Frontiers in PACS: DICOM Structured Reporting

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RadPharm
Outline

- Scope of DICOM
- Why use DICOM for reporting?
- What is DICOM Structured Reporting?
- Content encoding
- Templates
- Implementation
- Examples
DICOM Structured Reporting
Scope of DICOM

- Images
  - Radiology and cardiology
  - Nuclear Medicine
  - Ultrasound
  - Others …
    - Endoscopy
    - External photography
    - Microscopy
Scope of DICOM

- Images
- Radiotherapy
  - Plan
  - Dose
  - Structure Set
  - Image
  - Treatment Record
Scope of DICOM

- Images
- Radiotherapy
- Waveforms
  - ECG (12-lead, continuous, Holter)
  - Hemodynamic (pressure)
  - Voice Audio
  - Others …
DICOM Time-based Waveforms

- SEGMENT
- MULTISEGMENT
- MULTIPoint
- POINT

BEGIN

END
Scope of DICOM

- Images
- Radiotherapy
- Waveforms
- Workflow
  - Worklists (modality and general purpose)
  - Performed Procedure Step
What about Reports?

- Imaging studies are ordered to answer clinical questions.
- The primary product is the answer, not the images themselves.
- The answer is conveyed in the report.

Interoperability for reports as well.
Why use DICOM for reporting?

- Reports created in the imaging domain
- Relationship to images & waveforms
  - Image references (e.g. illustrate findings)
  - Spatial & temporal coordinates
- Mature persistent object paradigm
  - Installed base of archives adaptable
- Void to fill (few, if any, alternatives)
Traditionally …

- Films on a view box or alternator
- Text reports dictated and transcribed
- Interim reports hand-written
- Paper - creation and/or distribution
- If digital - proprietary systems
Evolution towards PACS

- Digital images, but reports still
  - Dictated
  - Transcribed (or speech recognition)
  - Separate equipment from image display
  - Proprietary entry/archive/distribution
- Best case: text for HL7 distribution
- Worse than before, e.g. no “wax pencil”
Doing better requires…

- Linking reports with images
- Integrating multiple vendors' systems
- Standards that preserve fidelity
- Leverage existing tools & standards …
  - DICOM
  - HL7
  - Web-based data entry & distribution
Smith, M.

Tagged cardiac MRI reveals a focal dyskinetic segment located in the left ventricle anteriorly.

DAC. 2000/06/04
Smith, M.

Tagged cardiac MRI reveals a focal dyskinetic segment located in the left ventricle anteriorly.

DAC. 2000/06/04
Structured Report *linked to* Images

Patient: Smith, M.
Procedure: tagged cardiac MRI
Finding: focal dyskinetic segment
  Anatomic Region: left ventricle
  Location: Anterior
  Spatial coordinates: Image:
Observer: DAC
Verification date: 2000/06/04
What is a Structured Report?

- A document with structure
  - headings, codes, measurements + text
- Contains a “tree” of information
- Looks complicated internally
- “Flattened out” for simple display to users
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
DICOM Structured Reporting

“Chest X-Ray Report”

**Context**
- **“Observer”** = “Clunie^David^^Dr^”
- **“Study Instance UID ...”** = “1.2.3.4.5.6.7.100”
- **“Subject”** = “Homer^Jane^^”

**Contains**
- **“Finding”** = “Mass”

**Properties**
- **“diameter”** = “1.3” “cm”
- **“margination”** = “infiltrative”

**Contains**
- **“Baseline”**

**Contains**
- **“Conclusions”**
- **“Conclusion”** = “probable malignancy”

**Contains**
- **“Specific Image Findings”**
- **“best illustration of findings”**

**Modifier**
- **“Views”** = “PA and Lateral”

**Context**
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**Contains**
- **“Specific Image Findings”**
- **“best illustration of findings”**

**Modifier**
- **“Views”** = “PA and Lateral”
Report of Chest X-Ray (PA and Lateral Views)

Patient Jane Homer
Study # 123456
Recorded by Dr. John Smith

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)
Types of structured “documents”

- Traditional diagnostic imaging reports
- Procedure and event logs
- Measurements
- Quality Control reports
- Computer Assisted Diagnosis (CADx)
- Flagging images (key object selection)
Why use DICOM for Reporting?

- Use of standard allows for interchange
- DICOM provides compatibility with image viewer and archive components
- Only reporting standard that combines images, waveforms & measurements
- Required by RSNA/HIMSS IHE
Relationship to Other Standards

- HL7 Clinical Document Architecture
  - CDA: Former Patient Record Architecture
  - Levels 1, 2, 3
  - XML encoding, V3 data types
- CORBAMed Clinical Observations Access Service (COAS)
- CEN TC 215 Electronic Healthcare Record Architecture
A few more details …
What is in a DICOM SR object?

