Quantitative Image Informatics for Cancer Research (QIICR)

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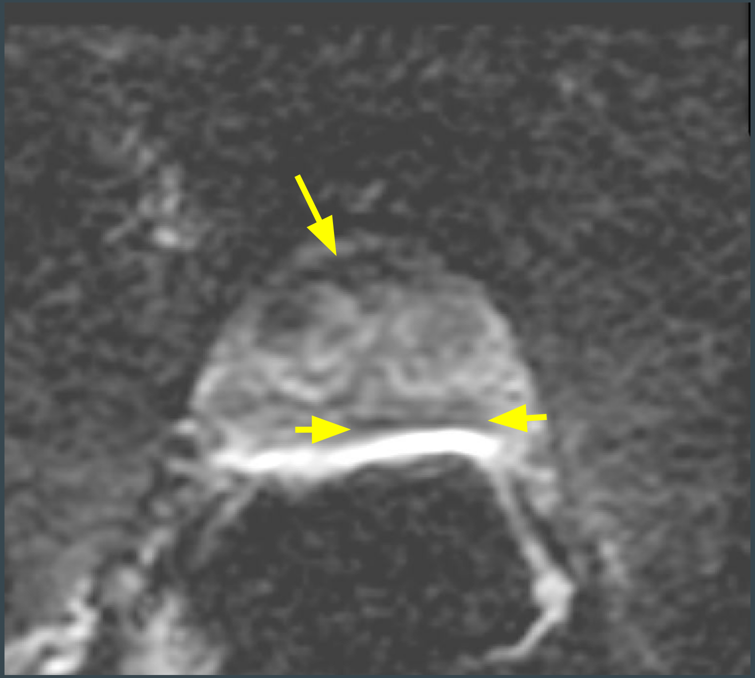
ITCR F2F - June 1, 2017
http://qiicr.org

Standard of care radiology report example



FINDINGS

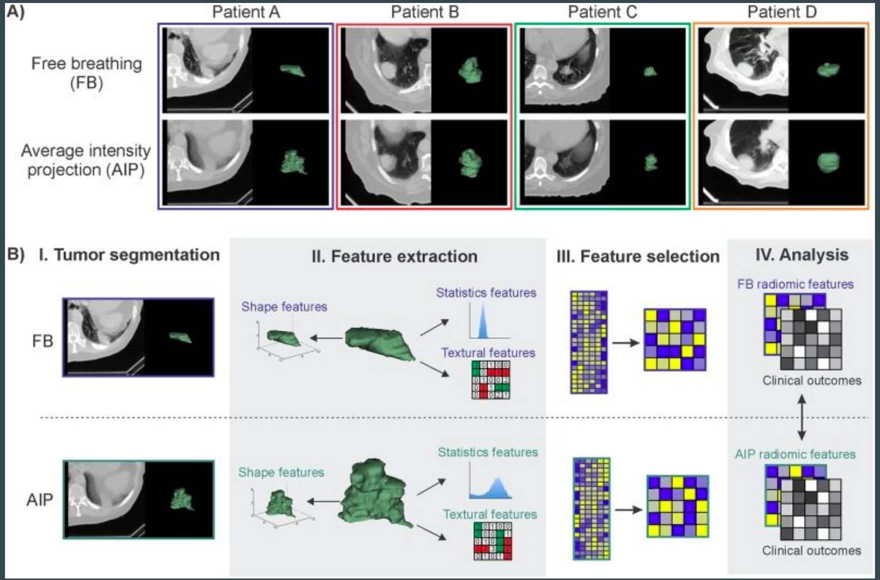
Size: 4.5 (cc) x 6 (transverse) x 3.9 (ap) cm

Prostate volume: 55 cc

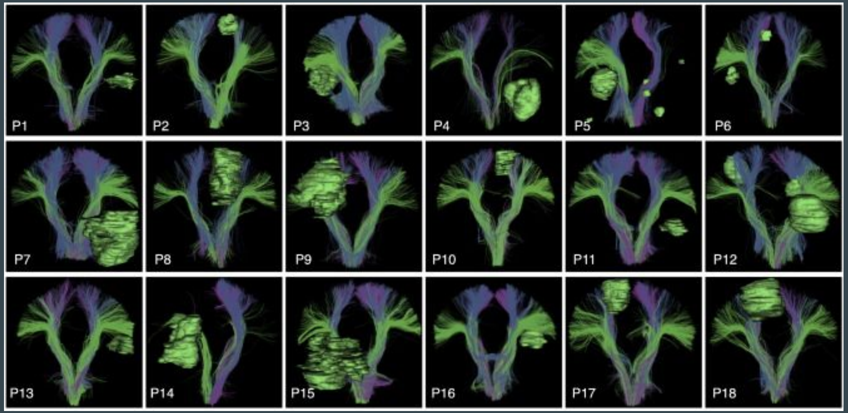
Transitional Zone: Foci of low signal intensity […] measuring 0.9 cm on the left and 0.7 cm on the right (series 8 image 9) with associated early enhancement [...]. Findings may represent neoplastic foci.

