(Informatics) Standards for Quantitative Imaging

David A. Clunie

PixelMed

What is Quantitative Imaging?

- ***"Quantitative imaging is the extraction of quantifiable features from medical images for the assessment of normal or the severity, degree of change, or status of a disease, injury, or chronic condition relative to normal … includes the development, standardization, and optimization of anatomical, functional, and molecular imaging acquisition protocols, data analyses, display methods, and reporting structures … permit the validation of accurately and precisely obtained image-derived metrics with anatomically and physiologically relevant parameters, including treatment response and outcome, and the use of such metrics in research and patient care."***

RSNA QIBA

"https://www.rsna.org/QIBA.aspx"

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Opportunities for Standardization

- **Methods, protocols & metrics**
- **Performance standards & benchmarks**
- **Evaluation methods**
- **Encoding of images & results**
- **Terminology & codes**

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- ***Encoding of images & results***
- ***Terminology & codes***

Sound familiar ?

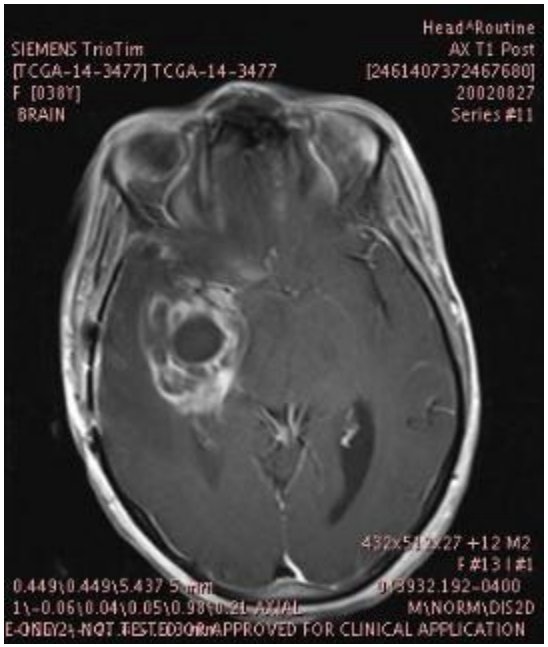
- **DICOM standards in clinical practice**
  - images from modalities
  - derived images – e.g., CBF
  - ROIs – e.g., CT Hounsfield units, PET SUV
  - size measurements – distance, area, volume
- **“Quantitative” imaging is nothing new**
  - different emphasis than narrative reporting

Greater Rigor in Deployment

- **Narrative reporting**
  - see it, compare it, dictate it
- **Quantitative reporting**
  - see it, analyze it, measure it, code it, re-use it
- **Same standards**
  - greater need for numbers & codes
  - more structure

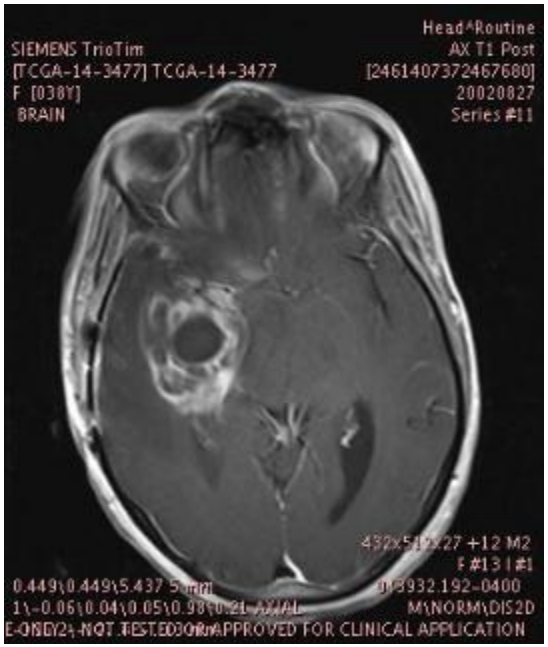
See It

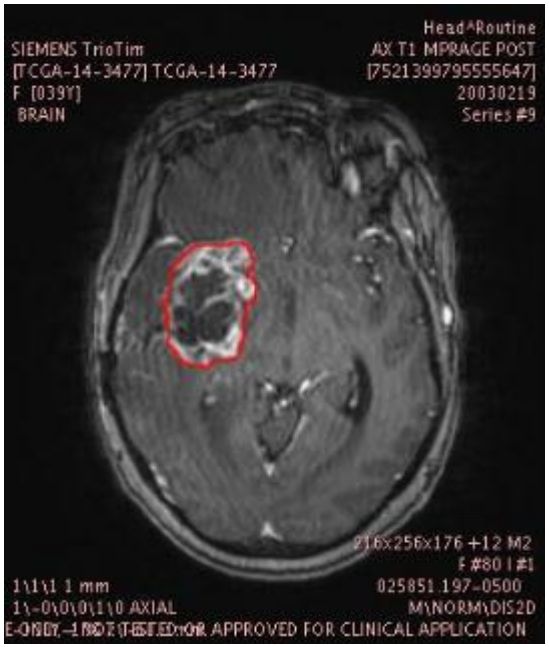
- **Hairy mass, rt. temporal lobe, bigger…**



See It, Analyze It, Measure It

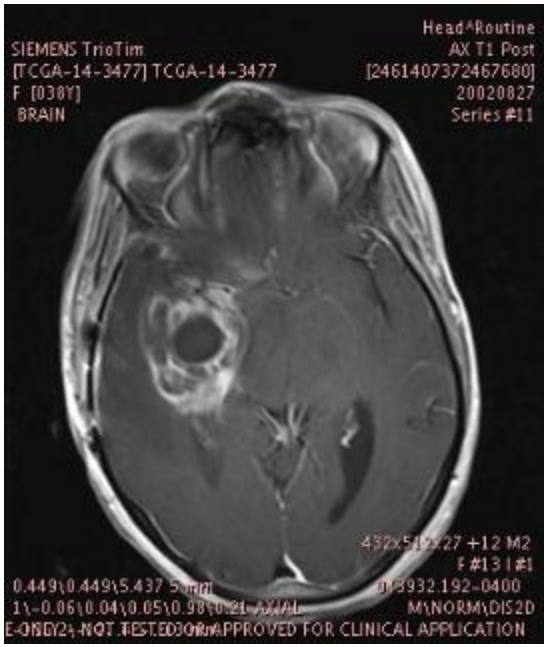
- **Segmented Lesion Volume 31,524 mm^3**





Code It

- **Why, how, what, where …**



(R-F8106,SRT, “Grand mal seizure”)

(24587-8,LN,“MR brain w/wo IVC”)

(F-04E4E,SRT,“Brain mass lesion”)