- “Header” of management information
  - Patient/Study/Series/Instance
  - State and status information
  - Source of “evidence” … to locate images
- “Tree” of “content”
  - Name-value pairs (e.g. “size” = “3” “cm”)
  - Relationships (e.g. “has properties”)

DICOM Structured Reporting
DICOM Structured Reporting

State and Status Information

- Complete or incomplete
- Verified or not; who & when
- List of evidence
  - Current
  - Relevant, e.g. prior reports
- Copies and versions
  - Rules for new UIDs for new versions
SR Content is a Tree

Root Node

Child Nodes:

1

1.1

1.2
Each Node (Content Item)

- Is a “name-value” pair
  - e.g. “finding” = “mass”
- The (concept) “name” is always coded
  - e.g. (27162, “99PMP”, “Finding”)
- The “value” may be one of several “value types”
DICOM Structured Reporting

Value Types

- TEXT
- CODE
- NUM
- PNAME
- DATE
- TIME
- DATETIME

- CONTAINER
- UIDREF
- COMPOSITE
- IMAGE
- WAVEFORM
- SCOORD
- TCOORD
Nodes linked by Relationships

Parent Node

Relationships

Child Nodes
DICOM Structured Reporting

Relationships

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

Value Types

- TEXT
- CODE
- NUM
- PNAME
- DATE
- TIME
- DATETIME

- CONTAINER
- UIDREF
- COMPOSITE
- IMAGE
- WAVEFORM
- SCOORD
- TCOORD
Structured Report **linked to** Images

Patient: Smith, M.
Procedure: tagged cardiac MRI
Finding: focal dyskinetic segment
  Anatomic Region: left ventricle
  Location: Anterior
  Spatial coordinates: Image:
Observer: DAC
Verification date: 2000/06/04
DICOM Structured Reporting

Image Reference

- Identify Image: SOP Instance UID
- Type of Image: SOP Class UID
- [Frame Number]
- [Presentation State]
  - Contrast transformations
  - Standard grayscale space
  - Spatial transformations
Importance of Presentation State
Importance of Presentation State

Original is wrong way around

Apply horizontal flip to correct orientation

Show retrocardiac mass by zoom/crop/adjust contrast
Spatial Coordinates

- POINT
- MULTIPOINT
- POLYLINE
- CIRCLE
- ELLIPSE
Temporal Coordinates

SEGMENT  MULTISEGMENT  MULTIPOINT  POINT

BEGIN       END

BEGIN       END

BEGIN       END
Temporal & Spatial Coordinates

LV outline end systole → TCOORD
SELECTED ROI → SCOORD
SELECTED ROI → IMAGE

DICOM Structured Reporting
Temporal Coordinates applied to both Images and Waveforms

R-wave peak at (time 10:03.296)
“Chest X-Ray Report”

1.1 Context
"Observer"="Clunie^David^Dr^"
PNAME

1.2 Context
"Study Instance UID ..."="1.2.3.4.5.6.7.100"
UIDREF

1.3 Context
"Subject"="Homer^Jane^^^"
PNAME

1.4 Contains
"Finding"="Mass"
CODE

1.4.1 Properties
"diameter"="1.3" "cm"
NUM

1.4.2 Properties
"margination"="infiltrative"
CODE

1.5 Contains
"Baseline"
IMAGE

1.6 Contains
"Conclusions"
CONTAINER

1.6.1 Contains
"conclusion"="probable malignancy"
CODE

1.7 Contains
"Specific Image Findings"
CONTAINER

1.7.1 Contains
"best illustration of findings"
CODE

1.8 Modifier
"Views"="PA and Lateral"
CODE

Context contains Subject, Observer, Study Instance UID, Finding, and Baseline. Subject is Homer^Jane, Observer is Clunie^David^Dr^, and Study Instance UID is 1.2.3.4.5.6.7.100. Finding is Mass with a diameter of 1.3 cm and a margination of infiltrative. Baseline contains an X-ray image. Conclusions include a conclusion of probable malignancy.
Simplest SR is a Title + Text

- Legacy support
- Importation of foreign data (e.g. lab)

```xml
<COUNTAINER:(29715,99PMP,"Chest X-ray Report")>
<TEXT:(29716,99PMP,"Description")=
  "Reason for exam: Shortness of breath, history of CCF
  Description of procedure: PA, lateral views were obtained
  followed by a left lateral decubitus
  Findings: Blunting of the left costo-phrenic angle, cardiomegaly and interstitial lines. Subsequently pleural fluid was seen on the left in the decubitus view
  Conclusions: Pulmonary oedema and pleural effusion">
```
Order from chaos … Templates

- Trees of arbitrary complexity
- Unconstrained choice of code sets
-> risk of interoperability problems
- Use pre-defined templates
  - constrain structure of tree
  - constrain choice of codes
- Templates for part of or whole object
Template examples

