

AAPM Annual Meeting 2013
Imaging Informatics 2

Radiation Dose
Structured Reports

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PixelMed Publishing

RDSR – Learning Objectives

- Basic concepts of DICOM structured reporting (SR)
- Relevant parts and sections of DICOM standard
- Radiation Dose Structured Report – current & new
- Proposed Patient RDSR

What is a Structured Report?

- A “report” with “structure”
- What is a “report”?
 - dictated by a radiologist (or other human)
 - plain text +/- voice recognition
 - “evidence documents” from machine/operator
 - CAD, ultrasound, coronary CT measurements
- What is “structure”?
 - outline, headings, nesting
 - measurements, codes, references, locations

What is a DICOM Structured Report?

- A “structured report” encoded in DICOM
 - structured data is recoverable
- As distinct from a rendered report
 - printed, sent as plain text, PDF
 - “pretty” but needs a human/NLP to interpret
- Other formats that encode structure
 - HL7 Clinical Document Architecture (CDA)
 - home-grown XML (proprietary schema)

A “Structured Report” to Encode as a DICOM SR

Chest X-ray Report:

Recording Observer: Clunie^David^A^Dr.

History: malignant melanoma excised 1Y

Findings:

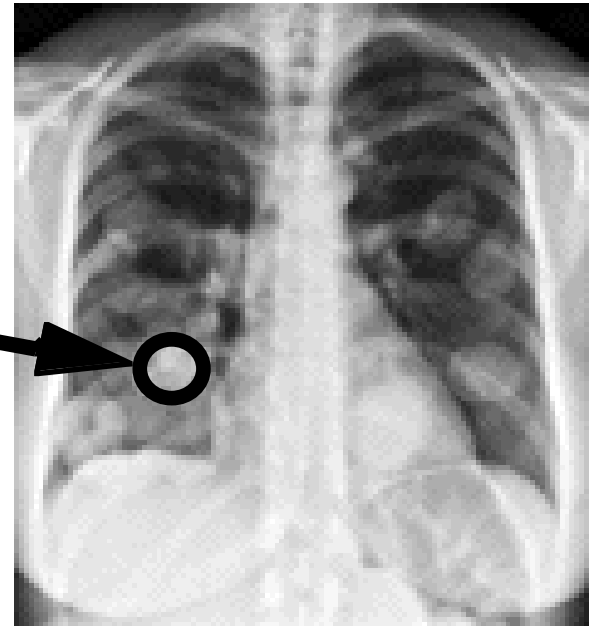
- finding: multiple masses in both lung fields
- best illustration of findings:

Conclusions:

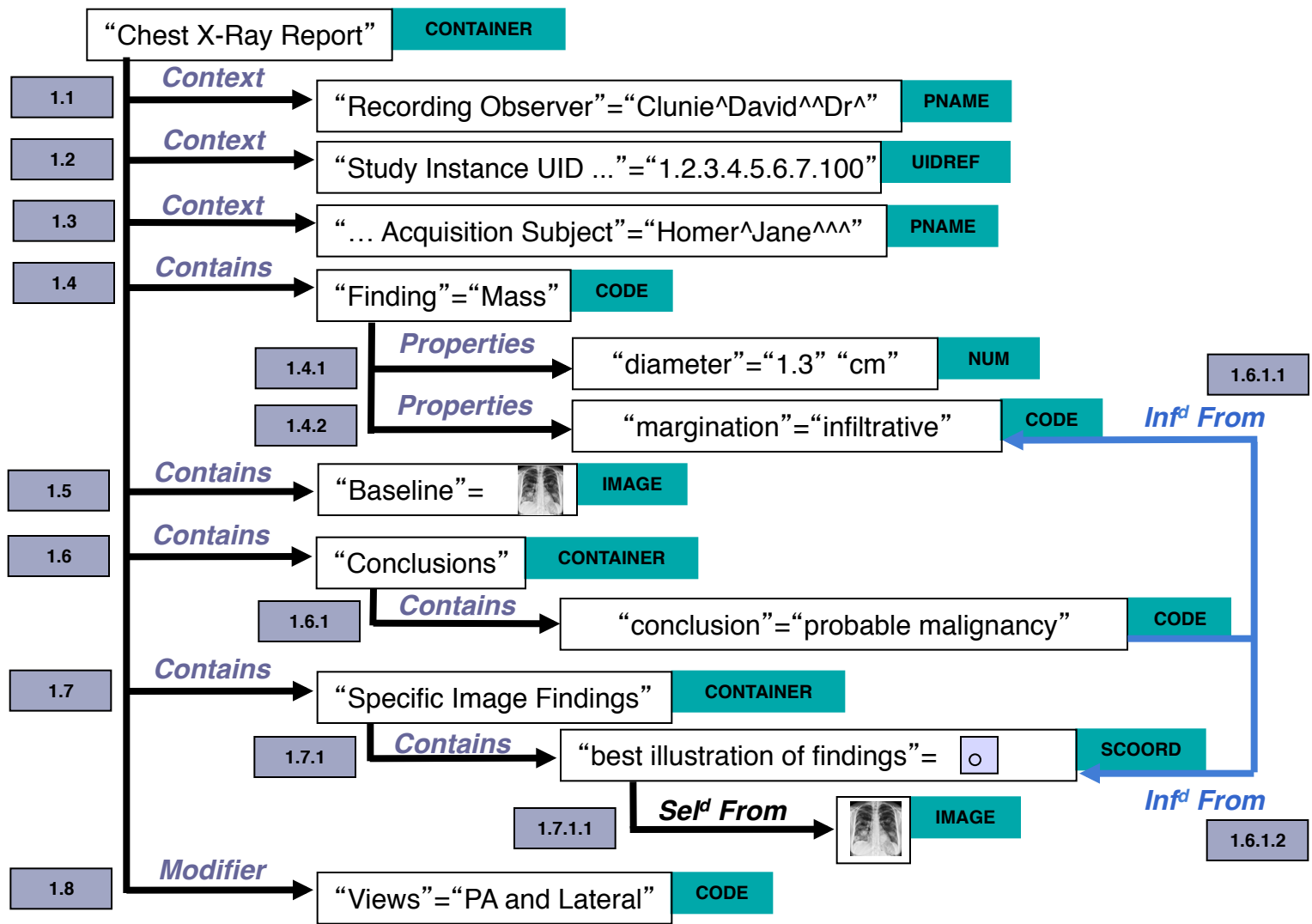
- conclusion: cannon-ball metastases
- conclusion: recurrent malignant melanoma