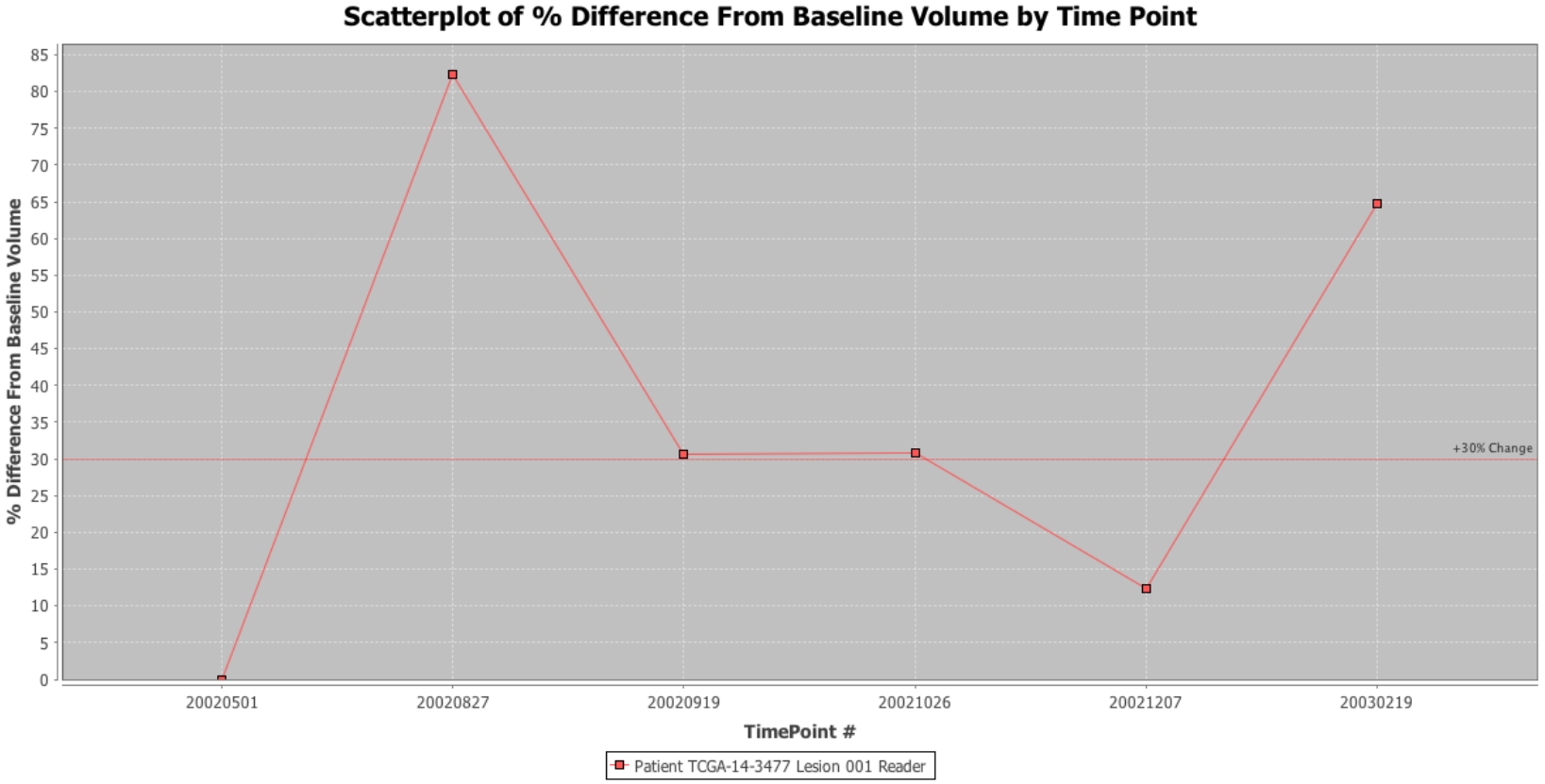
(RID6061,RADLEX, “Circumferential enhancement”)

(T-A250D,SRT,“Right Temporal Lobe)

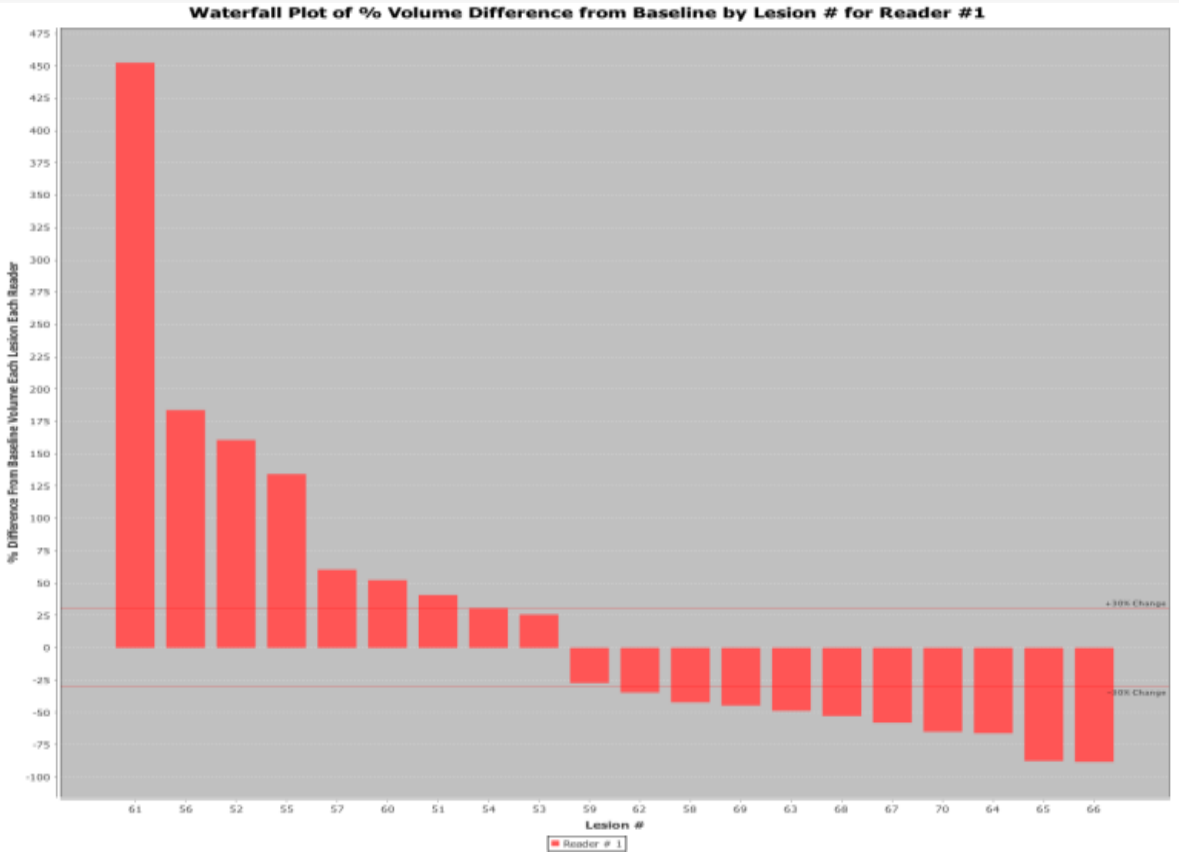
Tabulate It

Lesion #	TimePoint #	Volume	Auto LD	Auto SD	% From Baseline Volume
1	20020501	24120	57	27	0
1	20020827	43990	58	31	82
1	20020919	31524	46	37	31
1	20021026	31554	59	35	31
1	20021207	27081	49	27	12
1	20030219	39748	55	37	65

Graph It


Scatterplot of % Difference From Baseline Volume by Time Point
% Difference From Baseline Volume
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
+30% Change
20020501
20020827
20020919
20021026
20021207
20030219
TimePoint #
Patient TCGA-14-3477 Lesion 001 Reader

Aggregate It and Visualize It



Re-Use It

- **Quantitative analysis need not be a "dead end"**
  - can just transcribe or cut-and-paste numbers into a dictated or plain text report
  - but … pre-populated "merge" fields created from structured input provide a productivity and quality gain
  - can indeed save pretty tables & graphics as a PDF
  - but … much better to be able to re-use structure, numbers, codes next time for comparison, searching, mining and basis for quality improvement metrics

Informatics Standards

- **Approved medical device products**
  - already exist for quantitative image analysis & use in clinical practice
- **Inputs & outputs**
  - can they be standardized?
  - can they be stored & visualized in the PACS?
- **Change over time course of patient**
  - can these devices read and use each others' results?