- Whole document:
  - Basic imaging report
  - Key object selection
  - Mammography CAD report

- Part of tree:
  - Linear measurements
  - Individual findings
What about implementation?
Typical Design Goals

- Re-use existing components
- DICOM toolkit/image viewer/archive
- Consumer/open-source tools
- Web browser windows
- Java Server Page (JSP) engine
- XML tools (SAX/DOM parse, XSL-T)
Design Alternatives

- Hard-coded SR-specific application
- Literal XML instantiation & conversion
  - DOM (slow, flexible) or SAX (fast, XSL-T)
- SR-specific Object Model
  - Limited reusability; support for XSL-T?
- Virtual XML - simulate SAX events
  - Both DICOM parse & DICOM generate
Architecture: “round-trip”

- Only persistent object is binary DICOM
- DICOM parser returns SAX events
  - i.e. implicit virtual XML conversion
- SAX events drive XSL-T stylesheet
  - produces HTML form (+CSS for prettiness)
- Web browser renders form which user fills in
- Submit -> JSP makes SAX events from form
  - i.e. another implicit virtual XML conversion
- Either: cycle revised form or DICOM C-Store
Results of Experience

• Existing DICOM toolkit re-use:
  • No tag ordering or sequence building problems
  • Service/SOP Class/IOD support

• Existing application re-use:
  • No need to re-implement archive/database
  • Image viewer integration (shared context)

• Web/XML/XSL-T tool re-use:
  • Off-the-shelf browsers/parsers/stylesheet engine
Patient Anonymized; Study (00021231.000000)

Echocardiography Report

- Patient Characteristics
- Procedure Information
- Previous Procedure Information
- Summary
- Findings

Descriptive Findings

- M-Mode and 2D Measurements
- Doppler Measurements
- Estimated pressures

Left ventricle

- Visualized: Well
- Cavity size: --
- Ventricular shape: Eccentric hypertrophy
- Systolic function, global: +++
- Systolic function, regional: Wall motion abnormalities present
- Diastolic filling: Normal
- Thrombus: Absent
- Mass: Absent

Eccentric left ventricular hypertrophy with increased wall m.
Eccentric hypertrophy
Normal
Concentric hypertrophy - mild
Concentric hypertrophy - moderate
Concentric hypertrophy - severe
Asymmetric hypertrophy - anterior
Asymmetric hypertrophy - posterior
Asymmetric hypertrophy - septal
Asymmetric hypertrophy - lateral
Asymmetric hypertrophy - apical
Asymmetric hypertrophy - basal
Eccentric hypertrophy
Aneurysm - anterior
Aneurysm - posterior
Aneurysm - septal
Aneurysm - lateral
Aneurysm - apical
Aneurysm - basal
Pseudoaneurysm - anterior
Pseudoaneurysm - posterior
Pseudoaneurysm - septal
Pseudoaneurysm - lateral
Pseudoaneurysm - apical
Pseudoaneurysm - basal
### Echocardiography Report

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Ventricular End-Diastolic Dimension</td>
<td>65.0 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ventricular End-Systolic Dimension</td>
<td>50.0 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interventricular Septal Diastolic Thickness</td>
<td>11.0 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ventricular Posterior Wall Thickness</td>
<td>10.0 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ventricular Fractional Shortening</td>
<td>23.0 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ventricular Ejection Fraction</td>
<td>23.0 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ventricular Circumferential Shortening</td>
<td>146.0 /s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ventricular Rate of Circumferential Shortening</td>
<td>146.0 /s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ventricular Wall Mass</td>
<td>146.0 g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ventricular Wall Mass Index</td>
<td>146.0 g/m</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Patient Name: Anonymized ID: DOB: Sex: Age: Height: cm Weight: kg

Referred by:
Study Date: 00021231 Study Time: 000000 Report Date: 20010607 Report Time: 164814
Study ID: Accession #: Institution: Community Hospital Station:

Status: PARTIAL UNVERIFIED

- Echocardiography Report.
  - Patient Characteristics.
    - Height = 74.0 inch
    - Weight = 74.0 pound
    - BSA = 1.98 square meter
    - Heart Rate = 73.0 per minute
    - Systolic Blood Pressure = 123.0 mmHg
    - Diastolic Blood Pressure = 123.0 mmHg

- Procedure Information.
  - Operator = Harry
  - Study Type = Transthoracic echocardiogram
  - Study Quality = Technically adequate
  - Indication = Assess LV function

- Previous Procedure Information.
  - Study Type = None

- Summary.
  - Answer to question posed = Left ventricular dimension was moderately increased with mildly to moderately reduced systolic performance. Anterior and septal hypokinesis was the main finding. Despite ECG changes, the inferior and posterior walls appeared to move well.