Peripheral Zone: Low signal intensity foci seen in the posterior aspect of the peripheral zone at the level of the mid gland toward the apex measuring 0.9 cm on the left […]

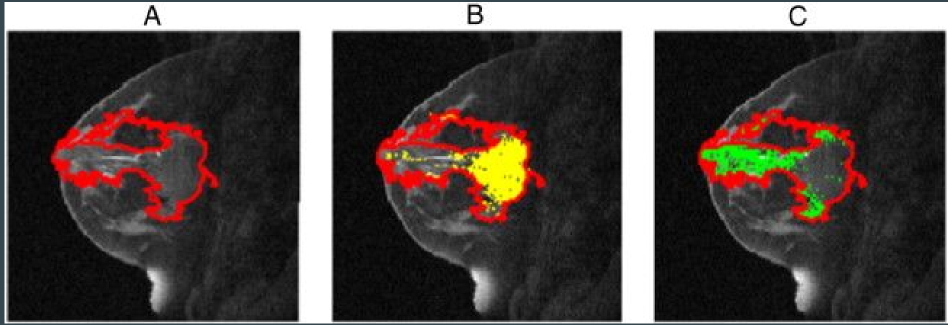
Quantitative imaging



Huynh et al. PloS One 2017
https://doi.org/10.1371/journal.pone.0169172



O'Donnell et al. Neuroimage: Clinical 2017
https://doi.org/10.1016/j.nicl.2016.11.023



