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IHE Radiology

Technical Framework Supplement

MR Diffusion Imaging (DIFF)

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Trial Implementation

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This is a supplement to the IHE Radiology Technical Framework Rev. 9.0.

It is submitted for Trial Implementation as of June 21, 2009. Comments are invited and may be submitted on the IHE forums at http://forums.rsna.org/forumdisplay.php?f=12 or by email to radiology@ihe.net.

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General Information about IHE® may be found at: www.ihe.net.

Information about the IHE Radiology domain may be found at: http://www.ihe.net/domains/index.cfm.

Information about the structure of IHE Technical Frameworks and Supplements may be found
30   at: http://www.ihe.net/about/process.cfm and http://www.ihe.net/profiles/index.cfm.

The current version of the IHE Radiology Technical Framework may be found at: http://www.ihe.net/technical_framework/index.cfm.

Editor's Note

35   This supplement describes the changes to the existing technical framework documents and where indicated amends text by addition (**bold underline**) or removal (**bold strikethrough**), as well as addition of large new sections introduced by editor's instructions to "add new text" or similar, which is not bolded or underlined for readability.

"Boxed" instructions like the sample below indicate to the volume editor how to integrate the
40   relevant section(s) into the relevant Technical Framework volume:

Replace Section X.X by the following:

<u>CONTENTS</u>

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Introduction

This supplement adds a new profile to the IHE Radiology Technical Framework to address interoperability of Diffusion imaging data encoded as Enhanced MR DICOM objects.

70 There are no new actors or transactions defined.

Additions are made to the following transactions:

- RAD 8 Modality Images Stored
- RAD 16 Retrieve Images
- RAD 18 Creator Images Stored

75 ## Profile Abstract

The MR Diffusion Imaging Integration Profile leverages enhanced MR diffusion images containing standard attributes for Diffusion B value, Diffusion gradient orientation and Diffusion image type. These objects are exchanged in an interoperable way allowing correct and convenient display. Applications using older single-frame DICOM image objects depended on
80 knowledge of private attributes for this information.

Open Issues and Questions

Closed Issues

1) Can Isotropic images generated in the reconstruction process still be "ORIGINAL"
85 images?
    Answer: No, all Isotropic images shall be "DERIVED". (WG-16)
2) Should Isotropic images when "DERIVED" have their own defined term for Frame type Value 4?
    Answer: Yes. A DICOM CP will be submitted to add ISOTROPIC to the list of defined
90 *terms for Frame Type Value 4. (WG-16)*
3) Should the allocation of certain Index Values be <u>prescribed</u> for otherwise unsorted attribute values (DICOM allows free allocation of index values).
    Answer: Yes this is done in section 4.8.4.1.2.n.1.
4) Should the order in which the frames are actually encoded be specified?
95 *Answer: Yes. This is exactly the function of the Dimension module*
5) Should the Profile address DIRECTIONAL encoded images or DTI results (in addition to ISOTROPIC diffusion images and DERIVED images like ADC maps)?
    Answer: Yes. DIRECTIONAL Images may be exchanged but should be ignored for presentation.

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    6) How should Concatenation be handled?

Answer: DICOM WG6 revisit the use of concatenation and provide guidelines for when it should be used. Until then, Concatenation is explicitly prohibited for this use case.

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Volume 1 – Integration Profiles

Glossary

Add the following terms to the Glossary:

110 *ADC: Apparent Diffusion Coefficient*

1.7 History of Annual Changes

<Brief overview of "what's new" in the given year of the Technical Framework.>

Add the following bullet to the end of the bullet list in section 1.7

- Added the MR Diffusion Imaging Profile.

115 2.1 Dependencies among Integration Profiles

Add the following row to Table 2-1

MR Diffusion Imaging	*none*	*none*	-

Add the following section to section 2.2

120 2.2.22 MR Diffusion Imaging Integration Profile

The MR Diffusion Imaging Integration Profile leverages enhanced MR diffusion images containing standard attributes for Diffusion b-value, Diffusion gradient orientation and Diffusion image type. These objects are exchanged in an interoperable way allowing correct and convenient display.

