DICOM Structured Reporting: Implementation Experience

David Clunie, MD.
Director of Healthcare Information Systems
ComView Corporation
Design Goals

• Cardiology image reporting system
• Multi-modality: Angio (XA) & Echo (US)
• Standards based: facilitate interchange
• Re-use existing components:
  • DICOM image acquire/view/archive
  • Consumer/open-source tools
Existing Tools

- DICOM toolkit
  - Java, Part 10, C-Store, dataset build/parse
- Image viewing application
- Web-browser window available
- Java Server Page (JSP) engine
- XML tools (SAX/DOM parse, XSL-T)
Report Features

- Very structured (especially echo)
  - By anatomic feature
  - By measurement type
- Both technologist & physician input
- Measurements not image-coupled (yet)
- Many specific variants:
  - Adult/pediatric, normal/stress, site-specific
Template Use & Design

• Little need for observation context
• WG 1/12 templates not yet mature
• Coding schemes not yet mature
• Therefore:
  • private templates
  • augment LOINC with private codes
  • generic input, editor and renderer
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
DICOM SR Implementation

Architecture: “round-trip”

• Only persistent object is binary DICOM
• DICOM parser returns SAX events
  • i.e. implicit virtual XSML conversion
• SAX events drive XSL-T stylesheet
  • produces HTML form (+CSS for prettiness)
• 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
Implementation Specifics - SAX

- SAX API is key interface boundary
  - Producer/consumer model
  - Producer is “document parser”
  - Consumer is “document handler”
- DICOM interface
  - Parser wrapped inside SAX parser
  - Generator wrapped inside SAX handler
Implementation Specifics - HTML

- HTML Pages are only interface to user
- Non-editable information
  - Rendered as non-form elements
- Editable information
  - Rendered as form elements
  - Naming scheme maps to header/SR tree
  - Pre-loaded from images/work-list etc.
DICOM SR Implementation

Implementation Specifics - HTML

• Limited HTML features required
  • Forms
  • Cascading Style-Sheets (CSS)
    • Prettiness
    • Customize appearance (e.g. site-specific)
    • Factor out appearance from JSP logic
  • No Javascript necessary (yet)
    • Future use: client-side field validation
Implementation Specifics - JSP

- Form submitted via CGI PUT method
- Type of “submit” dictates next step:
  - Update/render/print/store/sign etc.
- Recurse through named attributes
- Generate SAX events to XSL-T engine
- Pipe XSL-T output to servlet response
- Stateless: no cookies or server state
Implementation Specifics - XSLT

Two approaches:

- “pull” values into a specific format
  - always result in pre-defined format
  - ignores “un-pulled” attributes: not general
  - essentially highly template-dependent
- “rewrite rules” repeatedly applied
  - generic and extensible
  - can recognize “patterns” and optimize
Results of Experience - DICOM

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

- Existing application re-use:
  - No need to re-implement archive/database
  - Image viewer integration (share context)
DICOM SR Implementation

Results of Experience - Pick-lists

• Codes for Concept Names and values

• Where do lists of codes come from?
  • Dictionary/lexicon
  • Embedded in style-sheet

• Triggering context group selection
  • Very useful to keep context group choice encoded in data-set!
### In-band Context Identifier

<table>
<thead>
<tr>
<th>Code Meanig</th>
<th>Code Value</th>
<th>Code Set Extension Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code Value</td>
<td>(0008,0100)</td>
<td>1</td>
</tr>
<tr>
<td>Coding Scheme Designator</td>
<td>(0008,0102)</td>
<td>1</td>
</tr>
<tr>
<td>Coding Scheme Version</td>
<td>(0008,0103)</td>
<td>1C</td>
</tr>
<tr>
<td>Code Meaning</td>
<td>(0008,0104)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Context Identifier</strong></td>
<td><strong>(0008,010F)</strong></td>
<td>3</td>
</tr>
<tr>
<td>Mapping Resource</td>
<td>(0008,0105)</td>
<td>1C</td>
</tr>
<tr>
<td>Code Set Extension Flag</td>
<td>(0008,0106)</td>
<td>3</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
DICOM SR Implementation

In-band Context Identifier

- Allows style-sheet to trigger pick-list generation locally to content item
- No *a priori* knowledge of template required
- Strategy allows for editable documents in the absence of a template!
- Still need context group itself of-course
DICOM SR Implementation

Results of Experience - XML

- No XML ever actually instantiated
- "Virtual" XML in SAX events
- Still requires DTD (or Schema)
- Several DTDs
  - One specific to SR structure for round trip
  - One specific to DICOM tags for generation
Results of Experience - XML

- Advantage of “non-standard” DTDs
- Multiple DTDs specific to need
- Choose elements vs. attributes as desired
- Extensible to match evolving style-sheets
- Addition of state information to alter user interface:
  - E.g. container expand/collapse, tab view
DICOM SR Implementation

Results of Experience - XSL-T

- Pure rewriting approach
  - very generic - can render any SR
  - not always the prettiest rendering
- Combination pull and rewrite
  - Pull for:
    - initial creation (e.g. replicating conventional form or wizard)
    - “header” attributes - consistent presence and layout
  - Rewrite for editing/rendering
DICOM SR Implementation

Results of Experience - XSL-T

• Declarative approach of tree re-writing rules takes some getting used to
• X-PATH syntax for rule and value selection is very useful (esp. access to distant ancestors and descendants)
• HTML (or other text) output is very straightforward
• Include/import mechanism allows tool-generated rules to be added (e.g. code lists)
Results of Experience - SR