Ashraf et al. Trans Onc 2015
https://doi.org/10.1016/j.tranon.2015.03.005

QIICR goals

Development of standards, technology and use cases for

- Standardized machine-readable representation
- Reproducible calculation

of (candidate) imaging biomarkers in clinical imaging research

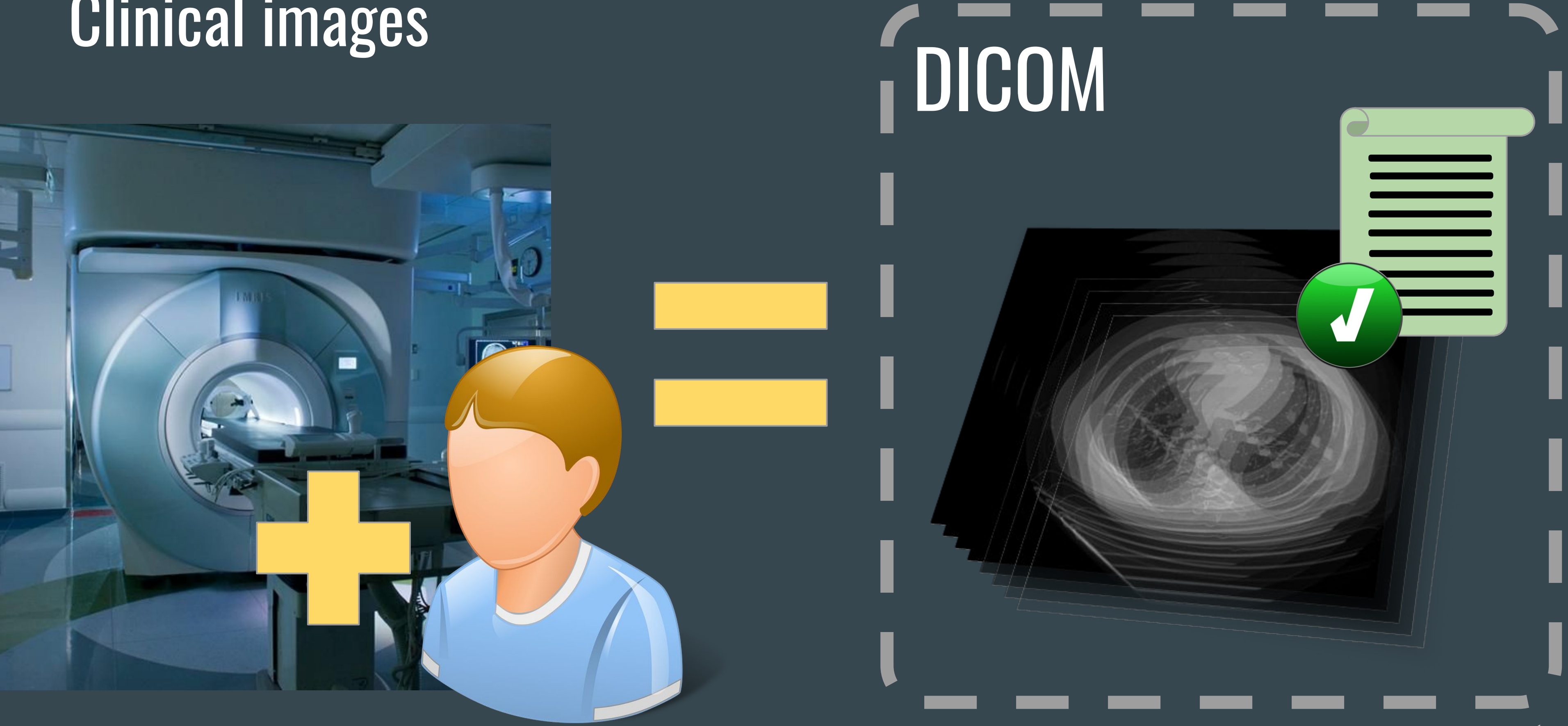
QIICR goals

Development of standards, technology and use cases for

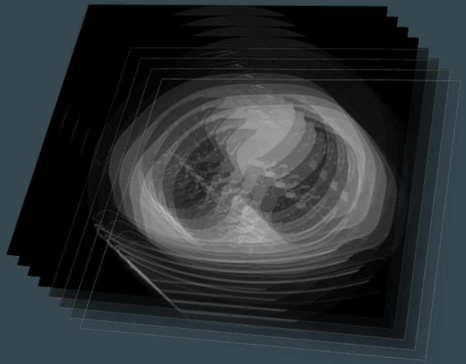
- Standardized machine-readable representation
- Open source tools for calculation

of (candidate) imaging biomarkers in clinical imaging research

Clinical images

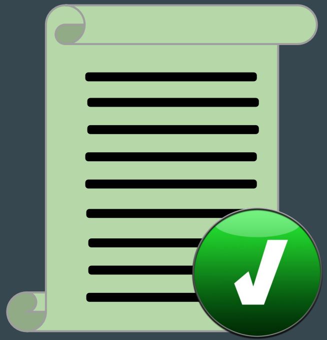


DICOM Image



Pixel data:

- Sparse measurements sampling a 2d or 3d volume



Non pixel data (a.k.a. “metadata”, or “header”):

- Patient identification, dates, image acquisition details, unique identifiers of the dataset, pointers to related evidence, annotation of the body part imaged, …

Image analysis: segmentation

Image analysis: radiological phenotype feature extraction

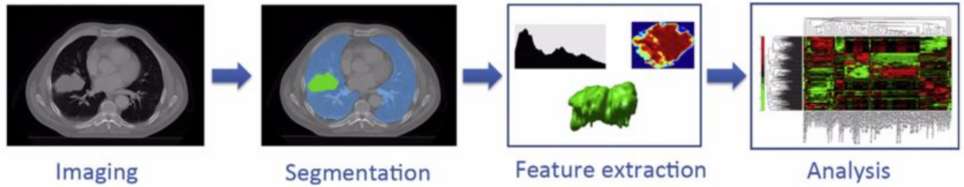
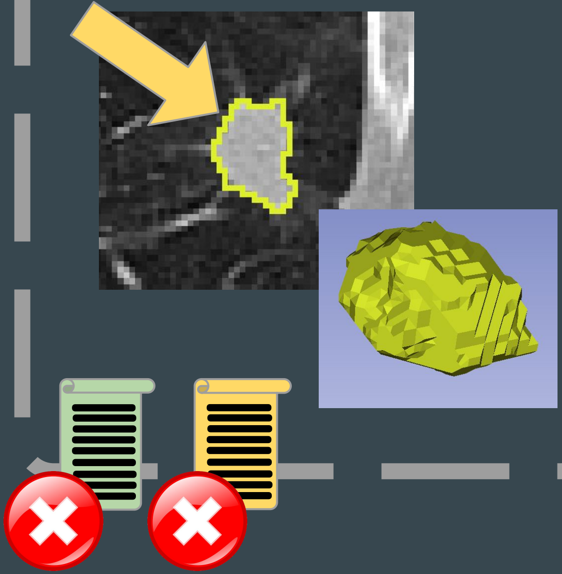