125 *Add a column to table 2.3-1 and place DIFF in the header and an X in rows:*

Acq. Modality;

Evidence Creator;

Image Archive;

Image Display;

130 *Image Manager*

<table>
<tr><td>

135

</td><td>

Add a column to table 2.3-2 and place DIFF in the header and an X in rows:

Modality Images Stored [RAD-8]

Storage Commitment [RAD-10]

Query Images [RAD-14]

Retrieve Images [RAD-16]

Creator Images Stored [RAD-18]

</td></tr>
</table>

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Add Section 24

24.   MR Diffusion Imaging Integration Profile

MR Diffusion Imaging creates stacks of images (slices) with different meaning and derived contrast by using techniques of MR Diffusion Weighted Imaging (DWI).

145   This Integration Profile defines how a set of images resulting from a completed MR Diffusion exam are stored and archived into frames of one Enhanced MR DICOM (Multi-frame) object so that they can later be retrieved and displayed in an unambiguous way on image viewers supporting Enhanced MR DICOM objects.

This enables widespread and adequate review and interpretation of b=0, ISOTROPIC and ADC
150   diffusion frames by radiologists in an environment where all Actors support the Enhanced MR DICOM objects; mixed environments that would need conversion of Enhanced objects into single-frame objects are out of scope. This Profile does not cover workflow or post-processing capabilities.

The display of anisotropic frames or other results of Diffusion-specific post processing like Fiber
155   Tracking are not addressed.

24.1 Actors/Transactions

Figure 24.1-1 diagrams the actors involved with this profile and the transactions between actors.
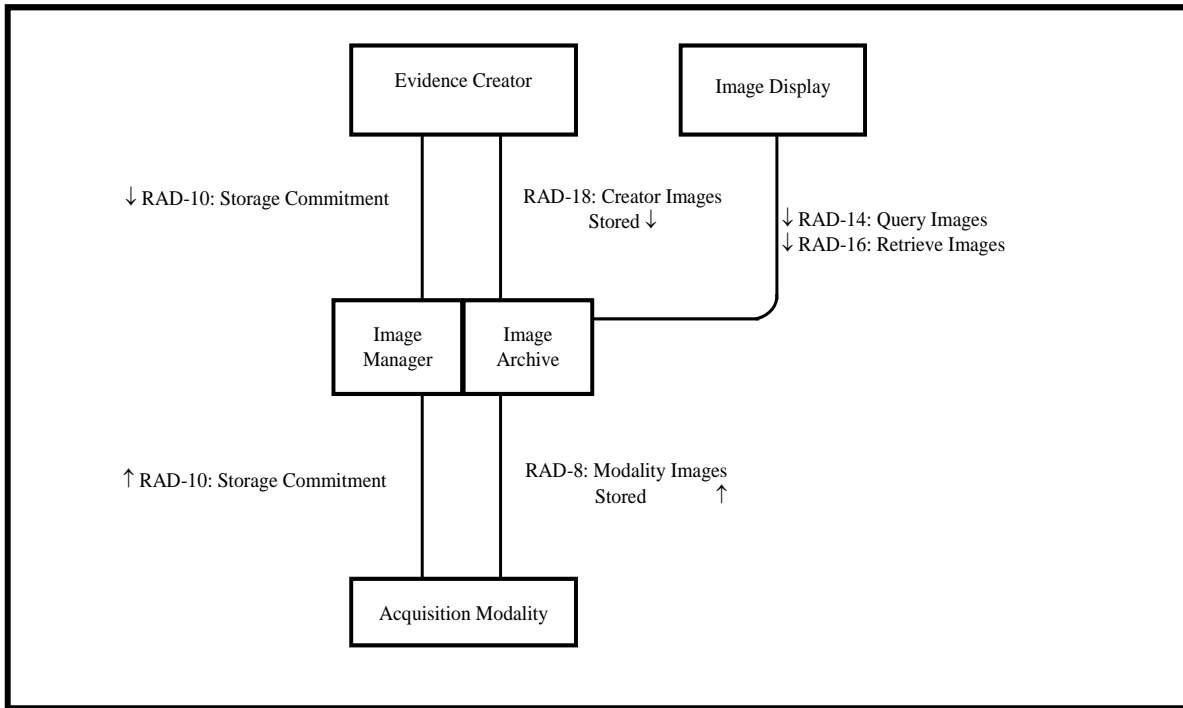
160

