Supplement 212:
XA Protocol Storage

Supplement is developed by DICOM Working Group 02
(WG-02 Projection Radiography and Angiography)

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Executive Summary

1. Motivation
2. Use Cases
3. Technical Highlights

--- Author Contacts ---

Technical Details

4. Background: Sup121 CT Protocol Storage
5. Overview of the XA Proposal
6. XA Protocol Parameters
7. Changes to the Standard

Appendix
Executive Summary
1. Motivation

**Existing Standard**
- Supp 121: Defines a method for storage and retrieval of CT acquisition protocols.

**Limitations on the Standard**
- Supp 121 includes CT modality only.
- XA Image & RDSR IODs include few protocol-related attributes.

**Goals of Sup 212 XA Protocol Storage**
- To define a method for storage and retrieval of XA protocols
- Similar use cases as for CT (see next slide)
- Facilitate compliance to NEMA XR-27: Export defined protocols from devices to a central repository to facilitate management of consistency and dose.
  - Refer to NEMA XR-27 “X-ray Equipment for Interventional Procedures User Quality Control Mode”

2. Use Cases

Use Cases (from Supp 121 – applicable to XA)

**Quality of Care**
→ Good, consistent image quality depends on good protocols, used consistently

**Dose Management**
→ Managing dose depends on managing protocols

**Analytics**
→ Summarizing data depends on consistent tagging
3. XA Acquisition Workflow: Series vs. Images

An **XA examination** performs minimally invasive image-guided diagnosis and/or treatment to a patient.

- It typically corresponds to a Requested Procedure selected in the Worklist → One Study UID
- It may be performed in several steps, typically corresponding to several Scheduled Procedure Steps → Several Series UID

XA examinations are not fully planned in advance, they are interactive because the physician’s actions will depend on real-time information from the live images, and on how the patient reacts to the treatment. During the examination:

- The physician may need to change sequentially the protocols and the anatomy being imaged (e.g. heart and carotids).
- The patient position on the table may change depending on the patient’s size and type of procedure.
- Different Series will be created as key Series attributes are changing during the examination (SPS, Patient Position).

On the other hand, for a given procedure step, many XA multi-frame images of different protocols and anatomies are acquired with the same patient position, and they are sent to Review Stations as they are acquired:

- Legacy review stations (e.g. Cardiology) expect that these images are grouped into the same Series for easy review and post-processing (e.g. image browsing). Typically, a new Series is created for a new Procedure Step (i.e. examination is resumed).
- DICOM requires all images in a Series to share the same Frame of Reference (geometrical context). So all images in the Series are inherently registered and can share the spatial calibration assumptions. A new Series is always created when the patient position changes.

Traditional XA IOD did not include protocol and anatomy attributes at image level, while Enhanced XA IOD and Radiation Dose SR included these attributes at Image level and Irradiation Event level.
3. Example of XA Acquisition Workflow

**Worklist Browser**
Select Requested Procedure & Scheduled Procedure Step #1

**XA Acquisition Device**
- Patient ID
- STUDY UID
- SPS ID1
- Protocol Code(s)

**Patient / Study Browser**
Start Examination

**Protocol List**
Select Patient Position

**Acquisition Console**
Select Protocol and Anatomy
Select Acquisition Mode and settings
DO Acquisitions

**PACS / Review Station**
Select SPS ID1, Protocol Code(s), Patient Position
Enhanced XA Images
- Protocol Name
- Anatomy
- Acquisition Mode
- Acquisition Settings

**PACS / Review Station**
- PATIENT
- STUDY
- SERIES #1
- SERIES #2
- XA IMAGE #1
- XA IMAGE #2
- XA IMAGE #3

**Worklist Browser**
Select Scheduled Procedure Step #2

**XA Acquisition Device**
Select SPS ID2
Protocol Code(s)

**Patient / Study Browser**
Resume Examination

**Protocol List**
Select Protocol and Anatomy
Select / change Patient Position

**Acquisition Console**
Select Acquisition Mode and settings
DO Acquisitions

**PACS / Review Station**
Enhanced XA Images
3. XA Technical Highlights

Main differences between XA and CT

1- XA studies are less planned than CT
   - XA protocol is typically selected manually from the device console.
   - Rules may exist on the device to pre-select a default protocol based on procedure type (e.g. neuro vs. cardiac) and patient characteristics (e.g. adult vs. pediatrics).

2- XA studies may use several protocols during the same series of images, CT uses one protocol per series
   - Each XA DICOM Image will include references to the Defined Protocol and Elements used.

3- XA protocol usage during the procedure is more interactive than CT
   - XA is changing continuously the acquisition modes (Fluoroscopy, DSA, Rotational Angio…) and the parameters (Field of View, frame rate, IQ/Dose levels). Several Performed Protocol Elements may be recorded for the same used Defined Protocol Element.

