Translating the IHE Teaching File and Clinical Trial Export (TCE) Profile Document Templates into Functional DICOM Structured Report Objects

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The Integrating the Healthcare Enterprise (IHE) Teaching File and Clinical Trial Export (TCE) integration profile describes a standard workflow for exporting key images from an image manager/archive to a teaching file, clinical trial, or electronic publication application. Two specific digital imaging and communication in medicine (DICOM) structured reports (SR) reference the key images and contain associated case information. This paper presents step-by-step instructions for translating the TCE document templates into functional and complete DICOM SR objects. Others will benefit from these instructions in developing TCE compliant applications.

KEY WORDS: Digital imaging and communications in medicine (DICOM), integrating healthcare enterprise (IHE), extensible markup language (XML), electronic teaching file, clinical trial, electronic, publishing

BACKGROUND

Integrating the Healthcare Enterprise (IHE) is an initiative founded and supported by the Radiological Society of North America (RSNA) and the Healthcare Information and Management Systems Society (HIMSS). IHE defines profiles for using existing standards to solve incompatibilities between health information systems.¹ The Teaching File and Clinical Trial Export (TCE) profile describes actors and transactions for exporting key images from an image manager/archive (i.e., picture archiving and communication system or PACS) to a teaching file, clinical trial, or electronic publication application.²

The TCE actors include export selector, export manager and receiver (Fig. 1). The export selector is a system that provides an interface for selection of key images and input of case information; and it generates the necessary structured reports for

export. Ideally, it is grouped with the image manager/archive. The export manager is a system that pseudonymizes the case attributes in the digital imaging and communication in medicine (DICOM) images and the structured reports, then exports to a receiver. The receiver is a system that accepts key images and structured reports, and it is the target destination of the case.

The TCE transactions include store export selection and store additional teaching file information. The transactions store instances [RAD-50] and export instances [RAD-53] do not require the creation of DICOM structured report (SR) objects and are out of the scope of this paper. The store export selection [RAD-51] transaction is a mandatory component of the profile and requires the creation of an export selection manifest, which is a specialized DICOM key object selection

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(KOS) SR object that references the exported key images and their intended destination. The store additional teaching file information [RAD-52] transaction is an optional component of the profile and requires the creation of an additional teaching file information (ATFI) object—a specialized DICOM-enhanced SR object that stores informa-

tion about the case, including the author, diagnosis, pathology, and anatomic location.^{3,4}

Figure 1 presents the workflow for the TCE profile. Key images are selected via the export selector, and the manifest is generated. In addition, the ATFI object is also generated. Then, the key images (i.e., instances), manifest and ATFI

Fig. 1. The IHE teaching file and clinical trial export (TCE) integration profile workflow.

object are sent from the export selector to the export manager via the RAD-50, RAD-51, and RAD-52 transactions. After appropriate pseudonymization, the key images, manifest and ATFI object are sent from the export manager to the receiver via the RAD-53 transaction. The profile does not require that all the case objects are sent together; however, given that the manifest references the key images and ATFI, it is able to group them appropriately upon receipt.

All DICOM SR objects are composed of modules with attributes. Some modules are common to all DICOM SR objects, whereas others are specific to the type of SR.⁵ The specific content of an SR object is contained within the SR document content module.⁵ The TCE documentation includes templates outlining the required and optional attributes of the content unique to the manifest and ATFI objects. However, they do not include the attributes of the common modules required in all DICOM SR objects. To fill in the gaps, one must refer to more than 50 pages within 1,500 pages of DICOM documentation.^{5,6} This paper presents straightforward, step-by-step instructions for translating these complex templates into functional and complete DICOM SR objects.

MATERIALS AND METHODS

Generating DICOM SR Objects

Although it is possible to generate DICOM SR objects directly, the easiest method is to construct an extensible markup language (XML) file and then convert the XML file into a DICOM SR object using a DICOM toolkit.^{7,8} It is important to note that the XML schema is not standardized and varies across toolkits. The examples in this manuscript represent the XML schema defined by the Oldenburg Research and Development Institute for Information Technology Tools and Systems (OFFIS) DICOM toolkit (DCMTK).⁹ However, the instructions in this manuscript still pertain to any toolkit used. If a different toolkit is used, one must become familiar with the XML schema of that toolkit and should use this paper as a guide to understanding the manifest and ATFI objects.

DICOM SR objects, like all DICOM objects, require three globally unique identifiers (UIDs): study instance UID, series instance UID, and

service-object pair (SOP) instance UID. The study instance UID and series instance UID identify the study and series, respectively, within which the object is a member.¹⁰ The SOP instance UID is unique to each object. Example methods for generating DICOM-compliant UIDs are documented (DICOM News Group <http://groups.google.com/group/comp.protocols.dicom/search?q=UID+root>).

The key images will have already been assigned these UIDs. The manifest and ATFI objects adopt the same study instance UID of the key images; however, an SR document does not reside in a series of images.⁵ Therefore, a single unique series instance UID is generated and applied to both documents. Finally, each object must have its own unique SOP instance UID. After generating the manifest and ATFI objects, the final study will contain multiple series; each series will contain its associated key images plus an additional series containing the manifest and ATFI; and the manifest and ATFI objects will be identified by their own SOP Instance UID.