Figure 24.1-1. MR Diffusion Imaging Diagram

Table 24.1-1 lists the transactions for each actor directly involved in the MR Diffusion Imaging
Integration Profile. To claim support of this Integration Profile, an implementation must perform
the required transactions (labeled "R"). Transactions labeled "O" are optional. A complete list of
165 options defined by this Integration Profile and that implementations may choose to support are
listed in Section 24.2.

Table 24.1-1. MR Diffusion Imaging - Actors and Transactions

Actors	Transactions	Optionality	Section in Vol. 2
Acquisition Modality	Modality Images Stored [RAD-8]	R	4.8
	Storage Commitment [RAD-10]	R	4.10
Evidence Creator	Creator Images Stored [RAD-18]	R	4.18
	Storage Commitment [RAD-10]	R	4.10
Image Manager/Archive	Modality Images Stored [RAD-8]	R	4.8
	Creator Images Stored [RAD-18]	R	4.18
	Storage Commitment [RAD-10]	R	4.10
	Query Images [RAD-14]	R	4.14
	Retrieve Images [RAD-16]	R	4.16
Image Display	Query Images [RAD-14]	R	4.14
	Retrieve Images [RAD-16]	R	4.16

170 ## 24.2 MR Diffusion Imaging Integration Profile Options

Options that may be selected for this Integration Profile are listed in the table 24.2-1 along with the Actors to which they apply. Dependencies between options when applicable are specified in notes.

Table 24.2-1. MR Diffusion Imaging – Actors and Options

Actor	Options	Vol & Section
Acquisition Modality	*No options defined*	-
Image Manager/ Image Archive	*No options defined*	-
Image Display	*No options defined*	-
Evidence Creator	*No options defined*	-

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24.3 MR Diffusion Imaging Process Flow

24.3.1 Typical flow – creating original and derived images as one activity

In the most common case, a complete set of original diffusion frames is acquired and derived
frames like ADC images or ISOTROPIC images are created in the same activity. The user
derives images from the originals at the modality.