Images In

- **Modalities make DICOM images**
  - often do not populate critical attributes for quantitative imaging in a standard way (private data elements)
  - anatomy, protocol, technique, contrast, timing
  - workflow challenge – copy from modality work list
  - user entry – need a place on screen, need to do it
  - copy to header – sometimes standard lags behind
  - quantitative pixel values – physical units

Measurements Out

- **Regions of Interest (ROI)**
- **Per-voxel values (“parametric maps”)**
- **Intermediate work products**
  - spatial registration (rigid & deformable)
  - fiducials
  - real-world values (physical units)

Measurements Out

- **DICOM encoding of ROIs**
  - Private data elements (evil & must be stopped)
  - Curves in image (weak semantics, old, retired)
  - Overlays in image (weak semantics)
  - Presentation States (weak semantics, PACS favorite)
  - Structured Reports (best choice, but more work)
  - RT Structure Sets (coordinates only)
  - Segmentations (per-voxel ROIs; use with SR)

DICOM Structured Reports

- **Hierarchical structure**
  - codes, numbers, coordinates, image references, etc.
- **Flexibility is constrained by templates**
  - just as XML is constrained by DTD or Schema
- **Standard DICOM binary representation**
  - easily stored in PACS though visualization remains challenging
  - easily transcoded to XML or JSON for processing
- **Widely used in existing quantitative modalities**
  - echo-cardiography, obstetric ultrasound

DICOM SR – Questions & Answers

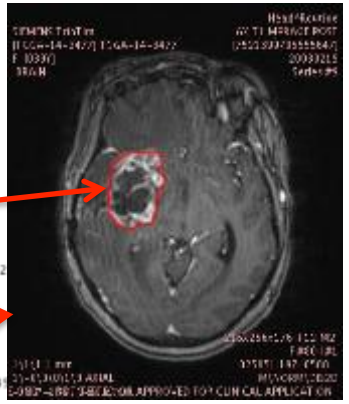
- **Basic structure is name-value pair**
  - name is the “question” (code)
  - value is the “answer” (text, code, numeric, etc.)
- **Different style choices possible, e.g.**
  - (M-54000,SRT,“Necrosis”) = (G-A203,SRT,“Present”)
  - (F-00005,SRT,“Finding”) = (M-54000,SRT,“Necrosis”)
- **Template of questions & value sets**
  - populated by human (pick lists from value sets)
  - encode image processing results (e.g., detect signal or pattern)
  - rule based (e.g., too small to measure)

DICOM SR – details inside

- CONTAINS: CONTAINER: Time Point [SEPARATE]
  - HAS OBS CONTEXT: TEXT: Subject Time Point Unique Identifier = 1.3.12.2.1107.5.1564572511.384.1353518214.8
  - HAS OBS CONTEXT: TEXT: Procedure Description = MRI Brain w/+ w/o Contrast
    - HAS PROPERTIES: UIDREF: Study Instance UID = 1.3.6.1.4.1.14519.5.2.1.2783.4001.230122590826962481167637416253
    - HAS PROPERTIES: CODE: Modality = Magnetic Resonance
    - HAS PROPERTIES: DATE: Study Date = 20021207
    - HAS PROPERTIES: TIME: Study Time = 165411
  - CONTAINS: CONTAINER: Lesion [SEPARATE]
    - CONTAINS: UIDREF: Tracking Unique Identifier = 1.3.12.2.1107.5.1564572511.1752.1353368560.7
    - CONTAINS: CODE: Calibration = No
    - CONTAINS: CONTAINER: Measurement Object [SEPARATE]
      - CONTAINS: UIDREF: Measurement Object UID = 1.3.12.2.1107.5.1564572511.2560.1353371564.19
      - CONTAINS: CODE: Measurement Object Type = Volume
      - HAS OBS CONTEXT: DATETIME: Observation Creation DateTime = 20121120003244
      - HAS OBS CONTEXT: DATETIME: Observation Modification DateTime = 20121121175419
      - CONTAINS: CODE: Discarded = No
      - CONTAINS: CONTAINER: Image Region [SEPARATE]
        - CONTAINS: CONTAINER: Image Sub-region [SEPARATE]
          - CONTAINS: CODE: Include Flag = Yes
          - CONTAINS: CODE: Segmentation Method = Random Walker 3D
          - CONTAINS: NUM: Area = 957.772564572239 mm2
          - CONTAINS: NUM: Volume = 27080.9186434825 mm3
            - HAS CONCEPT MOD: CODE: Measurement Method = Integration of sum of closed areas on contiguous slices
          - CONTAINS: NUM: Attenuation Coefficient = 688.37109375 Unspecified
            - HAS CONCEPT MOD: CODE: Derivation = Mean
          - CONTAINS: NUM: Attenuation Coefficient = 204 Unspecified
            - HAS CONCEPT MOD: CODE: Derivation = Minimum
          - CONTAINS: NUM: Attenuation Coefficient = 1520 Unspecified
            - HAS CONCEPT MOD: CODE: Derivation = Maximum
          - CONTAINS: NUM: Attenuation Coefficient = 681 Unspecified
            - HAS CONCEPT MOD: CODE: Derivation = Median
          - CONTAINS: NUM: Attenuation Coefficient = 259.674053 Unspecified
            - HAS CONCEPT MOD: CODE: Derivation = Standard Deviation
          - CONTAINS: NUM: Attenuation Coefficient = 14137088 Unspecified
            - HAS CONCEPT MOD: CODE: Derivation = Total
          - CONTAINS: NUM: Pixel Count = 20537 count
          - CONTAINS: IMAGE: Region Raster = 1.2.840.10008.5.1.4.1.1.66.4 : 1.2.276.0.7230010.3.1.4.1564572511.384.1353521414.70 (PS 1.2.840.10008.5.1.4.1.1.11.1 : 1.2.276.0.7230010.3.1.4.1564572511.384.1353521414.6
        - CONTAINS: CODE: Measurement Object Type = Biorthogonal Line Segments
        - CONTAINS: CONTAINER: Simple Measurement [SEPARATE]
          - HAS OBS CONTEXT: CODE: Automation = Automated
          - CONTAINS: NUM: Long Axis = 49.4704627990723 millimeter
            - INFERRED FROM: SCOORD: Source of Measurement = POLYLINE (179.733993530273,280.515991210938,205.328002929688,178.141006469727)
              - SELECTED FROM: IMAGE: = 1.2.840.10008.5.1.4.1.1.4 : 1.3.6.1.4.1.14519.5.2.1.2783.4001.305229386844192035439159616449[Frame 1] (PS 1.2.840.10008.5.1.4.1.1.11.1 : 1.2.276.0.7230010.3.1.4.1564572511
          - CONTAINS: NUM: Short Axis = 26.6379356384277 millimeter
- CONTAINS: CONTAINER: Time Point [SEPARATE]

DICOM SR – as visualized

Date	Volume	Auto LD	Auto SD
20021207	27080	49	27
…	…	…	…



SR Templates for Quantitation

- **Described in DICOM PS3.16**
  - templates for clinical quantitative applications, e.g., cardiovascular, OB/GYN
  - good basis for novel techniques, generic measurements, but insufficient
- **NCI QIICR project proposed new templates**
  - Quantitative Image Informatics for Cancer Research
  - accepted into DICOM as final text 2014/11
  - root template for generic “imaging measurements” (CP 1386)
  - uses planar/volumetric ROIs (CP 1112) as well as simple measurements
  - re-used improved “image library” to describe relevant image characteristics acquisition parameters (CP 1389)
  - code sets for perfusion (CP 1391), PET (CP 1392) methods and measurements
  - shared definition of “quantities” with separate real world value map improvements

