistical Model and Stimulus Presentation Model

XX.1 Procedure Ordering

The clinician determines the goals of the imaging work (e.g, identify motor strip, determine language laterality, etc.), which in turn dictates the anatomical, functional and physiological procedures to be performed on the patient. This order will direct the patient assessment and training to determine specific fMRI paradigms which will accomplish the clinical goals given the patient's capabilities.

XX.2 Patient Assessment and Training

Assess the patient's capabilities relative to the tasks to be performed. Use these together with the available paradigms to select the right set of paradigms to accomplish the above mentioned goals. Familiarize the patient with the involved tests that will be performed during the formal study. And document their performance.

XX.3 Data Acquisition

During the Data Acquisition phase the patient is scanned while the paradigm system is giving the stimuli and patient's responses are recorded. The paradigm is used to evoke different brain activity states that are recorded (for example rest or motor activity). To be able to correlate the activity and the brain region that is activated it is needed that the paradigm delivery system and the image acquisition system are synchronized in time. This is done by the recoding a time stamp in the images, usage of the time stamp information is outside the DICOM standard.

The time series is assumed to consist of 'N' volumes. Each volume has the same in plane dimensions of 'r' rows, 'c' columns and 's' slices. The time series is captured in with fixed time interval not relative to any patient activity.
The Enhanced MR Image object is used to store the image data consistently and with enough details.

If relevant also other physiological data can be captured, stored and later used for analysis.

Special role for performing physician and operator that we need to describe?

XX.4 Post-Acquisition Data Processing

During the Post-Acquisition Data Processing the acquired data is processed and analyzed to find the correlation for each voxel with the stimuli given over time. First step can be motion correction to remove small movements of the patient during the acquisition. Second step would be to determine for each voxel in the image volume the signal change corresponding to activation (e.g. BOLD signal change as a percentage of baseline). Based on this set of values of the voxel a statistical activation value is determined using statistical methods. The result is a volume (r*c*s voxels) representing the statistical activation map. The value of the voxel is an indication to how much the voxel is activated during the given stimuli.

The Statistical Activation Map is typically shown using a threshold and an anatomical image series. With the threshold the voxel values that are displayed are selected. Together with a color scale for the statistical activation values a color overlay is created. A typical example is shown in figure XX.4-1

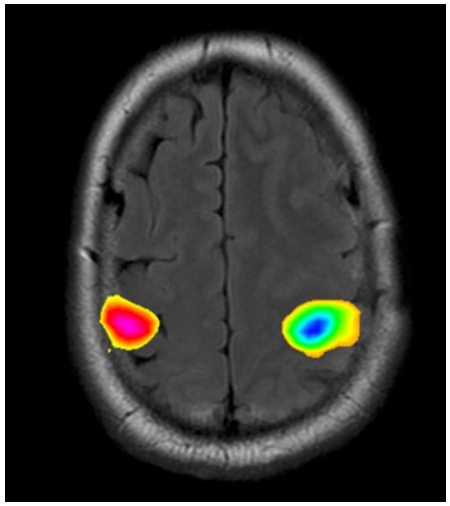


Figure XX.4-1 Sample Blending of Enhanced MR image and Statistical Activation Map image

XX.5 Interpretation and Results Distribution.

During the interpretation and distribution the physician can interpret and distribution the physician can adjust the threshold originally defined during the post-processing phase. It will result in a larger of smaller relevant area that will be shown in the overlay.

XX.6 APPLICATION CASES

XX.6.1 Case #1: Description of use case

As example for the objects created and there specific content we use the use case of a patient up for surgery and for this it is needed to identify the motor strip and determine language lateralization.

Procedure order delivers the plan for the Acquisition where a paradigm is created which will be acquired with only 5 volumes. The acquired anatomical dataset will be stored in one Enhanced MR object (could be a set of Classic objects), and a derived Parametric Map with a double threshold range (positive and negative) for the motor strip and a derived Parametric map with a positive threshold for the language lateralization.

Showing the main content of the Enhanced object related to the fMRI acquisition, which are the important parameters.

XX.6.1.1 User scenario

XX.6.1.2 Encoding outline

XX.6.1.3 Encoding details

XX.6.1.3.1 Enhanced MR Image IOD

XX.6.1.3.1.3 Frame of Reference

Attribute Name	Tag	Type	Attribute Description
Frame of Reference UID	(0020,0052)	1	Uniquely identifies the frame of reference for a Series. See Section C.7.4.1.1.1 for further explanation.

