DICOM for quantitative imaging research in 3D Slicer

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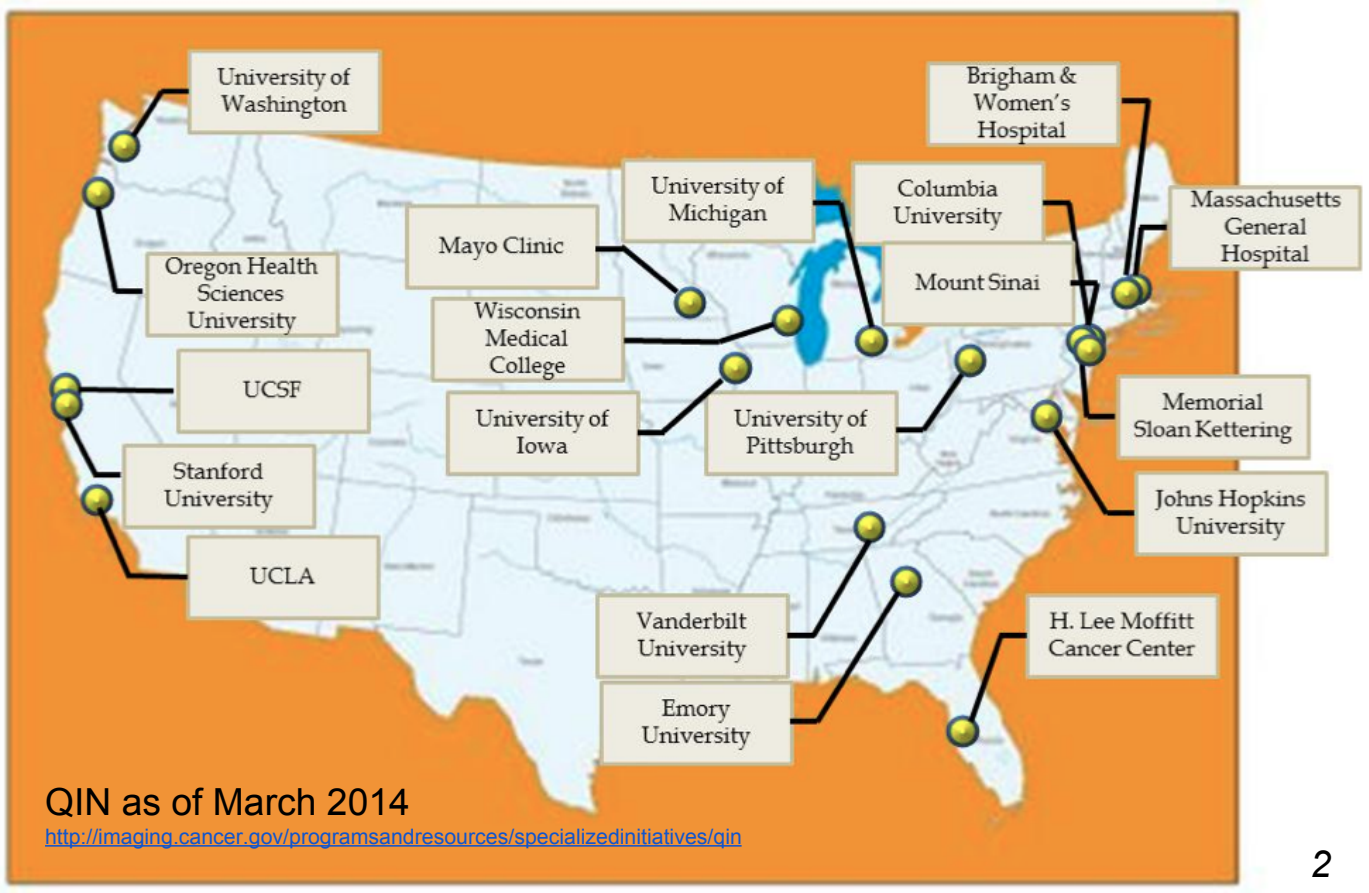
NCI Quantitative Imaging Network (QIN)

"The network is designed to promote research and development of quantitative imaging methods for the measurement of tumor response to therapies in clinical trial settings, with the overall goal of facilitating clinical decision making."



QIN as of March 2014

http://imaging.cancer.gov/programsandresources/specializedinitiatives/qin

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Motivation: The Iowa Use Case

From: Christian Bauer <christian-bauer@uiowa.edu>
Date: Mon, Apr 16, 2012 at 4:26 PM
Subject: Re: Iowa/BWH QIN meeting followup
To: Andriy Fedorov <fedorov@bwh.harvard.edu>
Cc: "Reinhard R. Beichel" <reinhard-beichel@uiowa.edu>

Andriy,

we got now some example datasets for you. You can download them from:
http://dl.dropbox.com/u/72378421/bwh_example_datasets.tar.gz

The file contains a data_description.txt which describes what data is stored how. It should be self explanatory.

Let me know if you have any question,
Christian

Motivation: The Iowa Use Case

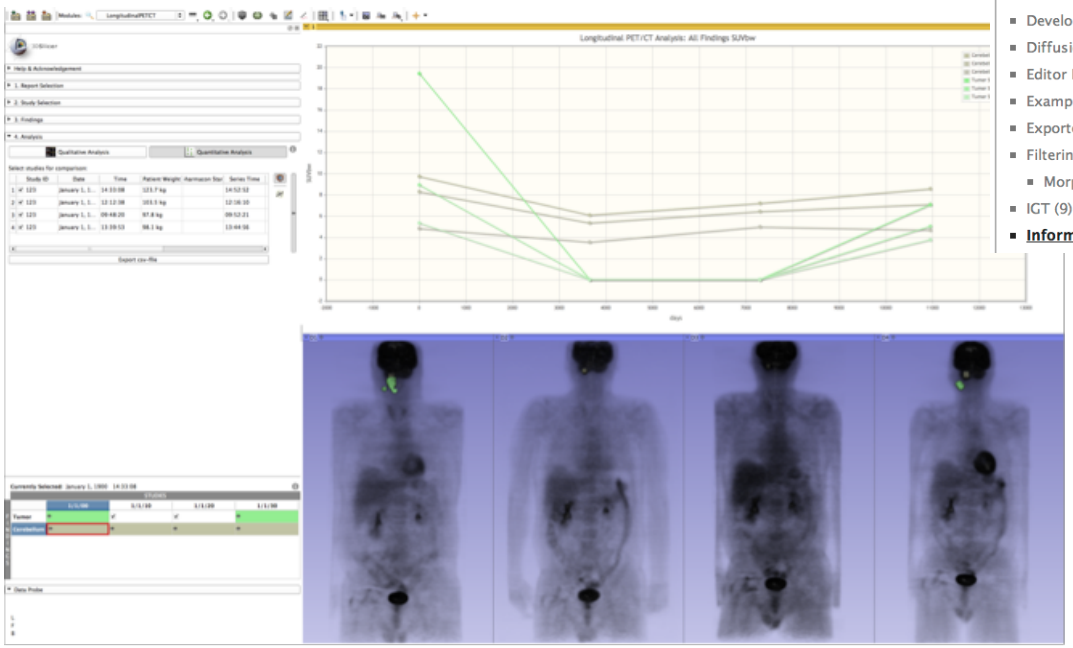
```
[fedorov@gridftp-spl patient62]$ tree .
.
├── scan1
|   ├── 1_aorta.nii.gz
|   ├── 1_cerebellum.nii.gz
|   ├── 1_CT.nrrd
|   ├── 1_liver.nii.gz
|   ├── 1_PT.nrrd
|   ├── 1_PT_regions.nrrd
|   ├── CT.vtk
|   └── PT.vtk
├── scan2
|   ├── 2_aorta.nii.gz
|   ├── 2_cerebellum.nii.gz
|   ├── 2_CT.nrrd
|   ├── 2_liver.nii.gz
|   ├── 2_PT.nrrd
|   ├── 2_PT_regions.nrrd
|   ├── CT.vtk
|   └── PT.vtk
├── scan3
|   ├── 3_aorta.nii.gz
|   ├── 3_cerebellum.nii.gz
|   ├── 3_CT.nrrd
|   ├── 3_liver.nii.gz
|   ├── 3_PT.nrrd
|   ├── 3_PT_regions.nrrd
|   ├── CT.vtk
|   └── PT.vtk
└── scan4
    ├── 4_aorta.nii.gz
    ├── 4_cerebellum.nii.gz
    ├── 4_CT.nrrd
    ├── 4_liver.nii.gz
    ├── 4_PT.nrrd
    ├── 4_PT_regions.nrrd
    ├── CT.vtk
    └── PT.vtk

4 directories, 32 files
```

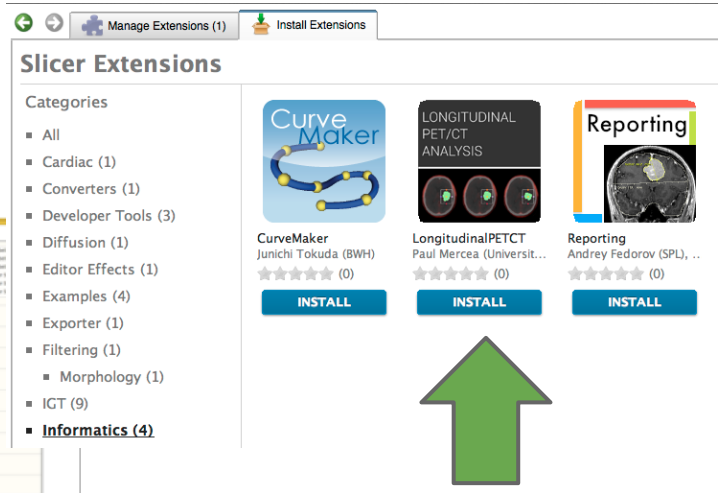
This example dataset consists of data for 3 patients with head/neck cancer:

Each of the patients has a pre-treatment PET/CT scan (scan1) and one or several post-treatment scans (scan2, scan3, ...). In each of the scans the tumors and hot lymph nodes were traced manually in the PET scans by a radiation oncologist and stored as a labeled volume dataset. As a convention, label 1 was used for the primary tumor, label 2 for the hottest lymph node, label 3, 4, 5 etc. for other uptake regions:

- Patient 62: Had initially a primary tumor and 1 hot node. Nothing was identified in scan 2 and 3. In scan 4 one hot node is present.
- Patient 71: Had initially a primary tumor and 6 hot nodes. In the second scan the primary tumor consisted of two unconnected parts (both have label 1), and 1 hot node is visible. In the third scan the primary tumor is gone but 1 hot node remains.
- Patient 244: Had initially 1 tumor and three hot nodes, all of them were gone in the first post-treatment scan. In the second post-treatment scan the patient showed a hot node in the lung adjacent to the heart. Note, that the utilized label for this distant node does not correspond to the node with the same label in the pre-treatment scan.

Motivation: The Iowa Use Case





Mercea P, Fedorov A, Pieper S, Beichel R, Park M-A, Hainer J, Kijewski MF, Horky L, Kikinis R, Dickhaus H. Quantification of longitudinal tumor changes using PET imaging in 3D Slicer. In Proc. of Computer Assisted Radiology and Surgery, 2013. Int J CARS 2013 (8) (Suppl 1):S285-S286.