Export Selection Manifest

The TCE profile defines the manifest as an instance of the KOS SOP Class and describes the manifest template, which is a specialization of the DICOM KOS template.⁶ However, generating a functional manifest actually starts with the KOS information object definition (IOD).⁵ The IOD outlines all modules that makeup a KOS object. Each module is either mandatory ("M"), conditional ("C"), or user optional ("U"). Herein, all TCE specific attributes of the manifest are addressed, as well as the mandatory common modules with their mandatory attributes.

It is easiest to follow the modules in the order they are listed in Table 1. Table 2 lists all mandatory attributes of the modules that are common between the Manifest and ATFI objects. Included are the name of the attribute, its requirement status ("Type"), and its description. If an attribute type is "1" it is mandatory and must contain a valid value. If it is "1C" it is mandatory if the stated condition is met and must contain a valid value. If it is "2" it is mandatory, but it may contain a null value. In addition, the attribute description section may contain enumerated value definitions and a note regarding the use of the specific attribute.

Table 1. Key Object Selection Document IOD Mandatory Modules

	Information Entity	Module
Common SR Modules	Document	SOP common
	Patient	Patient
	Study	General study
Manifest Modules	Equipment	General equipment
		Key object document series
	Series	Key object document SR document content
	Document	

Adopted from DICOM PS 3.3-2004 Table A.35.4-1 (pg 173)

The process begins with the SOP common module, which identifies the manifest as a key object selection document SOP class and contains the generated SOP instance UID (see “[Generating DICOM SR Objects](#)” above). The patient module identifies the patient’s name, ID, date of birth, and gender. The general study module identifies the study instance UID, study date and time, referring physician’s name, study ID, and accession number. Finally, the general equipment module identifies the manufacturer of the equipment that produced the associated key images. Information for the patient module, the general study module,

and the general equipment module can be obtained directly from the associated key images and should be the same between all key images, the manifest, and ATFI objects in the same study. Figure 2 is example XML code for these common structured report attributes.

Table 3 lists all mandatory attributes of the modules that are specific to the manifest. The key object document series module identifies the modality, series instance UID, and series number. The modality for a manifest is “KO,” the series instance UID is the newly generated UID that will contain the manifest and ATFI, and the series number can be an arbitrary number that has not already been assigned to one of the selected key images. It is recommended that the DICOM header of the selected key images be read to identify the highest series number already in use and assign the number just above that as the manifest series number. The referenced performed procedure step sequence attribute uniquely identifies the performed procedure step SOP instance for which the series was created and is a mandatory attribute but will be sent as null for the purposes of the manifest. By leaving it out of the XML file, the OFFIS DCMTK will generate the

Table 2. Common SR Modules Mandatory Attributes

Attribute Name	Type	Attribute Description
SOP common module (adopted from DICOM PS 3.3-2004 Table C.12-1 [pg 713])		
SOP Class UID	1	Uniquely identifies the SOP class KeyObjectSelectionDocument = 1.2.840.10008.5.1.4.1.1.88.59 EnhancedSR = 1.2.840.10008.5.1.4.1.1.88.22
SOP Instance UID	1	Uniquely identifies the SOP instance
Patient module (adopted from DICOM PS 3.3-2004 Table C.7-1 [pg 250])		
Patient's name	2	Patient's full name
Patient ID	2	Primary hospital identification number or code for the patient
Patient's birth date	2	Birth date of the patient
Patient's sex	2	Sex of the named patient Enumerated values: M, F, O
General study module (adopted from DICOM PS 3.3-2004 Table C.7-3 [pg 253])		
Study instance UID	1	Unique identifier for the study
Study date	2	Date the study started
Study time	2	Time the study started
Referring physician's name	2	Name of the patient's referring physician
Study ID	2	User or equipment-generated study identifier
Accession number	2	A RIS generated number that identifies the order for the study
General equipment module (adopted from DICOM PS 3.3-2004 Table C.7-8 (pg 266))		
Manufacturer	2	Manufacturer of the equipment that produced the composite instances

1 = Mandatory; 2 = Mandatory, but may contain a null value

element with null value in the final DICOM SR object. The key object document module identifies the instance number (embedded in the <instance> element in Fig. 2) and the date and time that the manifest was created (embedded in the <content> element in Fig. 4). In addition to being referenced in the SR document content module (described below), all key images must also be referenced in the current requested procedure evidence sequence. Here, the study instance UID is listed again. The SOP Class UID and SOP Instance UID of each key image are referenced (embedded in the <value> element in Fig. 3), and they are grouped in their respective series, referencing the series instance UID. In the tables and templates, the ">" symbol (not to be confused with the same symbol used as the last character in an XML tag) represents the embedment depth of the element. For example, the referenced SOP Class UID and referenced SOP Instance UID of each image are embedded within the referenced SOP sequence, which in turn, is embedded within the referenced series sequence (Table 3).

The SR document content module represents the meat of the manifest. This module defines the information required in the manifest and is used in combination with the export selection manifest template, as outlined in the TCE documentation (Table 4).² The module begins by identifying the date and time the content was generated. Then, according to the manifest template, comes the container, a specialized value type that contains all the content information. The container is flagged as "separate," meaning that the contents of the container are not logically linked in a continuous textual flow but rather are separate items.