XX.6.1.3.1.3 Synchronization

Table C.7-7. Synchronization Module Attributes

Attribute Name	Tag	Type	Attribute Description
Synchronization Trigger	(0018,106A)	1	Data acquisition synchronization with external equipment Enumerated Values: **SOURCE** this equipment provides synchronization channel or trigger to other equipment **EXTERNAL** this equipment receives synchronization channel or trigger from other equipment **PASSTHRU** this equipment receives synchronization channel or trigger and forwards it **NO TRIGGER** data acquisition not synchronized by common channel or trigger
...			
Acquisition Time Synchronized	(0018,1800)	1	Acquisition DateTime (0008,002A) synchronized with external time reference. Enumerated Values: **Y** **N** See Section C.7.4.2.1.4

Attribute Name	Tag	Type	Attribute Description
Time Source	(0018,1801)	3	ID of equipment or system providing time reference
Time Distribution Protocol	(0018,1802)	3	Method of time distribution used to synchronize this equipment. Enumerated Values: **NTP** Network Time Protocol **IRIG** Inter Range Instrumentation Group **GPS** Global Positioning System **SNTP** Simple Network Time Protocol **PTP** IEEE 1588 Precision Time Protocol
NTP Source Address	(0018,1803)	3	IP Address of NTP, SNTP, or PTP time source. IPv4 addresses shall be in dotted decimal (e.g., 192.168.1.1). The IPv6 addresses shall be in colon separated hexadecimal (e.g., 12:34:56:78:9a:bc:de:f0). Note Identity of this value in two instances acquired contemporaneously implies a common time base. The NTP Source Address might not persist over time.

XX.6.1.3.1.3 Multi-frame Functional Groups

Attribute Name	Tag	Type	Attribute Description
Shared Functional Groups Sequence	(5200,9229)	1	Sequence that contains the Functional Group Macros that are shared for all frames in this SOP Instance and Concatenation. Note The contents of this sequence are the same in all SOP Instances that comprise a Concatenation. Only a single Item shall be included in this sequence. See Section C.7.6.16.1.1 for further explanation.
>Include one or more Functional Group Macros that are shared by all frames. The selected Functional Group Macros shall not be present in the Per-frame Functional Groups Sequence (5200,9230).			For each IOD that includes this module, a table is defined in which the permitted Functional Group Macros and their usage is specified. The Item may be empty if the requirements for inclusion of the Functional Groups are not satisfied.
Per-frame Functional Groups Sequence	(5200,9230)	1	Sequence that contains the Functional Group Sequence Attributes

Attribute Name	Tag	Type	Attribute Description
			corresponding to each frame of the Multi-frame Image. The first Item corresponds with the first frame, and so on. One or more Items shall be included in this sequence. The number of Items shall be the same as the number of frames in the Multi-frame image. See Section C.7.6.16.1.2 for further explanation.
>Include one or more Functional Group Macros.			For each IOD that includes this module, a table is defined in which the permitted Functional Group Macros and their usage is specified. An Item may be empty if the requirements for inclusion of the Functional Groups for the corresponding frame are not satisfied.
...			

440

XX.6.1.3.1.3 Multi-frame Dimension

Attribute Name	Tag	Type	Attribute Description
Dimension Organization Sequence	(0020,9221)	1	Sequence that lists the Dimension Organization UIDs referenced by the containing SOP Instance. See Section C.7.6.17.2 for further explanation. One or more Items shall be included in this Sequence.
>Dimension Organization UID	(0020,9164)	1	Uniquely identifies a set of dimensions referenced within the containing SOP Instance. See Section C.7.6.17.2 for further explanation.
Dimension Organization Type	(0020,9311)	3	Dimension organization of the instance. Defined Terms: **3D** Spatial Multi-frame image of equally spaced parallel planes (3D volume set) **3D_TEMPORAL** Temporal loop of equally spaced parallel-plane 3D volume sets.
Dimension Index Sequence	(0020,9222)	1	Identifies the sequence containing the indices used to specify the dimension of the multi-frame object. One or more Items shall be included in this sequence.
>Dimension Index Pointer	(0020,9165)	1	Contains the Data Element Tag that is used to identify the Attribute connected with the index. See Section C.7.6.17.1 for further explanation.
~~>Dimension Index Private Creator~~	~~(0020,9213)~~	~~1C~~	**Only important when private tags are used**
>Functional Group Pointer	(0020,9167)	1C	Contains the Data Element Tag of the Functional Group Sequence that