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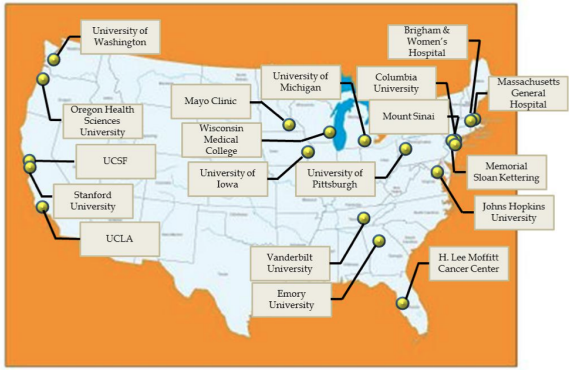
So what is the problem?

```
[fedorov@gridftp-spl scan1]$ head -n 14 1_CT.nrrd
NRRD0004
# Complete NRRD file format specification at:
# http://teem.sourceforge.net/nrrd/format.html
type: float
dimension: 3
space: left-posterior-superior
sizes: 512 512 297
space directions: (0.9765625,0,0) (0,0.9765625,0) (0,0,3.4000244140624996)
kinds: domain domain domain
endian: little
encoding: gzip
space origin: (-249.51171875,-450.51171875000006,-1555.4000244140632)
```



But I want to know more about the ...

- patient (date of scan, age, weight, ...)
- image (equipment, parameters, reconstruction, ...)
- analysis (algorithm, operator, parameters, …)
- clinical context (diagnosis, therapy, survival, …)

QIICR is about

Metadata

Provenance

Standards

From: Andriy Fedorov <fedorov@bwh.harvard.edu>
Date: Fri, Apr 20, 2012 at 9:47 AM
Subject: Re: Iowa/BWH QIN meeting followup
To: Christian Bauer <christian-bauer@uiowa.edu>
Cc: "Reinhard R. Beichel" <reinhard-beichel@uiowa.edu>

Christian,

Thank you, this looks very detailed. I will let you know if I have any questions. Do you happen to have the anonymized PET & CT DICOMs for these cases? They will be required if we wanted to use DICOM SR/SEG or AIM for storing the organized data.

[...]

DICOM PET

```
(0008,0020) DA [19870313]                          #   8, 1 StudyDate
(0008,0021) DA [19870313]                          #   8, 1 SeriesDate
(0008,0022) DA [19870313]                          #   8, 1 AcquisitionDate
(0008,0023) DA [19870313]                          #   8, 1 ContentDate
(0008,0030) TM [143308.198000]                     #  14, 1 StudyTime
(0008,0031) TM [145252.591000]                     #  14, 1 SeriesTime
(0008,0032) TM [145252.591000]                     #  14, 1 AcquisitionTime
(0008,0033) TM [152652.000000]                     #  14, 1 ContentTime
(0008,0050) SH [2076699673350889]                  #  16, 1 AccessionNumber
(0008,0060) CS [PT]                                #   2, 1 Modality
```

```
(0010,0010) PN [QIN-HEADNECK-01-0062]              #  20, 1 PatientName
(0010,0020) LO [QIN-HEADNECK-01-0062]              #  20, 1 PatientID
(0010,0030) DA (no value available)                #   0, 0 PatientBirthDate
(0010,0040) CS [M]                                 #   2, 1 PatientSex
(0010,1010) AS [048Y]                              #   4, 1 PatientAge
(0010,1030) DS [123.7]                             #   6, 1 PatientWeight
(0010,2110) LO [Removed for HIPAA compliance]      #  30, 1 Allergies
```

```
(0054,0016) SQ (Sequence with explicit length #=1)      # 106, 1 RadiopharmaceuticalInformationSequence
  (fffe,e000) na (Item with explicit length #=7)          #  98, 1 Item
    (0018,0000) UL 66                                       #   4, 1 GenericGroupLength
    (0018,1072) TM [132800.000000]                          #  14, 1 RadiopharmaceuticalStartTime
    (0018,1074) DS [568320010]                              #  10, 1 RadionuclideTotalDose
    (0018,1075) DS [6586.2]                                 #   6, 1 RadionuclideHalfLife
    (0018,1076) DS [0.97]                                   #   4, 1 RadionuclidePositronFraction
    (0054,0000) UL 8                                        #   4, 1 GenericGroupLength
    (0054,0300) SQ (Sequence with explicit length #=0)      #   0, 1 RadionuclideCodeSequence
```

* Output of DCMTK dcmdump tool http://support.dcmtk.org/docs/dcmdump.html

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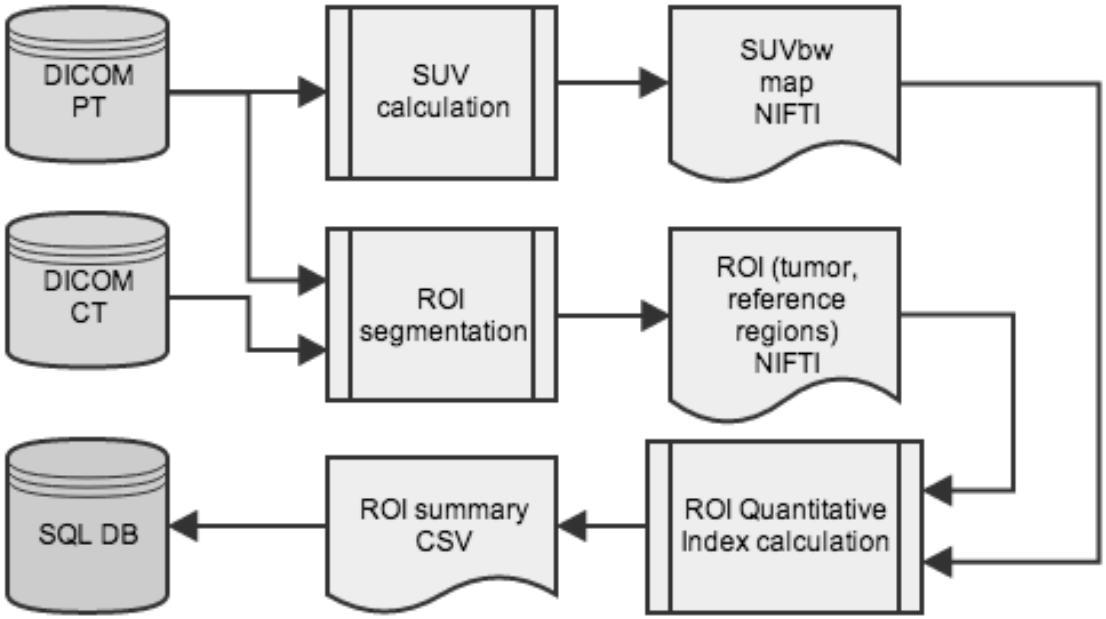
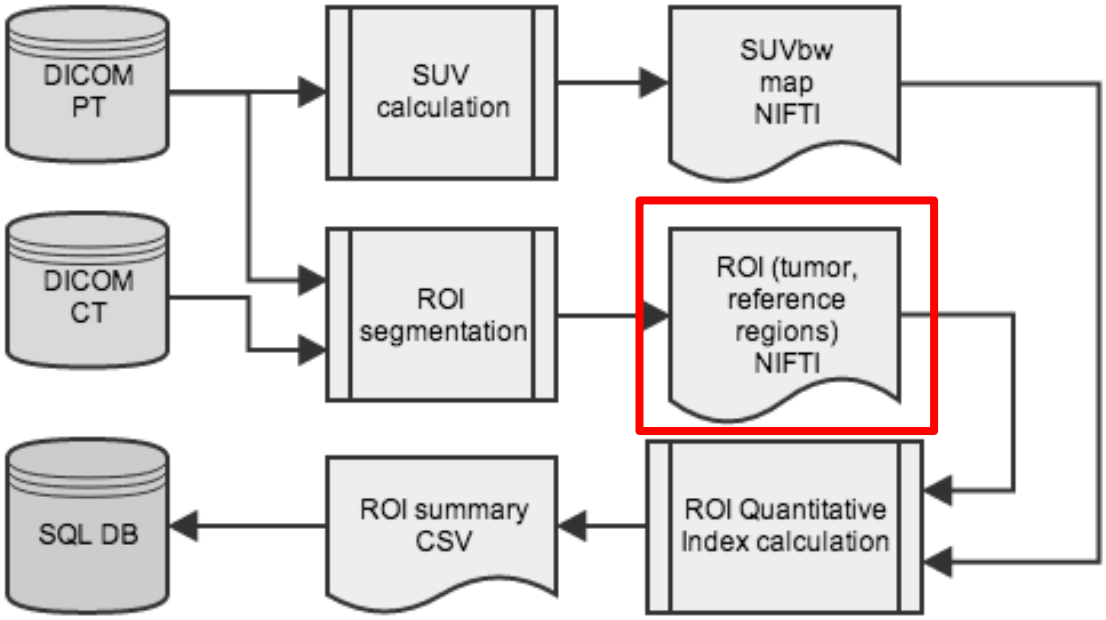

DICOM PT
SUV calculation
SUVbw map NIFTI
DICOM CT
ROI segmentation
ROI (tumor, reference regions) NIFTI
SQL DB
ROI summary CSV
ROI Quantitative Index calculation

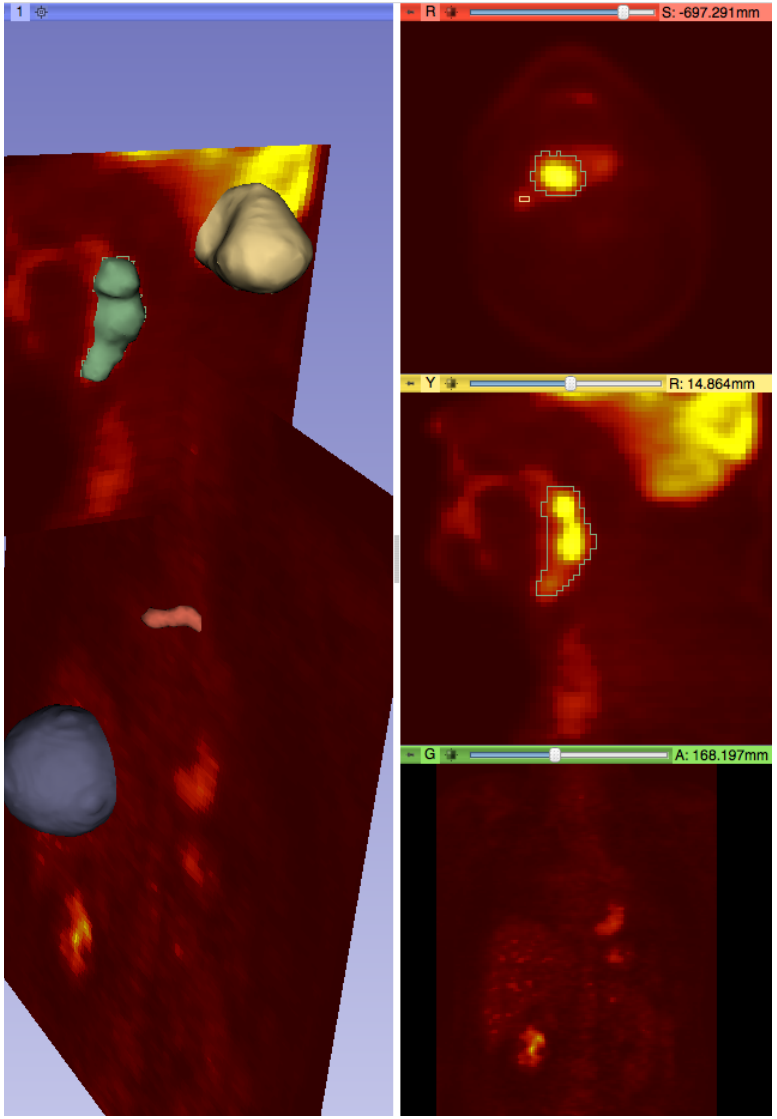
Data element	Research practice *	DICOM IOD counterpart
Image	.nrrd, .nifti, ...	(Enhanced) PT, MR, CT
Segmentation	.nrrd, .nifti, ...	SEG
Parameter map	.nrrd, .nifti, ...	(Enhanced) PT, MR, CT; RWVM
Measurements	.txt, .csv, ...	SR