- Findings.
  - Descriptive Findings.
    - Left ventricle.
      - Visualized = Well
      - Cavity size = Mildly to moderately decreased
      - Ventricular shape = Eccentric hypertrophy
      - Systolic function, global = Moderately increased

    - Systolic function, regional = Wall motion abnormalities present
      - Basal anterior segment = Hypokinetic (ASE 2)
      - Basal lateral segment = Normal (ASE 1)
      - Basal posterior segment = Normal (ASE 1)
      - Basal inferior segment = Normal (ASE 1)

    - Inferred from Ejection fraction = 35.0 Percent
    - Inferred from Fractional shortening = 45.0 Percent
DICOM Structured Reporting

- **Right atrium.**
  - Visualized = Well
  - Narrative finding = Right atrial size was normal.

- **Vena cavae.**
  - Visualized = Well
  - Narrative finding = The IVC was moderately dilated. Respirophasic change in IVC caliber was blunted, suggesting increased central venous pressure.

- **Pulmonic valve.**
  - Visualized = Well
  - Narrative finding = Normal.

- **Pulmonary artery.**
  - Visualized = Poorly
  - Narrative finding = Pulmonary artery dimensions appeared to be normal.

- **Pericardium.**
  - Visualized = Well
  - Narrative finding = No pericardial effusion.

- **M-Mode and 2D Measurements.**

<table>
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<tr>
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<tbody>
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<tr>
<td>Left Ventricular Wall Mass</td>
<td>146.0 g</td>
</tr>
<tr>
<td>Left Ventricular Wall Mass Index</td>
<td>146.0 g</td>
</tr>
<tr>
<td>Left Atrial Systolic Dimension</td>
<td>32.0 mm</td>
</tr>
<tr>
<td>Aortic Root Diastolic Diameter</td>
<td>32.0 mm</td>
</tr>
<tr>
<td>Aortic Annulus Diameter</td>
<td>32.0 mm</td>
</tr>
<tr>
<td>Aortic Valve Cusp Separation</td>
<td>32.0 mm</td>
</tr>
<tr>
<td>Left Ventricular Outflow Tract Systolic Diameter</td>
<td>32.0 mm</td>
</tr>
<tr>
<td>Mitral Valve Diastolic E-F Slope</td>
<td>32.0 cm/s</td>
</tr>
<tr>
<td>Mitral Valve Excursion</td>
<td>32.0 mm</td>
</tr>
<tr>
<td>Mitral Valve E Septal Separation</td>
<td>32.0 mm</td>
</tr>
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<td>Right Ventricular End-Diastolic Dimension</td>
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</tr>
</tbody>
</table>

- **Doppler Measurements.**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic Valve Peak Systolic Velocity</td>
<td>0.0 cm/s</td>
</tr>
<tr>
<td>Aortic Valve Time Velocity Integral</td>
<td>0.0 cm</td>
</tr>
<tr>
<td>Aortic Valve Maximum Instantaneous Systolic Gradient</td>
<td>0.0 mmHg</td>
</tr>
<tr>
<td>Aortic Valve Mean Systolic Gradient</td>
<td>0.0 mmHg</td>
</tr>
<tr>
<td>Aortic Valve Area (by Velocity)</td>
<td>0.0 cm2</td>
</tr>
</tbody>
</table>

Summary

• Reporting within the scope of DICOM
• Integration with DICOM archives
• DICOM SR provides a tree of content
• Encoded as name-value pairs
• Templates improve interoperability
• Implement using existing tools
  • DICOM toolkits and web technology
DICOM Structured Reporting

David A. Clunie

DICOM (Digital Imaging and Communications in Medicine) is the ubiquitous standard in the radiology and cardiology imaging industry for the exchange and management of images and image related information. It also has applications in other image related medical fields, such as pathology, endoscopy, dentistry, ophthalmology and dermatology. Structured Reporting is an extension to the DICOM standard that provides powerful features for encoding structured document such as reports, measurements and procedure logs. It is a vital tool in the pursuit of the fully electronic patient medical record.

**DICOM Structured Reporting** is a comprehensive review of the features of the Structured Reporting extension to the DICOM Standard.

This book is a pragmatic, “hands-on” guide for implementers, that explains the principles and philosophy behind DICOM SR, including how to create, encode and render structured reports. It covers basic material to help novices understand the DICOM standard itself, since Structured Reporting will be of relevance to many who are not already familiar with DICOM. Detailed examples of potential applications are provided, together with descriptions of their encoding. There is also extensive coverage of advanced features and as well as pitfalls for implementers. Proposed future extensions to the standard for templates and document imaging are also described.

David Clunie is industry co-chairman of the DICOM Committee and the current editor of the standard, as well as a member or chairman of many of the DICOM working groups. A neuro-radiologist by training, he is currently Director of Development of Medical Imaging Products at ComView Corporation.