Attribute Name	Tag	Type	Attribute Description
			contains the Attribute that is referenced by the Dimension Index Pointer (0020,9165). See Section C.7.6.17.1 for further explanation. Required if the value of Dimension Index Pointer (0020,9165) is the Data Element Tag of an Attribute that is contained within a Functional Group Sequence.
~~>Functional Group Private Creator~~	~~(0020,9238)~~	~~1C~~	**Only important when private tags are used**
>Dimension Organization UID	(0020,9164)	1C	Uniquely identifies a set of dimensions referenced within the containing SOP Instance. In particular the dimension described by this sequence item is associated with this Dimension Organization UID. See Section C.7.6.17.2 for further explanation. Required if the value of Dimension Organization Sequence (0020,9221) contains Items
>Dimension Description Label	(0020,9421)	3	Free text description that explains the meaning of the dimension.

XX.6.1.3.1.3 Enhanced MR Image

Attribute Name	Tag	Type	Attribute Description
Include Table C.8-83 "MR Image and Spectroscopy Instance Macro Attributes"			
Image Type	(0008,0008)	1	Image characteristics. See Section C.8.16.1 and Section C.8.13.1.1.1.
Include Table C.8-131 "Common CT/MR Image Description Macro Attributes"			
Include Table C.8-84 "MR Image Description Macro Attributes"			
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

Attribute Name	Tag	Type	Attribute Description
			less than the value in Bits Stored (0028,0101).
….			
Lossy Image Compression	(0028,2110)	1C	Specifies whether an Image has undergone lossy compression (at a point in its lifetime). Enumerated Values: **00** Image has NOT been subjected to lossy compression. **01** Image has been subjected to lossy compression. Once this value has been set to 01 it shall not be reset. See Section C.7.6.1.1.5. Required if SOP Class UID is not "1.2.840.10008.5.1.4.1.1.4.4" (Legacy Converted). May be present otherwise.
….			
>Include Table C.7-11b "Image Pixel Macro Attributes"			See Section C.7.6.1.1.6.
Include Table 10-25 "Optional View and Slice Progression Direction Macro Attributes"			

445 **XX.6.1.3.1.3 SOP Common**

Table C.8-xx. Functional MR Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Functional MR Sequence	(0018,xx01)	1	Identifies the Functional parameters of this frame. Only a single Item shall be included in this Sequence.
> Settling Phase Frame	(0020,xx01)	1C	Identifies if the frame is part of a Functional MR settling phase. All frames with the same combination of Stack ID (0020,9056) and Temporal Position Index (0020,9128) shall have the same value. Enumerated Values: YES NO Required if Functional Settling Phase Frames Present (0018,xx02) is YES

Attribute Name	Tag	Type	Attribute Description
> Functional Sync Pulse	(0018,xx03)	1	The date and time of the Functional Sync Pulse for this frame. See Section C.8.13.5.x.1

450

XX.6.1.3.1.3 SOP Common**Attribute Name**	Tag	Type	Attribute Description
SOP Class UID	(0008,0016)	1	Uniquely identifies the SOP Class. See Section C.12.1.1.1 for further explanation. See also PS3.4.
SOP Instance UID	(0008,0018)	1	Uniquely identifies the SOP Instance. See Section C.12.1.1.1 for further explanation. See also PS3.4.
...			

XX.6.1.3.2 Parametric Map IOD

455 #### XX.6.1.3.2.1 General Series

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of equipment that originally acquired the data used to create the images in this Series. See Section C.7.3.1.1.1 for Defined Terms.
...			
Protocol Name	(0018,1030)	3	User-defined description of the conditions under which the Series was performed. Note This attribute conveys series-specific protocol identification and may or may not be identical to the one presented in the Performed Protocol Code Sequence (0040,0260).
...			
Related Series Sequence	(0008,1250)	3	Identification of Series significantly related to this Series.