Example of Measurement Report

Table RRR.1-1. Volumetric ROI on CT Example

Node	Code Meaning of Concept Name	Code Meaning or Example Value	TID
1	Oncology Measurement Report		TID 1500
1.1	Language of Content Item and Descendants	English	TID 1204
1.2	Observation Context		TID 1001
1.2.1	Person Observer Name	Doe^Jane	TID 1003
1.3	Procedure Reported	Chest+Abd CT W+WO contr IV	TID 1500
1.4	Measurements		TID 1500
1.4.1	Measurement Group		TID 1411
1.4.1.1	Tracking Identifier	Object1	TID 1411
1.4.1.2	Tracking Unique Identifier	1.2.276.0.7230010...	TID 1411
1.4.1.3	Referenced Segment	IMAGE - Segmentation, Segment #1	TID 1411
1.4.1.4	Source image for segmentation	IMAGE - CT image #1	TID 1411
1.4.1.5	Source image for segmentation	IMAGE - CT image #2	TID 1411
1.4.1.6	Volume	3267.46 mm3	TID 1419

Example of PET Measurement -

1.4	Measurements		TID 1500
1.4.1	Measurement Group		TID 1411
1.4.1.1	Tracking Identifier	Liver	TID 1411
1.4.1.2	Tracking Unique Identifier	1.2.276.0.7230010...	TID 1411
1.4.1.3	Time Point	TP0	TID 1502
1.4.1.4	Referenced Segment	IMAGE - Segmentation, Segment #1	TID 1411
1.4.1.5	Source image for segmentation	IMAGE - PET image #1	TID 1411
1.4.1.6	Source image for segmentation	IMAGE - CT image #1	TID 1411
1.4.1.7	Finding Site	Liver	TID 1419
1.4.1.8	Real World Value Map used for measurement	RWVM - UID	TID 1419
1.4.1.9	SUVbw	3.90557 {SUVbw}g/ml	TID 1419
1.4.1.9.1	Derivation	Max	TID 1419 CID 7464

Example of PET Measurement - I

1.4.1.10	SUVbw	3.25653 {SUVbw}g/ml	TID 1419
1.4.1.10.1	Derivation	Peak Value Within ROI	TID 1419 CID 7464
1.4.1.11	SUVbw	2.34467 {SUVbw}g/ml	TID 1419
1.4.1.11.1	Derivation	Root Mean Square	TID 1419 CID 7464
1.4.1.12	Standardized Added Metabolic Activity (SAM)	20400.3 g	TID 1419 CID 7466
1.4.1.12.1	Measurement Method	SUV body weight calculation method	TID 1419
1.4.1.13	Volume	395512 mm3	TID 1419
1.4.1.13.1	Measurement Method	Sum of segmented voxel volumes	TID 1419 CID 7474

Example of Image Library

Table SSS.1-1. Image Library for PET-CT Example

Node	Code Meaning of Concept Name	Code Meaning or Example Value	TID
1.n	Image Library		TID 1600
1.n.1	Image Library Group		TID 1600
1.n.1.3	Modality	PET	TID 1602
1.n.1.4	Target Region	Whole Body	TID 1602
1.n.1.5	Study Date	20030417	TID 1602
1.n.1.6	Acquisition Date	20030417	TID 1602
1.n.1.7	Acquisition Time	094513	TID 1602
1.n.1.8	Frame of Reference UID	1.2.3.xyz	TID 1602
1.n.1.9	Pixel Data Rows	128	TID 1602
1.n.1.10	Pixel Data Columns	128	TID 1602
1.n.1.11	Horizontal Pixel Spacing	4.0 mm	TID 1604
1.n.1.12	Vertical Pixel Spacing	4.0 mm	TID 1604
1.n.1.13	Spacing Between Slices	4.0 mm	TID 1604
1.n.1.14	Slice Thickness	4.0 mm	TID 1604
1.n.1.15	Image Orientation (Patient) Row X	1	TID 1604
1.n.1.16	Image Orientation (Patient) Row Y	0	TID 1604
1.n.1.17	Image Orientation (Patient) Row Z	0	TID 1604

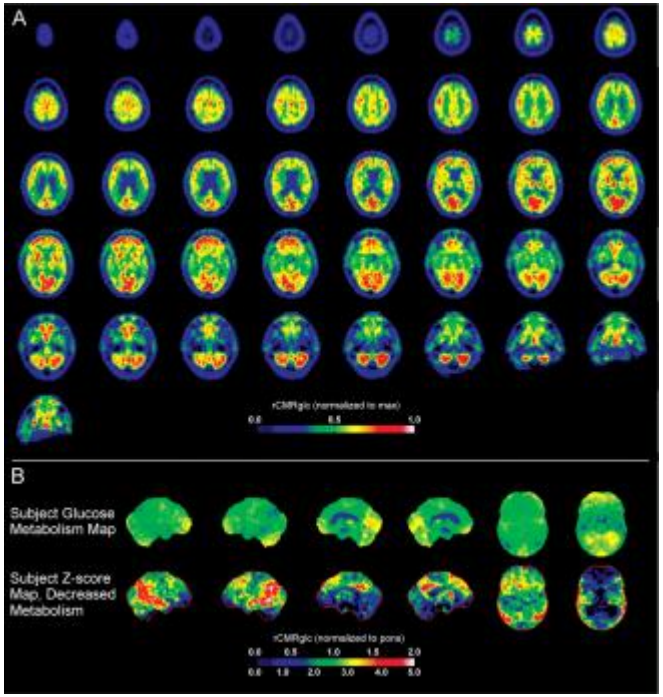
DICOM RT Structure Sets

- **Simple structure**
  - focus is iso-contour 3D coordinates of regions to treat & spare
  - very limited semantics
  - no standard or extensible measurements beyond simple volume
- **Standard DICOM binary representation**
  - easily transcoded to other DICOM objects like SR or PS if 3D (patient-relative) to 2D (image-relative) coordinate mapping is available (e.g., via source images or an SR image library)
- **Widely used in existing RT & non-RT workstations**
  - also understood by many academic software tools

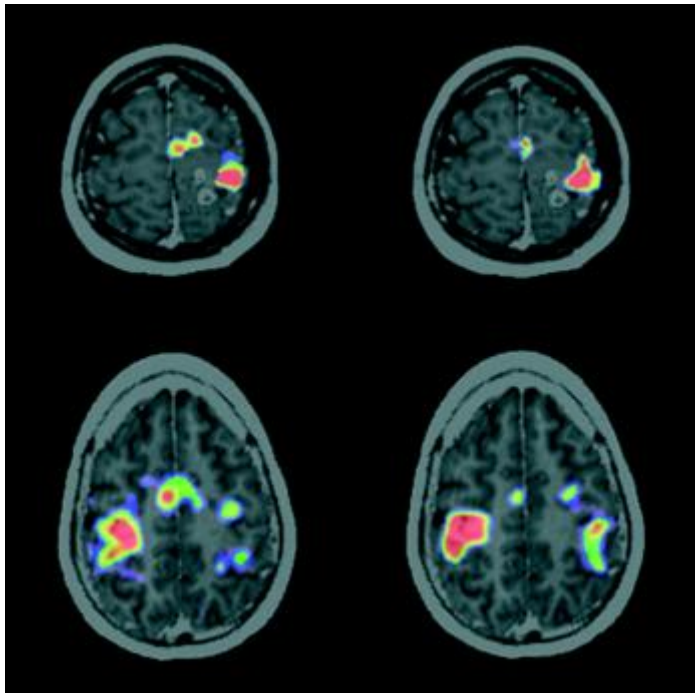
DICOM Presentation States

- **Intended to preserve appearance**
  - grayscale pipeline (window)
  - spatial transformation (pan/zoom)
  - annotation (text, overlays, vector graphics)
- **Lack semantics**
  - what does the text “mean”? (NLP)
  - which graphic is it associated with?
- **Overall, a poor choice for quantitative results**
  - may be all that is available in many PACS (to create & view)