Fig. 4. The Radiomics workflow. On the medical images, segmentation is performed to define the tumour region. From this region the features are extracted, e.g. features based on tumour intensity, texture and shape. Finally, these features are used for analysis, e.g. the features are assessed for their prognostic power, or linked with stage, or gene expression.

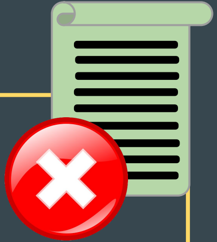
Lambin et al. Radiomics: extracting more information from medical images using advanced feature analysis. Eur J Cancer. 2012;48: 441–446. doi:10.1016/j.ejca.2011.11.036

Segmentations

non-DICOM

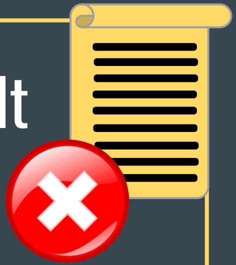


Composite context



- Patient identification, dates, image acquisition details, unique identifiers of the dataset, pointers to related evidence, annotation of the body part imaged

Structured metadata about analysis result



- Structure segmented, tissue type, body location, segmentation approach, references to the source images

Imaging features

Composite context

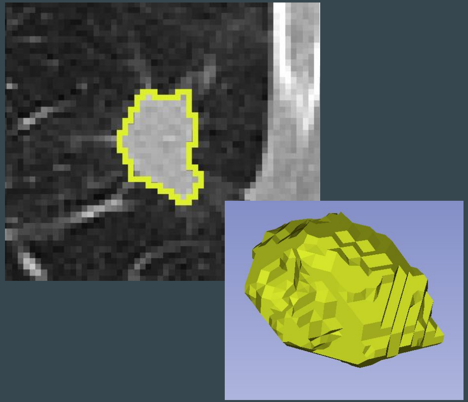
- Patient identification, dates, image acquisition details, unique identifiers of the dataset, pointers to related evidence, annotation of the body part imaged

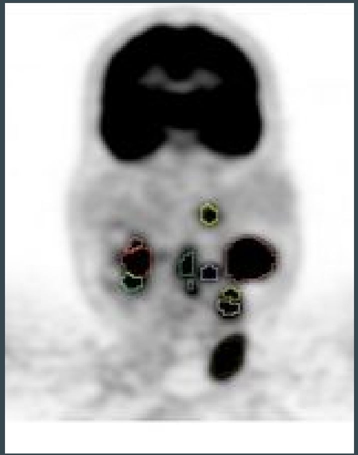
Structured metadata about analysis result

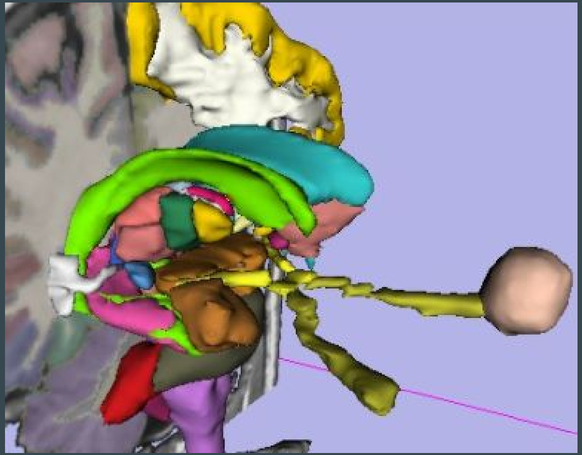
- Structured term defining the feature, units, computation parameters, references to the source images and segmentation

Consequences - problems with ...