Diagnosis Codes:

- diagnosis: 172.9/ICD9
- diagnosis: 197.0/ICD9



Tree of DICOM SR Content



Rendered form of DICOM SR


Report of Chest X-Ray (PA and LateralViews)

Patient Jane Homer

Study # 123456

Recorded by Dr. David Clunie

The finding is a mass measuring 1.3 cm in diameter with an infiltrative margin.

The baseline image is shown at  [\(Click to view\)](#)

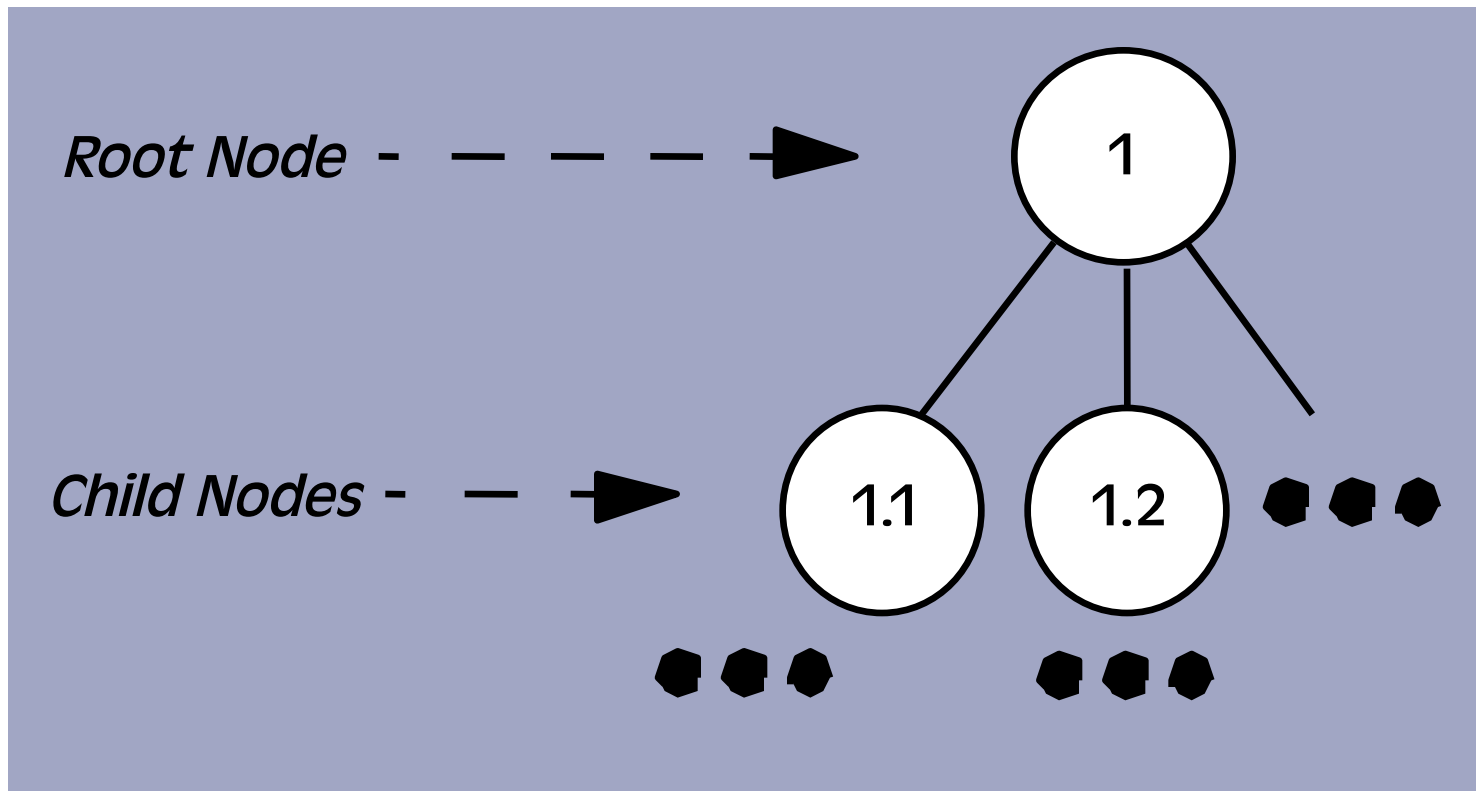
Conclusions

The conclusion is a probable malignancy, *inferred from* the infiltrative margin of the mass and the appearance shown by the best illustration of findings.

