Basic DICOM Concepts with Healthcare Workflow

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Co-Chair DICOM Standards Committee
Overview

• DICOM Terminology and Functionality!
• HL7 Terminology and Functionality!
• How DICOM & HL7 work together in the Healthcare Workflow?
• How does IHE fit in to this?
DICOM and HL7 have Common Goals

- They allow electronic healthcare information to be:
  - exchanged, integrated, shared, and retrieved

- They support:
  - clinical practice and management
  - delivery and evaluation of healthcare services

- They were specifically created to allow:
  - flexible, cost effective approaches, guidelines, methodologies and related services
  - for interoperability between healthcare information systems
The DICOM Standard

- **DICOM covers:**
  - Communication protocols over networks
  - Communication via interchangeable media
  - Data content
  - Functional application services
  - Consistent display of images across devices
  - Security and configuration management
  - Physician defined look and feel of display (Hanging Protocols)
  - Identifying and grouping related information (Structured Reports)
  - Etc.
The DICOM Standard

• **DICOM does not cover:**
  - Anything related to **implementation**
    - Database structure
    - Programming languages
    - Hardware
    - Operating systems
    - etc.
  - How and what data to process
  - Graphical user interface design
DICOM Message/File Content
(Information Object Definition – IOD)

Information Entities

Patient Information

Study Information

Series Information

Instance (Image) Information

Modules

Patient Module

General Study Module

Patient Study Module*

General Series Module

Frame of Reference Module

General Equipment Module

Attributes

Image Pixel Module

Row/Col Size

Photometric Interpretation

SOP Common Module

SOP Module

VOI LUT Module

Contrast/Bolus Module

Overlay Plane Module*

Image Plane Module

General Image Module

Image Module

DICOM 2005 International Conference
Budapest, Hungary
September 26, 2005
DICOM Transfer via Network or Media

Media Transfer = Meta Data + Data Set
  Group 2
    (Describes Data Set)
  Group 0
    (Describes Service: C-Store)

Network Transfer = Command + Data Set

DICOM [ . . . . . MESSAGE . . . . . ]

DICOM [ . . . . . FILE . . . . . . . . . . ]

Header

Image

Patient Name
Patient ID
Study Date
Study Time
Row Size
Column Size

Patient Name
Patient ID
Study Date
Study Time
Row Size
Column Size
DICOM Functional Service Groups

Image Related Information Transfer
- Persistent Object Storage
- Query Request
- Retrieve Request
- Persistent Object Storage

Image Related Workflow and Information Management

Print Management
- Print Images

Media Interchange
Functional DICOM Application Services (SOP Classes)

- DICOM supports many functions over Networks:
  - A CT transferring CT images to a remote archive for Storage
  - An MR workstation sending 12 images and a film layout to a departmental film printer for Printing a hardcopy film
  - An Ultra Sound device querying a Radiology Information System (RIS) for a list of all the patients scheduled for the next 8 hours, along with the procedures to be performed for each of the scheduled patients

- DICOM supports storage of data for many different applications on Interchangeable Media:
  - A technologist storing a patient's Digital X-Ray images on a CD so that the patient can take them to her personal doctor
  - A radiologist sending a Mammography study on a DVD to another radiologist for consultation (no network available)
Service Class

• A Service Class is a group of commonly functioning SOP Classes
  • Storage Service Class
  • Print Management Service Class
  • Study Management Service Class

• A Service Class has Rules and Behaviors that are defined and must be adhered by products that claim to be DICOM Compliant via a DICOM Conformance Statement
Handshake Requirements

**CT Config File**

<table>
<thead>
<tr>
<th>IP Addr</th>
<th>AE Title</th>
<th>Port #</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Fusion</td>
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</tr>
<tr>
<td>10.3.253.9</td>
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<td>4006</td>
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**Wkstn Config File**

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<th>AE Title</th>
<th>Port #</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.3.253.1</td>
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<td>104</td>
</tr>
<tr>
<td>10.3.253.8</td>
<td>CT_AE1</td>
<td>104</td>
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</table>

**Node Level Security**

**Association / Negotiation**

**ID:** CT_AE1  
**IP:** 10.3.253.8  
**Port:** 104

**ID:** WK_AE1  
**IP:** 10.3.253.9  
**Port:** 4006
Typical Network Flow

DICOM AE “A”

A-ASSOCIATE-RQ

DICOM AE “B”

A-ASSOCIATE-AC

or

A-ASSOCIATE-RJ

DICOM Messages

A-RELEASE-RQ

A-RELEASE-RSP

or

A-ABORT

Either AE

Only The AE Which Initiated The Association May Release It

However, Either May Initiate An A-ABORT
Providers and Users of DICOM Functions over the Network

• Service Class Provider (SCP):
  • Application that is Providing the Service for a particular DICOM Function (SOP Class).
  • Therefore, a device that can receive CT images over a network utilizing the DICOM protocol and stores those received CT images in its databases would be called, in DICOM terms:
    • a CT Image Storage SOP Class
    • that plays the network role of an SCP
    • and follows the rules of the Storage Service Class.

