DICOM INTERNATIONAL CONFERENCE & SEMINAR

Oct 9-11, 2010 Rio de Janeiro, Brazil

CBR 10
XXXIX Congresso Brasileiro de Radiologia

DICOM SM
Digital Imaging and Communications in Medicine

Extracting, Managing and Rendering DICOM Radiation Dose Information from Legacy & Contemporary CT Modalities

David Clunie

CoreLab Partners, Inc.

CoreLab PARTNERS

Background

- **Utilization of CT has exploded**
- **Technology allows faster delivery of higher doses**
- **Speed has led to newer applications that acquire many more slices at same location (e.g., perfusion)**
- **Dose may be cumulative & harmful**
- **Monitoring & alerting is required**

Jacoby Roth Incident

DICOM
Digital Imaging and Communications in Medicine

New York Times 2009/10/16 (supplied by family's attorney with PHI as published)

Standards for the Future

DICOM
Digital Imaging and Communications in Medicine

- **Way forward is clear**
  - all new equipment should encode dose in DICOM Radiation Dose Structured Reports (RDSR)
  - all devices should support IHE Radiation Exposure Monitoring (REM) profile, which addresses modality, storage, reporting and registry submission
- **Commitment by vendors to update**
  - “current platform” only

DICOM CT RDSR

CT RADIATION DOSE SR IOD TEMPLATES

The templates that comprise the CT Radiation Dose SR are interconnected as in Figure A-12

