Technical Challenges in Enterprise Imaging

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• Other: Owner of PixelMed Publishing
Technical Challenges

• Interoperability
• Metadata
• Workflow
• Simpler DICOM services (DICOMweb)
• Privacy and Security
• Anatomical pathology (whole slides)
• [Color consistency management]
• [Annotations]
Interoperability

“the ability of two or more systems or components to exchange information and to use the information that has been exchanged”

Interop
The Promise and Perils of Highly Interconnected Systems

JOHN PALFREY AND URS GASSER
37 years ago – radiology PACS and DICOM usage ubiquitous now!
DICOM – Diversity from early on …

- DICOM has been around a very long time (1985 ACR-NEMA)
- DICOM has been doing more than radiology for a long time too
- Cardiology – 1995
- Radiotherapy – 1996
- Visible Light – 1998 – including Slide Microscopy
- Even before that – Secondary Capture RGB – 1993
- Increasingly specialty specific image types and metadata
- Whole Slide Imaging – 2010
- Ophthalmic Tomography Angiography – 2017
Wide Variety of Images Integrated with the Online Patient Record

- Cardiology
- Bronchoscopy
- Gastrointestinal Endoscopy
- Hematology
- Pathology
- Surgery
- Nuclear Medicine
- Dental
- Radiology
- Dermatology
- Ophthalmology
- Podiatry
- Vascular
- Urology
- Nursing
- Electrocardiography
- Scanned Documents

"Kuzmak P, Dayhoff R. 10 Years of DICOM at the Department of Veterans Affairs. DICOM Workshop; 2003 Oct 1."
My mother used to puke in my mouth.
Storing anything and everything

• ... with DICOM ...
• Specific SOP Class and IOD – e.g., Ophthalmic Photography
• Generic SOP Class and IOD – e.g., VL Photographic
• Anything at all SOP Class & IOD – e.g., Secondary Capture
• Distinguished by Pixel Data restrictions & metadata
• Pixel Data “payload” – uncompressed or compressed (e.g., JPEG-*, MPEG-*)
• Metadata (“header”) – composite (shared) and modality (clinical application) specific
Visible Light IODs and SOP Classes

• VL Endoscopic Image (IOD and Storage SOP Class)
• VL Microscopic Image
• VL Slide-Coordinates Microscopic Image
• VL Photographic Image

• Video Endoscopic Image
• Video Microscopic Image
• Video Photographic Image

• VL Whole Slide Microscopy Image
Ophthalmic IODs and SOP Classes

- Ophthalmic Photography 8 bit Image
- Ophthalmic Photography 16 bit Image
- Ophthalmic Tomography Image
- Ophthalmic Refractive Measurements (Lensometry, Visual Acuity, ...)
- Ophthalmic Visual Field Static Perimetry Measurements
- Ophthalmic Thickness Map
- Wide Field Ophthalmic Photography Stereographic Projection Image
- Wide Field Ophthalmic Photography 3D Coordinates Image
- Ophthalmic Optical Coherence Tomography En Face Image
- Ophthalmic Optical Coherence Tomography B-scan Volume Analysis
It’s the metadata, stupid

http://medium.com/digital-trends-index/its-the-metadata-stupid-12a4fc121e45#.4zhwdz5y0
Composite Context

• All of the stuff that is the same across multiple images (files, instances) ... i.e., of the DICOM Composite Information Model:
  – Patient ... same for all instances for patient
  – Study ... same for all instances for procedure
  – Series ... new for each related acquisition or derivation
  – Equipment
  – Multi-Frame Dimensions
  – Frame of Reference ... e.g., if same slide coordinates

• Provides the basis for database/browser structure
Composite Information Model
Extreme Metadata – or not

• Every image needs the Pixel Data described (rows, columns, bit depth, etc.), and unique identifiers
• Beyond that lot or a little, whatever is needed
• Bare minimum – some identifier to match some other system – recipient does the matching work
• Everything and the kitchen sink – detailed description of the patient’s state, acquisition process, etc., using standard string values or codes – recipient is passive
• The latter is the norm in radiology
Minimum Chips