Each content item in the container may contain up to four types of information: value type, relationship, concept, and value. Value type describes what type of information is represented. In addition to container, the value types used in the manifest are code, PNAME, text, image, and composite, and each will be discussed below. Refer to Table 4 and Figure 4 for the manifest content and XML code associated with each example.

Fig. 2. Common SR modules mandatory attributes in XML format.

Table 3. Manifest Modules Mandatory Attributes

Attribute Name	Type	Attribute Description
Key object document series module (adopted from DICOM PS 3.3-2004 Table C.17.6-1 [pg 778])		
Modality	1	Modality type KO≡Key object selection
Series Instance UID	1	Unique identifier of the series
Series number	1	A number that identifies the series Uniquely identifies the performed procedure step SOP instance for which the series is created
Referenced performed procedure step sequence	2	Notes: This is not the reference list of key objects. It may be sent as null in the manifest
Key object document module (adopted from DICOM PS 3.3-2004 Table C.17.6-2 [pg 778–779])		
Instance number	1	A number that identifies the document
Content date	1	The date the document content creation started
Content time	1	The time the document content creation started
Current requested procedure evidence sequence	1	List of all composite SOP instances referenced in the content sequence Note: Only the set of instances referenced within the key object selection
>SOP instance reference macro (adopted from DICOM PS 3.3-2004 Table C.17-3 [pg 763])		
>Study instance UID	1	Unique identifier for the study
>Referenced series sequence	1	Sequence of repeating items where each item includes the attributes of a series containing referenced composite object(s)
>>Series instance UID	1	Unique identifier of a series that is part of this study and contains the referenced composite object(s)
>>Referenced SOP sequence	1	References to composite object SOP class/SOP instance pairs that are part of the study defined by study instance UID and the series defined by series instance UID
>>>Referenced SOP class UID	1	Uniquely identifies the referenced SOP class
>>>Referenced SOP instance UID	1	Uniquely identifies the referenced SOP instance
SR document content module (adopted from DICOM PS 3.3-2004 Table C.17-4 [pg 764])		
Content sequence	1	A nested sequence of items that conveys content Note: Source of content information is defined in the TCE profile documentation and outlined in Table 4
>Date	1	The date of the content item
>Time	1	The time of the content item
>Relationship type	1	The type of relationship between the (enclosing) source content item and the target content item
>Value type	1	The type of the value encoded in this content item
>Concept name code sequence	1C	Code describing the concept represented by this content item In the manifest: required if value type is container, code, PNAME, or text
>>Include `code sequence macro' (Table 5)		
>Continuity of content	1C	This flag specifies for a container whether the contained content items are logically linked in a continuous textual flow or are separate items Enumerated values: separate; continuous
>Concept code sequence	1C	This is the value of the code content item
>>Include `code sequence macro' (Table 5)		
>Person name	1C	This is the value of the PNAME content item
>Text value	1C	This is the value of the text content item
>Referenced SOP sequence	1C	References to image or composite object SOP class/SOP instance pairs
>>Referenced SOP class UID	1	Uniquely identifies the referenced SOP class
>>Referenced SOP instance UID	1	Uniquely identifies the referenced SOP instance

1≡Mandatory; 1C≡Conditional mandatory; 2≡Mandatory, but may contain a null value

Fig. 3. Manifest modules mandatory attributes in XML format.

Relationship describes how the item relates to its parent, the container. Three relationships are used in the manifest: has concept MOD, has OBS context, and contains.⁵ Has concept MOD (“has concept modifier”) is used with the CODE value type and qualifies or further describes the concept of its parent, the container. Has OBS context (“has observation context”) is used with the code and

PNAME value Types and describes the individual that assembled the collection of key images as opposed to the patient. Contains is used with the text, image, and composite value types to show they are contained by their parent, the container.

The container, code, PNAME, and text value types all contain a concept, which is a code describing the concept represented by the content

Table 4. Export Selection (“Manifest”) Template

Value Type	Type	Relationship	Concept			Value	Scheme Designator	Meaning
			Value	Scheme Designator	Meaning			
Container	1		TCE001 ^a	IHERADTF	For teaching file export	DCID Table 4.51.4-2		
> Code	3	Has concept MOD	113011	DCM	Document title modifier	delay reasons		
> Code	3	Has concept MOD	121049	DCM	Language of Content Item	eng	ISO639_2	English
> Code	3	Has OBS context	121005	DCM	Observer Type	121006	DCM	Person
> PNAME	1C	Has OBS context	121008	DCM	Person Observer	First name, last name		
> Text	3	Contains	113012	DCM	Key Object Description	Disposition		
> Image	1C	Contains				SOPClassUID, SOPInstanceUID		
> Composite	1C	Contains				SOPClassUID, SOPInstanceUID		

Adopted from the IHE TCE profile Rev. 1.1TI—2005-04-22 Table 4.51.4-1 (pg 24–25).

^a This assumes the manifest is generated for teaching file export. For clinical trial export use: TCE002, IHERADTF, “for clinical trial export.” For research collection export use: TCE007, IHERADTF, “for research collection export.”