• Service Class User (SCU):
  • Application using a particular DICOM Function (SOP Class)
DICOM Network Roles

- Successful communication - products must play “opposite roles”
  - Receive images = Service Class Provider (SCP)
  - Send images = Service Class User (SCU)

Network roles are defined for all DICOM Functions
DICOM Media Interchange

**DICOMDIR**
- A “directory file”, which is required for DICOM Media
- Contains pointers to a list of DICOM files on a CD, DVD, MOD, Flash Memory, etc.
- Used to locate and load DICOM files from a CD, DVD, etc.
- Is a file with a Meta Header (Group 2) + Directory Attributes (Group 4) + Key Attributes for Searching (regular Data Set Attributes)

**DICOM File**
- Is a file with a Meta Header (Group 2) + a Data Set
- Is pointed to by DICOMDIR
- Has filename of 1-8 Characters with NO extension
DICOM Media Interchange

- Application profiles define a selection of choices applicable to a specific context for exchanging media (e.g. Cardiac profile - 512 X-ray Angio, Lossless JPEG, CD-R)
- The profile “negotiates” the media capabilities
- More than one application profile may exist on a specific media
- A device may support one or more of the following roles:
  - File-Set Creator (FSC) - initialize new media and write SOP instances
  - File-Set Reader (FSR) - read the medical directory and selected SOP instances
  - File-Set Updater (FSU) - read and update the medical directory as well as SOP instances on the media
Network and Media Interchange

• **Common Image Types**
  • Single image, monochrome
  • Single image, color
  • Multiframe
    • Multiple image frames embedded into pixel data
    • One data set (message / file) can contain multiple images
    • Can be monochrome or color

• **Data Set Encoding**
  • Uncompressed Pixel Data (Transfer Syntax = Implicit VR Little Endian (Default for Network Only), Explicit VR Little Endian and Explicit VR Big Endian)
  • Compressed Pixel Data Only with Explicit VR Little Endian encoding
    • JPEG Lossless
    • JPEG Lossy
    • RLE (Run Length Encoded)
    • JPEG 2000 (Wavelet based)
  • Compressed Data Set
    • Deflated Explicit VR Little Endian (Public Domain “ZIP” format)
DICOM Transfer over Network & Media

**DICOM** [ . . . . . . . FILE . . . . . . . . . . ]

*Media Transfer* = *Meta Data* +

*Group 2* (Describes Data Set)

*Transfer Syntax is NOT* Implicit VR Little Endian

*Group 0* (Describes Service: C-Store)

Network Transfer = Command +

**DICOM** [ . . . . . . MESSAGE . . . . . . ]

- **Header**
  - Patient Name
  - Patient ID
  - Rows
  - Columns
  - Bits Stored
    - ...

- **Image**
  - Default Transfer Syntax is Implicit VR Little Endian
DICOM Conformance Statement

- It is Required!
- It is a Public Document
- It Conveys a Product’s DICOM Functionality
- It is Based on DICOM Vocabulary
  - Abstract Syntaxes (SOP Classes), Transfer Syntaxes, SCU/SCP…..
- It is Used to Compare Connectivity
- It is most Often on the Web @ Vendor Site
- It Does Not Address All of an Application’s Capabilities, but should Address All of the Application’s DICOM ones

A Major Step Towards Interoperability

Ok, you say its DICOM, prove it!
The HL7 Standard

Health Level Seven Text based Messages

- Messages are sent when an Event occurs
  - Patient gets registered for exam
  - Order is issued for exam
  - Patient arrives at hospital
  - Exam complete (Ready for Billing)

- How messages get where they are needed
  - Normally via a Network (TCP/IP over Ethernet or any of the hardware communication protocols, including wireless)
  - Probably via an Interface Engine
    - An intermediate application that can map HL7 messages from one interpretation to another and also route it to all the destinations that need it
Patient William A. Jones, III was admitted on August 18, 1988 at 11:23 a.m. To be attended by doctor Sidney J. Lebauer (#004777) for surgery (SUR). He has been assigned to room 2012, bed 01 on nursing unit 2000. His wife, Barbara K. Jones is a related family member (next of kin).
## Encoding Requirements of Previous Message - ADT^A01 v2.4