* add README.txt

Iowa quantitative PET analysis workflow



Iowa PET segmentation



- tumor and reference regions
- anatomical structures
- tumor tracking over the course of treatment
- anatomical location of the tumor
- manual vs automatic segmentation

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DICOM Segmentation IOD

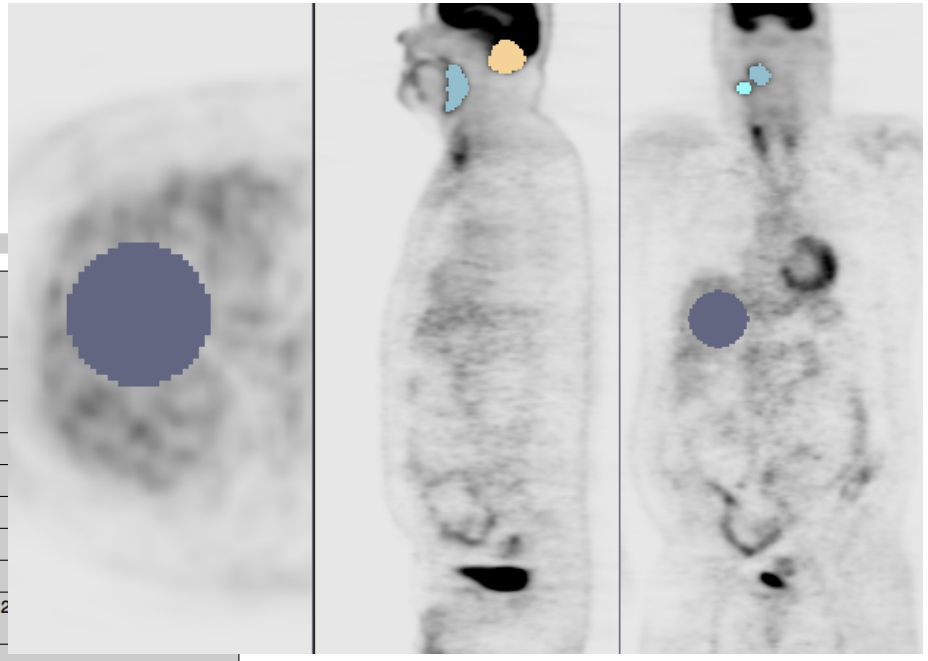

Table A.51-1. Segmentation IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Segmentation Series	C.8.20.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	C - Required if Derivation Image Functional Group (C.7.16.2 present otherwise.
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Segmentation	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Segmentation Image	C.8.20.2	M
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Specimen	C.7.6.22	U
	Common Instance Reference	C.12.2	C - Required if Derivation Image Functional Group (C.7.16.2.6) is present.
	SOP Common	C.12.1	M
	Frame Extraction	C.12.3	C - Required if the SOP Instance was created in response to a Frame-Level retrieve request

```
[fedorov@gridftp-spl patient62]$ tree .
.
├── scan1
│   ├── 1_aorta.nii.gz
│   ├── 1_cerebellum.nii.gz
│   ├── 1_CT.nrrd
│   ├── 1_liver.nii.gz
│   ├── 1_PT.nrrd
│   ├── 1_PT_regions.nrrd
│   ├── CT.vtk
│   └── PT.vtk
```

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Segmentation: provenance

```
(0010,0010) PN [QIN-HEADNECK-01-0062]                                  #  20, 1 PatientName
(0010,0020) LO [QIN-HEADNECK-01-0062]                                  #  20, 1 PatientID
(0010,0030) DA (no value available)                                    #   0, 0 PatientBirthDate
(0010,0040) CS [M]                                                     #   2, 1 PatientSex
(0018,1000) LO [0301032]                                               #   8, 1 DeviceSerialNumber
(0018,1020) LO [61d579c]                                               #   8, 1 SoftwareVersions
(0020,000d) UI [1.3.6.1.4.1.14519.5.2.1.2744.7002.947943264570090730628151251280] #  64, 1 StudyInstanceUID
(0020,000e) UI [1.2.276.0.7230010.3.1.3.0.85681.1413466373.426906] #  50, 1 SeriesInstanceUID
(0020,0010) SH (no value available)                                    #   0, 0 StudyID
(0020,0011) IS [4711]                                                  #   4, 1 SeriesNumber
(0020,0013) IS [1234]                                                  #   4, 1 InstanceNumber
(0020,0052) UI [1.3.6.1.4.1.14519.5.2.1.2744.7002.659051322069805318485858461350] #  64, 1 FrameOfReferenceUID
```

```
(0008,0060) CS [SEG]                                                   #   4, 1 Modality
(0008,0070) LO [CPS]                                                   #   4, 1 Manufacturer
(0008,0090) PN (no value available)                                    #   0, 0 ReferringPhysicianName
(0008,1030) LO [Thorax^1HEAD_NECK_PETCT]                               #  24, 1 StudyDescription
(0008,1090) LO [1023]                                                  #   4, 1 ManufacturerModelName
(0008,1115) SQ (Sequence with undefined length #=1)                    # u/l, 1 ReferencedSeriesSequence
  (fffe,e000) na (Item with undefined length #=2)                        # u/l, 1 Item
    (0008,114a) SQ (Sequence with undefined length #=299)                # u/l, 1 ReferencedInstanceSequence
      (fffe,e000) na (Item with undefined length #=2)                      # u/l, 1 Item
        (0008,1150) UI =PositronEmissionTomographyImageStorage           #  28, 1 ReferencedSOPClassUID
        (0008,1155) UI [1.3.6.1.4.1.14519.5.2.1.2744.7002.156917295776674257723287910607] #  64, 1 ReferencedSOPInstanceUID
      (fffe,e00d) na (ItemDelimitationItem)                              #   0, 0 ItemDelimitationItem
      (fffe,e000) na (Item with undefined length #=2)                    # u/l, 1 Item
        (0008,1150) UI =PositronEmissionTomographyImageStorage           #  28, 1 ReferencedSOPClassUID
        (0008,1155) UI [1.3.6.1.4.1.14519.5.2.1.2744.7002.180853035894851117565926871554] #  64, 1 ReferencedSOPInstanceUID
```

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Multi-segment, structured terminology, analysis provenance

```
(0062,0001) CS [BINARY]                                  #   6, 1 SegmentationType
(0062,0002) SQ (Sequence with undefined length #=5)      # u/l, 1 SegmentSequence
  (fffe,e000) na (Item with undefined length #=5)          # u/l, 1 Item
    (0062,0003) SQ (Sequence with undefined length #=1)      # u/l, 1 SegmentedPropertyCategoryCodeSequence
      (fffe,e000) na (Item with undefined length #=3)          # u/l, 1 Item
        (0008,0100) SH [T-D000A]                                 #   8, 1 CodeValue
        (0008,0102) SH [SRT]                                     #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [Anatomical Structure]                    #  20, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                    #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)                #   0, 0 SequenceDelimitationItem
    (0062,0004) US 1                                         #   2, 1 SegmentNumber
    (0062,0005) LO [Regions/cerebellum.nrrd label 1]         #  32, 1 SegmentLabel
    (0062,0008) CS [MANUAL]                                  #   6, 1 SegmentAlgorithmType
    (0062,000f) SQ (Sequence with undefined length #=1)      # u/l, 1 SegmentedPropertyTypeCodeSequence
      (fffe,e000) na (Item with undefined length #=3)          # u/l, 1 Item
        (0008,0100) SH [T-A6000]                                 #   8, 1 CodeValue
        (0008,0102) SH [SRT]                                     #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [Cerebellum]                              #  10, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                    #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)                #   0, 0 SequenceDelimitationItem
  (fffe,e00d) na (ItemDelimitationItem)                    #   0, 0 ItemDelimitationItem
  (fffe,e000) na (Item with undefined length #=5)          # u/l, 1 Item
    (0062,0003) SQ (Sequence with undefined length #=1)      # u/l, 1 SegmentedPropertyCategoryCodeSequence
      (fffe,e000) na (Item with undefined length #=3)          # u/l, 1 Item
        (0008,0100) SH [T-D000A]                                 #   8, 1 CodeValue
        (0008,0102) SH [SRT]                                     #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [Anatomical Structure]                    #  20, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                    #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)                #   0, 0 SequenceDelimitationItem
    (0062,0004) US 2                                         #   2, 1 SegmentNumber
    (0062,0005) LO [Regions/aorta_resampled.nrrd label 1]    #  36, 1 SegmentLabel
    (0062,0008) CS [MANUAL]                                  #   6, 1 SegmentAlgorithmType
    (0062,000f) SQ (Sequence with undefined length #=1)      # u/l, 1 SegmentedPropertyTypeCodeSequence
      (fffe,e000) na (Item with undefined length #=3)          # u/l, 1 Item
        (0008,0100) SH [T-42300]                                 #   8, 1 CodeValue
        (0008,0102) SH [SRT]                                     #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [Aortic Arch]                             #  12, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                    #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)                #   0, 0 SequenceDelimitationItem
```

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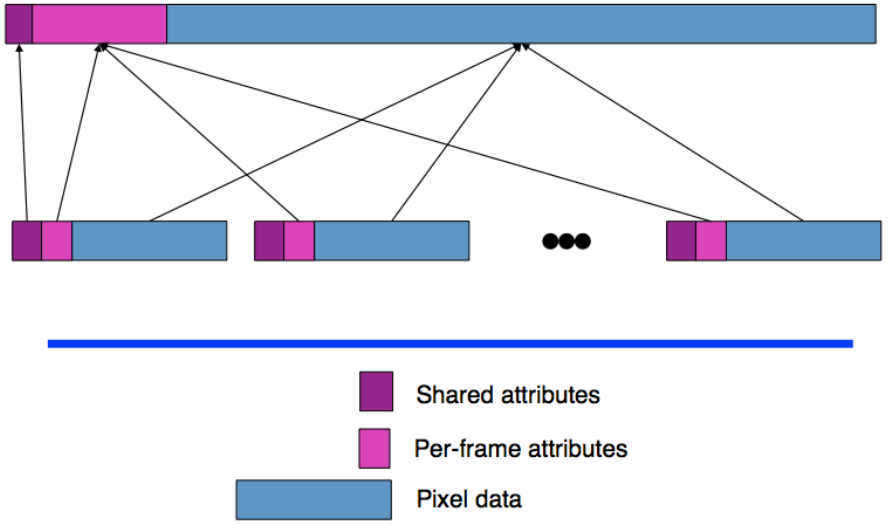
Multiframe, bit-encoded




```
(5200,9229) SQ (Sequence with undefined length #=1)     # u/l, 1 SharedFunctionalGroupsSequence
  (fffe,e000) na (Item with undefined length #=2)         # u/l, 1 Item
    (0020,9116) SQ (Sequence with undefined length #=1)     # u/l, 1 PlaneOrientationSequence
      (fffe,e000) na (Item with undefined length #=1)         # u/l, 1 Item
        (0020,0037) DS [1.000000e+00\0.000000e+00\0.000000e+00\0.000000e+00\1.000000e+00\0... #  78, 6 ImageOrientationPatient
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
    (0028,9110) SQ (Sequence with undefined length #=1)     # u/l, 1 PixelMeasuresSequence
      (fffe,e000) na (Item with undefined length #=2)         # u/l, 1 Item
        (0018,0088) DS [3.375000e+00]                           #  12, 1 SpacingBetweenSlices
        (0028,0030) DS [3.538000e+00\3.538000e+00]              #  26, 2 PixelSpacing
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
  (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
(fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
```