The Acquisition Modality and the Evidence Creator actors are grouped, therefore IHE does not
define how the newly acquired frames are transferred between them. Each of these two Actors
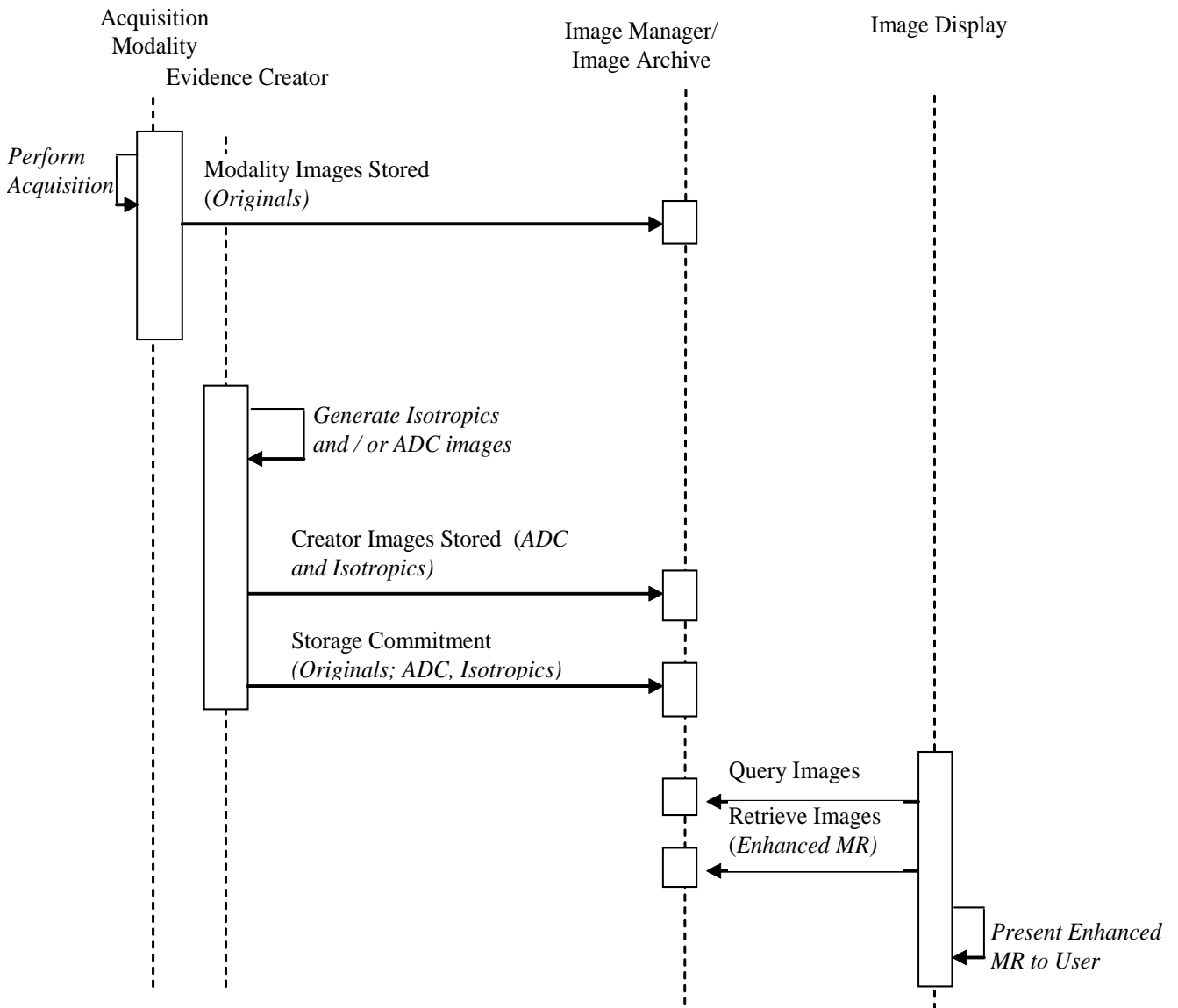may separately request storage commitment for the created objects.

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Figure X.3-1. MR Diffusion Imaging Process Flow

24.3.2 Creating derived images in a separate activity

190   In this case, the acquiring original frames at the Modality and deriving frames like ADC images or ISOTROPIC images are done as separate subsequent activities and most probably on separate systems, too.

First, the Modality creates a complete set of original frames and stores it to the Image Manager/ Image Archive as one Enhanced MR object.