4- XA stores DICOM 2D images and 3D volumes
   - XA reconstruction protocol parameters shall include 2D and 3D processing, for the creation of both 2D and/or 3D Instances.
3. Technical Highlights

New IODs in Supplement 212
- The work will introduce two new IODs
  - XA Defined Procedure Protocol IOD
  - XA Performed Procedure Protocol IOD
- These IODs will use the constructs of the existing CT protocol management IODs introduced by Supp 121.

XA Protocols Content
- XA Acquisition Protocols will contain the acquisition modes and their related acquisition parameters. Acquisition modes are encoded as Acquisition Protocol Elements. Acquisition parameters are those used to create the XA 2D ORIGINAL Instances.
- XA Reconstruction Protocols will contain the processing parameters to create 2D XA DERIVED and 3D XA Instances.
- Acquisition and Reconstruction Parameters may be both standard and private. New parameters have been defined specifically for XA.
- Several XA Defined Protocols may be used within one single DICOM Series.
- XA Performed Protocol will record the actual parameters applied during the various acquisition modes. Several Performed Protocol Elements may be recorded for the same used Defined Protocol Element.
Example of XA Defined Procedure Protocol database in the acquisition equipment

- Device Protocol Library
  - Defined Protocol
    - Acquisition Protocol Element: E.g. Fluoro, DSA, Rotational...
      - Acquisition Parameters
        - Set of acquisition techniques: E.g. frame rate, FOV, focal spot
    - Reconstruction Protocol Element: E.g. High Resolution, Subtracted Volumes...
      - Reconstruction Parameters
        - Set of reconstruction formats: E.g. volume size, voxel size, subtraction...
    - Storage Protocol Element: E.g. Angio Storage, Cardiac Storage...
      - Storage Parameters
        - Set of storage rules: E.g. Send all the Series to Angio PACS...
3. XA Protocol and Settings selection

Example of selecting the Defined Acquisition Protocol in the acquisition equipment

1. The XA Defined Acquisition Protocol is typically selected manually from the device console, although rules may exist on the device to pre-select a default protocol based on procedure type and patient characteristics. Each element of the protocol contains the parameters of one acquisition mode of either fluoroscopy or high dose acquisitions. In case of biplane system, the parameters for both planes are contained in the same protocol element.

2. After selecting the protocol, the parameter values are loaded on the device for all the acquisition modes enabled in the protocol, and for both fluoroscopy and high dose acquisitions. Some parameters of the protocol may be displayed on the console for further adjustments by the operator (e.g. patient position, anatomy…).

3. During the XA procedure the acquisition modes are selected manually on the console (e.g. DSA, Rotational, Fluoro Roadmap, etc.) plus some other selections (e.g. IQ preferences, etc.). The protocol elements corresponding to these selected modes are loaded, and their default values will be used. The X-Ray acquisitions are performed sequentially by activating the fluoroscopy or the high dose acquisition switches (e.g. pedal press).
3. Technical Highlights

Example of selecting the Defined Acquisition Protocol in the acquisition equipment

Modality Console

- Acquisition Protocol List
  - Cardiac category:
    - Heart Diagnostic
    - Heart Intervention
  - Neuro category:
    - Aneurysm
    - Carotids
    - Occlusion

- Acquisition Modes
  - DSA
  - CARDIAC
  - ROTA

- User Settings
  - Low Dose X-Ray
    - SUB
    - NOSUB
    - ROADMAP
  - High Dose X-Ray
    - SUB
    - NOSUB

Defined Protocol:

- Carotids Protocol
  - Acquisition Protocol Element #1
    - DSA
    - Acquisition Parameters for DSA
  - Acquisition Protocol Element #2
    - CHASE
    - Acquisition Parameters for CHASE
  - Acquisition Protocol Element #3
    - ROTA NOSUB
    - Acquisition Parameters for Rotational NOSUB
  - Acquisition Protocol Element #4
    - ROTA SUB
    - Acquisition Parameters for Rotational SUB
  - Acquisition Protocol Element #5
    - Fluoroscopy SUB
    - Acquisition Parameters Fluoro SUB
  - Acquisition Protocol Element #6
    - Fluoroscopy NOSUB
    - Acquisition Parameters Fluoro NOSUB
  - Acquisition Protocol Element #7
    - Fluoroscopy ROADMAP
    - Acquisition Parameters Fluoro ROADMAP

Example of Parameters:
- Frame Rate
- Field Of View
- Focal Spot
- IQ level [H/M/L]
- Filters [ON/OFF]
- Auto-injection settings

Example of Parameters:
-  Frame Rate
-  Field Of View
-  Focal Spot
-  IQ level [H/M/L]
-  Filters [ON/OFF]
-  Auto-injection settings

Load Carotids Protocol
Load ROTA SUB parameters for High Dose acquisitions
Load FLUORO ROADMAP parameters for Fluoroscopy