Multiframe

```
(5200,9230) SQ (Sequence with undefined length #=1495)  # u/l, 1 PerFrameFunctionalGroupsSequence
  (fffe,e000) na (Item with undefined length #=4)         # u/l, 1 Item
    (0008,9124) SQ (Sequence with undefined length #=1)     # u/l, 1 DerivationImageSequence
      (fffe,e000) na (Item with undefined length #=2)         # u/l, 1 Item
        (0008,2112) SQ (Sequence with undefined length #=1)     # u/l, 1 SourceImageSequence
          (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
            (0008,1150) UI =PositronEmissionTomographyImageStorage  #  28, 1 ReferencedSOPClassUID
            (0008,1155) UI [1.3.6.1.4.1.14519.5.2.1.2744.7002.156917295776674257723287910607] #  64, 1 ReferencedSOPInstanceUID
            (0040,a170) SQ (Sequence with undefined length #=1)     # u/l, 1 PurposeOfReferenceCodeSequence
              (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
                (0008,0100) SH [121322]                                 #   6, 1 CodeValue
                (0008,0102) SH [DCM]                                    #   4, 1 CodingSchemeDesignator
                (0008,0104) LO [Source image for image processing operation] #  44, 1 CodeMeaning
```

```
    (0020,9111) SQ (Sequence with undefined length #=1)     # u/l, 1 FrameContentSequence
      (fffe,e000) na (Item with undefined length #=1)         # u/l, 1 Item
        (0020,9157) UL 1\1                                      #   8, 2 DimensionIndexValues
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
    (0020,9113) SQ (Sequence with undefined length #=1)     # u/l, 1 PlanePositionSequence
      (fffe,e000) na (Item with undefined length #=1)         # u/l, 1 Item
        (0020,0032) DS [-2.262090e+02\-4.261630e+02\-1.554937e+03] #  42, 3 ImagePositionPatient
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
    (0062,000a) SQ (Sequence with undefined length #=1)     # u/l, 1 SegmentIdentificationSequence
      (fffe,e000) na (Item with undefined length #=1)         # u/l, 1 Item
        (0062,000b) US 1                                        #   2, 1 ReferencedSegmentNumber
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
```

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PET Standard Uptake Value (SUV)

– most widely used parameter for most tracers

– the only PET quantification method that can be realistically applied in daily clinical practice

$$SUV = \frac{radiotracer\ concentration}{\frac{injected\ activity}{normalization\ factor}}$$

–Commonly used normalization factors:

- body weight (BW)
- body surface (BSA)
- lean body mass (LBM)

Real World Value Mapping IOD

A.46 Real World Value Mapping IOD

The Real World Value Mapping Information Object Definition specifies a mapping of the stored pixel values of referenced images into some Real World value in defined units. This allows the capture of retrospectively determined mappings, e.g., for values that cannot be determined at the time of image acquisition and encoding.

Note

A particular use case is mapping of PET pixel values to counts, concentration, or selective uptake values (SUVs) normalized by one of several factors.

```
(0008,1115) SQ (Sequence with undefined length #=1)     # u/l, 1 ReferencedSeriesSequence
  (fffe,e000) na (Item with undefined length #=2)         # u/l, 1 Item
    (0008,114a) SQ (Sequence with undefined length #=299)   # u/l, 1 ReferencedInstanceSequence
      (fffe,e000) na (Item with undefined length #=2)         # u/l, 1 Item
        (0008,1150) UI =PositronEmissionTomographyImageStorage  #  28, 1 ReferencedSOPClassUID
        (0008,1155) UI [1.3.6.1.4.1.14519.5.2.1.2744.7002.323134652310950452738372664035] #  64, 1 ReferencedSOPInstanceUID
```

```
(0040,9096) SQ (Sequence with undefined length #=1)     # u/l, 1 RealWorldValueMappingSequence
  (fffe,e000) na (Item with undefined length #=9)         # u/l, 1 Item
    (0028,3003) LO [Standardized Uptake Value body weight]  #  38, 1 LUTExplanation
    (0040,08ea) SQ (Sequence with undefined length #=1)     # u/l, 1 MeasurementUnitsCodeSequence
      (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
        (0008,0100) SH [{SUVbw}g/ml]                            #  12, 1 CodeValue
        (0008,0102) SH [UCUM]                                   #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [Standardized Uptake Value body weight]  #  38, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
    (0040,9210) SH [{SUVbw}g/ml]                            #  12, 1 LUTLabel
    (0040,9211) US 10000                                    #   2, 1 RealWorldValueLastValueMapped
    (0040,9216) SS 0                                        #   2, 1 RealWorldValueFirstValueMapped
    (0040,9224) FD 0                                        #   8, 1 RealWorldValueIntercept
    (0040,9225) FD 0.000371997                              #   8, 1 RealWorldValueSlope
```

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Real World Value Mapping: Quantity

```
(0040,9220) SQ (Sequence with undefined length #=2)     # u/l, 1 Unknown Tag & Data
  (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
    (0040,a040) CS [CODE]                                   #   4, 1 ValueType
    (0040,a043) SQ (Sequence with undefined length #=1)     # u/l, 1 ConceptNameCodeSequence
      (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
        (0008,0100) SH [G-C1C6]                                 #   6, 1 CodeValue
        (0008,0102) SH [SRT]                                    #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [Quantity]                               #   8, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
    (0040,a168) SQ (Sequence with undefined length #=1)     # u/l, 1 ConceptCodeSequence
      (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
        (0008,0100) SH [126400]                                 #   6, 1 CodeValue
        (0008,0102) SH [DCM]                                    #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [Standardized Uptake Value]              #  26, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
  (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
  (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
    (0040,a040) CS [CODE]                                   #   4, 1 ValueType
    (0040,a043) SQ (Sequence with undefined length #=1)     # u/l, 1 ConceptNameCodeSequence
      (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
        (0008,0100) SH [G-C036]                                 #   6, 1 CodeValue
        (0008,0102) SH [SRT]                                    #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [Measurement Method]                     #  18, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
    (0040,a168) SQ (Sequence with undefined length #=1)     # u/l, 1 ConceptCodeSequence
      (fffe,e000) na (Item with undefined length #=3)         # u/l, 1 Item
        (0008,0100) SH [126410]                                 #   6, 1 CodeValue
        (0008,0102) SH [DCM]                                    #   4, 1 CodingSchemeDesignator
        (0008,0104) LO [SUV body weight calculation method]     #  34, 1 CodeMeaning
      (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
    (fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
  (fffe,e00d) na (ItemDelimitationItem)                   #   0, 0 ItemDelimitationItem
(fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
```

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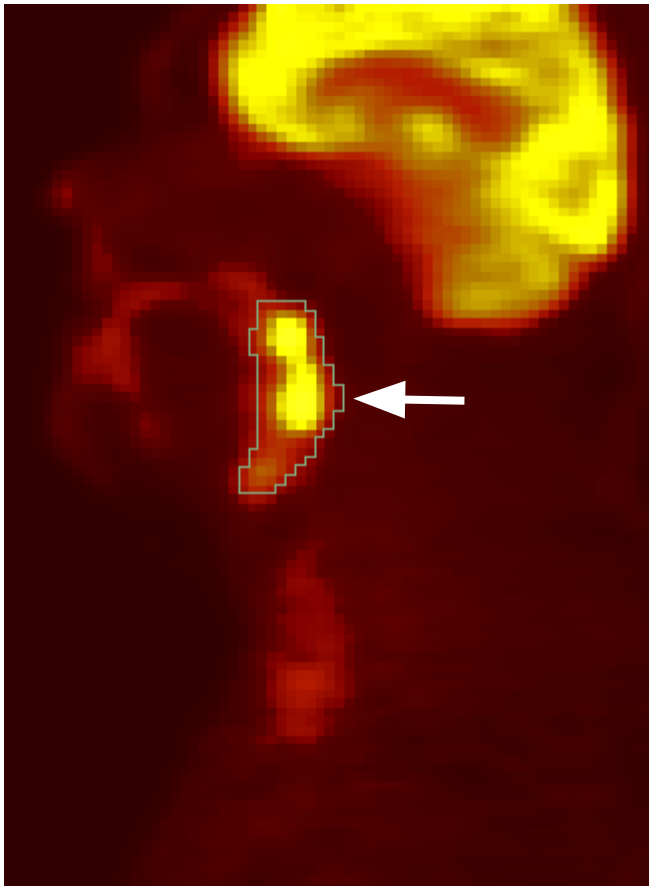
SUV quantification

Segmented region statistics

- Summary statistics (volume, min/max, mean, STD)
- Histogram statistics (quantiles)
- Peak, SAM, ...



DICOM Structured Reporting

Table TID 1500. Measurement Report

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			CONTAINER	DCID 7021 "Measurement Report Document Titles"	1	M		Root node
2	>	HAS CONCEPT MOD	INCLUDE	DTID 1204 "Language of Content Item and Descendants"	1	M		
3	>	HAS OBS CONTEXT	INCLUDE	DTID 1001 "Observation Context"	1	M		
4	>	HAS CONCEPT MOD	CODE	EV (121058, DCM, "Procedure reported")	1-n	M		BCID 100 "Quantitative Diagnostic Imaging Procedures"
5	>	CONTAINS	INCLUDE	DTID 1600 "Image Library" (CP-1389)	1	M		
6	>	CONTAINS	CONTAINER	EV (126010, DCM, "Imaging Measurements")	1	C	IF row 10 and 12 are absent	
7	>>	CONTAINS	INCLUDE	DTID 1410 "Planar ROI Measurements"	1-n	U		$Measurement = BCID 7469 "Generic Intensity and Size Measurements" $Units = BCID 7181 "Abstract Multi-dimensional Image Model Component Units" $Derivation = BCID 7464 "General Region of Interest Measurement Modifiers" $Method = BCID 6147 "Response Criteria"