Attribute Name	Tag	Type	Attribute Description
			One or more Items are permitted in this Sequence. Note 1. For example, for a combined CT and PET acquisition, the CT images and PET images would be in separate series that could cross-reference each other with multiple purpose of reference codes meaning same anatomy, simultaneously acquired and same indication. 2. The related series may have different Frames of Reference and hence require some sort of registration before spatial coordinates can be directly compared. 3. This attribute is not intended for conveying localizer reference information, for which Referenced Image Sequence (0008,1140) should be used.
>Study Instance UID	(0020,000D)	1	Instance UID of Study to which the related Series belongs
>Series Instance UID	(0020,000E)	1	Instance UID of Related Series
>Purpose of Reference Code Sequence	(0040,A170)	2	Describes the purpose for which the reference is made. Zero or more Items shall be included in this sequence. When absent, implies that the reason for the reference is unknown.
>>Include Table 8.8-1 "Code Sequence Macro Attributes"			*Defined CID 7210 "Related Series Purposes of Reference".*
...			

XX.6.1.3.2.3 Parametric Series

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Modality Type Note 1. It is expected that the majority of Parametric Maps will use the appropriate value for the acquisition modality, e.g. "MR", and so no specific Defined Terms or Enumerated Values are specified here. 2. If the image is derived from multiple modalities, then a value of "OT" is appropriate.
Series Number	(0020,0011)	1	A number that identifies this Series

XX.6.1.3.2.3 Frame of Reference

Attribute Name	Tag	Type	Attribute Description
Frame of Reference UID	(0020,0052)	1	Uniquely identifies the frame of reference for a Series. See Section C.7.4.1.1.1 for further explanation.

460

XX.6.1.3.2.3 Floating Point Image Pixel

Attribute Name	Tag	Type	Attribute Description
Samples per Pixel	(0028,0002)	1	Number of samples (planes) in this image. See Section C.7.6.3.1.1 for further explanation.
Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. Enumerated Values: **MONOCHROME2**
Rows	(0028,0010)	1	Number of rows in the image.
Columns	(0028,0011)	1	Number of columns in the image.
Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Each sample shall have the same number of bits allocated. See PS3.5 for further explanation. Enumerated Values: **32**
Float Pixel Data	(7FE0,0008)	1	A data stream of the pixel samples that comprise the Image. The order of pixels sent for each image plane is left to right, top to bottom, i.e., the upper left pixel (labeled 1,1) is sent first followed by the remainder of row 1, followed by the first pixel of row 2 (labeled 2,1) then the remainder of row 2 and so on.
Pixel Aspect Ratio	(0028,0034)	1C	Ratio of the vertical size and horizontal size of the pixels in the image specified by a pair of integer values where the first value is the vertical pixel size, and the second value is the horizontal pixel size. Required if the aspect ratio values do not have a ratio of 1:1 and the physical pixel spacing is not specified by Pixel Spacing (0028,0030), or Imager Pixel Spacing (0018,1164) or Nominal Scanned Pixel Spacing (0018,2010), either for the entire Image or per-frame in a Functional Group Macro. See Section C.7.6.3.1.7.
Float Pixel Padding Value	(0028,0122)	3	One limit (inclusive) of a range of pixel values used in an image to pad to rectangular format or to signal background that may be suppressed.
Float Pixel Padding Range Limit	(0028,0124)	1C	Pixel value that represents one limit (inclusive) of a range of padding

Attribute Name	Tag	Type	Attribute Description
			values used together with Float Pixel Padding Value (0028,0122). Required if Float Pixel Padding Value (0028,0122) is present. Note 1. If only a single padding value rather than a range is required, then both Float Pixel Padding Value (0028,0122) and Float Pixel Padding Range Limit (0028,0124) will contain the same value. 2. The general considerations described in Section C.7.5.1.1.2 may be helpful in understanding the corresponding floating point attributes, but are not normative.