Specific Image Findings

The best illustration of findings is  [\(Click to view\)](#)

SR Content is a Tree



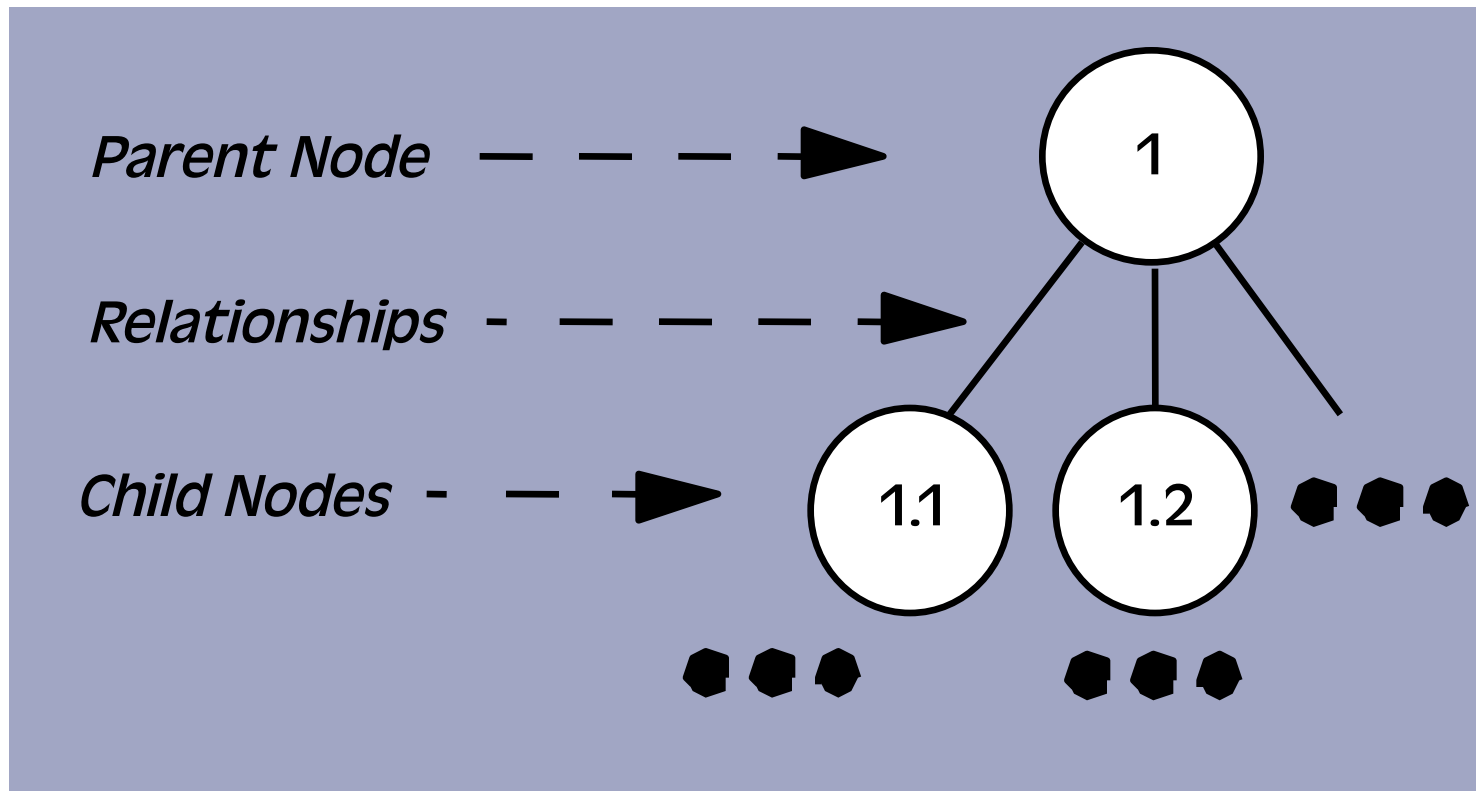
Each SR Node (Content Item)

- Is a “name-value” pair
 - e.g. “finding” = “mass”
- The (concept) “name” is always coded
 - e.g. (121071, DCM, “Finding”)
- The “value” may be one of several “value types”

Value Types

- TEXT
- CODE
- NUM
- PNAME
- DATE
- TIME
- DATETIME
- CONTAINER
- UIDREF
- COMPOSITE
- IMAGE
- WAVEFORM
- SCOORD
- SCOORD3D
- TCOORD

Nodes linked by Relationships



Relationships

- Contains
- Has Properties
- Inferred From
- Has Observation Context
- Has Acquisition Context
- Has Concept Modifier
- Selected From

Codes – Leverage Standard External Lexicons

- SNOMED
 - e.g., for anatomy (T-D4000, SRT, “Abdomen”)
- LOINC
 - e.g., for procedures (36952-0, LN, “Abdomen and Pelvis CT WO contrast”)
 - e.g., for observations (8867-4, LN, “Heart Rate”)
- UCUM
 - for units, e.g., (mGy.cm, UCUM, “mGy.cm”)
- DICOM-defined codes when no others
 - (113813, DCM, “CT Dose Length Product Total”)

DICOM SR IODs

- Information Object Definitions (PS 3.3)
- General purpose – any template
 - Basic Text, Enhanced, Comprehensive ...
- Specific – require specific template
 - Mammography CAD
 - Radiation Dose
 - ...