Store Fluoroscopy
6. XA Protocol Parameters

Defined Procedure Protocols: XA example of rotational acquisition & 3D reconstruction workflow

**X-Ray ACQUISITION Parameters:**
- Frame Rate
- Field Of View
- Focal Spot
- IQ level [H/M/L]
- Filters [ON/OFF]
- Auto-injection settings

**2D Raw Data Processing Parameters:**
- Detector Binning
- Bad pixel correction
- Dynamic range opt Correction of offset
- Correction for geometric distortion

**Fluoro Local Recording:**
- YES / NO

**ACQUISITION PROTOCOL ELEMENT**

**Perform Rotational Acquisition**

Raw Data

**Perform 2D Raw Data Processing**

**DICOM ORIGINAL 2D XA Pixels**

1-N

**Perform 2D Image Processing**

**PACS**

**Perform 3D RECON**

**DICOM ORIGINAL 3D XA voxels**

1-N

**Perform 3D Image Processing**

**PACS**

**3D Volume for DISPLAY**

**3D Volume for DISPLAY**

**3D Image PRESENTATION Processing Parameters:**
- Windowing

**2D Image PRESENTATION Processing Parameters:**
- DSA masking
- DSA LUTs
- Windowing
- Spatial filters

**Note:**
Reconstruction elements include 2D and 3D processing parameters. 2D parameters may be used also to generate 3D reconstruction.

Each element of the Reconstruction Protocol Element Specification Sequence shall indicate the purpose of the processing pipeline: either for 2D or for 3D.
3. Technical Highlights

Cross References between Defined Protocols and Images

The Reconstruction Protocol Elements contain a “pointer” to the Acquisition Protocol Elements to be reconstructed.

CT Solution

In CT it is assumed that the Raw Data “knows” the Acquisition Protocol Element used.

XA Problem Statement

In XA, the 2D Projections are created as a DICOM multi-frame Image, that can be sent to a Reconstruction Workstation. If the 3D workstation is a separate device on the network, it must be able to identify from the image header the Defined Acquisition Protocol Element used.

Indeed, the Series of images include the Defined Protocols used to create all the images of the Series (in the Referenced Defined Protocol Sequence (0018,990C)). However, XA practice often includes in the same Series several images created from different defined protocols. Therefore, there is no mechanism in the Series to identify the Defined Acquisition Protocol Element used to create each image.

XA Solution

Supp 212 has created a new Procedure Protocol Reference to Instance Macro, which contains references to Defined/Performed Protocols and Elements. This Macro has been added to the Image Modules: X-Ray Image Module, Enhanced XA/XRF Image Module, and X-Ray 3D Image Module.
3. Technical Highlights

CT Acquisition and Reconstruction (on same device)

CT Equipment

**Defined Protocols**

- Defined Protocol #1
  - ACQ Element #1 - SCOUT
  - ACQ Element #2 - AXIAL

**Performed Protocol SERIES**

- Series #1
  - CT IMAGE #1
  - CT IMAGE #2
  - CT IMAGE #3
  - CT IMAGE #4

- Series #2
  - CT IMAGE #1
  - CT IMAGE #2

**Performed Protocol #1**

- Source ACQ Element Number = #1
- Referenced SOP Instance UID = Perf UID_02

**Defined Protocol UID containing the RECON element**

- Def UID_01

**Image SERIES**

- Series #1
  - CT IMAGE #1
  - CT IMAGE #2
  - CT IMAGE #3
  - CT IMAGE #4

- Series #2
  - CT IMAGE #1
  - CT IMAGE #2

**Performed Protocol SERIES references the Defined Protocol UID containing the RECON element**

- Perf UID_02

**Image Acquisition**

- Image Acquision
- CT Raw data

**3D Reconstruction**

- PATIENT
- STUDY

**CT Internal Data**

- Def UID_01
- Acq Element #2

> Source ACQ Element Number = #2
> Referenced SOP Instance UID = Def UID_01

**RECON Element #1 – RECON AXIAL**

- Source ACQ Element Number = #2
- Referenced SOP Instance UID = Def UID_01

**CT Acquisition and Reconstruction (on same device)**

- CT Raw data
- CT Internal Data

**Performed Protocol SERIES references the Performed Protocol UID (not the elements)**

- Perf UID_02

**Image SERIES references the Performed Protocol UID (not the elements)**

- Perf UID_02

> Source ACQ Element Number = #1
> Referenced SOP Instance UID = Perf UID_02
3. Technical Highlights

Protocol and Image Cross References – Acquisition and Reconstruction on different devices

### XA Equipment

**Defined Protocols**

- Defined Protocol #1 - NEURO
  - ACQ Protocol Element #1 - DSA
  - ACQ Protocol Element #2 - FLUORO
- Defined Protocol #2 - CAROTID
  - ACQ Protocol Element #1 - FLUORO
  - ACQ Protocol Element #2 - ROTA