1 ≡ Mandatory; 1C ≡ Conditional mandatory; 3 ≡ User optional

```

...
<document>
  <content>
    <date>2006-04-10</date>
    <time>14:05:55</time>
    <container flag="SEPARATE">
      <concept>
        <value>TCE001</value>
        <scheme>
          <designator>IHERADTF</designator>
        </scheme>
        <meaning>For Teaching File Export</meaning>
      </concept>
    </code>
    <code>
      <relationship>HAS CONCEPT MOD</relationship>
      <concept>
        <value>121049</value>
        <scheme>
          <designator>DCM</designator>
        </scheme>
        <meaning>Language of Content Item and Descendants</meaning>
      </concept>
      <value>eng</value>
      <scheme>
        <designator>ISO639_2</designator>
      </scheme>
      <meaning>English</meaning>
    </code>
    <code>
      <relationship>HAS OBS CONTEXT</relationship>
      <concept>
        <value>121005</value>
        <scheme>
          <designator>DCM</designator>
        </scheme>
        <meaning>Observer Type</meaning>
      </concept>
      <value>121006</value>
      <scheme>
        <designator>DCM</designator>
      </scheme>
      <meaning>Person</meaning>
    </code>
    <pname>
      <relationship>HAS OBS CONTEXT</relationship>
      <concept>
        <value>121008</value>
        <scheme>
          <designator>DCM</designator>
        </scheme>
        <meaning>Person Observer Name</meaning>
      </concept>
      <value>
        <first>John</first>
        <last>Doc</last>
      </value>
    </pname>
  </content>
</document>

```

Fig. 4. SR document content module attributes for the manifest in XML format. Format: SR document content module (Table 3). Content: Export selection ("manifest") template (Table 4).


```

<text>
  <relationship>CONTAINS</relationship>
  <concept>
    <value>113012</value>
    <scheme>
      <designator>DCM</designator>
    </scheme>
    <meaning>Key Object Description</meaning>
  </concept>
  <value>John Doe's Teaching File</value>
</text>
<image>
  <relationship>CONTAINS</relationship>
  <value>
    <sopclass uid="1.2.840.10008.5.1.4.1.1.4">MR Image Storage</sopclass>
    <instance uid="1.3.46.670589.16.2.60.13252.1379" />
  </value>
</image>
<image>
  <relationship>CONTAINS</relationship>
  <value>
    <sopclass uid="1.2.840.10008.5.1.4.1.1.2">CT Image Storage</sopclass>
    <instance uid="1.3.46.670589.16.2.60.13253.2895" />
  </value>
</image>
<composite>
  <relationship>CONTAINS</relationship>
  <value>
    <sopclass uid="1.2.840.10008.5.1.4.1.1.88.22">EnhancedSR</sopclass>
    <instance uid="1.3.6.1.4.1.26204.1.2.4.40970.1152329004731.32777.4" />
  </value>
</composite>
</container>
</content>
</document>
</report>

```

Fig. 4. Continued

item. Each concept has three attributes (code value, coding scheme designator, and code meaning) called the code sequence macro that defines the method for coding the information (Table 5). At this time, IHE has defined three possible concepts for the container of the manifest (Table 4—footnote). Assuming the manifest is being generated for teaching file export, the concept of the manifest container would have a code value, coding scheme designator, and code meaning defined as “TCE001,” “IHERADTF,” and “for teaching file export,” respectively. The code sequence macro is embedded within the concept, which is embedded within the container (Fig. 4).

The value is where the actual information of a content item is stored. The different methods of

storing information in the value are dependent on the value type of the content item. Each value type used in the manifest and its associated Relationship, concept, and value are described below.

CODE. All coded information, such as a coded diagnosis or observer type, is stored as a CODE value type. Both the concept and value of a CODE value type require the three attributes of the code sequence macro (Table 5). The relationship is embedded directly within the CODE. The code value, coding scheme designator, and code meaning of the concept are embedded within the concept, which is embedded within the CODE. The code value, coding scheme designator, and code meaning of the value are embedded directly

Table 5. Common Attribute Set for Code Sequence Attributes

Attribute Name	Type	Attribute Description
Code value	1C	An identifier that is unambiguous within the coding scheme denoted
Coding scheme designator	1C	The coding scheme in which the code for a term is defined (as listed in PS 3.16 Table 8-1 pg 34–37) Text that has meaning to a human and that conveys the meaning of the term defined by the combination of code value and coding scheme designator, encoded for the convenience of applications that do not have access to such a dictionary
Code meaning	1C	

Referenced as ‘code sequence macro’; Adopted from DICOM PS 3.3-2004 Table 8.8-1 (pg 69)

1C≡Mandatory conditional, required for each sequence item in the manifest container (Table 4)

within the CODE. The CODE is embedded within the container. The observer type is a CODE value type and has a relationship (“has OBS context”), a Concept (“121005,” “DCM,” “observer type”), and a value (“121006,” “DCM,” “person”). It is recommended that an observer type along with the PNAME value type person observer (see below) be identified in the manifest to aid routing to the individual that assembled the collection of key images. Both language of content item and descendants and document title modifier are CODE value types and are formatted in the same manner as the observer type.