<table>
<thead>
<tr>
<th>Segment</th>
<th>Description</th>
<th>Chapter</th>
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<tr>
<td>MSH</td>
<td>Message Header</td>
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<tr>
<td>EVN</td>
<td>Event Type</td>
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<tr>
<td>PID</td>
<td>Patient Identification</td>
<td>3</td>
</tr>
<tr>
<td>[ PD1 ]</td>
<td>Additional Demographics</td>
<td>3</td>
</tr>
<tr>
<td>[{ ROL }]</td>
<td>Role</td>
<td>12</td>
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<td>[{ NK1 }]</td>
<td>Next of Kin / Associated Parties</td>
<td>3</td>
</tr>
<tr>
<td>PV1</td>
<td>Patient Visit</td>
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<tr>
<td>[ PV2 ]</td>
<td>Patient Visit - Additional Info.</td>
<td>3</td>
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<tr>
<td>[{ ROL }]</td>
<td>Role</td>
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<td>[{ DB1 }]</td>
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</tr>
<tr>
<td>[{ OBX }]</td>
<td>Observation/Result</td>
<td>7</td>
</tr>
<tr>
<td>[{ AL1 }]</td>
<td>Allergy Information</td>
<td>3</td>
</tr>
<tr>
<td>[{ DG1 }]</td>
<td>Diagnosis Information</td>
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<td>[{ DRG }]</td>
<td>Diagnosis Related Group</td>
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<td>[{ GT1 }]</td>
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<td>[{ IN1 }]</td>
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<td>[{ IN3 }]</td>
<td>Insurance Additional Info - Cert.</td>
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<td>[{ ROL }]</td>
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<tr>
<td>[ ACC ]</td>
<td>Accident Information</td>
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<tr>
<td>[ UB1 ]</td>
<td>Universal Bill Information</td>
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<tr>
<td>[ UB2 ]</td>
<td>Universal Bill 92 Information</td>
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</tr>
<tr>
<td>[ PDA ]</td>
<td>Patient Death and Autopsy</td>
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</table>

Extracted From HL7 v2.4 3.3.1

This is a Message defined by Segments

= Required
[ ] = Optional
{ } = Repeatable
### PID - Patient ID Segment Table (partial)

<table>
<thead>
<tr>
<th>SEQ</th>
<th>LEN</th>
<th>DT</th>
<th>OPT</th>
<th>RP/#</th>
<th>TBL#</th>
<th>ITEM#</th>
<th>ELEMENT NAME</th>
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<td>1</td>
<td>4</td>
<td>SI</td>
<td>O</td>
<td></td>
<td></td>
<td>00104</td>
<td>Set ID - Patient ID</td>
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<tr>
<td>2</td>
<td>20</td>
<td>CX</td>
<td>O</td>
<td></td>
<td></td>
<td>00105</td>
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<td>3</td>
<td>20</td>
<td>CX</td>
<td>R</td>
<td>Y</td>
<td></td>
<td>00106</td>
<td>Patient ID (Internal ID)</td>
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<td>4</td>
<td>20</td>
<td>CX</td>
<td>O</td>
<td>Y</td>
<td></td>
<td>00107</td>
<td>Alternate Patient ID - PID</td>
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<tr>
<td>5</td>
<td>48</td>
<td>XPN</td>
<td>R</td>
<td>Y</td>
<td></td>
<td>00108</td>
<td>Patient Name</td>
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<tr>
<td>6</td>
<td>48</td>
<td>XPN</td>
<td>O</td>
<td></td>
<td></td>
<td>00109</td>
<td>Mother's Maiden Name</td>
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<tr>
<td>7</td>
<td>26</td>
<td>TS</td>
<td>O</td>
<td></td>
<td></td>
<td>00110</td>
<td>Date/Time of Birth</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>IS</td>
<td>O</td>
<td></td>
<td>0001</td>
<td>00111</td>
<td>Sex</td>
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<td>O</td>
<td>Y</td>
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<td>00112</td>
<td>Patient Alias</td>
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<td>O</td>
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<td>O</td>
<td>Y</td>
<td></td>
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<td>Y</td>
<td></td>
<td>00116</td>
<td>Phone Number - Home</td>
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</tbody>
</table>

MSH|^~\&|ADMIN|MCM|LABADT|MCM|198808181126|SECURITY|ADT^A01|MSG00001|P|2.4<cr>

EVN|A01|198808181123<cr>

PID|1||PATID1234^5^M11^ADT1^MR^MCM~123456789^^^^USSSA^SS||JONES^WILLIAM^A^III||19610615|M^-|C|1200 N ELM STREET^^GREENSBORO^NC^27401-1020|GL|(919)379-1212|(919)271-3434|M||PATID12345001^2^M10^ADT1^AN^A|123456789|9-87654^NC|<cr>

NK1|1|JONES^BARBARA^K|WI^WIFE|||NK^NEXT OF KIN<cr>

PV1|1||2000^2012^01|||004777^LEBAUER^SIDNEY^J.||SUR|||ADM|A0-|<cr>
Primary HL7 Messages used for PACS