- As little as possible in one of the generic SOP Classes
- Very few required Type 1 (required) attributes
- Type 2 required attributes may be “empty” if unknown
- Can omit Type 3 (optional) attributes and entire optional modules
- Only Patient ID (empty name, DOB, age, sex – server will lookup, coerce)
- Send Content (or Acquisition) Date and Time only – server (or user) can match to other records captured contemporaneously
- Absent/empty Accession Number, Admission ID, Service Episode ID
- Make up some (Study, Series, Instance) UIDs
- With STOW-RS, can even omit the Pixel Data description, and let the server figure it out from the JPEG payload
More than the minimum

- Can do better by adding what is relevant to the recipient
- Textual descriptions (e.g., in Study/Series Description, Image Comments)
- Modality – more specific than “other”
- A little anatomy – may be hardwired (e.g., knee arthroscopy, colonoscopy, retinal fundoscopy) or user controlled (e.g., handheld skin lesion photos) – is best coded (e.g., SNOMED, FMA, clinical specialty codes such as NYU Melanoma CCG) rather than just text string
- Guiding principle – what can the recipient benefit from that is not too burdensome to capture?
- Radiology experience – rich metadata drives hanging protocols, prior pre-fetching, finding the right stuff in the study/series browser
Surface Anatomy – NYU, Mayo
## Surface Anatomy in DICOM

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</table>
Extremely rich metadata

• All sorts of stuff relevant to the interpretation
• Even if another local source, needed when image is exported
• Identification and description of the patient
• Other Patient IDs, age, height, weight
• Patient (or specimen) preparation, positioning
• Acquisition process (e.g., illumination, filtration)
• Special aspects of the technique (e.g., fluorescence)
Why does this matter?

- Why not just save “consumer format” data in a content management system, and let it worry about the metadata?
- Export beyond the system (enterprise) – transfer, referrals
- Import from elsewhere – where does the metadata come from?
- Migrations – VNAs, CMS, EMRs go end-of-life just like PACS do – do you really want to repeat the pain of your last legacy PACS migration with its proprietary database and non-standard internal file format and proprietary compression?
- Mergers and acquisitions – when a company gets swallowed, new owner will want to assimilate products, and standards (DICOM) help
Camera

File system
+/-
metadata
in filename
or pathname

JPEG Metadata
- EXIF, ICC Profile
- Pixel Structure

Compressed
Pixel Data Bitstream
Metadata – Solution 1

Do it with DICOM
DICOM File

File system
+/- metadata in filename or pathname

JPEG Metadata
- EXIF, ICC Profile
- Pixel Structure

Compressed Pixel Data Bitstream
DICOM File

Camera

File system
+/- metadata
in filename
or pathname

DICOM Metadata
- Identification
- Acquisition Description
- Pixel Structure

JPEG Metadata
- EXIF, ICC Profile
- Pixel Structure

Compressed
Pixel Data Bitstream
DICOM Fileset

System

File system
+/- metadata in filename or pathname

Database
Index of (subset of) Metadata

DICOM Metadata
– Identification
– Acquisition Description
– Pixel Structure

JPEG Metadata
– EXIF, ICC Profile
– Pixel Structure

Compressed Pixel Data Bitstream

Camera
Metadata – Solution 2

Do it with EMR

“non-DICOM images”
EMR
Export, Migration, Analysis, ...

File system
 +/- metadata
 in filename or pathname

JPEG Metadata
 – EXIF, ICC Profile
 – Pixel Structure

Compressed
Pixel Data Bitstream
EMR
Export, Migration, Analysis, ...

- What patient?
- What body part?
- What encounter?
- What date?
- ...