DICOM SR Templates

- Tabular form (PS 3.16)
- What “containers” (tree structure/depth)
 - grouping and nesting of content items
- Which content items (name-value pairs)
 - required or permitted
 - what codes to use for name
- What value sets (context groups)
 - what codes to use for values

Example DICOM SR Template

TID 10012
CT ACCUMULATED DOSE DATA
Type: Extensible Order: Significant

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			CONTAINER	EV (113811, DCM, "CT Accumulated Dose Data")	1	M		
2	>	CONTAINS	NUM	EV (113812, DCM, "Total Number of Irradiation Events")	1	M		Units = EV ({events} UCUM, "events")
3	>	CONTAINS	NUM	EV (113813, DCM, "CT Dose Length Product Total")	1	M		Units = EV (mGy.cm, UCUM, "mGy.cm")
4	>	CONTAINS	NUM	EV (113814, DCM, "CT Effective Dose Total")	1	U		Units = EV (mSv, UCUM, "mSv")
5	>>	HAS PROPERTIES	TEXT	EV (121406, DCM, "Reference Authority")	1	MC	XOR row 6	
6	>>	HAS PROPERTIES	CODE	EV (121406, DCM, "Reference Authority")	1	MC	XOR row 5	DCID (10015) CT Dose Reference Authority
7	>>	HAS CONCEPT	CODE	EV (G-C036, SRT, "Reference Authority")	1	M		DCID (10011) Effective Dose Estimation Method

Example DICOM SR Context Group (Value Set)

CID 10015

CT Dose Reference Authorities

Context ID 10015

CT Dose Reference Authorities

Type: Extensible

Version: 20081027

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	113808	ICRP Pub 60
DCM	113841	ICRP Pub 103

Example DICOM SR Code Definitions

113807	Free Acquisition	The CT acquisition was performed while rotating the source about the gantry while the table movement is under direct control of a human operator or under the control of an analysis application (e.g. fluoro).	
113808	ICRP Pub 60	Reference authority 1990 Recommendations of the International Commission on Radiological Protection (ICRP Publication 60, published as the Annals of the ICRP Vol. 21, No. 1-3, Pergamon Press, 1991)	
113809	Start of X-Ray Irradiation	Start, DateTime of the first X-Ray Irradiation Event of the accumulation within a Study	

How DICOM SR is Encoded

- Tree representation “layered” on top of traditional DICOM Data Set
- Is “object” (SOP Instance) like an image
- No Pixel Data
- Content Sequence instead (recursive)
- Each “content item” is a sequence item
- Attributes defined by Value Type
- Constrained by IOD and templates

**Table C.17-4
SR DOCUMENT CONTENT MODULE ATTRIBUTES**


Attribute Name	Tag	Type	Attribute Description
			<i>Include Document Content Macro Table C.17-5. with a Value Type (0040,A040) of CONTAINER</i>
			<i>Include Document Relationship Macro Table C.17-6.</i>

**Table C.17-5
DOCUMENT CONTENT MACRO ATTRIBUTES**

Attribute Name	Tag	Type	Attribute Description
Value Type	(0040,A040)	1	<p>The type of the value encoded in this Content Item.</p> <p>Defined Terms:</p> <p>TEXT NUM CODE DATETIME DATE TIME UIDREF PNAME COMPOSITE IMAGE WAVEFORM SCORD SCORD3D TCOORD CONTAINER</p> <p>See C.17.3.2.1 for further explanation.</p>
Concept Name Code Sequence	(0040,A043)	1C	Code describing the concept represented by this Content Item. Also conveys the value of

**Table C.18.1-1
NUMERIC MEASUREMENT MACRO ATTRIBUTES**

Attribute Name	Tag	Type	Attribute Description
Measured Value Sequence	(0040,A300)	2	This is the value of the Content Item. Shall consist of a Sequence of Items conveying the measured value(s), which represent integers or real numbers and units of measurement. Zero or one Item shall be included in this sequence.
>Numeric Value	(0040,A30A)	1	Numeric measurement value. Only a single value shall be present.
>Measurement Units Code Sequence	(0040,08EA)	1	Units of measurement. Only a single Item shall be included in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			<i>Defined CID 82.</i>
Numeric Value Qualifier Code Sequence	(0040,A301)	3	Qualification of Numeric Value in Measured Value Sequence, or reason for absence of Measured Value Sequence Item. Only a single Item is permitted in this sequence.
>Include 'Code Sequence Macro' Table 8.8-1			<i>Defined CID 42.</i>

- ▶ : CONTAINER: X-Ray Radiation Dose Report [SEPARATE] (DCMR,10011)
 - ▶ HAS CONCEPT MOD: CODE: Procedure reported = Computed Tomography X-Ray
 - ▶ HAS OBS CONTEXT: CODE: Observer Type = Device
 - ▶ HAS OBS CONTEXT: UIDREF: Device Observer UID = 1.3.46.670589.33.1.2200303521616
 - ▶ HAS OBS CONTEXT: TEXT: Device Observer Name = MACHINE4019
 - ▶ HAS OBS CONTEXT: TEXT: Device Observer Manufacturer = Philips
 - ▶ HAS OBS CONTEXT: TEXT: Device Observer Model Name = Ingenuity CT
 - ▶ HAS OBS CONTEXT: TEXT: Device Observer Serial Number = 1234
 - ▶ HAS OBS CONTEXT: TEXT: Device Observer Physical Location During Observation = PMSTL
 - ▶ HAS OBS CONTEXT: DATETIME: Start of X-Ray Irradiation = 20120717090534.295
 - ▶ HAS OBS CONTEXT: DATETIME: End of X-Ray Irradiation = 20120717090550.572
 - ▶ HAS OBS CONTEXT: CODE: Scope of Accumulation = Study
 - ▼ CONTAINS: CONTAINER: CT Accumulated Dose Data [SEPARATE]
 - ▶ CONTAINS: NUM: Total Number of Irradiation Events = 1 events
 - ▶ CONTAINS: NUM: CT Dose Length Product Total = 4030.6 mGy.cm 
 - ▼ CONTAINS: CONTAINER: CT Acquisition [SEPARATE]
 - ▶ CONTAINS: TEXT: Acquisition Protocol = Brain Helical /Head
 - ▶ CONTAINS: CODE: Target Region = Brain
 - ▶ CONTAINS: CODE: CT Acquisition Type = Spiral Acquisition
 - ▶ CONTAINS: CODE: Procedure Context = Diagnostic radiography with contrast media
 - ▶ CONTAINS: UIDREF: Irradiation Event UID = 1.3.46.670589.33.1.37611252433939500353.30094418194092846479
 - ▼ CONTAINS: CONTAINER: CT Acquisition Parameters [SEPARATE]
 - ▶ CONTAINS: NUM: Exposure Time = 3009 s
 - ▶ CONTAINS: NUM: Scan Length = 187 mm