- Def UID_01
- Def UID_02

### 3D Workstation

**Defined Protocols**

- Defined Protocol #1 - 3D RECON
  - RECON Protocol Element #1 – 3D CT NOSUB

- Def UID_03

> Source Acquisition Protocol Element Number = #2
> Referenced SOP Instance UID = Def UID_02

### Image Acquisition

- XA IMAGE #1 DSA
- XA IMAGE #2 Fluoro
- XA IMAGE #3 Fluoro
- XA IMAGE #4 ROTA

### Network

**Image #4**

**3D Reconstruction**

- PATIENT
- STUDY

**Series #1**

**Series #2**

**Series #3**

**Series #4**

**Performed Protocol #1**

- Perf UID_01
  - Perf UID_02

**Performed Protocol #2**

**Performed Protocol #3**

- Perf UID_03

**Def UID_01**

**Def UID_02**

**Def UID_03**

Jan 14 2020

DICOM WG-02 / Supp 212 XA PROTOCOL STORAGE
3. Technical Highlights

XA Performed Procedure Protocol

XA Performed Protocol records the actual parameters applied during the various acquisition modes.

General Series Module references the Performed Protocol Instances that describe the conditions by which this Series was generated. In CT it is assumed that all images in the series described by the same performed protocol. However, in XA, the same Series contains images acquired/reconstructed described by several performed protocols, and by several elements within the same protocol.

For Quality Control: For a given XA image, we need to identify the Performed Acquisition and Reconstruction Protocol Elements allowing to know exactly what protocol parameters have been used. They can be used to the interpretation of the image quality and dose.

3. Technical Highlights – Cross references

There are cross-references between

- Protocols and Protocol Codes
- Defined Procedure Protocol
- Performed Procedure Protocol

through the overall workflow

- Modality Worklist
- Device Defined Procedure Protocols
- Images
- Performed Procedure Protocols
3. Technical Highlights – Cross references

**DICOM Modality Worklist**

**Requested Procedure:**
- STUDY UID
- Procedure ID / Description
- Procedure Code

**Scheduled Procedure Step:**
- SPS ID / Description
- Modality <CT, XA…>
- Referenced Defined Protocol UID
- Scheduled Protocol Code(s)

**Acquisition Equipment**

**DEFINED PROCEDURE PROTOCOL:**
- SOP Instance UID
- Potential Scheduled Protocol Code(s)
- Protocol Elements with parameters pre-defined

**PERFORMED PROCEDURE PROTOCOL:**
- SOP Instance UID
- Protocol Elements with parameters actually used

**DICOM Patient Study**

**STUDY:**
- STUDY UID
- Study ID
- Performed Procedure Code(s)

**SERIES (Images):**
- Modality <XA>
- Requested Attributes Sequence
  - Requested Procedure ID / Desc.
  - SPS ID / Description
  - Scheduled Protocol Code(s)
- Protocol Name
- Performed Protocol Code(s)
- Ref. to Performed Procedure Protocol SOP Instance UID(s)

**SERIES (Protocols):**
- Modality <XAPROTOCOL>
- Ref. to Defined Procedure Protocol SOP Instance UID & Element
- Ref. to Performed Procedure Protocol SOP Instance UID & Element
- Acquisition Protocol Name
- Acquisition Mode
- Acquisition Settings/Parameters

The Modality selects one Scheduled Procedure Step (SPS) and maps it to one Defined Procedure Protocol… but several defined protocols may be used.
In this example:

The **Defined protocol 1** (Head) is selected on the device:
- An XA image 1 is created in Series 1, and its corresponding Performed protocol 1 (and element) is created in Series 2

Then, the **Defined protocol 2** (Carotids) is selected on the device:
- An XA image 2 is created in Series 1, and its corresponding Performed protocol 2 (and element) is created in Series 2
- Settings are changed on the device: an XA image 3 is created in Series 1, and a new element is created in Performed protocol 2

Then, the image 3 is reconstructed by the **Defined protocol 3** (Head) – on the device or on a 3D Workstation:
- An XA 3D volume 1 is created in Series 3, and its corresponding Performed protocol 1 (and element) is created in Series 4
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Thank you for your attention!
Technical Details
4. Background

**Protocol**
A Protocol is a specification of actions prescribed by a Procedure Plan to perform a specific Procedure Step. A Scheduled Procedure Step (from Modality Worklist) contains only one Protocol, which may be conveyed by one or more Protocol Codes. A Protocol may be specified by a Defined Procedure Protocol to be used on any appropriate patient. A Protocol can be documented, once a Procedure Step has been performed, in a Performed Procedure Protocol.