- Searching the data - representation optimized for image/statistical analysis
- Aggregation of results from different sources
- Separation of the source image data from the analysis results
- Interoperability across analysis tools - tool-specific conventions
- Commercial tools not using research data formats
- Secondary use of analysis results







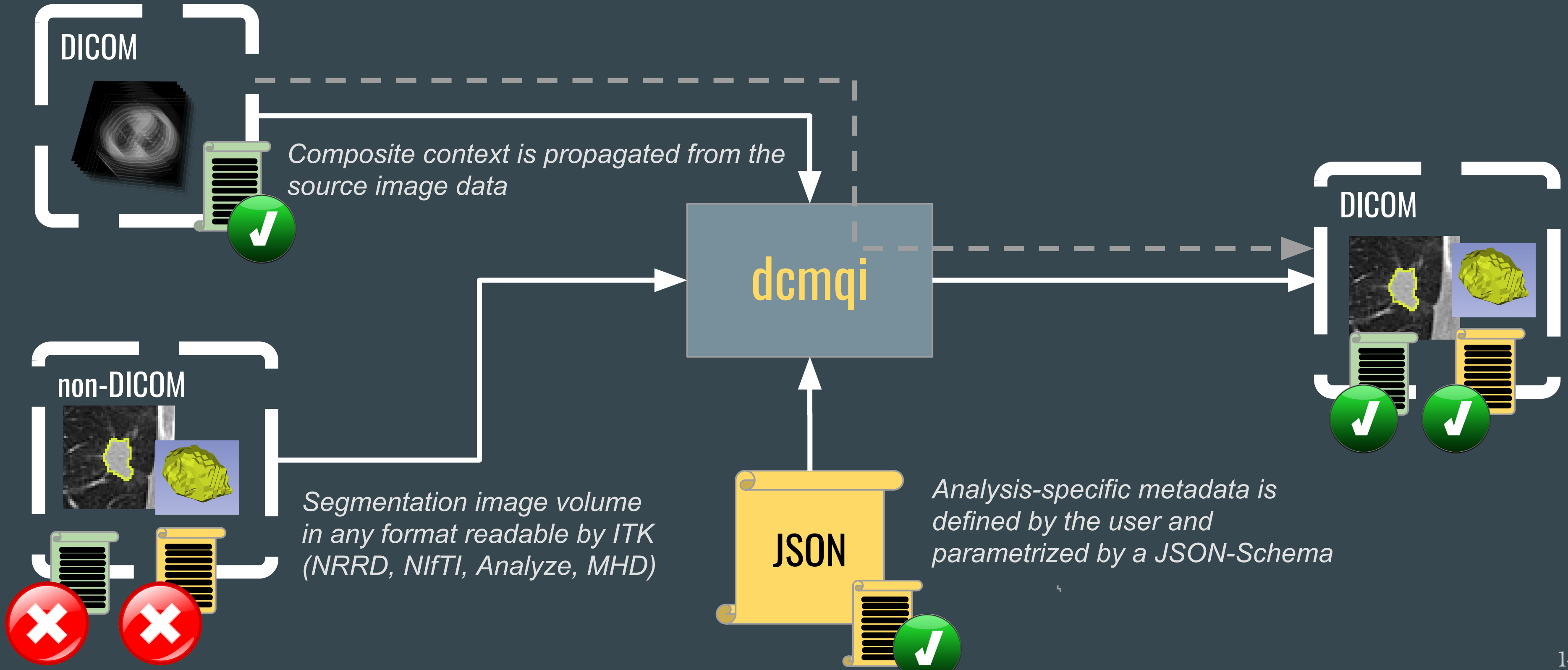
Our approach

dcmqi: DICOM for Quantitative Imaging library

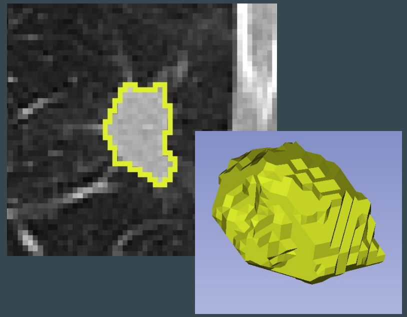
Command-line converters and API for converting commonly encountered types of quantitative image analysis results into the standard DICOM representation

- Free open source on GitHub: https://github.com/qiicr/dcmqi
- Ready to use binaries for Windows, Linux and macOS
- Docker images on DockerHub: https://hub.docker.com/r/qiicr/dcmqi/
- User guide and reference documentation: https://qiicr.gitbooks.io/dcmqi-guide
- 3D Slicer extension: https://qiicr.gitbooks.io/quantitativereporting-guide