- ▼ Item 12
 - ▶ (0x0040,0xa043) ConceptNameCodeSequence = <{113811,DCM,CT Accumulated Dose Data}>
 - ▼ (0x0040,0xa730) ContentSequence = <{CONTAINS,NUM,<{113812,DCM,Total Number of Irradiation Events}>,<{<ul style="list-style-type: none;"> - ▶ Item 1
 - ▼ Item 2
 - ▼ (0x0040,0xa043) ConceptNameCodeSequence = <{113813,DCM,CT Dose Length Product Total}>
 - ▼ Item 1
 - (0x0008,0x0104) CodeMeaning = CT Dose Length Product Total
 - (0x0008,0x0100) CodeValue = 113813
 - (0x0008,0x0102) CodingSchemeDesignator = DCM
 - ▼ (0x0040,0xa300) MeasuredValueSequence = <{<{mGy.cm,UCUM,1.4,mGy.cm}>,4030.6}>
 - ▼ Item 1
 - ▼ (0x0040,0x08ea) MeasurementUnitsCodeSequence = <{mGy.cm,UCUM,1.4,mGy.cm}>
 - ▼ Item 1
 - (0x0008,0x0104) CodeMeaning = mGy.cm
 - (0x0008,0x0100) CodeValue = mGy.cm
 - (0x0008,0x0102) CodingSchemeDesignator = UCUM
 - (0x0008,0x0103) CodingSchemeVersion = 1.4
 - (0x0040,0xa30a) NumericValue = 4030.6
 - (0x0040,0xa010) RelationshipType = CONTAINS
 - (0x0040,0xa040) ValueType = NUM
 - (0x0040,0xa050) ContinuityOfContent = SEPARATE
 - (0x0040,0xa010) RelationshipType = CONTAINS
 - (0x0040,0xa040) ValueType = CONTAINER
- ▶ Item 13

- ▼ Item 12
 - ▶ (0x0040,0xa043) ConceptNameCodeSequence = <{113811,DCM,CT Accumulated Dose Data}>
 - ▼ (0x0040,0xa730) ContentSequence = <{CONTAINS,NUM,<{113812,DCM,Total Number of Irradiation Events}>,<{<ul style="list-style-type: none;"> - ▶ Item 1
 - ▼ Item 2
 - ▼ (0x0040,0xa043) ConceptNameCodeSequence = <{113813,DCM,CT Dose Length Product Total}>
 - ▼ Item 1
 - (0x0008,0x0104) CodeMeaning = CT Dose Length Product Total
 - (0x0008,0x0100) CodeValue = 113813
 - (0x0008,0x0102) CodingSchemeDesignator = DCM
 - ▼ (0x0040,0xa300) MeasuredValueSequence = <{<{mGy.cm,UCUM,1.4,mGy.cm}>,4030.6}>
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 - ▼ (0x0040,0x08ea) MeasurementUnitsCodeSequence = <{mGy.cm,UCUM,1.4,mGy.cm}>
 - ▼ Item 1
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 - (0x0008,0x0102) CodingSchemeDesignator = UCUM
 - (0x0008,0x0103) CodingSchemeVersion = 1.4
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 - ▼ (0x0040,0xa730) ContentSequence = <{CONTAINS,NUM,<{113812,DCM,Total Number of Irradiation Events}>,<{<ul style="list-style-type: none;"> - ▶ Item 1
 - ▼ Item 2
 - ▼ (0x0040,0xa043) ConceptNameCodeSequence = <{113813,DCM,CT Dose Length Product Total}>
 - ▼ Item 1
 - (0x0008,0x0104) CodeMeaning = CT Dose Length Product Total
 - (0x0008,0x0100) CodeValue = 113813
 - (0x0008,0x0102) CodingSchemeDesignator = DCM
 - ▼ (0x0040,0xa300) MeasuredValueSequence = <{<{mGy.cm,UCUM,1.4,mGy.cm}>,4030.6}>
 - ▼ Item 1
 - ▼ (0x0040,0x08ea) MeasurementUnitsCodeSequence = <{mGy.cm,UCUM,1.4,mGy.cm}>
 - ▼ Item 1
 - (0x0008,0x0104) CodeMeaning = mGy.cm
 - (0x0008,0x0100) CodeValue = mGy.cm
 - (0x0008,0x0102) CodingSchemeDesignator = UCUM
 - (0x0008,0x0103) CodingSchemeVersion = 1.4
 - (0x0040,0xa30a) NumericValue = 4030.6
 - (0x0040,0xa010) RelationshipType = CONTAINS
 - (0x0040,0xa040) ValueType = NUM
 - (0x0040,0xa050) ContinuityOfContent = SEPARATE
 - (0x0040,0xa010) RelationshipType = CONTAINS
 - (0x0040,0xa040) ValueType = CONTAINER
- ▶ Item 13