**Defined Procedure Protocol**
A Defined Procedure Protocol describes a set of parameters and associated details for the prescribed action. The Defined Procedure Protocol may provide specific values for relevant parameters, or may provide constraints on those parameters (such as an acceptable range) to guide the choice of specific values. Defined Procedure Protocol is not associated with any particular Patient or Scheduled Procedure Step. A Defined Procedure Protocol may contain parameters specific to a particular model or version of device, or it may be generic in that it only describes parameters common to multiple device models. A Defined Procedure Protocol may include information such as the clinical purpose, indications, and appropriate device models, intended for selection and management.

**Performed Procedure Protocol**
A Performed Procedure Protocol encodes the parameter values used. A Performed Procedure Protocol is always associated with a specific Patient and Performed Procedure Step. The Performed Procedure Protocol may reference the Defined Procedure Protocol on which it was based, but does not otherwise record the original constraints and whether or not they were satisfied by the final values as recorded in the Performed Procedure Protocol.
4. Background

Defined Procedure Protocols

- Vendor/Model Specific content
- Private tags expected for model-specific details
- Specifies Constraints on Parameters (Specific value, set, range, etc)
- Instructions to tech

Device ONLY encodes the parameters it needs/supports

Performed Procedure Protocols

- Encodes the parameter values used
- Always associated with a specific Patient and Performed Procedure Step

**DEFINITION OF PROCEDURE PROTOCOL SOP Instance**

- Equipment information
- Protocol Context
- Clinical Trial Context
- Patient Specification
- Equipment Specification
- Instructions
- Patient Positioning

**Acquisition Protocol Element Specification Sequence (0018,991F)**

1-n

**Reconstruction Protocol Element Specification Sequence (0018,9933)**

1-n

**Storage Protocol Element Specification Sequence (0018,9935)**

1-n
4. Background

CT Procedure Step Example of Defined Protocol usage

**Equipment Sequential Tasks**

- **Acquisition Protocol Element #1**
  - Acquisition Parameters (1.A1)

- **Acquisition Protocol Element #2**
  - Acquisition Parameters (1.A2)

- **Reconstruction Protocol Element #1**
  - Reconstruction Parameters (1.R1)

- **Reconstruction Protocol Element #2**
  - Reconstruction Parameters (1.R2)

- **Storage Protocol Element #1**
  - Storage Parameters (1.S1)

**Send Recon Scout and Recon Axial to PACS**

**Acquisition Protocol Element Specification Sequence (0018,991F)**

**Reconstruction Protocol Element Specification Sequence (0018,9933)**

**Storage Protocol Element Specification Sequence (0018,9935)**

**Defined Protocol UID #1**

- **Do Scan 1**
- **Do Recon 1**
- **Do Scan 2**
- **Do Recon 2**
- **Export Recon 1 & 2**
6. XA Protocol Parameters

Defined Procedure Protocols: XA example of DSA acquisition

Clarifications of the meaning of Acquisition and Reconstruction Protocol Elements:

**Acquisition**: creation of DICOM 2D ORIGINAL pixel data (including Image-Independent corrections as defined in IEC 62220-1-3). The access to the Raw Data is locked and not intended to be kept for re-processing.

**Reconstruction**: manipulation of DICOM 2D ORIGINAL pixel data to create a DICOM 2D DERIVED or 3D RECONSTRUCTED data

**Note**: Parameters to display an image on a non-persistent device (e.g. on monitors) should not be in the protocols, rather in another Presentation workflow. However, if the parameters are used to create a DERIVED image within the acquisition workflow (e.g. DSA subtracted pixels) then the parameters can be in the Reconstruction Protocol.

IEC 62220-1-3 Par.5 Corrections of RAW DATA

The following linear and image-independent corrections of the RAW DATA are allowed in advance of the processing of the data for the determination of the CONVERSION FUNCTION, the NOISE POWER SPECTRUM, and the MODULATION TRANSFER FUNCTION.

All the following corrections if used shall be made as in normal clinical use:

- replacement of the RAW DATA of bad or defective pixels by appropriate data;
- a flat-field correction comprising correction of the non-uniformity of the RADIATION FIELD; correction for the offset of the individual pixels; and gain correction for the individual pixels;
- a correction for geometrical distortion.

**NOTE 1**  Some detectors execute linear image processing due to their physical concept. As long as this image processing is linear and image-independent, these operations are allowed as an exception.

**NOTE 2**  Image correction is considered image-independent if the same correction is applied to all images independent of the image contents.
6. XA Protocol Parameters

Example of XA Procedure Step – Acquisition and Reconstruction on same device

- **Acquisition Protocol Element #1**
  - **Fluoroscopy Acq Parameters** (1.A1)
  - **DSA Acq Parameters** (1.A2)
  - **Rotational Acq Parameters** (1.A3)

- **Reconstruction Protocol Element #1**
  - **Reconstruction Parameters** (1.R1)

- **Storage Protocol Element #1**
  - **Recon Storage Parameters** (1.S1)

- **Storage Protocol Element #2**
  - **DSA Storage Parameters** (1.S2)