In a nutshell

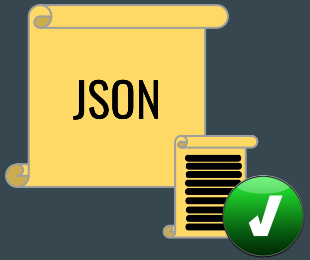


Populating analysis-specific metadata

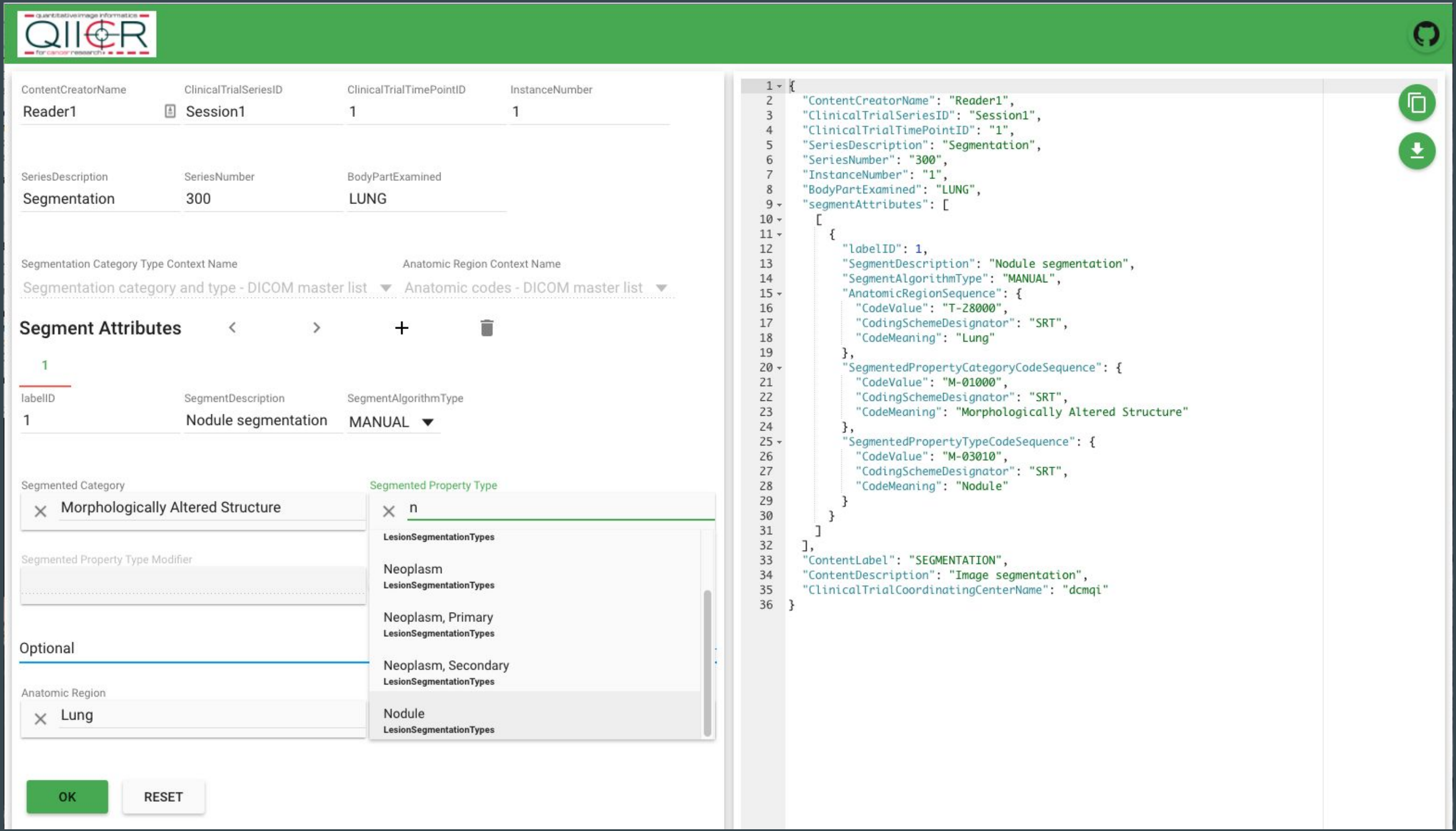


lung_tumor_reader1.nrrd


```
"AnatomicRegionSequence": {
  "CodeValue": "T-28000",
  "CodingSchemeDesignator": "SRT",
  "CodeMeaning": "Lung"
},
"SegmentedPropertyCategoryCodeSequence": {
  "CodeValue": "M-01000",
  "CodingSchemeDesignator": "SRT",
  "CodeMeaning": "Morphologically Altered Structure"
},
"SegmentedPropertyTypeCodeSequence": {
  "CodeValue": "M-03010",
  "CodingSchemeDesignator": "SRT",
  "CodeMeaning": "Nodule"
}
```