- ▼ Item 12
 - ▶ (0x0040,0xa043) ConceptNameCodeSequence = <{113811,DCM,CT Accumulated Dose Data}>
 - ▼ (0x0040,0xa730) ContentSequence = <{CONTAINS,NUM,<{113812,DCM,Total Number of Irradiation Events}>,<{<ul style="list-style-type: none;"> - ▶ Item 1
 - ▼ Item 2
 - ▼ (0x0040,0xa043) ConceptNameCodeSequence = <{113813,DCM,CT Dose Length Product Total}>
 - ▼ Item 1
 - (0x0008,0x0104) CodeMeaning = CT Dose Length Product Total
 - (0x0008,0x0100) CodeValue = 113813
 - (0x0008,0x0102) CodingSchemeDesignator = DCM
 - ▼ (0x0040,0xa300) MeasuredValueSequence = <{<{mGy.cm,UCUM,1.4,mGy.cm}>,4030.6}>
 - ▼ Item 1
 - ▼ (0x0040,0x08ea) MeasurementUnitsCodeSequence = <{mGy.cm,UCUM,1.4,mGy.cm}>
 - ▼ Item 1
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 - (0x0008,0x0100) CodeValue = mGy.cm
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 - (0x0040,0xa010) RelationshipType = CONTAINS
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 - (0x0040,0xa050) ContinuityOfContent = SEPARATE
 - (0x0040,0xa010) RelationshipType = CONTAINS
 - (0x0040,0xa040) ValueType = CONTAINER
- ▶ Item 13

Date	Modality	Description	DLP Total mGy.cm	DLP HEAD16 mGy.cm	DLP BODY32 mGy.cm	Manufacturer	Model	From
2012/07/17 09:05:34	CT	Brain Helical	4030.6 (HEAD16)			Philips	Ingenuity CT	RDSR MOD

Patient: Unknown SERVICE_Anonymous (other, #00000040)
Study: Brain Helical (#5)
Manufacturer: Philips
Completion Flag: COMPLETE
Verification Flag: UNVERIFIED
Content Date/Time: 2012-07-17 09:06:48

X-Ray Radiation Dose Report

Concept Modifier: Procedure reported [[Annex 1](#)]
Observation Context: Observer Type = Device (121007, DCM)
Observation Context: Device Observer UID = 1.3.46.670589.33.1.2200303521616
Observation Context: Device Observer Name = "MACHINE4019"
Observation Context: Device Observer Manufacturer = "Philips"
Observation Context: Device Observer Model Name = "Ingenuity CT"
Observation Context: Device Observer Serial Number = "1234"
Observation Context: Device Observer Physical Location During Observation = "PM"
Observation Context: Start of X-Ray Irradiation = 2012-07-17 09:05:34
Observation Context: End of X-Ray Irradiation = 2012-07-17 09:05:50
Observation Context: Scope of Accumulation [[Annex 2](#)]

CT Accumulated Dose Data

Total Number of Irradiation Events:

CT Dose Length Product Total:
4030.6 mGy.cm

CT Acquisition

Acquisition Protocol:
Brain Helical /Head
Target Region:
Brain (T-A0100, SRT)
CT Acquisition Type:
Spiral Acquisition (P5-08001, SRT)
Procedure Context:
Diagnostic radiography with contrast media (P5-00100, SRT)
Irradiation Event UID:
1.3.46.670589.33.1.37611252433939500353.30094418194092846479

CT Acquisition Parameters

Exposure Time:
3009 s

Scanning Length:
187 mm
Nominal Single Collimation Width:
0.625 mm
Nominal Total Collimation Width:
40 mm
Pitch Factor:
0.14 {ratio}
Number of X-Ray Sources:
1 {X-Ray sources}

CT X-Ray Source Parameters

Identification of the X-Ray Source:
A
KVP:
140 kV
Maximum X-Ray Tube Current:
332 mA
X-Ray Tube Current:
332 mA
Exposure Time per Rotation:
0.42 s

CT Dose

Mean CTDIvol:
188 mGy
CTDIw Phantom Type:
IEC Head Dosimetry Phantom (113690, DCM)
DLP:
4030.6 mGy.cm

Dose Check Alert Details

DLP Alert Value Configured:
Yes (R-0038D, SRT)
CTDIvol Alert Value Configured:
Yes (R-0038D, SRT)
DLP Alert Value:
150 mGy.cm
CTDIvol Alert Value:
150 mGy
Accumulated DLP Forward Estimate:
4030.6 mGy.cm
Accumulated CTDIvol Forward Estimate:
188 mGy
Reason for Proceeding:
Person Name:

FGN

Properties: Person Role in Procedure = Irradiation Authorizing (113850, DCM)

Dose Check Notification Details

DLP Notification Value Configured:
No (R-00339, SRT)
CTDIvol Notification Value Configured:
Yes (R-0038D, SRT)
CTDIvol Notification Value:
80 mGy
CTDIvol Forward Estimate:
188 mGy
Comment:
Source of Dose Information:
Automated Data Collection (113856, DCM)

Annex

[Annex 1](#)

Procedure reported:

Computed Tomography X-Ray (P5-08000, SRT)

Concept Modifier: Has Intent = Diagnostic Intent (R-408C3, SRT)

[Annex 2](#)

Scope of Accumulation:

Study (113014, DCM)

Properties: Study Instance UID = 1.3.46.670589.33.1.2398042563164384074.299371

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RDSR – Practical Matters

- Layering of SR on DICOM data elements
- Makes creation/parsing “non-trivial”
- Hand-coding it would be “inefficient”
- Use a toolkit with DICOM SR support
- Use a toolkit with RDSR support
- Convert to something else structured
- XML + XPath (XSL-T) for extraction