- **Defined Protocol UID #1**
  - Acquisition Protocol Element Specification Sequence (0018,991F)
  - Reconstruction Protocol Element Specification Sequence (0018,9933)
  - Storage Protocol Element Specification Sequence (0018,9935)

**Note:** In this example, Fluoroscopy is not stored as a DICOM instance.

**Note:** If LIH or complete Fluoro is stored, a Storage Protocol Element should be pointing to the Acquisition Protocol Element #1.
6. XA Protocol Parameters

Cross References between Defined Protocols and Images

**XA DEFINED PROTOCOLS**

- Defined Procedure Protocol SOP Instance UID
  - Potential Scheduled Protocol Code(s)
    - Acquisition Protocol Element Specification Sequence (0018,991F)
    - Reconstruction Protocol Element Specification Sequence (0018,9933)
    - Storage Protocol Element Specification Sequence (0018,9935)

**XA CREATED IMAGES**

- Series (of Images) UID (General Series Module)
  - Modality <XA>
  - Requested Attributes Sequence
  - Protocol Name
  - Performed Protocol Code(s)

- Referenced Performed Protocol Sequence (0018,990D) [1..n]
  - > Performed Procedure Protocol SOP Instance UID

- Defined Procedure Protocol SOP Instance UID
  - Defined Procedure Protocol (0018,990C) [1]
    - Procedure Protocol Reference on instance Sequence (xxxx,xx90)
      - > Referenced Defined Protocol Sequence (0018,990C) [1]
        - >> Defined Procedure Protocol SOP Instance UID
  - Source Acquisition Protocol Element Number (0018,9938)
  - Source Reconstruction Protocol Element Number (0018,993A)
6. XA Protocol Parameters

Cross References between Defined and Performed Protocols

**XA DEFINED PROTOCOLS**

- **DEFINED PROCEDURE PROTOCOL SOP Instance UID**
  - Potential Scheduled Protocol Code(s)
  - Acquisition Protocol Element Specification Sequence (0018,991F)
    - Acquisition Protocol Element(s)
  - Reconstruction Protocol Element Specification Sequence (0018,9933)
    - Reconstruction Protocol Element(s)
  - Storage Protocol Element Specification Sequence (0018,9935)
    - Storage Protocol Element(s)

**XA PERFORMED PROTOCOLS**

- **PERFORMED PROCEDURE PROTOCOL SOP Instance UID**
  - Acquisition Protocol Element Sequence (0018,9920)
    - Acquisition Protocol Element(s)
  - Reconstruction Protocol Element Sequence (0018,9934)
    - Reconstruction Protocol Element(s)
  - Storage Protocol Element Sequence (0018,9936)
    - Storage Protocol Element(s)

**SERIES (of PROTOCOLS) UID**
- Modality < XAPROTOCOL >
- Requested Attributes Sequence
- Protocol Name
- Performed Protocol Code(s)

Multiple Items in the Sequence (0018,990C) may represent an XA procedure where several Defined Procedure Protocols resulted in several Performed Procedure Protocols stored in the same Series.

Multiple Defined Protocols used during the Study may result in ONE Protocol Series with multiple Performed Protocols.
6. XA Protocol Parameters

Cross References between Performed Protocols and Images

**XA PERFORMED PROTOCOLS**

**SERIES (of PROTOCOLS) UID**
- Modality <XAPROTOCOL>
- Requested Attributes Sequence
- Protocol Name
- Performed Protocol Code(s)

Referenced Defined Protocol Sequence (0018,990C) [1..n]
> Defined Procedure Protocol SOP Instance UID

**PERFORMED PROCEDURE PROTOCOL SOP Instance UID**
- Acquisition Protocol Element Sequence (0018,9920)
- Reconstruction Protocol Element Sequence (0018,9934)
- Storage Protocol Element Sequence (0018,9936)

1-n

**XA CREATED IMAGES**

**SERIES (of IMAGES) UID** (General Series Module)
- Modality <XA>
- Requested Attributes Sequence
- Protocol Name
- Performed Protocol Code(s)

Referenced PERFORMED Protocol Sequence (0018,990D) [1..n]
> Performed Procedure Protocol SOP Instance UID

**IMAGE**
- SOP Instance UID / Irradiation Event UID
- Acquisition Protocol Name

Procedure Protocol Reference on Instance Sequence (xxxx,xx90)
> Referenced PERFORMED Protocol Sequence (0018,990D) [1]
>> Performed Procedure Protocol SOP Instance UID

>> Source Acquisition Protocol Element Number (0018,9938)
>> Source Reconstruction Protocol Element Number (0018,993A)
6. XA Protocol Parameters

Performed Protocol Storage: Example of one single Series

Study with XA Images and Protocols

STUDY 1

SERIES 1 - XA

Scheduled Procedure Step #1

Select Defined Acquisition Protocol #1

SERIES 101 - XAPROTOCOL

References to Defined Protocol #1

Performed Acquisition Protocol #1

Acquisition Protocol Element #1 (Fluoro)
Parameters (1.a1-default)