465 **XX.6.1.3.2.3 Parametric Map Image**

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. Enumerated Values for Value 1: **DERIVED** Enumerated Values for Value 2: **PRIMARY** Value 3 shall be Image Flavor, Defined Terms for which are specified in Section C.8.16.1.3. Value 4 shall be Derived Pixel Contrast, common Defined Terms for which are specified in Section C.8.16.1.4 and MR-specific Defined Terms for which are specified in Section C.8.13.1.1.1.4.
Include Table 10-12 "Content Identification Macro"			
...			
Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Enumerated Values if Pixel Data (7FE0,0010) or Pixel Data Provider URL (0028,7FE0) is present: **16** Enumerated Values if Float Pixel Data (7FE0,0008) is present: **32**

Attribute Name	Tag	Type	Attribute Description
			Enumerated Values if Double Float Pixel Data (7FE0,0009) is present: **64**
Bits Stored	(0028,0101)	1C	Number of bits stored for each pixel sample. Enumerated Values: **16** Required if Pixel Data (7FE0,0010) or Pixel Data Provider URL (0028,7FE0) is present.
High Bit	(0028,0102)	1C	Most significant bit for pixel sample data. Enumerated Values: **15** Required if Pixel Data (7FE0,0010) or Pixel Data Provider URL (0028,7FE0) is present.
...			
Lossy Image Compression	(0028,2110)	1	Specifies whether an Image has undergone lossy compression (at a point in its lifetime), or is derived from lossy compressed images. Enumerated Values: **00** Image has NOT been subjected to lossy compression. **01** Image has been subjected to lossy compression. Once this value has been set to 01 it shall not be reset. See Section C.8.32.2.1 and Section C.7.6.1.1.5.
...			
Parametric Map Threshold Sequence			

XX.6.1.3.2.3 Multi-frame Functional Groups

Attribute Name	Tag	Type	Attribute Description
Shared Functional Groups Sequence	(5200,9229)	1	Sequence that contains the Functional Group Macros that are shared for all frames in this SOP Instance and Concatenation. Note

Attribute Name	Tag	Type	Attribute Description
			The contents of this sequence are the same in all SOP Instances that comprise a Concatenation. Only a single Item shall be included in this sequence. See Section C.7.6.16.1.1 for further explanation.
>Include one or more Functional Group Macros that are shared by all frames. The selected Functional Group Macros shall not be present in the Per-frame Functional Groups Sequence (5200,9230).			For each IOD that includes this module, a table is defined in which the permitted Functional Group Macros and their usage is specified. The Item may be empty if the requirements for inclusion of the Functional Groups are not satisfied.
Per-frame Functional Groups Sequence	(5200,9230)	1	Sequence that contains the Functional Group Sequence Attributes corresponding to each frame of the Multi-frame Image. The first Item corresponds with the first frame, and so on. One or more Items shall be included in this sequence. The number of Items shall be the same as the number of frames in the Multi-frame image. See Section C.7.6.16.1.2 for further explanation.
>Include one or more Functional Group Macros.			For each IOD that includes this module, a table is defined in which the permitted Functional Group Macros and their usage is specified. An Item may be empty if the requirements for inclusion of the Functional Groups for the corresponding frame are not satisfied.
...			
Representative Frame Number	(0028,6010)	3	The frame number selected for use as a pictorial representation (e.g., icon) of the multi-frame Image.
....			

XX.6.1.3.2.3 Multi-frame Dimension

Attribute Name	Tag	Type	Attribute Description
Dimension Organization Sequence	(0020,9221)	1	Sequence that lists the Dimension Organization UIDs referenced by the containing SOP Instance. See Section C.7.6.17.2 for further explanation. One or more Items shall be included in this Sequence.
>Dimension Organization UID	(0020,9164)	1	Uniquely identifies a set of dimensions referenced within the containing SOP Instance. See Section C.7.6.17.2 for further explanation.
Dimension Organization Type	(0020,9311)	3	Dimension organization of the instance. Defined Terms: **3D** Spatial Multi-frame image of equally spaced parallel planes (3D volume set) **3D_TEMPORAL** Temporal loop of equally spaced parallel-plane 3D volume sets.
Dimension Index Sequence	(0020,9222)	1	Identifies the sequence containing the indices used to specify the dimension of the multi-frame object. One or more Items shall be included in this sequence.
>Dimension Index Pointer	(0020,9165)	1	Contains the Data Element Tag that is used to identify the Attribute connected with the index. See Section C.7.6.17.1 for further explanation.
>Dimension Index Private Creator	(0020,9213)	1C	Identification of the creator of a group of private data elements. Required if the Dimension Index Pointer (0020,9165) value is the Data Element Tag of a Private Attribute.
>Functional Group Pointer	(0020,9167)	1C	Contains the Data Element Tag of the Functional Group Sequence that contains the Attribute that is referenced by the Dimension Index Pointer (0020,9165). See Section C.7.6.17.1 for further explanation. Required if the value of Dimension Index Pointer (0020,9165) is the Data Element Tag of an Attribute that is contained within a Functional Group Sequence.
>Functional Group Private Creator	(0020,9238)	1C	Identification of the creator of a group of private data elements. Required if the Functional Group Pointer 0020,9167) value is the Data Element Tag of a Private Attribute.
>Dimension Organization UID	(0020,9164)	1C	Uniquely identifies a set of dimensions referenced within the containing SOP Instance. In particular the dimension described by this sequence item is associated with this Dimension Organization UID. See Section C.7.6.17.2 for further explanation. Required if the value of Dimension Organization Sequence (0020,9221) contains Items