Parametric Maps

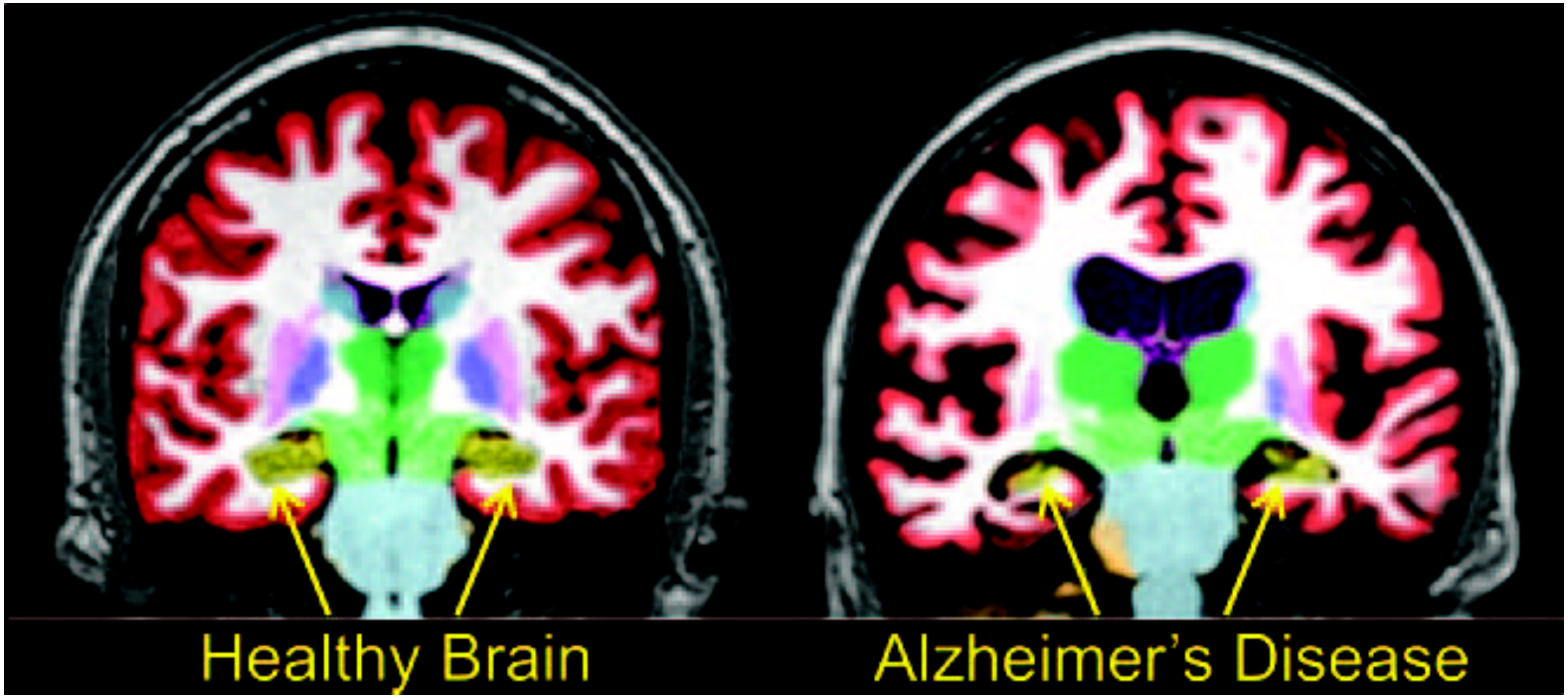


Foster N L et al. Brain 2007;130:2616-2635



Meyer P T et al. J Neurol Neurosurg Psychiatry 2003;74:471-478

Label Maps



Brewer J et al. AJNR 2009; 30:578-580

DICOM Parametric & Label Maps

- **Per-voxel encoding of numeric or label values**
- **Ordinary images but not just “pretty pictures”**
  - modality-specific or secondary capture; single or multi-frame
- **Segmentations (label maps, ROIs)**
  - binary, probability, fractional occupancy
  - multiple segments (multiple labels)
- **Parametric Maps - integer or floating point values**
  - integers rescaled to floats (usable by any viewer)
  - recent extension to floating point voxels
- **Leave “fusion” (superimposition) to application**
  - Blending Presentation State to specify what to fuse

Parametric Maps

- **Can be encoded as:**
  - "traditional" modality-specific images of "derived" type
  - new Parametric Map Storage SOP Class
- **Parametric Map Storage SOP Class (Sup 172)**
  - integer or floating point (32 or 64 bit) pixels
  - single "sample" per frame (i.e., monochrome)
  - pseudo-coloring for rendering defined separately
  - an enhanced MF family object (dimensions, functional groups)
  - for intermediate files (to propagate composite context)
  - uses Real World Value Map to define "meaning" of values

Segmentations

- **Uses**
  - tissue segmentation, functional segmentation, artifact identification for quantification or visualization, atlases
  - alternative method to encode ROIs: voxel based, rather than contours
- **Encoding**
  - supports segmentation of entire volumes, single slices, smaller sub-regions, or 2D frames
  - coded description of segment category can be anatomical or property based or both
  - an enhanced multi-frame image
  - each frame is a 2D plane or a slice of a single segment category

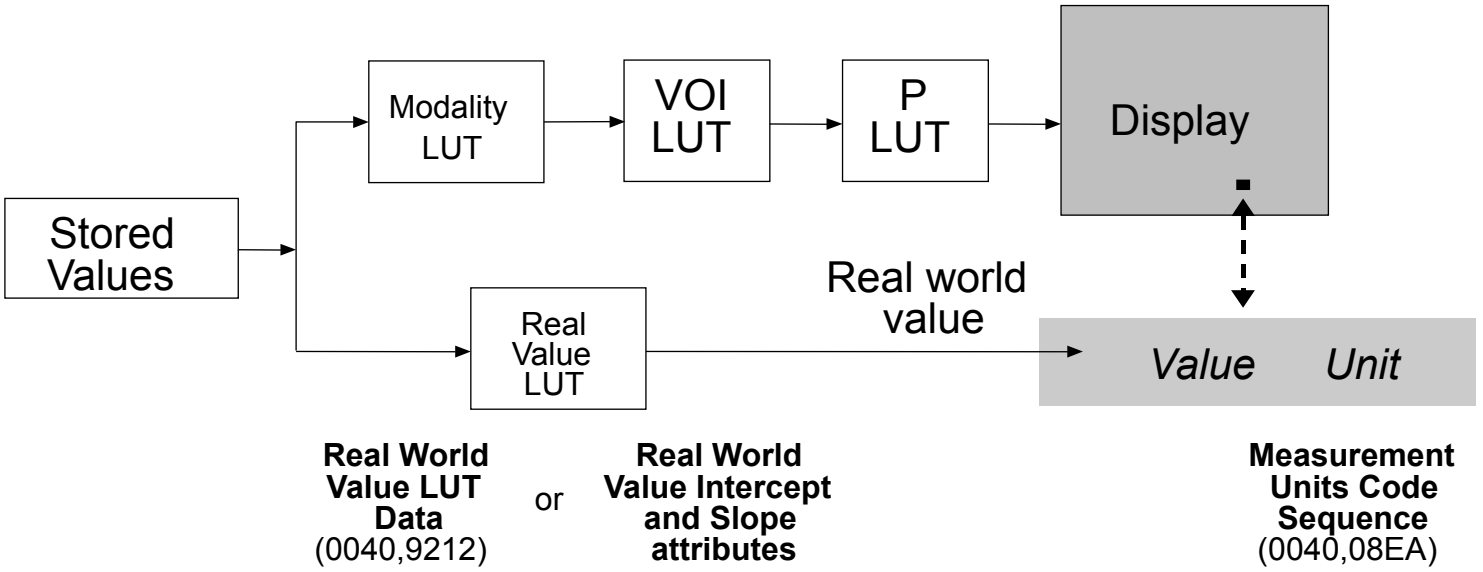
DICOM Registration & Fiducials

- **Mapping between 3D coordinates**
  - DICOM Registration – rigid matrix
  - DICOM Deformable Registration
- **Location of specific points**
  - DICOM Fiducial
- **Used to save manual or automated results**
  - save application state for further work later
  - re-use for other purposes
  - e.g., sync'd scrolling, 3D cursor, resampling, lesion propagation