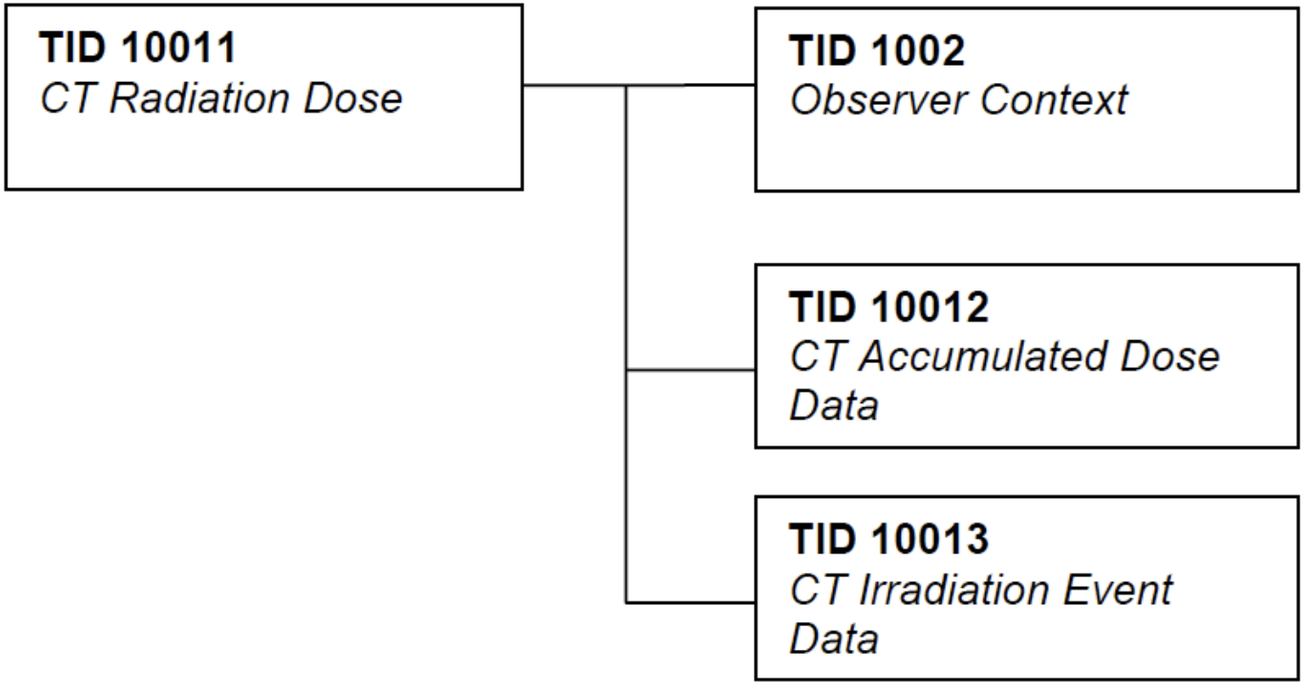


Figure A-12: CT Radiation Dose SR IOD Template Structure

DICOM CT RDSR

DICOM℠
Digital Imaging and Communications in Medicine

- : CONTAINER: X-Ray Radiation Dose Report [SEPARATE] (DCMR,10011)
  - HAS CONCEPT MOD: CODE: Procedure reported = Computed Tomography X-ray
    - HAS CONCEPT MOD: CODE: Has Intent = Diagnostic Intent
  - HAS OBS CONTEXT: CODE: Observer Type = Device
  - HAS OBS CONTEXT: TEXT: Device Observer Name = ilqhfaatc1ws444
  - HAS OBS CONTEXT: TEXT: Device Observer Manufacturer = Philips
  - HAS OBS CONTEXT: TEXT: Device Observer Model Name = Brilliance 64
  - HAS OBS CONTEXT: TEXT: Device Observer Physical Location During Observation = PMSTL
  - HAS OBS CONTEXT: DATETIME: Start of X-ray Irradiation = 20100422162839.030
  - HAS OBS CONTEXT: CODE: Scope of Accumulation = Study
    - HAS PROPERTIES: UIDREF: Study Instance UID = 1.2.840.113704.1.111.6084.1271942101.12
  - CONTAINS: CONTAINER: CT Accumulated Dose Data [SEPARATE]
    - CONTAINS: NUM: Total Number of Irradiation Events = 2 events
    - CONTAINS: NUM: CT Dose Length Product Total = 19.67375 mGycm
  - CONTAINS: CONTAINER: CT Acquisitions [SEPARATE]
  - CONTAINS: CONTAINER: CT Acquisitions [SEPARATE]
    - CONTAINS: CODE: Acquisition Type = Sequenced Acquisition
    - CONTAINS: CODE: Procedure Context = CT without contrast
    - CONTAINS: UIDREF: Irradiation Event UID = 1.2.840.113704.1.111.6084.1271942101.12.2
    - CONTAINS: CONTAINER: CT Acquisition Parameters [SEPARATE]
      - CONTAINS: NUM: Exposure Time = 4254 s
      - CONTAINS: NUM: Scanning Length = 10 mm
      - CONTAINS: NUM: Nominal Single Collimator Width = 0.625 mm
      - CONTAINS: NUM: Nominal Total Collimator Width = 1.25 mm
      - CONTAINS: NUM: Number of X-ray Sources = 1 X-ray sources
      - CONTAINS: CONTAINER: CT X-ray Source Parameters [SEPARATE]
    - CONTAINS: CONTAINER: CT Dose [SEPARATE]
      - CONTAINS: NUM: Mean CTDIvol = 1.3978125 mGy
      - CONTAINS: CODE: CTDIw Phantom Type = IEC Body Dosimetry Phantom
      - CONTAINS: NUM: DLP = 16.77375 mGycm
    - CONTAINS: CODE: Device Role in Procedure = Irradiating Device
      - HAS PROPERTIES: TEXT: Device Manufacturer = Philips
      - HAS PROPERTIES: TEXT: Device Model Name = Brilliance 64
  - CONTAINS: CODE: Source of Dose Information = Automated Data Collection