File system
 +/- metadata
 in filename
 or pathname

JPEG Metadata
 - EXIF, ICC Profile
 - Pixel Structure

Compressed
 Pixel Data Bitstream
Metadata – Solution 2

Do it with EMR

“Non-DICOM images”
Metadata – Solution 3

Do it with XDS

“non-DICOM images”
XDS

System

File system
+/- metadata in filename or pathname

Database
Index of Metadata

JPEG Metadata
- EXIF, ICC Profile
- Pixel Structure

Compressed Pixel Data Bitstream

Camera

IHE XDS

Viewer
XDS
Export, Migration, Analysis, ...
XDS
Export, Migration, Analysis, ...

• What patient?
• What body part?
• What encounter?
• What date?
• ...

JPEG Metadata
  – EXIF, ICC Profile
  – Pixel Structure

Compressed
Pixel Data Bitstream
Metadata - Solution 3

Do it with XDS

“Non-DICOM images”
I feel nothing.

Detachment Sucks!

without embedded metadata, that is
From whence cometh metadata

• Manual data entry sucks (and is error prone)
• It lives naturally in HIS, departmental IS, EMR
• Broadcast/multicast HL7 V2 messages when various “trigger events” occur
• Asynchronous stuff sucks (since it may come when the acquisition device is least/not expecting it) – devices may be “intermittently connected”
• A 3rd party can cache it and respond to queries for it – hence DICOM Modality Worklist (MWL) "broker" was born
• Today one might reinvent MWL with queries on FHIR resources
• HL7 V2 queries have never been popular, but do work
MWL beyond Radiology

- DICOM MWL does NOT depend on their being an order (despite myth)
- E.g., a scheduled clinic visit can trigger creation of a worklist entry
- Admission, Service Episode IDs sent in work lists to match to “encounters”
- E.g., Cardiac Cath. – typically not “ordered” and even if ordered, morph during the procedure (e.g., from diagnostic cath to interventional)
- Extensive use by VA of MWL for ophthalmology, endoscopy, dentistry
Order-Based
Encounter-Based
IHE-Workflow mit der DICOM Camera

Setzen Sie einen integrierten Workflow um, der Ihrer Arbeitsweise entspricht.

Patientenliste → HIS/RIS/Praxisprogramm → Aufnahmen

Patient auswählen oder Fallnummer scannen → Fotografieren
IHE EBIW for Lightweight Devices

• Encounter-Based Imaging Workflow (EBIW)
• Updated trial implementation, but still WIP
• Source of metadata
  – decided DICOM MWL (used for radiology, POC ultrasound) too burdensome
  – HL7 v2 queries not popular
  – so added DICOMweb UPS-RS in addition to C-FIND MWL
  – still fantasizing about FHIR
• Sending images
  – still only C-STORE for now, but plan to add STOW-RS in future revision
• What does it add over a demographics query (e.g., mPDQ in WIC)?
  – information about the encounter
“Life is not meant to be easy, my child but take courage: it can be delightful.”

Back to Methuselah (1921)
“Life is not meant to be easy, my child but take courage: it can be delightful.”

Back to Methuselah (1921)
DICOM Made Easy

- Absolute minimum metadata in JSON + JPEG pixel data payload
- DICOMweb
- WADO-RS
- STOW-RS
- IHE Web-based Image Capture (WIC)
**Study Resources and Actions**

<table>
<thead>
<tr>
<th>Verb</th>
<th>Path</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>POST</td>
<td>(s)/studies</td>
<td>Store PS3.18 6.6.1</td>
<td>Store instances</td>
</tr>
<tr>
<td>GET</td>
<td>(s)/studies?...</td>
<td>Query PS3.18 6.7.1</td>
<td>Query for matching studies</td>
</tr>
<tr>
<td>GET</td>
<td>(s)/studies/{studyUID}</td>
<td>Retrieve PS3.18 6.5.1</td>
<td>Retrieve entire study</td>
</tr>
<tr>
<td>POST</td>
<td>(s)/studies/{studyUID}</td>
<td>Store PS3.18 6.6.1</td>
<td>Store instances</td>
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<td>Retrieve PS3.18 6.5.6</td>
<td>Retrieve metadata</td>
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<tr>
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<td>Query PS3.18 6.7.1</td>
<td>Query for matching series in a study</td>
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<td>Retrieve series metadata</td>
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<tr>
<td>GET</td>
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<td>Query PS3.18 6.7.1</td>
<td>Query for matching instances in a series</td>
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<td>Retrieve instance</td>
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<td>GET</td>
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<td>Retrieve PS3.18 6.5.4</td>
<td>Retrieve frames in an instance</td>
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**Workflow Resources and Actions**