DICOM Real World Value Maps

- **Separate pipelines based on pixels**
  - what to show on the display
  - what the pixel (voxel) “means”
- **e.g., MR pixel values**
  - signal intensity windowed for display
  - mapped to physical unit (e.g. velocity for phase contrast)
- **DICOM implementation**
  - within image or separate object (e.g., derived later)
  - linear equation or LUT, applied to all or sub-set of range
  - point operation (all voxels) (unlike US Region Calibration)

Real World Value Mapping

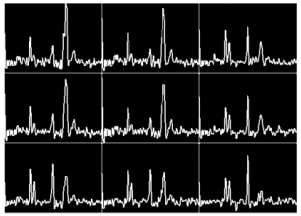


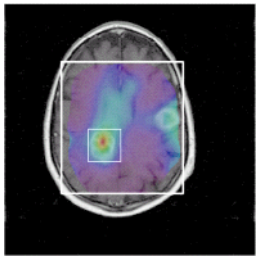
Real World Value Mapping

- **Units:**
  - Unified Code for Units of Measure (UCUM)
- **Quantity defined (extensibly) as:**
  - (G-C1C6,SRT,“Quantity”)
  - (121401,DCM,“Derivation”)
  - (G-C036,SRT,“Measurement Method”)
- **E.g., Cerebral Blood Flow (CBF)**
  - Measurement Units Code Sequence
    - (ml/[100]g/min,UCUM,“milliliter per 100 gram per minute”)
  - Quantity Definition Sequence
    - (G-C1C6,SRT,“Quantity”) = (113055,DCM,“Regional Cerebral Blood Flow”)

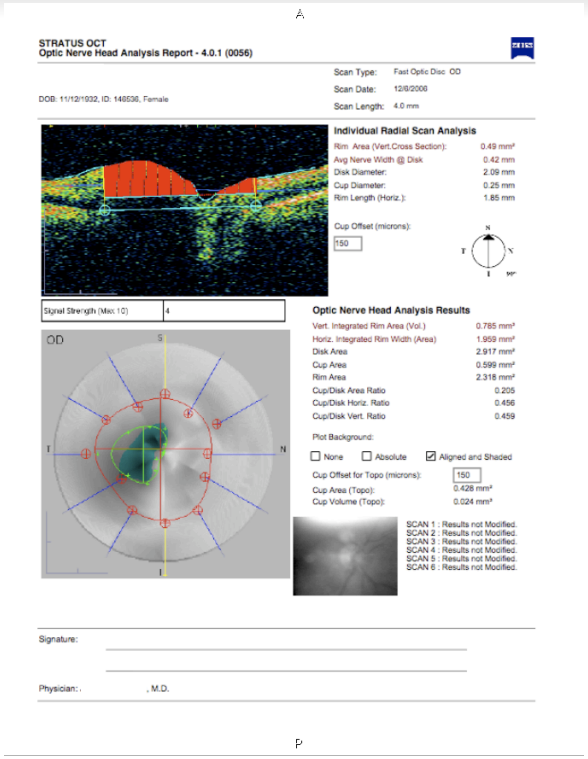
Other Bulk Data Storage

- **Time-based Waveforms**
  - ECG
  - Hemodynamic
  - Audio
- **MR Spectroscopy**
  - Single voxel
  - Multi-voxel
  - Multi-frame
  - Metabolite maps (CSI) as images
- **Raw Data IOD**





Encapsulated PDF



STRATUS OCT
Optic Nerve Head Analysis Report - 4.0.1 (0056)

Scan Type: Fast Optic Disc OD
Scan Date: 12/8/2000
Scan Length: 4.0 mm

DOB: 11/12/1932, ID: 146536, Female

Individual Radial Scan Analysis

Rim Area (Vert.Cross Section):	0.49 mm²
Avg Nerve Width @ Disk	0.42 mm
Disk Diameter:	2.09 mm
Cup Diameter:	0.25 mm
Rim Length (Horiz.):	1.85 mm

Cup Offset (microns): 150

Signal Strength (Max 10): 4

OD

Optic Nerve Head Analysis Results

Vert. Integrated Rim Area (Vol.)	0.785 mm³
Horiz. Integrated Rim Width (Area)	1.959 mm²
Disk Area	2.917 mm²
Cup Area	0.599 mm²
Rim Area	2.318 mm²
Cup/Disk Area Ratio	0.205
Cup/Disk Horiz. Ratio	0.456
Cup/Disk Vert. Ratio	0.459

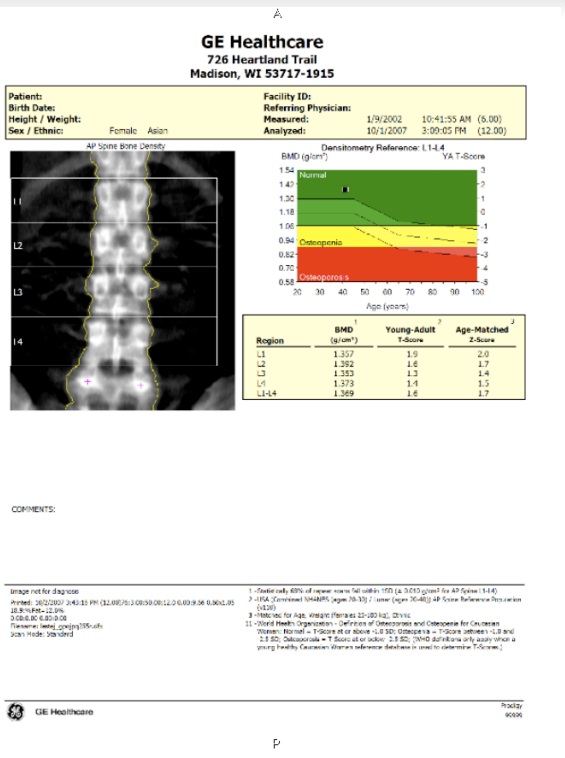
Plot Background:
☐ None ☐ Absolute ☑ Aligned and Shaded

Cup Offset for Topo (microns): 150
Cup Area (Topo): 0.428 mm²
Cup Volume (Topo): 0.024 mm³

SCAN 1 : Results not Modified.
SCAN 2 : Results not Modified.
SCAN 3 : Results not Modified.
SCAN 4 : Results not Modified.
SCAN 5 : Results not Modified.
SCAN 6 : Results not Modified.

Signature:

Physician: , M.D.