Acquisition Protocol Element #2 (Fluoro)
Parameters (1.a1-modified)

Acquisition Protocol Element #3 (DSA)
Parameters (1.a2-default)

Acquisition Protocol Element #4 (DSA)
Parameters (1.a2-modified)

Defined Acquisition Protocol Element #1 (Fluoro)
Parameters (1.a1-default)

IMAGE 1
IMAGE 2
IMAGE 3
IMAGE 4

Parameters (1.a1-modified)
Modified by the user or automatically

IMAGE 5

Defined Acquisition Protocol Element #2 (DSA)
Parameters (1.a2-default)

IMAGE 6
IMAGE 7

Parameters (1.a2-modified)
Modified by the user or automatically

IMAGE 8
IMAGE 9
Example 1: Single XA Device for Acquisition and Reconstruction

One Defined Protocol with three protocols elements (Acquisition, Reconstruction, Storage) on the Acq System

Example 2: Two XA Devices for Acquisition and Reconstruction

One protocol on both Acq and Recon devices: Two elements applicable to the Acq System (Acquisition, Storage) and two elements applicable to the 3D station (Reconstruction, Storage) Two use cases of how the protocols can be selected:
A: user selects the protocol elements manually
B: user selects one acquisition protocol, the storage is automatically triggered. Then in workstation, the reconstruction and further storage are triggered automatically based on the references from the image header

Example 3: QA and Creation of AAPM-based Defined Protocols

Add a use case of taking a generic protocol (e.g. AAPM) and transforming it into a specific device that does not support all the parameters defined by AAPM. And with parameters not defined yet in DICOM Part 3 (e.g. new features on the vendor model). Perform acquisition, record the Performed Protocol parameters, do QA on the images.
7. Changes to the Standard

### Table A.1-9. Composite Information Object Modules

<table>
<thead>
<tr>
<th>Overview - Protocols</th>
<th>XA Performed Procedure Protocol</th>
<th>XA Defined Procedure Protocol</th>
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### Section A.82.Y1

**XA Performed Procedure Protocol IOD**

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7. Changes to the Standard

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<td>Table C.34.8-1 Patient Positioning Module Attributes</td>
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## 7. Changes to the Standard

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<td>Section C.34.14</td>
<td>Performed Storage Module</td>
<td>Add XA Performed Procedure Protocol Storage SOP Class UID in the conditions and in the enumerated terms</td>
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<tr>
<td>Section C.34</td>
<td>Procedure Protocol Modules</td>
<td>Add modules for the two new XA Protocol IODs at the end of Section C.34: C.34.X1 XA Protocol Series Module C.34.X3 Performed XA Acquisition Module C.34.X5 Performed XA Reconstruction Module</td>
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### Part 4: Service Class Specifications

<table>
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<tr>
<th>Section B.5</th>
<th>Standard SOP Classes</th>
<th>Add new SOP Class for XA Performed Procedure Protocol Storage</th>
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<tbody>
<tr>
<td>Section B.5.1</td>
<td>Specialization for Standard SOP Classes</td>
<td>Add section: B.5.1.X1 XA Performed Procedure Protocol Storage SOP Class</td>
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<tr>
<td>Section GG.3</td>
<td>SOP Classes</td>
<td>Add new SOP Class for XA Defined Procedure Protocol Storage to the Non-Patient Object Storage Service Class definition</td>
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<tr>
<td>Section GG.6</td>
<td>Application Behavior for Standard SOP Classes</td>
<td>Make GG.6.4 not CT-specific. Add GG.6.4.1 for CT-Specific. Add GG.6.4.2 with details to XA Defined Procedure Protocol Storage</td>
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### Part 6: Data Dictionary

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<tr>
<th>Section A</th>
<th>Registry of DICOM Unique Identifiers (UIDs) (Normative)</th>
<th>Add two new SOP Classes for XA Defined and Performed Procedure Protocol Storage</th>
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<td>Registry of DICOM Unique Identifiers (UIDs) (Normative)</td>
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### Part 16: Content Mapping Resource

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<th>Section A</th>
<th>DCMR Context Groups (Normative)</th>
<th>Add new CIDs XAProt01 &quot;Contraindications For XA Imaging&quot;</th>
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### Part 17: Explanatory Information

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<tr>
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<td>Add sections for XA-specific examples of Protocol Storage AAAAA.X1 XA Best Practice Defined Procedure Protocol AAAAA.X2 Single XA Device for Acquisition and Reconstruction AAAAA.X3 Two XA Devices for Acquisition and Reconstruction</td>
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</table>
CT Acquisition and Reconstruction Workflow

CT Defined Procedure Protocols: example of acquisition & 3D reconstruction workflow