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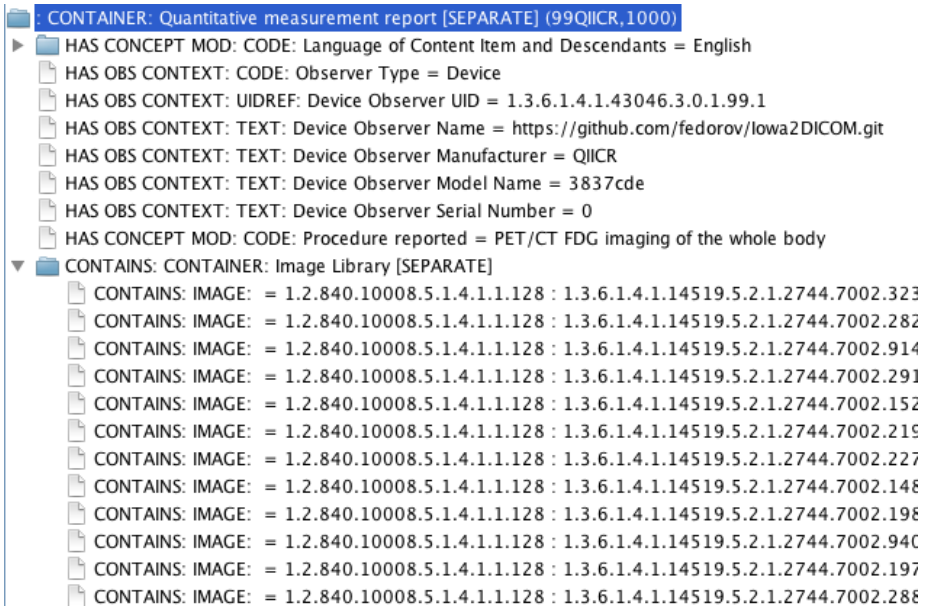
DICOM Structured Reporting

Structured Report Template

Table TID 1500. Measurement Report

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			CONTAINER	DCID 7021 "Measurement Report Document Titles"	1	M		Root node
2	>	HAS CONCEPT MOD	INCLUDE	DTID 1204 "Language of Content Item and Descendants"	1	M		
3	>	HAS OBS CONTEXT	INCLUDE	DTID 1001 "Observation Context"	1	M		
4	>	HAS CONCEPT MOD	CODE	EV (121058, DCM, "Procedure reported")	1-n	M		BCID 100 "Quantitative Diagnostic Imaging Procedures"
5	>	CONTAINS	INCLUDE	DTID 1600 "Image Library" (CP-1389)	1	M		
6	>	CONTAINS	CONTAINER	EV (126010, DCM, "Imaging Measurements")	1	C	IF row 10 and 12 are absent	
7	>>	CONTAINS	INCLUDE	DTID 1410 "Planar ROI Measurements"	1-n	U		$Measurement = BCID 7469 "Generic Intensity and Size Measurements" $Units = BCID 7181 "Abstract Multi-dimensional Image Model Component Units" $Derivation = BCID 7464 "General Region of Interest Measurement Modifiers" $Method = BCID 6147 "Response Criteria"

Structured Report instance



* Output of PixelMed StructuredReportBrowser tool http://www.dclunie.com/pixelmed/software/

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Reporting measurements

Structured Report Template

9	>>	CONTAINS	INCLUDE	DTID 1501 "Measurement Group"	1-n	U		$Measurement = BCID 7469 "Generic Intensity and Size Measurements" $Units = BCID 7181 "Abstract Multi-dimensional Image Model Component Units" $Derivation = BCID 7464 "General Region of Interest Measurement Modifiers" $Method = BCID 6147 "Response Criteria"

Table TID 1501. Measurement Group

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1		CONTAINS	CONTAINER	EV (125007, DCM, "Measurement Group")	1	M		
2	>	HAS OBS CONTEXT	TEXT	DT (112039, DCM, "Tracking Identifier")	1	M		
3	>	HAS OBS CONTEXT	UIDREF	EV (112040, DCM, "Tracking Unique Identifier")	1	M		
4	>	CONTAINS	INCLUDE	DTID 1502 "Time Point Context"	1	U		
5	>	HAS CONCEPT MOD	CODE	EV (G-C036, SRT, "Measurement Method")	1	U		$Method
6	>	HAS CONCEPT MOD	CODE	EV (G-C0E3, SRT, "Finding Site")	1	U		$TargetSite
7	>>	HAS CONCEPT MOD	CODE	EV (G-C171, SRT, "Laterality")	1	U		DCID 244 "Laterality"
8	>>	HAS CONCEPT MOD	CODE	DT (G-A1F8, SRT, "Topographical modifier")	1	U		$TargetSiteMod
9	>	CONTAINS	COMPOSITE	EV (CP-1388 dd3001, DCM, "Real World Value Map used for measurement")	1	U		SOP Class UID shall be Real World Value Mapping Storage ("1.2.840.10008.5.1.4.1.1.67")
10	>	CONTAINS	INCLUDE	DTID 300 "Imaging Measurement"	1-n	M		$Measurement = $Measurement $Units = $Units $ModType = $ModType

Structured Report instance

- CONTAINS: CONTAINER: Measurements [SEPARATE]
  - CONTAINS: CONTAINER: Measurement Group [SEPARATE]
    - HAS OBS CONTEXT: TEXT: Tracking Identifier = Aortic arch
    - HAS OBS CONTEXT: UIDREF: Tracking Unique Identifier = 1.3.6.1.4.1.43046.3.1.4.0.58727.14
    - CONTAINS: IMAGE: Referenced Segment = 1.2.840.10008.5.1.4.1.1.66.4 : 1.2.276.0.723001
    - CONTAINS: UIDREF: Source series for image segmentation = 1.3.6.1.4.1.14519.5.2.1.2744.70
    - CONTAINS: NUM: SUVbw = 1.96772 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = Mean
      - INFERRED FROM: COMPOSITE: Real World Value Map used for measurements = 1.2.840.10(
    - CONTAINS: NUM: SUVbw = 1.98081 Standardized Uptake Value body weight
    - CONTAINS: NUM: Variance = 0.0516817 Gram**2/milliliter**2
    - CONTAINS: NUM: SUVbw = 2.72994 Standardized Uptake Value body weight
    - CONTAINS: NUM: SUVbw = 1.3504 Standardized Uptake Value body weight
    - CONTAINS: NUM: Volume = 7350.11 Milliliter
    - CONTAINS: NUM: Total Lesion Glycolysis (TLG) = 14463 Gram
    - CONTAINS: NUM: Glycolysis Within First Quarter of Intensity Range = 1173.02 Gram
    - CONTAINS: NUM: Glycolysis Within Second Quarter of Intensity Range = 7198.55 Gram
    - CONTAINS: NUM: Glycolysis Within Third Quarter of Intensity Range = 5457.6 Gram
    - CONTAINS: NUM: Glycolysis Within Fourth Quarter of Intensity Range = 633.782 Gram
    - CONTAINS: NUM: Percent Within First Quarter of Intensity Range = 0.103448 Percent
    - CONTAINS: NUM: Percent Within Second Quarter of Intensity Range = 0.517241 Percent
    - CONTAINS: NUM: Percent Within Third Quarter of Intensity Range = 0.344828 Percent
    - CONTAINS: NUM: Percent Within Fourth Quarter of Intensity Range = 0.0344828 Percent
    - CONTAINS: NUM: SUVbw = 1.83977 Standardized Uptake Value body weight
    - CONTAINS: NUM: SUVbw = 1.97609 Standardized Uptake Value body weight
    - CONTAINS: NUM: SUVbw = 2.11241 Standardized Uptake Value body weight
    - CONTAINS: NUM: SUVbw = 2.51672 Standardized Uptake Value body weight
    - CONTAINS: NUM: Standardized Added Metabolic Activity (SAM) = 380.462 Gram
    - CONTAINS: NUM: SUVbw = 1.91596 Standardized Uptake Value body weight
    - CONTAINS: NUM: SUVbw = 7.71835e-42 Standardized Uptake Value body weight
  - CONTAINS: CONTAINER: Measurement Group [SEPARATE]
  - CONTAINS: CONTAINER: Measurement Group [SEPARATE]
  - CONTAINS: CONTAINER: Measurement Group [SEPARATE]

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DICOM Segmentation IOD

Table A.51-1. Segmentation IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Segmentation Series	C.8.20.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	C - Required if Derivation Image Functional Group (C.7.16.2.6) is not present. May be present otherwise.
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Segmentation	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Segmentation Image		
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Specimen	C.7.6.22	U
	Common Instance Reference	C.12.2	C - Required
	SOP Common	C.12.1	M
	Frame Extraction	C.12.3	C - Required request

Table C.8.20-2. Segmentation Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Value 1 shall be DERIVED. Value 2 shall be PRIMARY. No other values shall be present.
Include Table 10-12 "Content Identification Macro Attributes"			
Samples Per Pixel	(0028,0002)	1	Enumerated Values: 1
Photometric Interpretation	(0028,0004)	1	Enumerated Values: MONOCHROME2
Pixel Representation	(0028,0103)	1	Enumerated Values: 0
Bits Allocated	(0028,0100)	1	See Section C.8.20.2.1. Enumerated Values if Segmenta 1 Enumerated Values if Segmenta BINARY: 8

Table 10-12. Content Identification Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Instance Number	(0020,0013)	1	A number that identifies this SOP Instance.
Content Label	(0070,0080)	1	A label that is used to identify this SOP Instance.
Content Description	(0070,0081)	2	A description of the content of the SOP Instance.
Alternate Content Description Sequence	(0070,0087)	3	A sequence containing alternate descriptions suitable for presentation to the user, e.g., in different languages. One or more Items are permitted in this sequence. ***Note*** *The values of Specific Character Set for the entire Data set need to be sufficient to encode all Items of this sequence correctly, e.g., using a single value with broad support such as UTF-8, or multiple values with escape sequences.*
>Content Description	(0070,0081)	1	An alternate description that is used to identify this SOP Instance.
>Language Code Sequence	(0008,0006)	1	The language in which Content Description (0070,0081) within this sequence item is written. A single Item shall be present.
>>Include Table 8.8-1 "Code Sequence Macro Attributes"			*Defined CID 5000 "Languages".*