Attribute Name	Tag	Type	Attribute Description
>Dimension Description Label	(0020,9421)	3	Free text description that explains the meaning of the dimension.

470

XX.6.1.3.2.3 SOP Common

Attribute Name	Tag	Type	Attribute Description
SOP Class UID	(0008,0016)	1	Uniquely identifies the SOP Class. See Section C.12.1.1.1 for further explanation. See also PS3.4.
SOP Instance UID	(0008,0018)	1	Uniquely identifies the SOP Instance. See Section C.12.1.1.1 for further explanation. See also PS3.4.
...			
Timezone Offset From UTC	(0008,0201)	3	Contains the offset from UTC to the timezone for all DA and TM Attributes present in this SOP Instance, and for all DT Attributes present in this SOP Instance that do not contain an explicitly encoded timezone offset. Encoded as an ASCII string in the format "&ZZXX". The components of this string, from left to right, are & = "+" or "-", and ZZ = Hours and XX = Minutes of offset. Leading space characters shall not be present. The offset for UTC shall be +0000; -0000 shall not be used. Note 1. This encoding is the same as described in PS3.5 for the offset component of the DT Value Representation. 2. This Attribute does not apply to values with a DT Value Representation, that contains an explicitly encoded timezone offset. 3. The corrected time may cross a 24 hour boundary. For example, if Local Time = 1.00 a.m. and Offset = +0200, then UTC = 11.00 p.m. (23.00) the day before. 4. The "+" sign may not be omitted. Time earlier than UTC is expressed as a negative offset. Note For example: UTC = 5.00 a.m. Local Time = 3.00 a.m.

Attribute Name	Tag	Type	Attribute Description
			Offset = -0200 The local timezone offset is undefined if this Attribute is absent.
Contributing Equipment Sequence	(0018,A001)	3	Sequence of Items containing descriptive attributes of related equipment that has contributed to the acquisition, creation or modification of the composite instance. One or more Items are permitted in this Sequence. See Section C.12.1.1.5 for further explanation.
>Purpose of Reference Code Sequence	(0040,A170)	1	Describes the purpose for which the related equipment is being referenced. Only a single Item shall be included in this sequence. See Section C.12.1.1.5 for further explanation.
>>Include Table 8.8-1 "Code Sequence Macro Attributes"			*Defined CID 7005 "Contributing Equipment Purposes of Reference".*
...			
>Contribution DateTime	(0018,A002)	3	The Date & Time when the equipment contributed to the composite instance.
>Contribution Description	(0018,A003)	3	Description of the contribution the equipment made to the composite instance.
...			

XX.6.1.3.2.3 Common Instance Reference

Attribute Name	Tag	Type	Attribute Description
Referenced Series Sequence	(0008,1115)	1C	Sequence of Items each of which includes the Attributes of one Series. One or more Items shall be included in this sequence. Required if this Instance references Instances in this Study.
>Series Instance UID	(0020,000E)	1	Unique identifier of the Series containing the referenced Instances.
>Referenced Instance Sequence	(0008,114A)	1	Sequence of Items each providing a reference to an Instance that is part of the Series defined by Series Instance UID (0020,000E) in the enclosing Item. One or more Items shall be included in this

Attribute Name	Tag	Type	Attribute Description
			sequence.
>>Include Table 10-11 "SOP Instance Reference Macro Attributes"			
Studies Containing Other Referenced Instances Sequence	(0008,1200)	1C	Sequence of items each identifying a Study other than the Study of which this Instance is a part, which Studies contain Instances that are referenced elsewhere in this Instance. One or more Items shall be included in this sequence. Required if this Instance references Instances in other Studies.
>Study Instance UID	(0020,000D)	1	Unique identifier of the Study containing the referenced Instances.
>Include Table 10-4 "Series and Instance Reference Macro Attributes"			

475 PUT in the functional groups for the parametric map.

Copy for second parametric map.