GE Healthcare
726 Heartland Trail
Madison, WI 53717-1915

Patient:
Birth Date:
Height / Weight:
Sex / Ethnic: Female Asian

Facility ID:
Referring Physician:
Measured: 1/9/2002 10:41:55 AM (6.00)
Analyzed: 10/1/2007 3:00:05 PM (12.00)

AP Spine Bone Density

Densitometry Reference: L1-L4

BMD (g/cm²) YA T-Score
Normal
Osteopenia
Osteoporosis
Age (years)

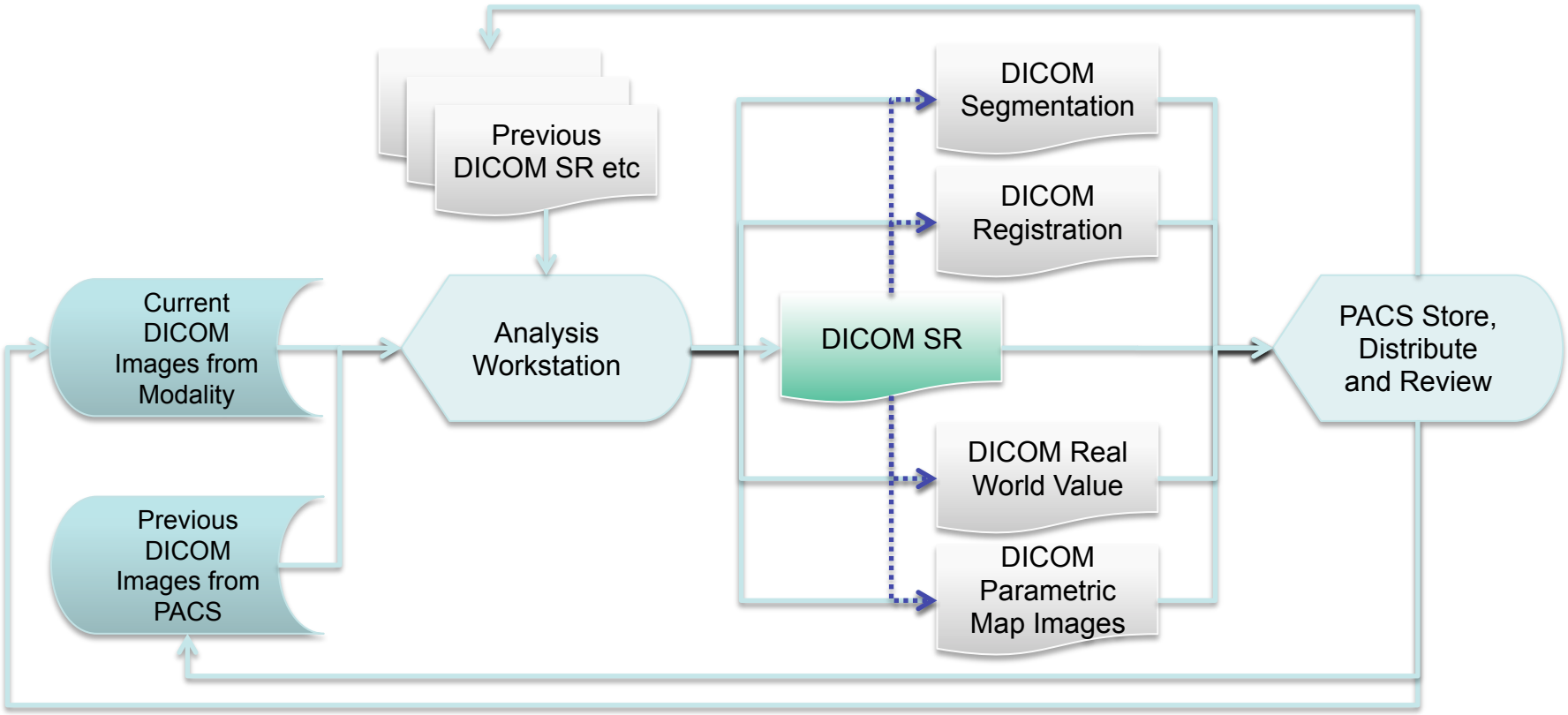
Region	BMD (g/cm²)	Young-Adult T-Score	Age-Matched Z-Score
L1	1.357	1.9	2.0
L2	1.392	1.6	1.7
L3	1.353	1.3	1.4
L4	1.373	1.4	1.5
L1-L4	1.369	1.6	1.7

COMMENTS:

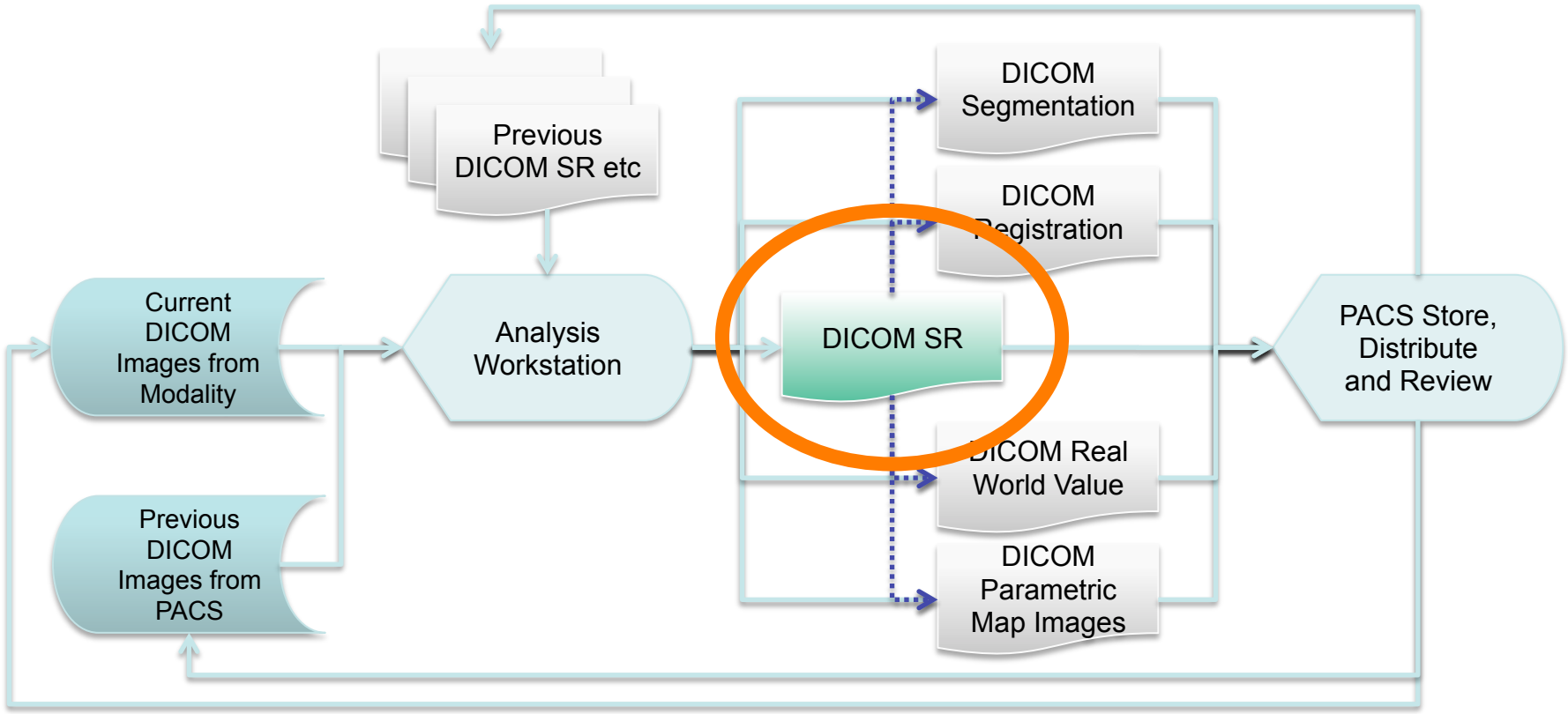
GE Healthcare

A "prettier" alternative to Secondary Capture Images for "pretty pictures"

Putting it all together …



Putting it all together …



What about Codes?