PNAME. The person observer is stored as a PNAME value type. A person observer must be referenced with a relationship (“has OBS context”), a concept (“121008,” “DCM,” “person observer”), and a value (the first and last name of the person). The relationship and concept are embedded in the same manner as in the CODE value type. The individual’s first and last names are embedded within the value, which is embedded directly within the PNAME. The PNAME is embedded within the container.

TEXT. Any noncoded text information, such as a keyword for the case, is stored as a TEXT value type. The key object description is the disposition or the target purpose of the case. If the case is intended for the personal teaching file of John Doe, the disposition could be “John Doe’s Teaching File.” The key object description is a TEXT value type with a relationship (“contains”), a concept (“113012,” “DCM,” “key object description”), and a value (the disposition). The relationship and concept are embedded in the same manner as in the CODE and PNAME value types. The disposition is embedded as the value within the TEXT, which is embedded within the container.

IMAGE. The SOP Class UID and SOP Instance UID of each key image are stored as an IMAGE value type. The core information of the manifest is the reference to the selected key images. Key images have a relationship (“contains”) but do not have a concept. The IMAGE value is the SOP Class UID and SOP Instance UID of the referenced key image. The relationship and value are embedded directly within the IMAGE, which is embedded within the container.

Table 6. Enhanced SR IOD Modules

	Information Entity	Module
Common SR modules	Document	SOP common
	Patient	Patient
	Study	General study
ATFI modules	Equipment	General equipment
	Series	SR document series
	Document	SR document general SR document content

Adopted from DICOM PS 3.3-2004 Table A.35.2-1 (pg 169)

COMPOSITE. The SOP Class UID and SOP Instance UID of any SR object (including the ATFI) are stored as a composite value type. When an associated ATFI object accompanies the manifest, it is referenced by the manifest in a similar manner as a key image instance. The ATFI has a relationship (“contains”) and a value (the SOP Class UID and SOP Instance UID). The relationship and value are embedded directly within the COMPOSITE, which is embedded within the container.

Table 7. Additional Teaching File Information Modules Mandatory Attributes

Attribute Name	Type	Attribute Description
SR document series module (adopted from DICOM PS 3.3-2004 Table C.17-1 [pg 759])		
		Modality type
Modality	1	SR≡SR document
Series instance UID	1	Unique identifier of the series
Series number	1	A number that identifies the series
Referenced performed procedure step sequence	2	Uniquely identifies the performed procedure step SOP instance for which the series is created Notes: This may be sent as null if unknown
SR document general module (adopted from DICOM PS 3.3-2004 Table C.17-2 [pg 760–763])		
Instance number	1	A number that identifies the SR document The estimated degree of completeness
Completion flag	1	Partial≡partial content; complete≡complete content Indicates whether this SR document is verified
Verification flag	1	Unverified≡not attested to; verified≡attested to The person or persons authorized to verify documents of this type and accept responsibility for the content of this document
Verifying observer sequence	1C	Required if verification flag is verified The person authorized by the verifying organization to verify documents of this type and who accepts responsibility for the content of this document
Verifying observer name	1	Coded identifier of verifying observer. Zero or one item shall be permitted in this sequence
Verifying observer identification code sequence	2	
Include `code sequence macro' (Table 5)		
Verifying organization	1	Organization to which the verifying observer name is accountable for this document in the current interpretation procedure
Verification DateTime	1	Date and time of verification by the verifying observer name
Performed procedure code sequence	2	Zero or one items shall be permitted in this sequence
Content date	1	The date the document content creation started
Content time	1	The time the document content creation started
SR document content module (adopted from DICOM PS 3.3-2004 Table C.17-4 [pg 764])		
		A nested sequence of items that conveys content Note: Source of content information is defined in the TCE Profile documentation and outlined in Table 8
Content sequence	1	
Date	1	The date of the content item
Time	1	The time of the content item
Relationship type	1	The type of relationship between the (enclosing) source content item
Value type	1	The type of the value encoded in this content item Code describing the concept represented by this content item
Concept name code sequence	1C	In the ATFI object: required if value type is code or text
Include `code sequence macro' (Table 5)		
Concept code sequence	1C	This is the value of the code content item
Include `Code sequence macro' (Table 5)		
Text value	1C	This is the value of the text content item

1≡Mandatory; 1C≡Conditional mandatory; 2≡Mandatory, but may contain a null value

Additional Teaching File Information

The TCE profile defines the ATFI object as an instance of Enhanced SR SOP Class. It provides a template of both mandatory and optional information to be included in an ATFI document.² Gener-

ating a functional ATFI object is very similar to that of generating the manifest. A DICOM key object selection object is, in fact, a specialized type of DICOM SR object. The ATFI and manifest objects both contain the same SOP common module, the patient module, the general study module, and

Fig. 5. Additional teaching file information modules mandatory attributes in XML format.

the general equipment module (Table 6). For the ATFI, these are created in the same fashion as described in the “[Export Selection Manifest](#)” of this manuscript. The SR document series module, the SR document general module, and the SR document content module are different and warrant further discussion.

Table 7 lists all mandatory attributes of the ATFI specific modules. Figure 5 is an example XML code for the mandatory ATFI attributes. The SR document series module identifies the modality, series instance UID, and series number. The modality is “SR,” the series instance UID and series number are the same as the associated manifest. The referenced performed procedure step sequence is tagged as mandatory but will be sent as null for the purposes of the ATFI object

and is omitted from the XML file when using the OFFIS DCMTK for XML to DICOM conversion. The SR document general module identifies the instance number (embedded in the `<instance>` element in Fig. 6) and the date and time that the ATFI object was created (embedded in the `<content>` element in Fig. 7).