195   Later, the Radiologist at a workstation retrieves this Enhanced object including the original
       diffusion frames from the Image Manager/ Image Archive and creates one Enhanced MR object
       with derived ADC frames and one Enhanced MR object with derived ISOTROPIC frames. These
       objects then are strored at the Image Manager/Image Archive and storage commit is requested.
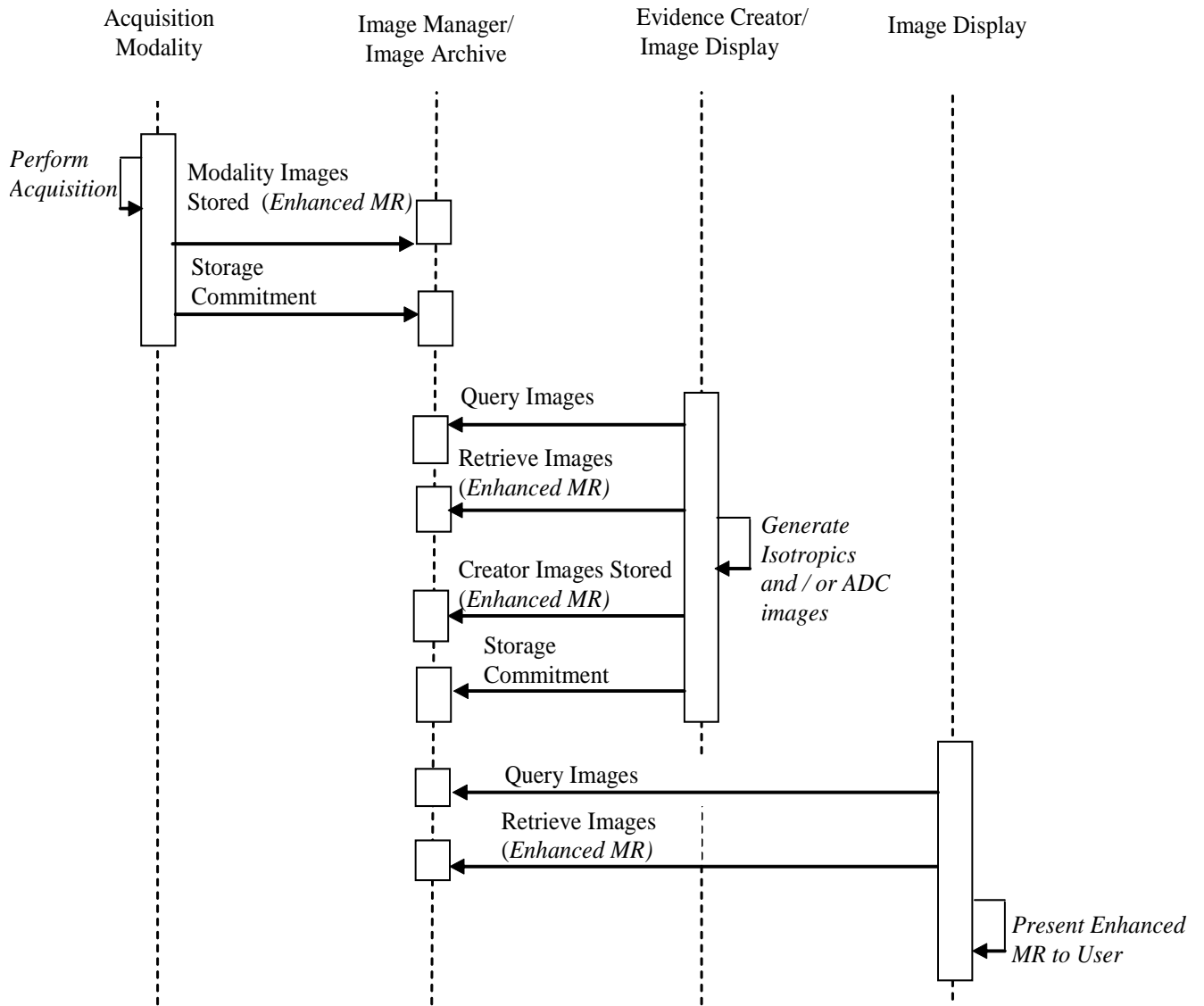
Figure 24.3-2. MR Diffusion Imaging Process Flow

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Volume 2 - Transactions

Append section 4.8.1.2 with the following subsection and substitute .n with the appropriate serial number

4.8.4.1.2.5 Storage of Enhanced DICOM Objects

Acquisition Modality actors supporting the MR Diffusion Imaging or CT/MR Perfusion Imaging with Contrast Integration Profile are required to support attributes as described in table
210   4.8.4.1.2.5.-1 in addition to attributes already required by the DICOM standard.