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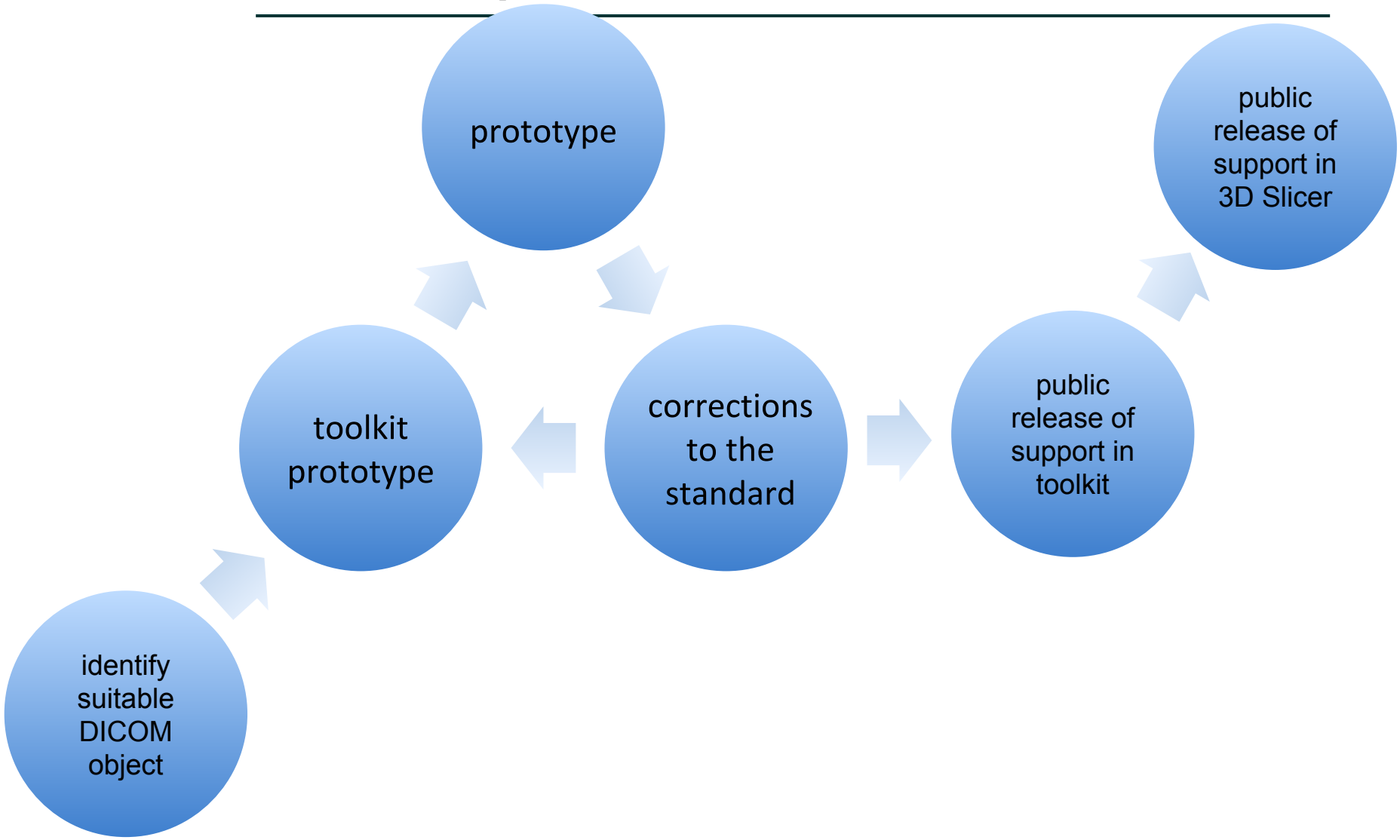
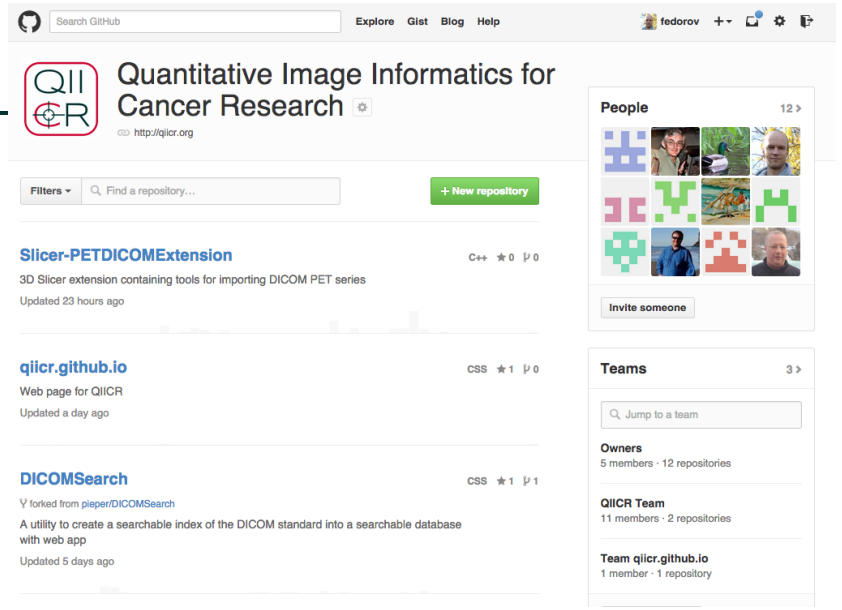
QIICR software process

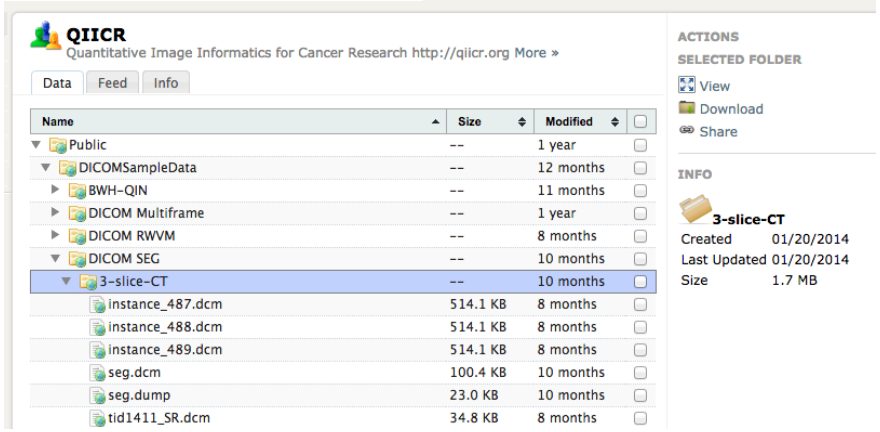


```
117   /* Initialize dimension module */
118   char dimUID[128];
119   dcmGenerateUniqueIdentifier(dimUID, QIICR_UID_ROOT);
120   IODMultiframeDimensionModule &mfdim = segdoc->getDimensions();
121   CHECK_COND(mfdim.addDimensionIndex(DCM_ReferencedSegmentNumber, dimUID, DCM_SegmentIdentificationSequence,
122                              DcmTag(DCM_ReferencedSegmentNumber).getTagName()));
123   CHECK_COND(mfdim.addDimensionIndex(DCM_ImagePositionPatient, dimUID, DCM_PlanePositionSequence,
124                              DcmTag(DCM_ImagePositionPatient).getTagName()));
125
126   /* Initialize shared functional groups */
127   FGInterface &segFGInt = segdoc->getFunctionalGroups();
128
129   // Find mapping from the segmentation slice number to the derivation image
130   // Assume that orientation of the segmentation is the same as the source series
131   std::vector<int> slice2derimg(inputDICOMImageFileNames.size());
132   for(int i=0;i<inputDICOMImageFileNames.size();i++){
133     OFString ippStr;
134     DcmFileFormat sliceFF;
135     DcmDataset *sliceDataset = NULL;
136     ImageType::PointType ippPoint;
137     ImageType::IndexType ippIndex;
138     CHECK_COND(sliceFF.loadFile(inputDICOMImageFileNames[i].c_str()));
139     sliceDataset = sliceFF.getDataset();
140     for(int j=0;j<3;j++){
141       CHECK_COND(sliceDataset->findAndGetOFString(DCM_ImagePositionPatient, ipp
142       ippPoint[j] = atof(ippStr.c_str());
143     }
144     if(!labelImage->TransformPhysicalPointToIndex(ippPoint, ippIndex)){
145       std::cerr << "ImagePositionPatient maps outside the ITK image!" << std::end
146       return -1;
147     }
148     slice2derimg[ippIndex[2]] = i;
149   }
```

prototype



http://github.com/qiicr



http://slicer.kitware.com/midas3/community/27

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DICOM Correction proposals and supplements motivated/contributed by QIICR

Correction proposals:

- CP 1386 Addition of Measurement Report Root Template for Planar and Volumetric ROIs - Final Text
- CP 1387 Addition of Quantity Descriptors to Real World Value Maps - Final Text
- CP 1388 Add Real World Value Map Reference to Measurements - Final Text
- CP 1389 Factor Common Descriptions Out of Image Library Entries - Final Text
- CP 1390 Generalize Concepts in Abstract Multi-dimensional Image Model Component Semantics - Final Text
- CP 1391 Addition of Quantity Descriptors for Perfusion and Tracer Kinetic Modelling - Final Text
- CP 1392 Addition of Quantity Descriptors and Measurements for PET - Final Text
- CP 1406 Add codes for tumor sites - Ballot
- CP 1426 Correct condition in Pixel Measures, Plane Position and Orientation Functional Groups for Segmentation - Work

Supplements:

- Supp 172 Parametric Map Storage - Final Text - supports encoding of floating point pixels

https://github.com/QIICR/ProjectIssuesAndWiki/wiki/Documentation

DICOM Standard Status

Maintained by David A. Clunie dclunie@dclunie.com.

Last Updated: Sat Nov 15 07:57:58 EST 2014

Table Of Contents

DICOM
Digital Imaging and Communications in Medicine

At any point in time the offical standard consists of the most recent yearly edition of the base standard (currently 2014b) PLUS all the supplements and correction items that have been approved as Final Text.

The PDF versions are the official documents; other formats (such as DocBook, HTML, Word and ODT) are also made available for the convenience of implementors who may need to extract machine-readable content, or copy tables and sections of text, but when a discrepancy exists, the PDF form is authoritative.

Spreadsheets used by DICOM WG 6 to track the status of work in progress including work items, supplements and CPs can be found at ftp://medical.nema.org/medical/Dicom/Overviews-CPs-Sups-WIs/

Final Text Supplements additional to 2014b Base Standard

Supplement	Affected	Title	Status	Applies To	Document
Supp 171	Parts 4,17,18	Unified Procedure Step by REpresentational State Transfer (REST) Services	Standard	2014b	
Supp 172	Parts 2,3,4,5,6,16,17,18,19	Parametric Map Storage	Standard	2014b	

http://www.dclunie.com/dicom-status/status.html

corrections to the standard

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DICOM@OFFIS

DCMTK - DICOM Toolkit

dicom.offis.de

Version in

- Home
- General Information
  - Standardization
  - Introduction to DICOM
- DICOM Demos
  - DICOM Networks
  - Media Exchange
  - Display Consistency
  - Image Conformance
- DICOM Software
  - DCMTK
  - DICOMscope
  - DCMPRINT
  - DCMCHECK
  - DCMJP2K
  - DCMPPS
  - DCMPPSCU

Description

DCMTK is a collection of libraries and applications implementing large parts the DICOM standard. It includes software for examining, constructing and converting DICOM image files, handling offline media, sending and receiving images over a network connection, as well as demonstrative image storage and worklist servers. DCMTK is written in a mixture of ANSI C and C++. It comes in complete source code and is made available as "open source" software.

DCMTK has been used at numerous DICOM demonstrations to provide central, vendor-independent image storage and worklist servers (CTNs - Central Test Nodes). It is used by hospitals and companies all over the world for a wide variety of purposes ranging from being a tool for product testing to being a building block for research projects, prototypes and commercial products.

The DCMTK software can be compiled under Windows and a wide range of Unix operating systems including Linux, Solaris, HP-UX, IRIX, FreeBSD, OpenBSD and MacOS X. All necessary configuration scripts and project makefiles are supplied.