CT ACQUISITION Parameters:
- KVP
- X-Ray Tube Current in mA
- Revolution Time
- Single Collimation Width
- Total Collimation Width
- Spiral Pitch Factor
- Exposure Modulation Type
- CTDivol Notification Trigger
- DLP Notification Trigger
- CTDivol

Perform CT Scan Acquisition → CT Raw data

3D RECONSTRUCTION Parameters:
- Reconstruction Algorithm
- Convolution Kernel
- Reconstruction Diameter
- Reconstruction Field of View
- Slice Thickness
- Pixel Spacing

Perform 3D RECON → DICOM ORIGINAL 3D CT voxels

3D Image DISPLAY Processing Parameters:
- Window Center
- Window Width

Perform 3D Image Processing for DISPLAY → Displayed 3D volume
CT Example

CT Procedure Step Example of Defined Protocol

Within the Defined Protocol, in order to say to the 3D workstation that the Reconstruction Element #1 shall be applied to acquisitions of the Acquisition Element #1 of the Defined Protocol UID #1:

Use the following tags as selector attributes in the Reconstruction Element Sequence:

(0018,9938) Source Acquisition Protocol Element Number = #1
(0008,1155) Referenced SOP Instance UID = UID1.

Similarly, to say what objects to be stored (e.g. to PACS), use the following tags as selector attributes in the Storage Element Sequence:

(0018,9938) Source Acquisition Protocol Element Number = #1
(0018,993A) Source Reconstruction Protocol Element Number = #1
(0008,1155) Referenced SOP Instance UID = UID1.
Examples

Data Structure of CT Acquisition Workflow

Example of usage of Defined Protocols and mapping with Worklist protocols:

**Worklist**
- Requested Procedure 1
  - Scheduled Procedure Step 1
    - Defined Protocol SOP Class UID
    - Defined Protocol SOP Instance UID
    - Scheduled Protocol Code #1.1
    - Scheduled Protocol Code #1.2
    - Scheduled Protocol Code #1.3
    - ...
  - Scheduled Procedure Step 2
    - Defined Protocol SOP Class UID
    - Defined Protocol SOP Instance UID
    - Scheduled Protocol Code #2.1
    - Scheduled Protocol Code #2.2
    - Scheduled Protocol Code #2.3
    - ...

**CT Images**
- STUDY 1
  - Requested Procedure #1
    - Sch. Procedure Step #1
      - Defined Acquisition Protocol #1
      - Defined Reconstruction Protocol #1
    - Acquisition Protocol Element #1
      - Parameters (1.a1)
    - Reconstruction Protocol Element #1
      - Parameters (1.r1)
  - SERIES 1
    - IMAGE 1
    - IMAGE 2
    - ...
  - SERIES 2
    - Sch. Procedure Step #2
      - Defined Acquisition Protocol #2
      - Defined Reconstruction Protocol #2
    - Acquisition Protocol Element #1
      - Parameters (2.a1)
    - Reconstruction Protocol Element #1
      - Parameters (2.r1)

Example of usage of Defined Protocols and mapping with Worklist protocols:

- Defined Protocol SOP Class UID
- Defined Protocol SOP Instance UID

Added in CP 1716
Examples

Data Structure of XA Acquisition Workflow

Example of usage of Defined Protocols and mapping with Worklist protocols:

![Diagram of XA Acquisition Workflow](image)

- **Worklist**
  - Requested Procedure 1
    - Scheduled Procedure Step 1
      - Defined Protocol SOP Class UID
      - Defined Protocol SOP Instance UID
      - Scheduled Protocol Code #1.1
      - Scheduled Protocol Code #1.2
      - Scheduled Protocol Code #1.3
      - ...
    - Scheduled Procedure Step 2
      - Defined Protocol SOP Class UID
      - Defined Protocol SOP Instance UID
      - Scheduled Protocol Code #2.1
      - Scheduled Protocol Code #2.2
      - Scheduled Protocol Code #2.3
      - ...

- **XA Images**
  - STUDY 1
    - Requested Procedure #1
    - Sch. Procedure Step #1
      - Defined Acquisition Protocol #1
        - Acquisition Protocol Element #1 Parameters (1.a1)
      - Defined Reconstruction Protocol #1
        - 3D Reconstruction Protocol Element #1 Parameters (1.r1)
  - SERIES 1
    - IMAGE 1
      - DSA
    - IMAGE 2
      - Rotational
  - SERIES 2
    - IMAGE 3
      - 3D Volume
  - SERIES 3
    - IMAGE 5
      - Fluoro
### CT Protocols IODs & modules in PS3.3

#### Table A.1.9: Composite Information Object Modules Overview

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#### Table A.82.1.3-1: Table CT Performed Procedure Protocol IOD Modules

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#### Table A.82.2.3-1: CT Defined Procedure Protocol IOD Modules

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#### Table A.82.3.1-1: Protocol Approval IOD Modules