Table 4.8.4.1.2.5.-1. Generic Enhanced Object Attributes

Attribute Name	Tag	Requirement
Frame Content functional group macro		
Frame Content Sequence	(0020,9111)	
>Stack ID	(0020,9056)	R+
>In-Stack Position Number	(0020,9057)	R+

Enhanced DICOM Objects shall contain the Dimension Module and shall have a Dimension Index Sequence (0020,9222) that contains Dimension Index Pointers (0020,9165) for all
215   attributes listed in table 4.8.4.1.2.5.-1.

4.8.4.1.2.5.1 MR Diffusion

Acquisition Modality actors in the MR Diffusion Imaging Profile shall create objects with Image Type and Frame Type values as shown in table 4.8.4.1.2.5.1-1.

220   **Table 4.8.4.1.2.5.1-1. Image Type and Frame Type values**

	Original Scan		
	Image Type	**Frame Type**	
Content		**b = 0**	**Gradient Directions**
Value 1	ORIGINAL	ORIGINAL	ORIGINAL
Value 3	DIFFUSION	DIFFUSION	DIFFUSION
Value 4	-	-	-

Note: value 2 is, by definition, always PRIMARY

For the original acquisition, the Acquisition Modality shall create a single Enhanced MR SOP Instance which shall contain the frames for all Diffusion b-values for each In-Stack Position (0020,9057) and Stack ID (0020,9056). For each Diffusion b-value there may be a number of frames for different diffusion gradient directions. For any combination of Stack ID (0020,9057), In-Stack Position(0020,9056), Diffusion b-value (0018,9057) and Diffusion Gradient Orientation (0018,9089) there shall be only one frame.

For the original acquisition, the Per Frame Functional Groups Sequence (5200,9230) shall contain the MR Diffusion Sequence (which also means the Shared Functional Groups Sequence (5200,9229) shall NOT contain an MR Diffusion Sequence).

The Dimension Index Pointer (0020,9165) shall be populated with the attribute tags of:

1. Stack ID (0020,9056)

2. In-Stack Position Number (0020,9057)

3. Diffusion b-value (0018,9087)

The Diffusion b-value index shall be populated according to ascending Diffusion b-values (0018, 9087).

Derived images (Isotropic and ADC) shall each be in separate SOP Instances from the original SOP Instance. See transaction RAD-18 Creator Images Stored for details on storing the derived images.

Add the following row to table 4.8.-1

Table 4.8-1. Suggested Image SOP Classes

SOP Class UID	SOP Class Name
…	
1.2.840.10008.5.1.4.1.1.4	MR Image Storage
1.2.840.10008.5.1.4.1.1.4.1	**Enhanced MR Image Storage**
1.2.840.10008.5.1.4.1.1.20	Nuclear Medicine Image Storage
…	

Add the following text to the end on section 4.8.4.1.3.1

… images from the Acquisition Modality, and make both available for retrieval, but is not required to be able to make "For Processing" images "presentable".

Acquisition Modalities and Image Manager/Image Archives claiming the MR Diffusion Imaging Profile are required to support all of the SOP classes listed in Table 4.8-5 below.

Table 4.8-5. Diffusion Image SOP Classes

SOP Class UID	SOP Class Name
1.2.840.10008.5.1.4.1.1.4.1	Enhanced MR Image Storage

255

> *Append section 4.16.4.1.3 with the following subsection and substitute .n with the appropriate serial number*

4.16.4.1.3.4 MR Diffusion Imaging Profile

Image Manager/Image Archive and Image Displays actors that claim the MR Diffusion Imaging Profile shall support all the SOP Classes specified in Table 4.8-5 in section 4.8.