See the documentation included with the distribution for the latest information about changes in DCMTK between releases. A summary of the highlights of the current release is available in the ANNOUNCE file. An overview of the toolkit's modules is included in the distribution's README file. The COPYRIGHT text and the history of DCMTK's development are also available online. Frequently asked questions are answered in the FAQ.

http://dicom.offis.de/dcmtk.php.en

michaelonken / dcmtk PRIVATE

branch: seg

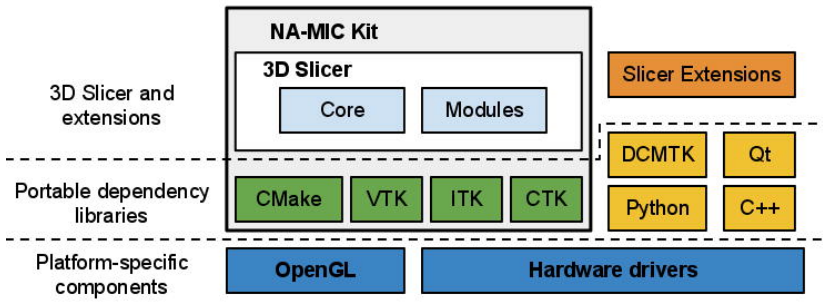
Commits on Nov 6, 2014

- Big improvements on funct. groups / segmentations ... — michaelonken authored 9 days ago

Commits on Nov 5, 2014

- New functions to get number of frames and segments — michaelonken authored 10 days ago
- Renamed numFrames() to getNumberOfFrames() — michaelonken authored 10 days ago
- Return numbers instead of strings for pix measures — michaelonken authored 10 days ago
- Fix cloning of Derivation Image FG — michaelonken authored 11 days ago

toolkit prototype



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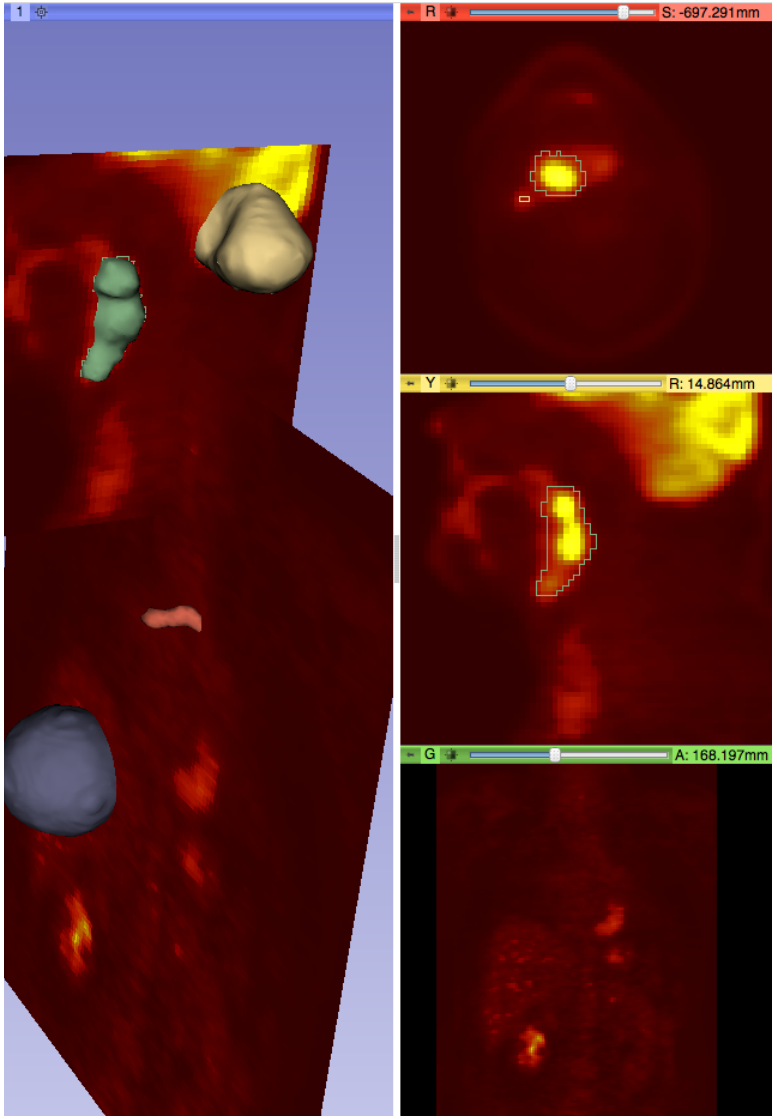
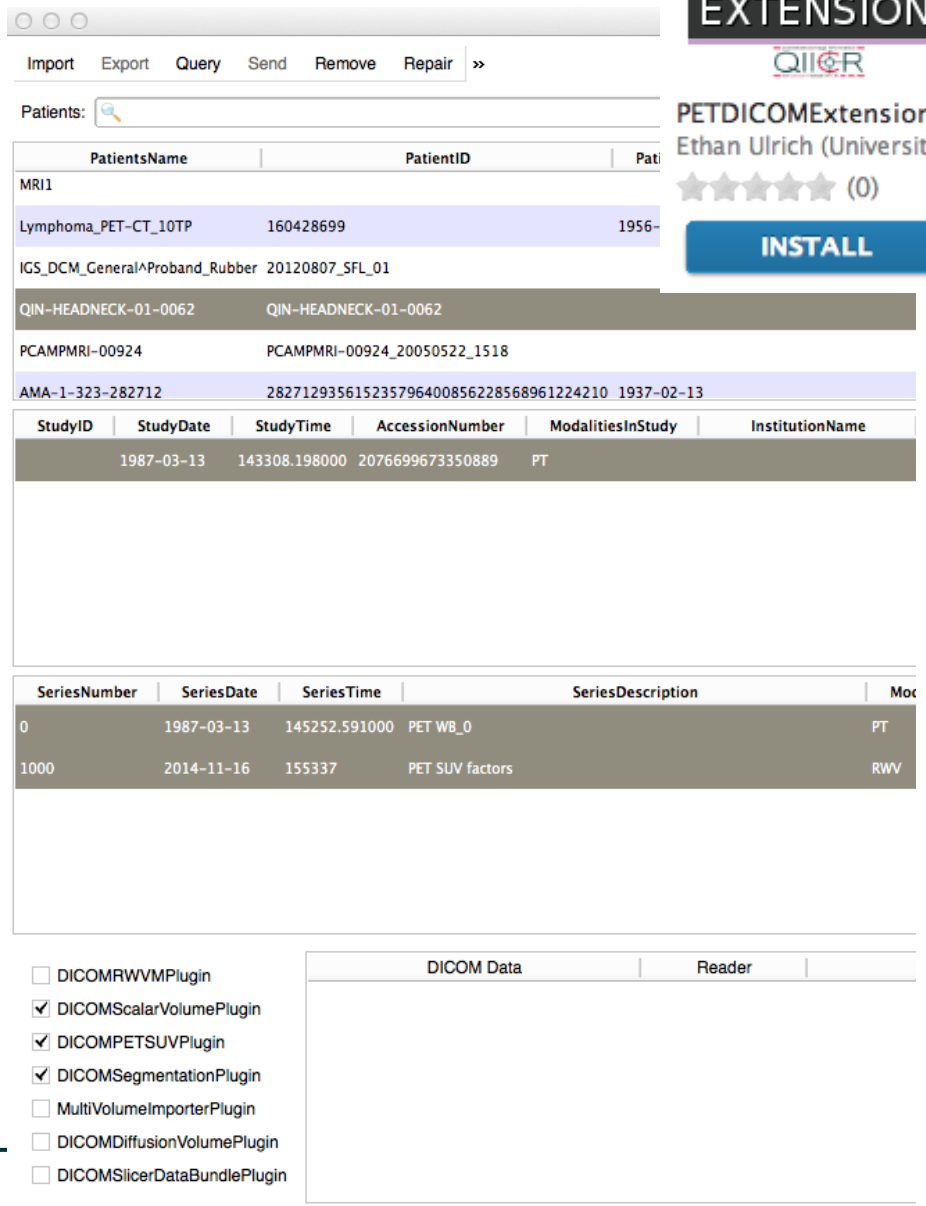
PET SUV analysis extension





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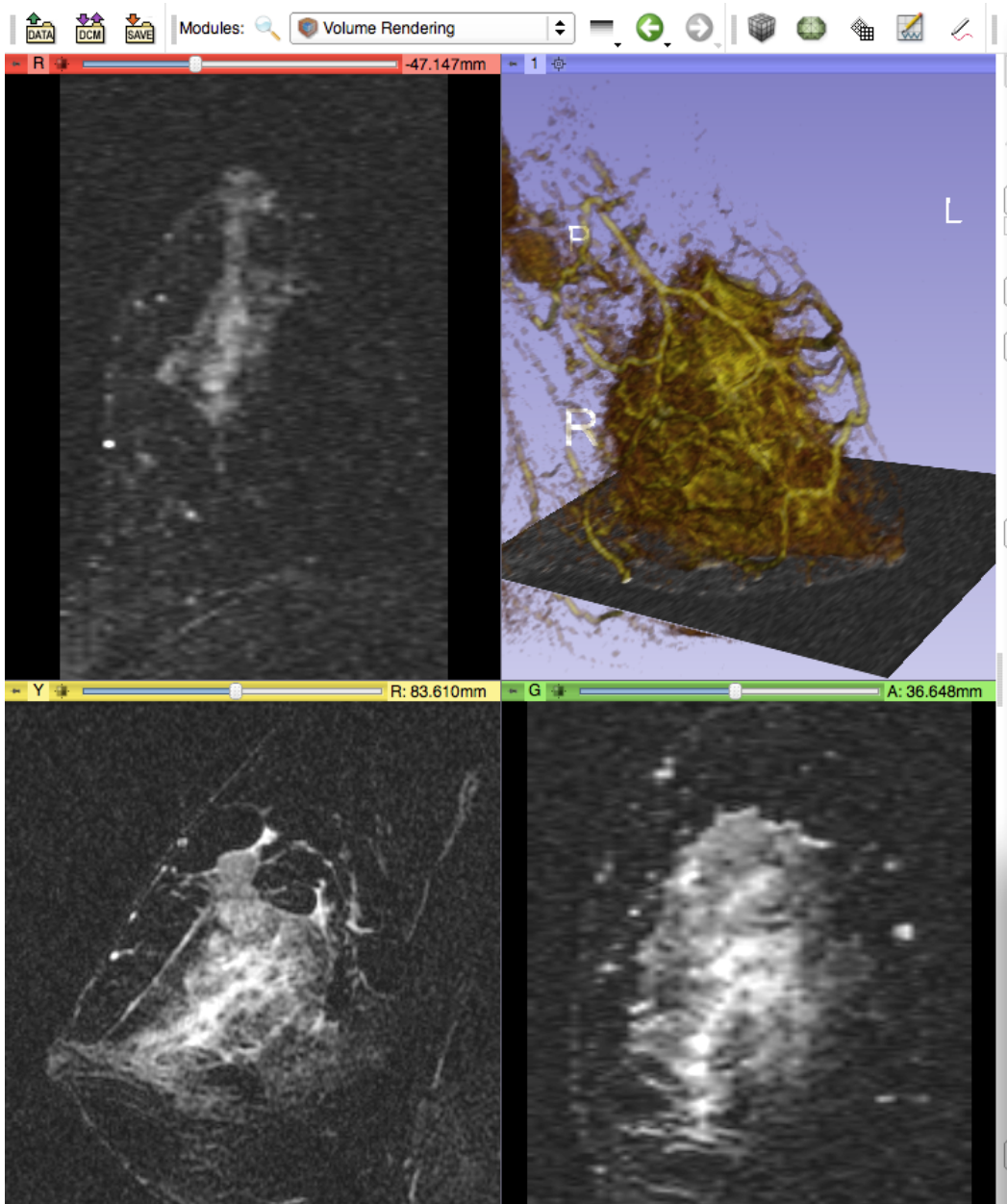
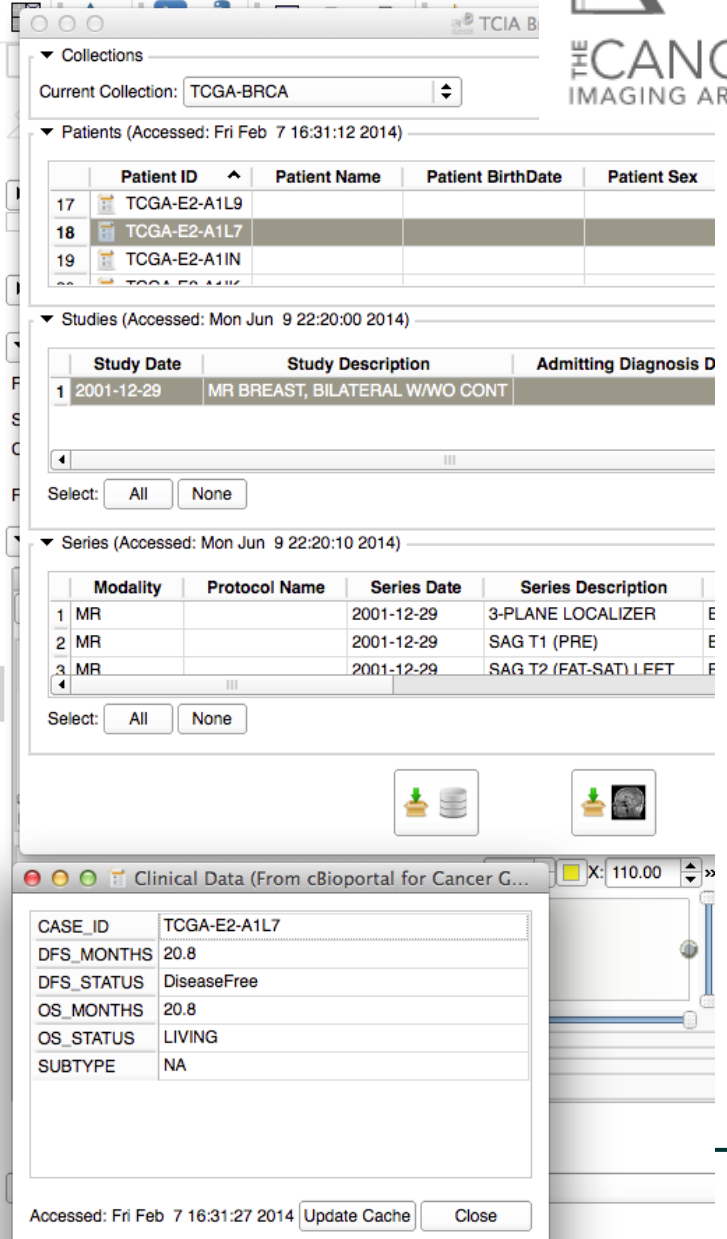
TCIA browser