• Rule against non-null values
  • “fill in the blanks” objects illegal
  • -> “chicken and egg” problem
• Mandatory units for NUM annoying
• How to (usefully) render different relationship types
• How to render by-reference links
DICOM SR Implementation

Results of Experience - Templates

- “Headings” == “Containers”
  - Expand/collapse or tab through containers
  - Want everything at top level a container
- Unnecessary containers annoying
  - CONTAINER “cardiac measurement contains “stroke volume” = “70” “ml”
- Homogeneous container contents
  - e.g. all NUM -> render as HTML table
DICOM SR Implementation

Results of Experience - Templates

- Re-usable mini-template “components”
- Achieve consistency of rendering
  - e.g.
    - Numeric tables
    - Normal range
    - Qualitative assessment (hi/lo/normal)
Future Directions

• Adopting standard templates:
  • Easier with generic approach
  • Re-use of common rendering elements
  • Installed base of reports still usable

• Example:
  • Support of ACC 2001 demo CD SR
    • Trivial effort to render (same style-sheet)
    • Editable once context groups added
Future Directions

- Integration with images & coordinates
  - Shared (bi-directional) context approach
  - Create/edit:
    - HTML form element triggers capture of current image viewer context -> JSP
- Render:
  - Javascript or anchor in XSL-T-generated-HTML triggers JSP to update viewer context
Future Directions

- Improved rendering
  - To other than HTML
    - e.g. directly to HL7 V2.x. OBX segment
  - Multi-lingual rendering
  - Narrative conversion of code entries
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_
Echocardiography Report

Patient Characteristics

Procedure Information

Previous Procedure Information

Summary

Findings

Descriptive Findings

M-Mode and 2D Measurements

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

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

Referred by:
Study Date: 0002131 Study Time: 000000 Report Date: 20010607 Report Time: 164414
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
        - inferred from Ejection fraction = 35.0 Percent
        - inferred from Fractional shortening = 45.0 Percent
      - 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)
**Echocardiography Report**

- **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>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Ventricular End–Diastolic Dimension</td>
<td>65.0 mm</td>
<td>(0.0 mm – 0.0 mm)</td>
</tr>
<tr>
<td>Left Ventricular End–Systolic Dimension</td>
<td>50.0 mm</td>
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</tr>
<tr>
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<td>(0.0 % – 0.0 %)</td>
</tr>
<tr>
<td>Left Ventricular Circumferential Shortening</td>
<td>146.0 %</td>
<td>(0.0 % – 0.0 %)</td>
</tr>
<tr>
<td>Left Ventricular Rate of Circumferential Shortening</td>
<td>146.0 ls</td>
<td>(0.0 ls – 0.0 ls)</td>
</tr>
<tr>
<td>Left Ventricular Wall Mass</td>
<td>146.0 g</td>
<td>(0.0 g – 0.0 g)</td>
</tr>
<tr>
<td>Left Ventricular Wall Mass Index</td>
<td>146.0 g/m</td>
<td>(0.0 g/m – 0.0 g/m)</td>
</tr>
<tr>
<td>Left Atrial Systolic Dimension</td>
<td>32.0 mm</td>
<td>(0.0 mm – 0.0 mm)</td>
</tr>
<tr>
<td>Aortic Root Diastolic Diameter</td>
<td>32.0 mm</td>
<td>(28.0 mm – 34.0 mm)</td>
</tr>
<tr>
<td>Aortic Annulus Diameter</td>
<td>32.0 mm</td>
<td>(28.0 mm – 34.0 mm)</td>
</tr>
<tr>
<td>Aortic Valve Cusp Separation</td>
<td>32.0 mm</td>
<td>(28.0 mm – 34.0 mm)</td>
</tr>
<tr>
<td>Left Ventricular Outflow Tract Systolic Diameter</td>
<td>32.0 mm</td>
<td>(28.0 mm – 34.0 mm)</td>
</tr>
<tr>
<td>Mitral Valve Diastolic E–F Slope</td>
<td>32.0 cm/s</td>
<td>(28.0 cm/s – 34.0 cm/s)</td>
</tr>
<tr>
<td>Mitral Valve Excursion</td>
<td>32.0 mm</td>
<td>(28.0 mm – 34.0 mm)</td>
</tr>
<tr>
<td>Mitral Valve E Septal Separation</td>
<td>32.0 mm</td>
<td>(28.0 mm – 34.0 mm)</td>
</tr>
<tr>
<td>Right Ventricular End–Diastolic Dimension</td>
<td>65.0 mm</td>
<td>(0.0 mm – 0.0 mm)</td>
</tr>
</tbody>
</table>

**Doppler Measurements.**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic Valve Peak Systolic Velocity</td>
<td>0.0 cm/s</td>
<td>(0.0 cm/s – 0.0 cm/s)</td>
</tr>
<tr>
<td>Aortic Valve Time Velocity Integral</td>
<td>0.0 cm</td>
<td>(0.0 cm – 0.0 cm)</td>
</tr>
<tr>
<td>Aortic Valve Maximum Instantaneous Systolic Gradient</td>
<td>0.0 mmHg</td>
<td>(0.0 mmHg – 0.0 mmHg)</td>
</tr>
<tr>
<td>Aortic Valve Mean Systolic Gradient</td>
<td>0.0 mmHg</td>
<td>(0.0 mmHg – 0.0 mmHg)</td>
</tr>
<tr>
<td>Aortic Valve Area (by Velocity)</td>
<td>0.0 cm2</td>
<td>(0.0 cm2 – 0.0 cm2)</td>
</tr>
</tbody>
</table>
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 neuroradiologist by training, he is currently Director of Development of Medical Imaging Products at ComView Corporation.