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> *Append section 4.16.4.2.2. with the following subsection and substitute .n with the appropriate serial number*

4.16.4.2.2.6 Display of MR Diffusion Imaging objects

The contents of this section are required for Image Displays claiming the MR Diffusion Imaging Profile.

265 The following requirements are intended to establish a baseline level of capabilities.

The Image Display shall be capable of using the information from the Dimension Index Values (0020,9157) to separately display frames from different SOP Instances in different viewports. Selection, sorting and scrolling shall be configurable.

As an example of using the information from the Dimension Index Values (0020,9157):

270
- The Image Display shall have the capability to provide at least one row of three or more viewports for the display of frames with different diffusion images for the same In-Stack Position Number (0020,9057).

- As a minimum, frames with b-value b=0 and the corresponding Isotropic and ADC frames created for the maximal b-value shall be displayed. Note that the Isotropic and ADC objects
275 have the same Dimension Organization and In-Stack Position Number index as the object containing the original frames.

- The Image Display shall have the capability to filter (exclude) frames in the Original object based on the Diffusion b-value index: only frames with Diffusion b-value index 1 (b=0) are presented, other indices are ignored for presentation.

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- In case there are more In-Stack Position Numbers than there are vertical viewports, the Image Display shall have the capability of synchronized scrolling through corresponding Stack ID / In-Stack Position Number.

Image Display actors supporting the MR Diffusion Imaging Profile shall be able to display per frame the values of all attributes in the Dimension Index Pointer (0020,9165), i.e.:

285

1. Stack ID (0020,9056)

2. In-Stack Position Number (0020,9057)

3. Diffusion b-value (0018, 9087)

This requirement is in addition to any display of slice offset in mm and frame number.

Append section 4.18.4.1.2. with the following subsection and substitute .n with the appropriate serial
290 *number*

4.18.4.1.2.5 Storage of MR Diffusion Imaging Derived Images (Isotropic and ADC)

Evidence Creator actors in the MR Diffusion Imaging Profile shall create objects for Derived Images with Image Type and Frame Type values as shown in table 4.18.4.1.2.5-1.

295   Isotropic and ADC images shall each be in separate objects.

Table 4.18.4.1.2.5-1. Image Type and Frame Type values

	Isotropic		ADC	
	Image Type	Frame Type	Image Type	Frame Type
content	Isotropic image	Isotropic frames	ADC image	ADC frames
Value 1	DERIVED	DERIVED	DERIVED	DERIVED
Value 3	DIFFUSION	DIFFUSION	DIFFUSION	DIFFUSION
Value 4	ISOTROPIC	ISOTROPIC	ADC	ADC

Note 1:   Value 2 is, by definition, always PRIMARY

300   The Per Frame Functional Groups Sequence in these objects shall contain the MR Diffusion Sequence (which also means the Shared Functional Groups Sequence shall NOT contain an MR Diffusion Sequence).

The Dimension Index Pointer (0020,9165) shall be populated with the:

1. Stack ID (0020,9056)

305   2. In-Stack Position Number (0020,9057)

3. Diffusion b-value (0018, 9087)

For these dimensions, the Dimension Organization UID (0020,9164) in the Dimension Index Sequence (0020,9222) of the derived image shall be identical to the Dimension Organization UID (0020,9164) of the corresponding dimension of the Source Images.

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The method used for derivation shall be specified in the Derivation Image Sequence (0008,9215). Codes relevant for this use case (excerpted from DICOM CID 7203) shall be selected from the values summarized in table 4.18.4.1.2.5-2.

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Table 4.18.4.1.2.5-2. Image Derivation Codes

Image Type Frame Type	Code Value (0008,0100)	Coding Scheme Designator (0008,0102)	Code Meaning (0008,0104)
ADC	113041	DCM	Apparent Diffusion Coefficient
ISOTROPIC	113043	DCM	Diffusion weighted

The Source Image Sequence (0008,2112) shall reference the SOP Class UID and SOP Instance UID of the images from which these images were derived.