RDSR Toolkit Example

- Create

```
CTDose ctDose = new CTDose(...);  
ctDose.setDLPTotal(4030.6);
```

- Read

```
AttributeList list= new AttributeList(); list.read(file);  
CTDose ctDose = new CTDose(list);  
ctDose.getDLPTotal();
```

SR Toolkit Example

- Create

```
ContentItem dlptoti = new NumericContentItem(  
parent, "CONTAINS",  
new CodedSequenceItem("113813", "DCM",  
"CT Dose Length Product Total"),  
4030.6,  
new CodedSequenceItem("mGy.cm", "UCUM", "1.8",  
"mGy.cm"));
```

XML Conversion Example

```
<DicomStructuredReport>
...
<DicomStructuredReportContent>
...
<container ID="ci_1.12" continuity="SEPARATE"
relationship="CONTAINS">
<concept cm="CT Accumulated Dose Data" csd="DCM" cv="113811" />
...
<num ID="ci_1.12.2" relationship="CONTAINS">
<concept cm="CT Dose Length Product Total" csd="DCM" cv="113813" />
<value>4030.6</value>
<units cm="mGy.cm" csd="UCUM" csv="1.4" cv="mGy.cm" />
</num>
</container>
...
```


XML Conversion Example

```
Document srDocument = new  
XMLRepresentationOfStructuredReportObjectFactory  
(sr,list);
```

```
newXPath().evaluate("/DicomStructuredReport/  
DicomStructuredReportContent/container[concept/  
@cv='113701' and @csd='DCM']/container[concept/  
@cv='113811' and @csd='DCM']/num[concept/  
@cv='113813' and @csd='DCM']/value",srDocument);
```

```
newXPath().evaluate("//num[concept/@cv='113813']/  
value",srDocument);
```

Toolkits

- API – RDSR, SR, XML, XPath, XSL-T
- Command line utilities
- GUI utilities
- Validators (IOD, template conformance)

- PixelMed Java toolkit (mine)
- OFFIS dcmtk C++

Legacy and OCR

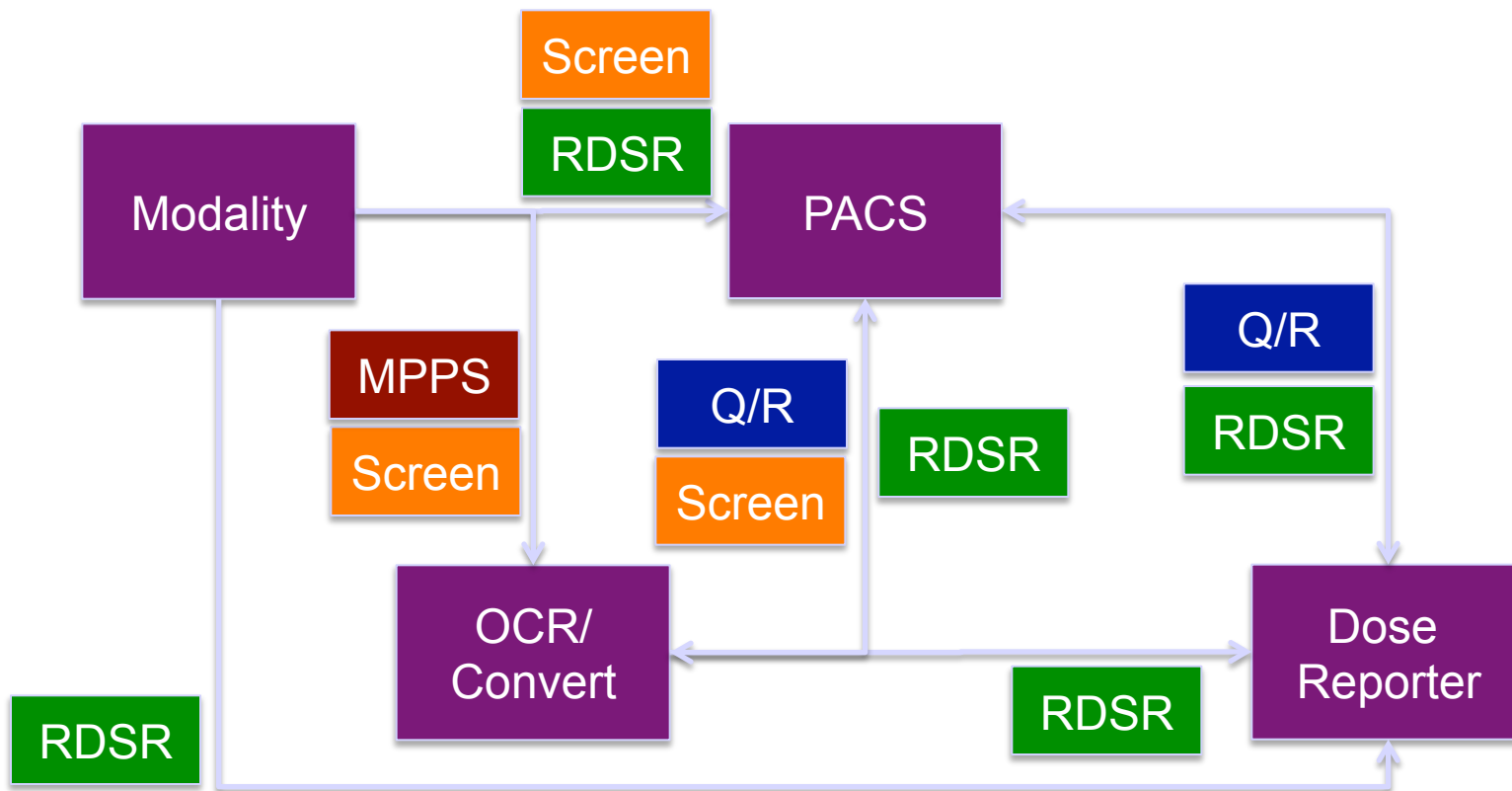
- Other places dose sometimes lives ...
 - image headers
 - Modality Performed Procedure Step (MPPS)
 - dose “screen” secondary captures
- Conversion tools to make RDSR