- **DICOM uses external lexicons**
  - SNOMED
  - LOINC
  - RADLEX
  - defines DCM codes & definitions only if no other good home
- **EHR push towards more reliable codes**
  - e.g., in USA, strong emphasis on codes in Meaningful Use
  - RIS, modalities and PACS implementations could do better
  - institutions really need to standardize internal procedure codes

Codes for Quantitative Imaging

- **Codes needed for**
  - entities, e.g., lesions, tumors, tissue types
  - location, e.g., anatomic site
  - characteristics, e.g., edges, enhancement
  - measurements, e.g., volume, sum of areas, mean
  - units, e.g., HU, mm
- **Availability**
  - many already - SNOMED, LOINC, RADLEX, DCM, NCI, UCUM
  - more being defined every day
  - can use private codes in the interim & re-map later

Quantitative Codes & Definitions

Table CID 4109. Model-Independent Dynamic Contrast Analysis Parameters

Coding Scheme Designator	Code Value	Code Meaning
DCM	126320	IAUC
DCM	126321	IAUC60
DCM	126322	IAUC90
DCM	126370	Time of Peak Concentration
DCM	126372	Time of Leading Half-Peak Concentration
DCM	126371	Bolus Arrival Time
DCM	113069	Time To Peak
DCM	126374	Temporal Derivative Threshold
DCM	126375	Maximum Slope
DCM	126376	Maximum Difference
DCM	126377	Tracer Concentration

126374	Temporal Derivative Threshold	A threshold applied to the temporal derivative of the concentration-time curve. E.g., used to establish BAT. See Shpilfoygel Med Phys 2008. doi: 10.1118/1.1288669	
126375	Maximum Slope	The maximum rate of signal intensity change within a measured region of a time-activity curve. See Boonsirikamchai, Piyaporn, Harmeet Kaur, Deborah A. Kuban, Edward Jackson, Ping Hou, and Haesun Choi. “Use of Maximum Slope Images Generated From Dynamic Contrast-Enhanced MRI to Detect Locally Recurrent Prostate Carcinoma After Prostatectomy: A Practical Approach.” American Journal of Roentgenology 198, no. 3 (March 1, 2012): W228–W236. doi:10.2214/AJR.10.6387.	

Segmentation Codes

Table CID 7150. Segmentation Property Categories

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID
SRT	T-D0050	Tissue	85756007	C0040300
SRT	T-D000A	Anatomical Structure	123037004	C1268086
SRT	A-00004	Physical object	260787004	C0085089
SRT	M-01000	Morphologically Altered Structure	49755003	C0221198
SRT	R-42019	Function	246464006	C0542341
SRT	R-42018	Spatial and Relational Concept	309825002	C0587374
SRT	T-D0080	Body Substance	91720002	C0504082

Table CID 7159. Lesion Segmentation Types

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID
SRT	M-41610	Abscess	44132006	C0000833
SRT	M-35000	Blood clot	75753009	C0302148
SRT	M-3340A	Cyst	367643001	C0010709
SRT	M-36300	Edema	79654002	C0013604
SRT	M-35300	Embolus	55584005	C1704212
SRT	M-37000	Hemorrhage	50960005	C0019080
SRT	M-40000	Inflammation	23583003	C0021368
SRT	M-03000	Mass	4147007	C0577559
SRT	M-54000	Necrosis	6574001	C0027540
SRT	M-8FFFF	Neoplasm	108369006	C0027651
SRT	M-03010	Nodule	27925004	C0028259

Reality Check

- **The standards exist – are they implemented?**
  - widely, where use is critical & reimbursable (e.g. SR in echo and OB US, Radiation Dose, RTSS in radiotherapy planning & QC)
  - increasingly so elsewhere, as quantitation grows in popularity (e.g., oncology, esp. PET)
- **Need better and more widespread toolkit support**
  - many toolkits do include basic multi-frame, SR and XML
  - many need more convenient APIs for abstractions
- **Need greater 3rd party viewer & workstation support**
  - many still use “proprietary” annotation formats, e.g., Osirix

What is a “standard” anyway?

- **Generic definition**
  - *“something established by authority, custom, or general consent …” (Merriam-Webster)*
- **Technical Standards definition**
  - *“an established norm or requirement about technical systems … usually a formal document that establishes uniform engineering or technical criteria, methods, processes and practices” (Wikipedia)*

What is a “standard” anyway?

- **Standards are developed by “Standards Organizations”**
  - “*any organization whose primary activities are developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise producing technical standards that are intended to address the needs of some relatively wide base of affected adopters” (Wikipedia)*

DICOM as a Standard

- **DICOM is a standard**
  - long history of modality & PACS vendor support
  - global investment & representation of stake holders
  - open – free to get it and free to implement it
  - commonality across many modalities & applications
  - grows in sophistication to meet evolving technology
  - patient and workflow centric

Anti-Standards - Vendors

- **Many systems do not go beyond images**
  - mistaken perception that DICOM is only for images
  - hampered by lack of platform toolkit support
  - do not see value in “sharing” (or saving) results
  - users satisfied with secondary capture screen shots
  - believe it is sufficient to save/restore “state” locally
  - or hidden inside private data elements or SOP Class
  - so, “Yet Another Proprietary File Format” (YAPFF)

Anti-Standards - Academics

- **Many academics don't like DICOM**
  - DICOM is "old-fashioned" (e.g., not XML based)
  - easier to make up your own format than to re-use
  - so, "Yet Another Academic File Format" (YAAFF)
  - legitimate legacy of working code predating DICOM
  - effort to retain required identifiers through pipeline
  - but policy (leadership, funding) is evolving favorably
  - e.g., QIN, QIICR, NWU, ePAD DICOM segmentation

Anti-Standards & Wrong Standards

- **AIM**
- **Analyze**
- **GIPL**
- **MINC**
- **NIfTI**
- **NRRD**
- **VTK**
- **BMP**
- **JPEG**
- **PNG**
- **TIFF**
- **NetPBM**
- **HDF**
- **NetCDF**

Translation to Clinical Practice

- **“Benchmark to Bedside”**
  - for “quantitative imaging” to reach clinical practice, tools and standards must be commercially viable
- **No place for YA[PA]FFs & generic formats**
  - no patient & workflow & analysis metadata
  - no support in PACS
  - little or no support in viewers & workstations
  - can claim is a “standard” but doesn’t make it so

Beyond the Scope …

- **Many other related standard activities …**
  - DICOM WG 23 Application Hosting
  - DICOMweb: WADO-WS, WADO-RS, STOW, QIDO access
  - DICOM XML and JSON metadata encoding
  - IHE Post-Processing Workflow
  - IHE XDS-I (cross-enterprise)
  - DICOM De-identification (Sup 142, now in PS 3.15)
  - DICOM WG 18 Research and Clinical Trials
  - DICOM WG 30 Small Animal Imaging

Conclusion

- **Pretty pictures are not enough**
  - saving a screen shot/PDF to view in PACS is better than nothing
  - but doesn't enable further searching, analysis or re-use
- **Standards are needed and already exist to fully support quantitative imaging in clinical practice**
  - most gaps are in implementation and deployment, not lack of standards
  - DICOM is being and will continue to be extended as needed
  - "chicken & egg" problem with implementation is not an excuse

Conclusion

- **No place for non-standard or inappropriate formats**
  - not just for input, but output as well
  - for results from commercial products to be distributable and survive migration (version/product/vendor), must use standards
  - for academic quantitative projects to be translated to clinical practice, they must embrace existing, true “standards”, (i.e., DICOM), not “made up” formats that claim to be “standards”
- **Greater use of standard codes is probably inevitable**
  - creates opportunity for better tools to search & mine content

Acknowledgements

- **Quantitative Image Informatics for Cancer Research (QIICR) - PAR-12-287 Advanced Development of Informatics Technology (U24) ("http://qiicr.org/")**