The SR document content module represents the meat of the ATFI object. This module defines the information required for ATFI and is used in combination with the additional teaching file information template, as outlined in the TCE documentation (Table 8).² The module begins by again identifying the date and time. Next is the container that is flagged as “separate” and contains all the ATFI information. Like the manifest, the ATFI container has a concept

Table 8. Additional Teaching File Information Template

Value Type	Type	Relationship	Concept			Value Set Constraint
			Value	Scheme Designator	Meaning	
Container	1		TCE006	IHERADTF	Additional teaching file information	
Text	1	Contains	TCE101	IHERADTF	Author	
Text	3	Has properties	TCE102	IHERADTF	Affiliation	
Text	3	Has properties	TCE103	IHERADTF	Contact	
Text	1	Contains	TCE104	IHERADTF	Abstract	
Text	1C	Contains	TCE105	IHERADTF	Keywords	
Code	1C	Contains	TCE105	IHERADTF	Keywords	ACR/MESH/ICD9CM codes
Text	3	Contains	121060	DCM	History	
Code	3	Contains	121060	DCM	History	
Text	3	Contains	121071	DCM	Finding	
Code	3	Contains	121071	DCM	Finding	
Text	3	Contains	TCE106	IHERADTF	Discussion	
Text	3	Contains	111023	DCM	Differential diagnosis/impression	
Code	3	Contains	111023	DCM	Differential diagnosis/impression	
Text	3	Contains	TCE107	IHERADTF	Diagnosis	
Code	3	Contains	TCE107	IHERADTF	Diagnosis	
Text	3	Contains	112005	DCM	Radiographic anatomy	
Code	3	Contains	112005	DCM	Radiographic anatomy	
Text	3	Contains	111042	DCM	Pathology	
Code	3	Contains	111042	DCM	Pathology	
Text	3	Contains	TCE108	IHERADTF	Organ system	
Code	3	Contains	TCE108	IHERADTF	Organ system	
Code	3	Contains	121139	DCM	Modality	Table 10 acquisition modality ^a
Code	1	Contains	TCE109	IHERADTF	Category	Table 11 categories ^a
Code	3	Contains	TCE110	IHERADTF	Level	Table 12 levels ^a
Code	3	Contains	TCE111	IHERADTF	Diagnoses confirmed	Table 13 yes-no ^a

Adopted from the IHE TCE profile Rev. 1.1TI—2005-04-22 Table Q-1 (pg 39–40); 1≡Mandatory; 1C≡Conditional mandatory; 3≡User optional

^aTable 10–13 are available at http://uuhsc.utah.edu/rad/TCE_Tables.htm

Table 9. Identical Documents Sequence Attributes

Attribute Name	Type	Attribute Description
Identical documents sequence	1C	Duplicates of this document, stored with different SOP instance UIDs; required if this KOS document references instances in more than one study ^a
> SOP instance reference macro (adopted from DICOM PS 3.3-2004 Table C.7-8 [pg 266])		
> Study instance UID	1	Unique identifier for the study
> Referenced series sequence	1	Sequence of repeating items where each item includes the attributes of a series containing referenced composite object(s)
>> Series instance UID	1	Unique identifier of a series that is part of this study and contains the referenced composite object(s)
>> Referenced SOP sequence	1	References to composite object SOP class/SOP instance pairs that are part of the study defined by study instance UID and the series defined by series instance UID
>>> Referenced SOP class UID	1	Uniquely identifies the referenced SOP class
>>> Referenced SOP instance UID	1	Uniquely identifies the referenced SOP instance

From the final item of DICOM PS 3.3-2004 Table C.17.6-2 (pg 779)

^a“If the current requested procedure evidence sequence references SOP instances both in the current study and in one or more other studies, this document shall be duplicated into each of those other studies, and the duplicates shall be referenced in the identical documents sequence.” Thus, a KOS document that references images in the current study as well as in a prior or comparison study would be duplicated into the other study. This allows an application displaying that other study to easily access notes relevant to that study's SOP instances.

```

...
<document>
  <content>
    <date>2006-04-10</date>
    <time>14:05:55</time>
    <container flag="SEPARATE">
      <concept>
        <value>TCE006</value>
        <scheme>
          <designator>IHERADTF</designator>
        </scheme>
        <meaning>Additional Teaching File Information</meaning>
      </concept>
      <text>
        <relationship>CONTAINS</relationship>
        <concept>
          <value>TCE101</value>
          <scheme>
            <designator>IHERADTF</designator>
          </scheme>
          <meaning>Author</meaning>
        </concept>
        <value>John Doe</value>
      </text>
      <text>
        <relationship>CONTAINS</relationship>
        <concept>
          <value>TVE104</value>
          <scheme>
            <designator>IHERADTF</designator>
          </scheme>
          <meaning>Abstract</meaning>
        </concept>
        <value>Interesting Case</value>
      </text>
      <text>
        <relationship>CONTAINS</relationship>
        <concept>
          <value>TVE105</value>
          <scheme>
            <designator>IHERADTF</designator>
          </scheme>
          <meaning>Keywords</meaning>
        </concept>
        <value>lung neoplasm</value>
      </text>
    </container flag="SEPARATE">
  </content>
</document>