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<thead>
<tr>
<th>Verb</th>
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<td>(s)/workitems</td>
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<td>GET</td>
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<tr>
<td>POST</td>
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<td>PS3.18 6.9.7</td>
<td>CreateSubscription</td>
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<td>POST</td>
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<td>SuspendGlobalSubscription</td>
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<td>DELETE</td>
<td>(s)/workitems/({AFFECTED SOP Instance UID})/subscribers/({AETitle})</td>
<td>PS3.18 6.9.9</td>
<td>DeleteSubscription</td>
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<td>PS3.18 6.9.11</td>
<td>SendEventReport</td>
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**Payloads**

**XML**

```xml
<NativeDicomModel>
  <DicomAttribute Tag="00080020" "00080020"> "00080020":
  <Value>
    "Value":
    number="1">20130409</value>
</DicomAttribute>
  <DicomAttribute Tag="00080030" "00080030"> "00080030":
  <Value>
    "Value":
    number="1">131600.0000</value>
</DicomAttribute>
</NativeDicomModel>
```

**JSON**

```json
{
  "DicomAttribute": {
    "Tag": "00080020",
    "Value": "00080020",
    "number": "1": "20130409",
    "DicomAttribute": {
      "Tag": "00080030",
      "Value": "00080030",
      "number": "1": "131600.0000"
    }
  }
}
```

(These payloads are excerpts to show payload structure; these are not complete)

**More Information**

Security concerns

- You will be breached
- There is no such thing as a “secure internal” network – trend to "zero trust" paradigm
- All transactions should be secured (encrypted: DICOM, HTTP over TLS)
- This includes scanner to PACS, camera to PACS, viewer to PACS, ...
- Mobile devices – lack of physical control, BYOD, need to purge cached content, ...
- Encryption at rest (on disk) as well as in transit (on wire, in air)
- Think beyond regulatory (HIPAA, GDPR) compliance: availability – ransomware
- DICOM defines access control, integrity and encryption mechanisms – but hardly anybody implements or activates them
- DICOMweb inherits multitude of standard web approaches for RESTful APIs
- Access control standards – IHE Internet User Authentication (IUA) – OAuth, JWT
- Confidentiality, integrity and availability (CIA triad)
- A primary motivation for “enterprise” imaging is enterprise level security/reliability
Privacy concerns

• Largely ignored for radiology in the past
• Especially challenging for some types of enterprise imaging
• E.g., nude whole body/genitalia, pediatric, distressing (burn/trauma) photography
• Balance risk against utility, user acceptance and safety
• Genuine patient/worker concern v. obsessive political correctness
• Sensitivity classification model/attributes/flags (different policy for different images)
• Patient consent or restriction model/attributes/flags
• Role-based access control (RBAC), Attribute-based access control (ABAC), ...
• Patient-specific care team + role in care + off-hours coverage
• Genuine restriction of access versus policy + retrospective audit
• Beyond state of the art in current EMRs, PACS, VNAs? Separate "pools"?
• Leverage enterprise-wide identity management solutions across EMR & PACS
DICOM and Whole Slide Imaging

DICOM C-STORE

Leica
MICROSYSTEMS

PHILIPS

Roche

Motic

HURON Digital Pathology

NEAGEN

PACS +/- APLIS

Archive

Manager

DICOM WADO-RS

SECTRA

Pathcore

Workstations

DPA PV 2018
DICOM and Whole Slide Imaging

DICOM C-STORE

DICOM WADO-RS

PACS +/- APLIS

Archive

Manager

Slide Scanner

Slide Scanner

Slide Scanner

Slide Scanner

Workstations
We are from Enterprise IT and are here to help you!