DICOM CT RDSR

DICOM℠
Digital Imaging and Communications in Medicine

- : CONTAINER: X-Ray Radiation Dose Report [SEPARATE] (DCMR,10011)
  - HAS CONCEPT MOD: CODE: Procedure reported = Computed Tomography X-ray
    - HAS CONCEPT MOD: CODE: Has Intent = Diagnostic Intent
  - HAS OBS CONTEXT: CODE: Observer Type = Device
  - HAS OBS CONTEXT: TEXT: Device Observer Name = ilqhfaatc1ws444
  - HAS OBS CONTEXT: TEXT: Device Observer Manufacturer = Philips
  - HAS OBS CONTEXT: TEXT: Device Observer Model Name = Brilliance 64
  - HAS OBS CONTEXT: TEXT: Device Observer Physical Location During Observation = PMSTL
  - HAS OBS CONTEXT: DATETIME: Start of X-ray Irradiation = 20100422162839.030
  - HAS OBS CONTEXT: CODE: Scope of Accumulation = Study
    - HAS PROPERTIES: UIDREF: Study Instance UID = 1.2.840.113704.1.111.6084.1271942101.12
  - CONTAINS: CONTAINER: CT Accumulated Dose Data [SEPARATE]
    - CONTAINS: NUM: Total Number of Irradiation Events = 2 events
    - CONTAINS: NUM: CT Dose Length Product Total = 19.67375 mGycm
  - CONTAINS: CONTAINER: CT Acquisitions [SEPARATE]
  - CONTAINS: CONTAINER: CT Acquisitions [SEPARATE]
    - CONTAINS: CODE: Acquisition Type = Sequenced Acquisition
    - CONTAINS: CODE: Procedure Context = CT without contrast
    - CONTAINS: UIDREF: Irradiation Event UID = 1.2.840.113704.1.111.6084.1271942101.12.2
    - CONTAINS: CONTAINER: CT Acquisition Parameters [SEPARATE]
      - CONTAINS: NUM: Exposure Time = 4254 s
      - CONTAINS: NUM: Scanning Length = 10 mm
      - CONTAINS: NUM: Nominal Single Collimator Width = 0.625 mm
      - CONTAINS: NUM: Nominal Total Collimator Width = 1.25 mm
      - CONTAINS: NUM: Number of X-ray Sources = 1 X-ray sources
      - CONTAINS: CONTAINER: CT X-ray Source Parameters [SEPARATE]
    - CONTAINS: CONTAINER: CT Dose [SEPARATE]
      - CONTAINS: NUM: Mean CTDIvol = 1.3978125 mGy
      - CONTAINS: CODE: CTDIw Phantom Type = IEC Body Dosimetry Phantom
      - CONTAINS: NUM: DLP = 16.77375 mGycm
    - CONTAINS: CODE: Device Role in Procedure = Irradiating Device
      - HAS PROPERTIES: TEXT: Device Manufacturer = Philips
      - HAS PROPERTIES: TEXT: Device Model Name = Brilliance 64
  - CONTAINS: CODE: Source of Dose Information = Automated Data Collection

Dilemma

- **What to do about older scanners**
  - that are not yet updated, and may never be
  - vast majority of global installed base
  - what existing capabilities can be leveraged ?
- **What about new objects in old PACS ?**
  - new modalities may produce RDSR, but …
  - site has no system to view, aggregate, report
- **Even for old images in the archive …**
  - Vast collection of reference dose information
  - Manual recording is tedious (== expensive)
  - Prior data for patients with new studies

Old Scanners

- **Usually no explicit dose information**
  - just technique (kVP, mA, etc.)
  - scanner-specific dosimetry efforts (ImPACT)
  - Garcia MS et al. 2009
- **Human-readable "dose screens"**
  - provided by vendors in response to German reporting initiative
  - CTDIvol and DLP per series & total DLP
  - not (generally) machine-readable

Dose Screen - GE

DICOM
Digital Imaging and Communications in Medicine

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

Key Fields to Extract

DICOM℠
Digital Imaging and Communications in Medicine

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

Additional Fields to Extract

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

Available from “Header”

DICOM
Digital Imaging and Communications in Medicine

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

Dose Screen - Siemens

15-Jul-20

Ward:
Physician:
Operator:

Total mAs 15323 Total DLP 1601 mGy*cm

	Scan	kV	mAs / ref.	CTDIvol mGy	DLP mGy*cm	TI s	cSL mm
Patient Position H-SP							
AP Scout	1	120	36 mA			2.7	0.6
Lateral Scout	2	120	36 mA			2.7	0.6
CCS	3D	120	150	8.49	122	0.2	3.0
Last scan no.	10						
PreMonitoring	11	120	20	0.90	1	0.33	10.0
I.V. Bolus							
Monitoring	12	120	20	9.73	10	0.33	10.0
Last scan no.	22						
Coronary Angio	23D	120	350	91.74	1468	0.33	0.6

Key Fields to Extract

DICOM℠
Digital Imaging and Communications in Medicine

15-Jul-20

Ward:
Physician:
Operator:

Total mAs 15323 | Total DLP 1601 mGy*cm

	Scan	kV	mAs / ref.	CTDIvol mGy	DLP mGy*cm	TI s	cSL mm
Patient Position H-SP							
AP Scout	1	120	36 mA			2.7	0.6
Lateral Scout	2	120	36 mA			2.7	0.6
CCS	3D	120	150	8.49	122	0.2	3.0
Last scan no.	10						
PreMonitoring	11	120	20	0.90	1	0.33	10.0
I.V. Bolus							
Monitoring	12	120	20	9.73	10	0.33	10.0
Last scan no.	22						
Coronary Angio	23D	120	350	91.74	1468	0.33	0.6

Additional Fields to Extract

DICOM
Digital Imaging and Communications in Medicine

15-Jul-20

Ward:
Physician:
Operator:

Total mAs 15323 Total DLP 1601 mGy*cm

	Scan	kV	mAs / ref.	CTDIvol mGy	DLP mGy*cm	TI s	cSL mm
Patient Position H-SP							
AP Scout	1	120	36 mA			2.7	0.6
Lateral Scout	2	120	36 mA			2.7	0.6
CCS	3D	120	150	8.49	122	0.2	3.0
Last scan no.	10						
PreMonitoring	11	120	20	0.90	1	0.33	10.0
I.V. Bolus							
Monitoring	12	120	20	9.73	10	0.33	10.0
Last scan no.	22						
Coronary Angio	23D	120	350	91.74	1468	0.33	0.6

Goals

- **What to extract ?**
  - minimal information (e.g., Total DLP)
  - enough to “create” a valid DICOM RDSR
- **Why ?**
  - feed proprietary reporting/database system
  - contribute to IHE REM (pseudo-modality)

How ?

- **Optical Character Recognition (OCR)**
  - more straightforward than for scanned paper
  - consistent font, spacing and alignment
- **Parsing of Extracted Text**
  - also straight forward
  - keywords, headings, column layout of data
  - can use regular expressions for matching
- **Matching extracted values to header**
  - to get other acquisition info like kVP

Challenges

- **Query and retrieval of dose screens**
- **Extracting sufficient information**
  - matching against actual series
  - information from reconstructed images
  - extracting anatomy and procedure
  - extracting phantom information
  - extracting scanning range
  - establishing scope of accumulation
  - absent Irradiation Event UID

Challenges – Retrieval

- **Retrieving just dose screens**
  - entire study may be very large size
  - Series Number
    - GE Series 999 (screen), 997 (RDSR)
    - Siemens Series 501 (screen)
  - Series Description
    - may not be consistent across languages
  - Image Type
    - GE DERIVED\SECONDARY\SCREEN SAVE
    - Siemens DERIVED\SECONDARY\OTHER\CT_SOM5 PROT
    - Philips – contains DOSE_INFO, DOSE-INFO or LOCALIZER

Challenges – Series

- **Matching against actual series**
  - Series or Acquisition Number ?
    - GE – Series Number
    - Siemens – Acquisition Number
  - what if dose changes *during* series
    - GE – Series Number repeated
    - may need to match scanning ranges

Challenges – Images

- **Is information needed from reconstructed image "headers" ?**
  - RDSR distinguishes (and requires)
    - accumulated information
    - per-acquisition (irradiation event) information
  - large data volume to scan (slow)
  - match by series or acquisition
  - extract
    - technique (kVP, mA, pitch, mode)
    - anatomy