```

Fig. 6. SR document content module attributes for ATFI in XML format. Format: SR document content module (Table 7). Content: additional teaching file information template (Table 8).

```

<code>
  <relationship>CONTAINS</relationship>
  <concept>
    <value>111042</value>
    <scheme>
      <designator>DCM</designator>
    </scheme>
    <meaning>Pathology</meaning>
  </concept>
  <value>RL1034</value>
  <scheme>
    <designator>99RADLEX</designator>
  </scheme>
  <meaning>Neoplastic Disease</meaning>
</code>
<code>
  <relationship>CONTAINS</relationship>
  <concept>
    <value>TCE108</value>
    <scheme>
      <designator>IHERADTF</designator>
    </scheme>
    <meaning>Organ System</meaning>
  </concept>
  <value>RL30</value>
  <scheme>
    <designator>99RADLEX</designator>
  </scheme>
  <meaning>thorax</meaning>
</code>
<code>
  <relationship>CONTAINS</relationship>
  <concept>
    <value>121139</value>
    <scheme>
      <designator>DCM</designator>
    </scheme>
    <meaning>Modality</meaning>
  </concept>
  <value>CT</value>
  <scheme>
    <designator>DCM</designator>
  </scheme>
  <meaning>Computed Tomography</meaning>
</code>
<code>
  <relationship>CONTAINS</relationship>
  <concept>
    <value>121139</value>
    <scheme>
      <designator>DCM</designator>
    </scheme>
    <meaning>Modality</meaning>
  </concept>
  <value>MR</value>
  <scheme>
    <designator>DCM</designator>
  </scheme>
  <meaning>Magnetic Resonance</meaning>
</code>

```

Fig. 6. Continued

```

<code>
  <relationship>CONTAINS</relationship>
  <concept>
    <value>TCE109</value>
    <scheme>
      <designator>IHERADTF</designator>
    </scheme>
    <meaning>Category</meaning>
  </concept>
  <value>TCE301</value>
  <scheme>
    <designator>IHERADTF</designator>
  </scheme>
  <meaning>Musculoskeletal</meaning>
</code>
<code>
  <relationship>CONTAINS</relationship>
  <concept>
    <value>TCE110</value>
    <scheme>
      <designator>IHERADTF</designator>
    </scheme>
    <meaning>Level</meaning>
  </concept>
  <value>TCE202</value>
  <scheme>
    <designator>IHERADTF</designator>
  </scheme>
  <meaning>Intermediate</meaning>
</code>
<code>
  <relationship>CONTAINS</relationship>
  <concept>
    <value>TCE111</value>
    <scheme>
      <designator>IHERADTF</designator>
    </scheme>
    <meaning>Diagnoses confirmed</meaning>
  </concept>
  <value>R-0038A</value>
  <scheme>
    <designator>SRT</designator>
  </scheme>
  <meaning>Undetermined</meaning>
</code>
</container>
</content>
</document>
</report>

```

Fig. 6. Continued

section defined as “TCE006,” “IHERADTF,” and “additional teaching file information” for the code value, coding scheme designator, and code meaning, respectively. However, unlike the manifest, the ATFI content items in the container fall into one of only two value types (code or text), and almost all attributes maintain a contains relationship with the container. Figure 6 demonstrates example XML code for the required ATFI content items.

Identical Documents

According to the DICOM standard, when radiologists select key images from multiple patients, even if selected for the same educational or research focus, they must be referenced in different manifests.² This means that if the case author selects two key images from one study of Patient A (A1 and A2) and two key images from one study of Patient B (B1 and B2), images A1

and A2 will be referenced by Manifest A and images B1 and B2 will be referenced by Manifest B. Each manifest will have its own SOP Instance UID. In addition, Manifest A will have the same series instance UID as ATFI A, and both will have the same study instance UID as images A1 and A2, likewise for Manifest B.

In addition, the DICOM standard explains that when radiologists select key images from multiple studies of the same patient separate Manifest and ATFI with their own, DICOM UIDs are required for each study.⁵ Thus, if images B1 and B2 are from different studies of the same patient, one copy of Manifest B (Manifest B1) will be assigned the study instance UID of image B1, and a second copy of Manifest B (Manifest B2) will be assigned the study instance UID of image B2. Each manifest will have its own SOP Instance UID and reference the SOP Instance UID of the other copy using the identical document sequence attributes outlined in Table 9, with example XML code in Figure 7 (embedded between the open <document> tag and the open <content> tag in Fig. 4). Manifest B1 and B2 are called identical documents, meaning that they both have identical information except they each have their own SOP Instance UID, they have different study instance UIDs based on the study within, which they are associated, they have different series instance UIDs, and they reference their “twin” manifest in the identical document sequence.

ATFI objects follow the same guidelines. Similar to the above example of for Manifest B1 and B2, there would also be ATFI B1 and ATFI B2 as identical documents with their own SOP Instance UIDs, and they would reference each other.