Dose Utility Prototype

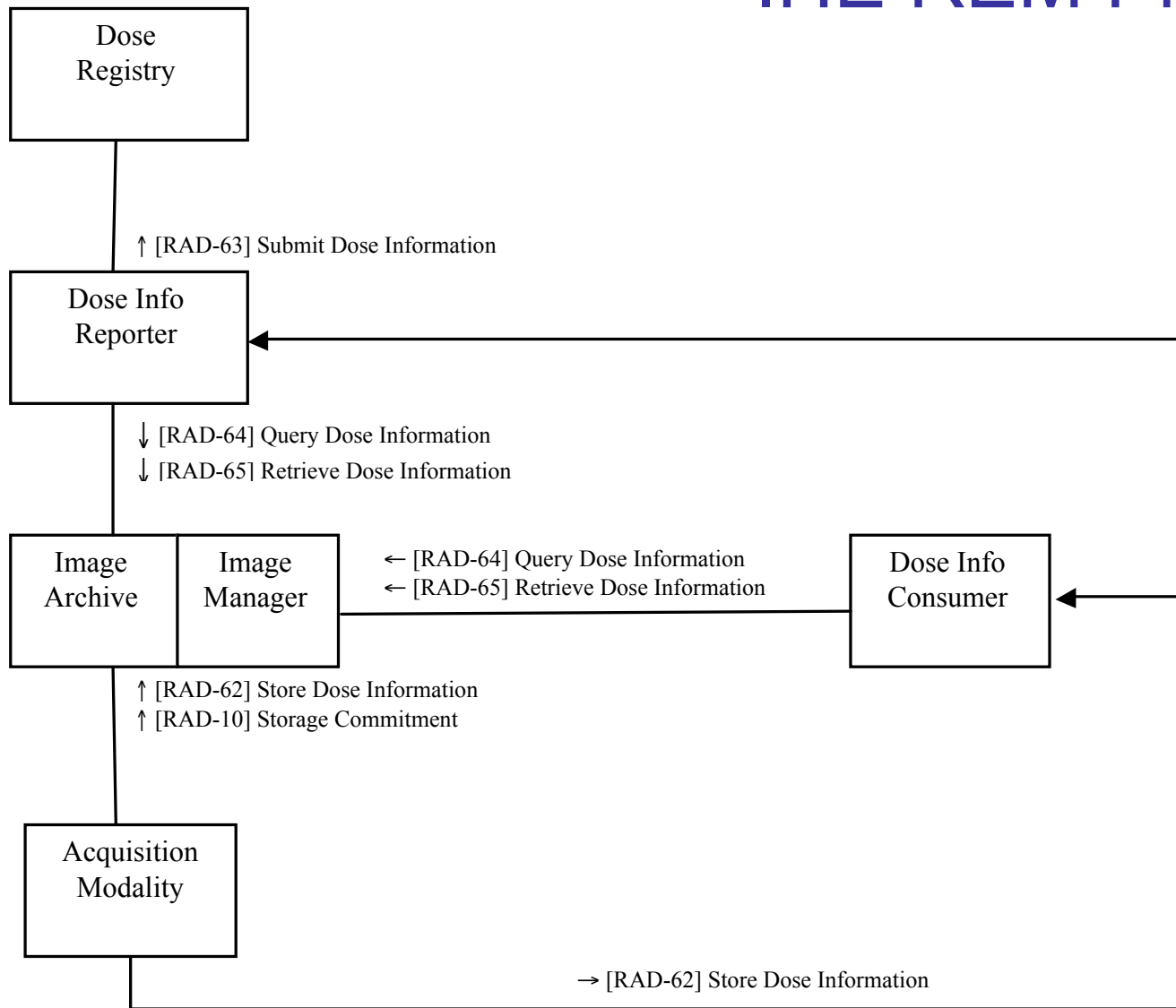
Patient Name:		Exam no:			
Accession Number:					
Patient ID:		Discovery CT750 HD			
Exam Description: CT HALS/THORAX/ABDOMEN					
Dose Report					
Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	S15.750-I650.250	5.10	373.00	Body 32
5	Helical	S188.000-I105.000	5.10	182.72	Body 32
Total Exam DLP:				555.72	
1/1					

Reporting started
Dose 2009/08/10 13:03:28 CT CT HALS/THORAX/ABDOMEN DLP Total=555.72 mGycm
Series=2 Helical S15.750-I650.250 mm 5.10 mGy 373.00 mGycmBODY32
Series=5 Helical S188.000-I105.000 mm 5.10 mGy 182.72 mGycmBODY32
Reporting complete

RDSR & OCR or MPPS Deployment



IHE REM Profile



Conclusion

- DICOM RDSR is the accepted standard for encoding modality dose information, including for registries
- All new and current platform CT modalities
- A template on top of DICOM SR
- DICOM SR may appear daunting, but with the right toolkit is straightforward to create, parse, analyze and render
- Content available as “merge fields” in VR systems
- RDSR is comprehensive and extensible to new content and new concepts