- **ADT** – Admit, Discharge, Transfer Message
  - Used for registering a patient for a specific exam
  - Used for admitting a patient into the hospital
  - Used for discharging a patient from the hospital

- **ORM** – Order Message
  - Used for ordering a specific exam

- **ORU** – Report Message
  - Used to send a report to a place where it is needed
Link HIS/RIS Data Into Images

Information Entities

- **Patient Information**
- **Study Information**
- **Series Information**
- **Instance (Image) Information**

**Modules**

- Patient Module
- General Study Module
- Patient Study Module
- General Series Module
- Frame of Reference Module
- General Equipment Module
- Image Module
- Overlay Plane Module
- VOI LUT Module
- SOP Common Module

**Attributes**

- Patient’s Name
- Patient’s ID
- Patient’s Birthdate
- Patient’s Sex
- Patient’s Weight
- Referring Physician’s Name
- Accession Number
- Study Instance UID

... other information
The e-Health Workflow

**Internal**
- Admin
- Tech
- Radiologist
- Finance

**External**
- Patients
- Referring Physicians
- Payers

- Referrals / Orders
- Reimbursement

- Images
- Reports
- Claims
A Sample Workflow

1. A. Patient visits Physician, who then determines that some diagnostic imaging exam must be done.

2. B. Request for Service is Faxed from Referring Physician to Medical Orders Department in Hospital.

3. C. Scheduling Department orders appropriate Procedure to be Performed at a specific time, by a specific Modality.

4. D. Lab/Results (ORM)

5. E. Patient Admittance (ADT)

6. F. Lab/Results ORU

7. G. Ordered Procedure (ORM)

8. H. Modality requests Worklist from RIS via DICOM

9. I. Modality sends information about Procedure Performed to RIS via DICOM

10. J. RIS sends information about When, How, and What procedure steps have been completed to the HIS via HL7

11. K. RIS sends notification of Performed Procedure to PACS

12. L. PACS systems requests selected info about Performed Procedure from RIS via DICOM

13. M. Modality sends Images to PACS system via DICOM

14. N. Modality request PACS system to let it know when all images sent have been reliably stored via STORE

15. O. After all requested Images are safely Archived to the PACS, the system sends a COMMITMENT NOTIFY.

16. P. PACS systems requests selected info about Performed Procedure from RIS via DICOM

17. Q. The PACS sends requested, pre-fetched, and auto-routed MWL.

18. R. Rad Rvw

19. S. The WEB Server can query and retrieve for whatever

20. T. The PACS sends requested, pre-fetched, and auto-routed MWL.

21. U. Final Diagnostic Reports are sent to either or both the Lab and WEB Server usually has final Diagnostic Reports as well.

22. V. Lab Results Charges

23. W. ADT/ORU

24. X. Insurance and Billing might be done utilizing the X.12 standard (one of many used in conjunction with HL7).

DICOM

- Modality Performed Procedure Step (MPPS)
- Modality Worklist (MWL)
- Store Images
- MPPS Notify
- MPPS Retrieve
- Store Report SR or ORU
- Query/Retrieve
- Store Images
- Store ORU

WEB Server

- Query/Retrieve
- Referring Physician / Surgeon / E-R / ??

Lab

- Lab/Results ORU
- ADT/ORU
- HL7
- X.12
- ASTM
IHE
Integrating the Healthcare Enterprise

Initiative promoting and supporting the integration of systems in the healthcare enterprise

Improve the efficiency and effectiveness of clinical practice by improving information flow
What is IHE?

- Standards based communication between healthcare systems
  - HL7 and DICOM are two of these standards
- **Actors**: perform communications roles between systems
- **Transactions**: messages sent between systems
- **Integration Profiles**: grouping of actors and transactions to perform specific workflows
Usage of IHE

• Integration Profiles
  • Integrated solutions that support specific workflows in Radiology, Information Technology, Cardiology, Laboratory, Radiation Oncology, etc.

• User and Vendor Communications
  • Integration Profiles provide common language for discussion
    • To help specify which specific clinical functions are needed within a product
    • To help identify what kind of information must be sent or received to accomplish those clinical functions
IHE brings Reality to the Healthcare Workflow

- It is not a standard, but utilizes Standards.
- It is really a blueprint trying to solve tricky workflow problems.
- There is enormous intellectual property in IHE and extremely thorough solutions to problems.
- Tapping into the experience and knowledge is free.
- In many ways IHE is the lessons learned from all those who have tried to go soft-copy in the past decade and ran into stumbling blocks, plus much more.
DICOM Does Not Stand Alone!

Many standards and initiatives work together to help us implement the electronic information workflow within our healthcare environments.

DICOM is just one of those standards.