Translating the XML to DICOM

After the XML documents for the manifest and ATFI are created, they must be translated into DICOM SR objects. A DICOM toolkit reads the XML document and generates a functional DICOM SR object with the correct information associated with the appropriate DICOM elements. This is essential to the TCE profile because the export manager and receiver actors must be able to receive and interpret the manifest and ATFI as DICOM objects.

Functionality Evaluation

The OFFIS DCMTK toolkit was used to generate test manifest and ATFI objects for this manuscript.⁹ The Medical Imaging Resource Center (MIRC) export manager was installed on a standard personal computer running Windows XP Pro operating system.¹¹ The test objects were sent to the export manager via the standard DICOM send.

RESULTS

The methods described have been followed to effectively generate functional, TCE-compliant manifest and ATFI objects for selection of images across multiple patients and studies. The test objects were correctly received, pseudoidentified, and queued for export by the MIRC Export Manager.^{2,11,12}

DISCUSSION

The TCE profile presents an excellent solution for the use of standard transactions for exporting

Fig. 7. Referencing identical documents in XML format

key images for education, research and publication. This paper compliments the TCE profile documentation in providing the necessary instructions for future development of TCE compliant Export Selector applications.

During this project it became apparent that the complexity seemed disproportionate to the desired objective (as described). One of the reasons is the conflict between traditional DICOM and more recent web application technology utilizing XML. Whereas there are available packages (described in paper) for converting between DICOM header information and XML and the reverse and putting DICOM wrappers around report information, maybe it is time to consider another approach.^{7-9,13} This new approach (DICOM 4?) would integrate XML and web application technology with the spirit of DICOM. Preliminary informal discussions with imaging modality vendors have been negative because of the large installed base. In spite of that, it is time to begin exploring a better way to do this.

CONCLUSION

The IHE TCE profile provides a standard workflow for harvesting key images for education, clinical research, and publication. This manuscript describes the TCE profile and focuses on step-by-step instructions for generating the two TCE DICOM SR objects: the manifest and ATFI report. Creating these DICOM SR objects is not a trivial task; therefore, we strive to present these instructions in a straightforward understandable manner. In addition, all the information necessary for generating this objects is contained herein. We call for widespread acceptance of this standard and implementation by PACS vendors. Although, harvesting of key images can be accomplish external to PACS, the most ideal clinical workflow calls for tight PACS integration.

REFERENCES

1. Siegel EL, Channin DS: Integrating the healthcare enterprise: a primer. Part 1. Introduction. *Radiographics* 21 (5):1339-1341, Sep-Oct 2001
2. Committee IRT: Teaching file and clinical trial export (TCE). Available at: http://www.ihe.net/Technical_Framework/upload/IHE_TF_Suppl_Teaching_File_Clinical_Trial_Export_TI_2005-04-22.pdf. Accessed May 26, 2007, pp 26, 39-40 (Table Q-21)
3. Hussein R, Engelmann U, Schroeter A, Meinzer HP: DICOM structured reporting: Part 1. Overview and characteristics. *Radiographics* 24(3):891-896, May-Jun 2004
4. Noumeir R: Benefits of the DICOM Structured Report. *J Digit Imaging* 19(4):295-306, Dec 2006
5. NEMA: DICOM Part 3: Information Object Definitions (PS 3.3-2004). Available at: ftp://medical.nema.org/medical/dicom/2007/07_03pu.pdf. Accessed May 26, 2007, pp 167, 173 (Section A.135.164), 759, 764, 773, 779-780
6. NEMA: DICOM Part 16: content mapping resource (PS 3.16-2004). Available at: ftp://medical.nema.org/medical/dicom/2007/07_16pu.pdf. Accessed May 26, 2007, pp 58-59
7. Zhao L, Lee KP, Hu J: Generating XML schemas for DICOM structured reporting templates. *J Am Med Inform Assoc* 12(1):72-83, Jan-Feb 2005
8. Noumeir R: DICOM structured report document type definition. *IEEE Trans Inf Technol Biomed* 7(4):318-328, Dec 2003
9. OFFIS: OFFIS DICOM Software, DCMTK-DICOM toolkit. Available at: <http://dicom.offis.de/dcmtnk.php.en>. Accessed May 26, 2007
10. NEMA: DICOM Part 5: data structures and encoding (PS 3.5-2004). Available at: ftp://medical.nema.org/medical/dicom/2007/07_05pu.pdf. Accessed May 26, 2007, p 54
11. Perry J: MIRC TCE export manager. Available at: http://mircwiki.rsna.org/index.php?title=MIRC_TCE_Export_Manager. Accessed May 26, 2007
12. Kamaau AWC, DuVall SL, Liimatta A, Wiggins 3rd, RH, Avrin DE: Implementing the IHE Teaching File and Clinical Trial Export Profile to develop a MIRC-compliant vendor-neutral export selector that uses RadLex terminology. Paper presented at: Radiological Society of North America (RSNA), McCormick Place, Chicago, Illinois, 2006
13. Van Nguyen A, Avrin DE, Tellis WM, Andriole KP, Arenson RL: What digital imaging and communication in medicine (DICOM) could look like in common object request broker (CORBA) and extensible markup language (XML). *J Digit Imaging* 14(2 Suppl 1):89-91, Jun 2001