Blending object needs to be defined and also have the example here.

Table C.11.14-1. Presentation State Blending Module Attributes

480

Attribute Name	Tag	Type	Attribute Description
Blending Sequence	(0070,0402)	1	A Sequence of Items, one identifying and describing transformations upon a set of underlying grayscale images, and the other identifying and describing transformations upon a set of superimposed grayscale images. Two Items shall be included in this sequence See Section C.11.14.1.1.
>Blending Position	(0070,0405)	1	Whether or not the contents of the Item represent the superimposed or underlying image set. Enumerated Values: **SUPERIMPOSED** **UNDERLYING**

Attribute Name	Tag	Type	Attribute Description
>Study Instance UID	(0020,000D)	1	Unique identifier for the Study that contains the images, which may differ from the Study in which the presentation state is contained.
>Include Table C.11.11-1b "Presentation State Relationship Macro Attributes"			
>Include Table C.11-1b "Modality LUT Macro Attributes" if a Modality LUT is to be applied to referenced image(s).			
>Softcopy VOI LUT Sequence	(0028,3110)	1C	Defines a sequence of VOI LUTs or Window Centers and Widths and to which images and frames they apply. No more than one VOI LUT Sequence containing a single Item or one pair of Window Center/Width values shall be specified for each image or frame. One or more Items shall be included in this sequence. Required if a VOI LUT is to be applied to referenced image(s).
>>Referenced Image Sequence	(0008,1140)	1C	Sequence of Items identifying images that are defined in the enclosing Item of Blending Sequence (0070,0402), to which this VOI LUT or Window Center and Width applies. One or more Items shall be included in this sequence. Required if the VOI LUT transformation in this Item does not apply to all the images and frames in the enclosing Item of Blending Sequence (0070,0402).
>>>Include Table 10-3 "Image SOP Instance Reference Macro Attributes"			
>>Include Table C.11-2b "VOI LUT Macro Attributes"			
Relative Opacity	(0070,0403)	1	A value from 0.0 to 1.0 indicating the relative opacity of the pixels of the superimposed image, where 1.0 means that pixels of the superimposed image completely replace the pixels of the underlying image, and 0.0 means that the pixels of the underlying image completely replace the pixels of the superimposed image. See PS3.4 for a detailed description of the blending operation.

Attribute Name	Tag	Type	Attribute Description
Referenced Spatial Registration Sequence	(0070,0404)	3	A reference to Spatial Registration Instances that may be used to register the underlying and superimposed images. One or more Items are permitted in this sequence. Note A Spatial Registration Instance may identify registration between frames of reference, or between explicitly identified images. In the latter case, the list of images referenced by the Presentation State, not the list of images referenced by the Spatial Registration Instance, are to be blended.
>Include Table C.17-3 "Hierarchical SOP Instance Reference Macro Attributes"			

Graphic overlay IS NEEDED BUT NOT required

How to standardize the Color scale information. This would be needed on Parametric map level, how this is displayed is up to the display system but is will be recommended to be able to switch between the different scales.

Spatial transformation is not needed

Graphic group not sure.

Color information needs to be a sequence as Parametric MAP has no color information for the float objects.

ICC profile also not needed

Displayed area will be present, typically it will be the complete image.

Might look at MultiPlanar PS.

XX.6.2 Case #2: Description of use case

As example for the objects created and there specific content we use the use case of a patient up for surgery and for this it is needed to identify the motor strip.

Procedure order delivers the plan for the Acquisition where a paradigm is created which will be acquired with only 5 volumes. The acquired data will be stored in two Enhanced MR objects, and a Parametric Map with a single threshold range.

Showing the main content of the Enhanced objects related to the fMRI acquisition, which are the important parameters.

XX.6.2.1 User scenario

XX.6.2.2 Encoding outline

XX.6.2.3 Encoding details

XX.6.2.3.1 Enhanced MR Image IOD

505

XX.6.2.3.2 Parametric Map IOD