Challenges - Anatomy

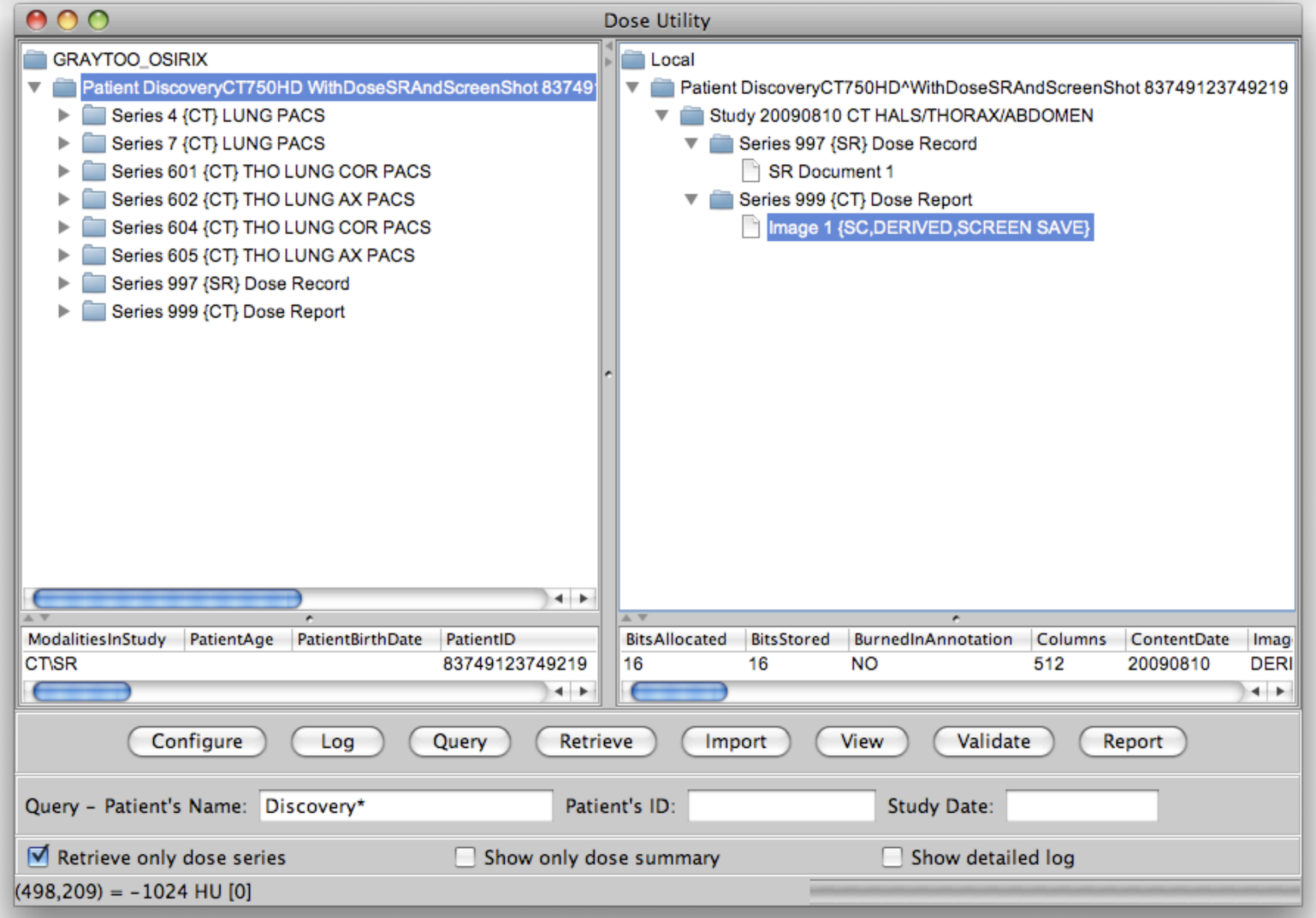
- **No coded anatomy information present**
  - legacy scanner consoles
    - no place to select anatomy from standard list
    - not available from Modality Work List (MWL)
    - not copied from protocols
  - so Body Part Examined and Anatomic Region Sequence usually empty or absent
- **Attempt to parse plain text**
  - challenging across multiple languages
  - abbreviations and punctuation are problematic
    - C/A/P versus CAP versus Chest/Abdomen/Pelvis
  - can make a “best effort” at Study & Series levels

Implementation

- **Added to Pixelmed DICOM toolkit**
  - pure Java, open source
  - existing support for Structured Reports
  - added own primitive minimal sufficient OCR
  - classes to parse known screen patterns
  - classes to represent dose information model
  - classes to extract coded anatomy from plain text
- **DoseUtility**
  - demonstration Java Web Start (JWS) app
  - query/retrieve/parse/view/report screen & SR

Dose Utility Prototype

DICOM
Digital Imaging and Communications in Medicine



Dose Utility Prototype

DICOM
Digital Imaging and Communications in Medicine

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 mGycm BODY32
	Series=5	Helical	S188.000-I105.000 mm	5.10 mGy	182.72 mGycm BODY32

Reporting complete

Clear

Experience with Prototype

- **OCR**
  - easy to train, robust enough, 100% accuracy
- **Regular expression pattern matching**
  - easy to write, 100% accuracy, regression testing
- **Series/acquisition matching**
  - awkward and less reliable
- **Anatomy extraction**
  - often too narrow (e.g., chest, not C/A/P)
- **Patient characteristics**
  - sex, age, weight, height often not populated

Other Topics

- **Philips dose screens & localizers**
  - sensibly included numbers in header
  - no need for OCR
  - tool extracts from Exposure Dose Sequence
- **Modality Performed Procedure Step**
  - a transient message, not a persistent object
  - need to be on-site to get access
  - ? used in practice – not yet in toolkit

Conclusions

- **Legacy dose extraction of critical parameters is straightforward**
- **More detailed technique parameters are harder to extract reliably**
- **Vendors & operators fail to populate critical attributes like anatomy and patient characteristics, limiting use**
- **May be sufficient to compare against or establish reference levels**

Future Directions

- **Toolkit focus is on extraction & SR**
  - populate databases, reporting tools, web services (other developers)
- **On-going and planned work**
  - support more vendors' screens
  - comparison against reference levels
  - automated polling of the PACS to extract
  - insertion inline to the acquisition workflow to automatically generate SR files