DICOM searchable index

fedorov.cloudant.com/dicom_search-2014a-chtml/.site/index.html

A Searchable Index of the DICOM Base Standard 2014a

Word to search for: real world value mapp
Results per query ◉10 ○20 ○100 ○200
Select options

Results for "real world value mapping iod" (10 hits)

PS3.3
A.46 Real World Value Mapping IOD

PS3.3
A.46.2 Real World Value Mapping IOD Modules

PS3.3
Real World Value Mapping

PS3.3
Real World Value Mapping

PS3.3
Real World Value Mapping

PS3.3
Real World Value Mapping

PS3.3
Real World Value Mapping

A.46 Real World Value Mapping IOD

The Real World Value Mapping Information Object Definition specifies a mapping of the stored pixel values of referenced images into some Real World value in defined units. This allows the capture of retrospectively determined mappings, e.g., for values that cannot be determined at the time of image acquisition and encoding.

Note

A particular use case is mapping of PET pixel values to counts, concentration, or selective uptake values (SUVs) normalized by one of several factors.

A.46.1 Real World Value Mapping IOD Entity-Relationship Model

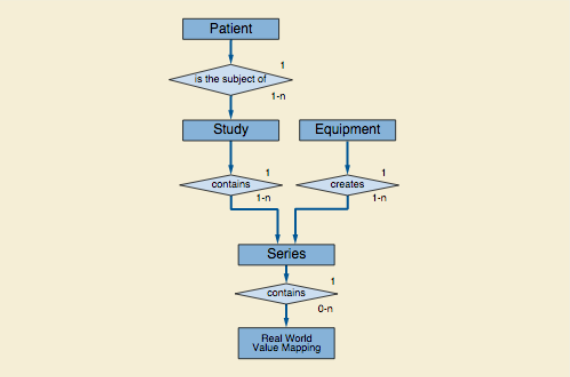


Figure A.46-1. Real World Value Mapping Information Object Definition E-R Model

A.46.2 Real World Value Mapping IOD Modules

Table A.46-1. Real World Value Mapping IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M

This interface provided by QIICR © 2014. The DICOM Standard is © NEMA 2014. Related projects include: 3D Slicer NA-MIC NAC NCIGT CTK

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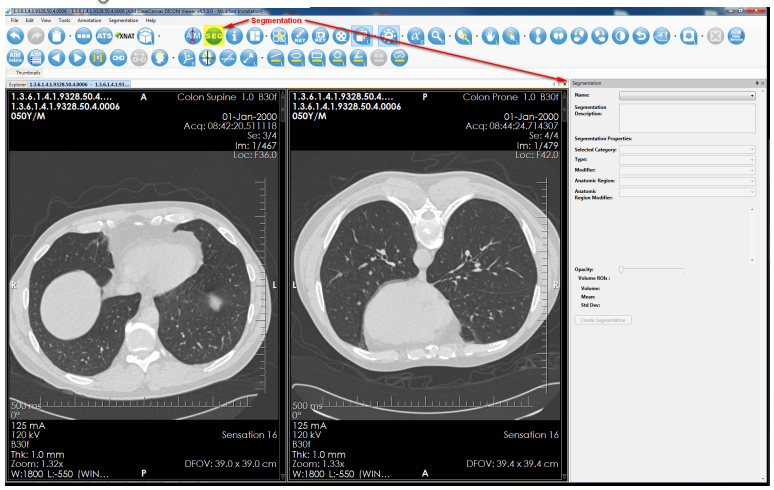
Beyond 3D Slicer: Research workstations

clearcanvas
imagination is all it takes...



ePAD web-based platform for quantitative imaging in the clinical workflow

https://epad.stanford.edu/

Creating DICOM Segmentations (new in 4.5)

Two files, `AnatomicRegionAndModifier.xml` and `SegmentationCategoryTypeModifier.xml` are used to describe DICOM segmentations that you can create based on the DICOM standard. You may choose to create and import your own descriptions for anatomic regions and segmentation categories. In this case, you must follow XML schemas designed for an anatomic

https://wiki.nci.nih.gov/display/AIM/AIM+on+ClearCanvas+Workstation+4.5+User%27s+Guide

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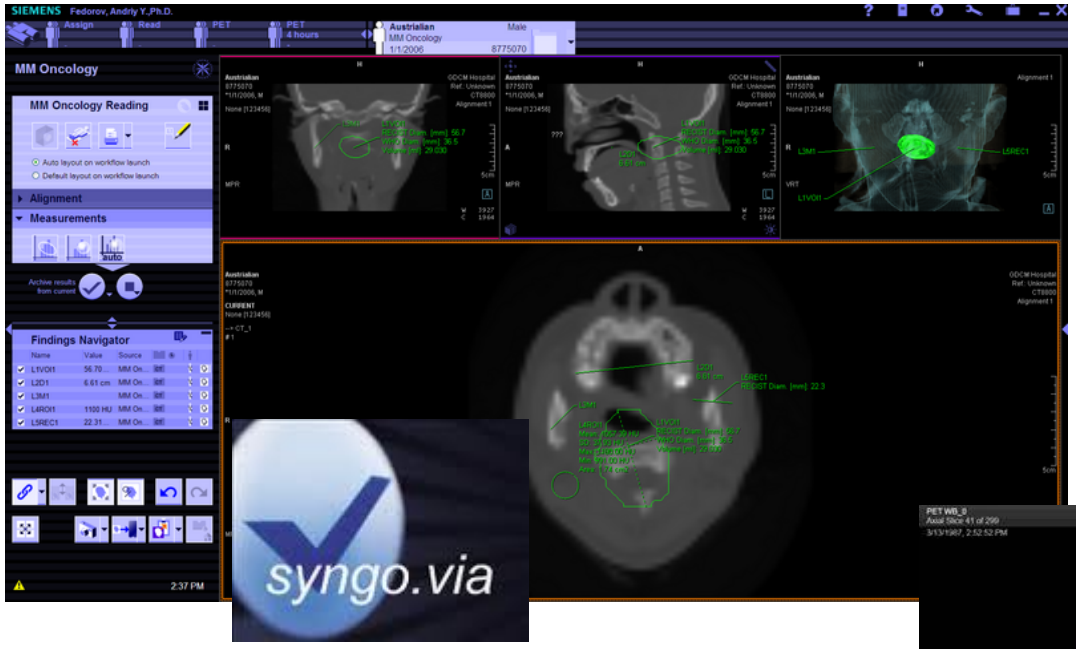
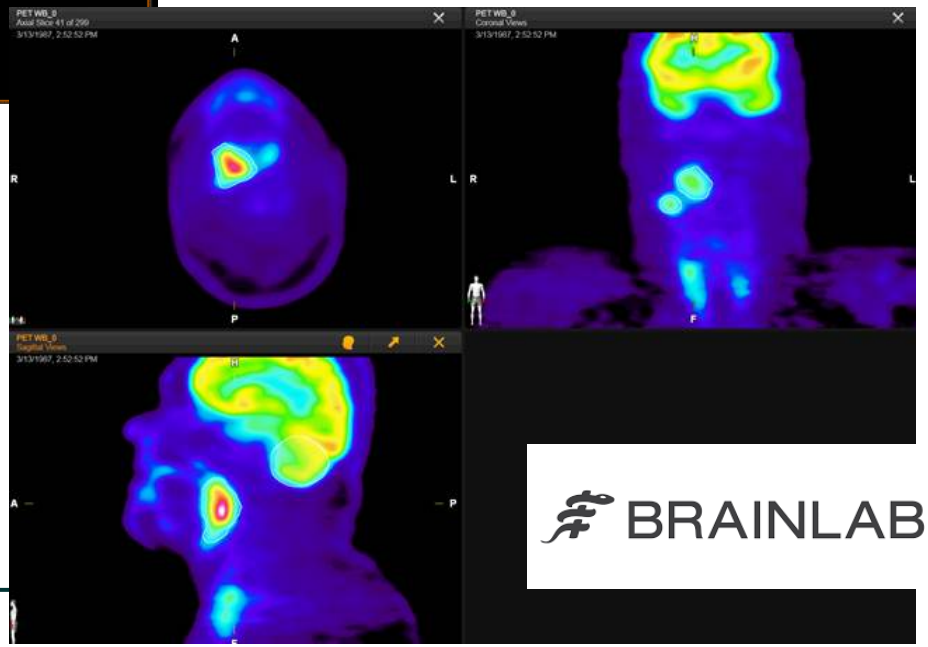
Beyond 3D Slicer: Commercial workstations





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