http://qiicr.org/dcmqi/#/seg



Usability

- Development infrastructure
  - Continuous integration and testing (CircleCI, Travis and Appveyor)
  - Automatic update and versioning of the Docker image
  - Automatic generation of OS-specific binaries
- Documentation
  - Reference user guide
  - Tutorial videos
  - FAQ and developed use cases
- Web applications
  - metadata generation and validation

Downloads

- dcmqi-1.0.5-linux-20170525-77edeff.tar.gz
- dcmqi-1.0.5-mac-20170525-77edeff.tar.gz
- dcmqi-1.0.5-win64-20170525-77edeff.zip
- Source code (zip)
- Source code (tar.gz)

Docker	version v1.0.5	version latest

	Linux	macOS	Windows
Build Status for latest	PASSED	build passing	build passing

https://github.com/qiicr/dcmqi

“Validation” of the approach

- Development of community-driven use cases
- Quantitative Imaging Network (QIN) as the driver
- Augment traditional publications with DICOM data produced using *dcmqi*
- Active QIN use-cases under development
  - PET/CT - head and neck cancer
  - Multiparametric MRI - prostate cancer
  - CT - lung cancer

PET/CT - head and neck cancer

- Methods paper: Medical Physics
- Data paper: PeerJ
    - 156 subjects, segmentations, measurements, clinical data
- Data: public on TCIA
- Tools: public in *dcmqi* and *3D Slicer*
- QIN project: U. Iowa (PIs Buatti, Beichel)

Semiautomated segmentation of head and neck cancers in 18F-FDG PET scans: A just-enough-interaction approach

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Beichel et al. 2016. Semiautomated segmentation of head and neck cancers in 18F-FDG PET scans: A just-enough-interaction approach. Medical physics 43:2948. DOI: 10.1118/1.4948679.

PeerJ

✔ PEER-REVIEWED

DICOM for quantitative imaging biomarker development: a standards based approach to sharing clinical data and structured PET/CT analysis results in head and neck cancer research

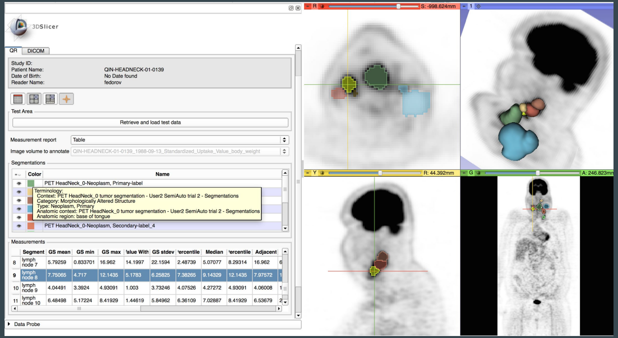
Bioinformatics | Clinical Trials | Oncology | Radiology and Medical Imaging

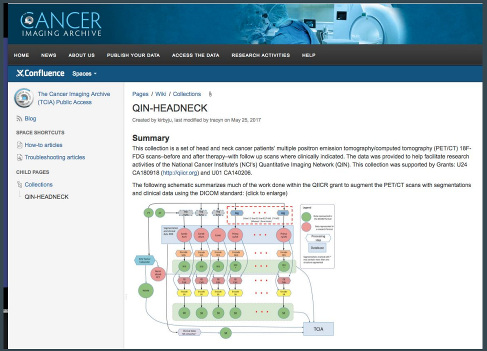
Andriy Fedorov[1,2], David Clunie[3], Ethan Ulrich[4,5], Christian Bauer[4,5], Andreas Wahle[4,5], Bartley Brown[6], Michael Onken[7], Jörg Riesmeier[8], Steve Pieper[9], Ron Kikinis[1,2,10,11], John Buatti[12], Reinhard R. Beichel[4,5,13]

Published May 24, 2016

Note that a Preprint of this article also exists, first published November 26, 2015.

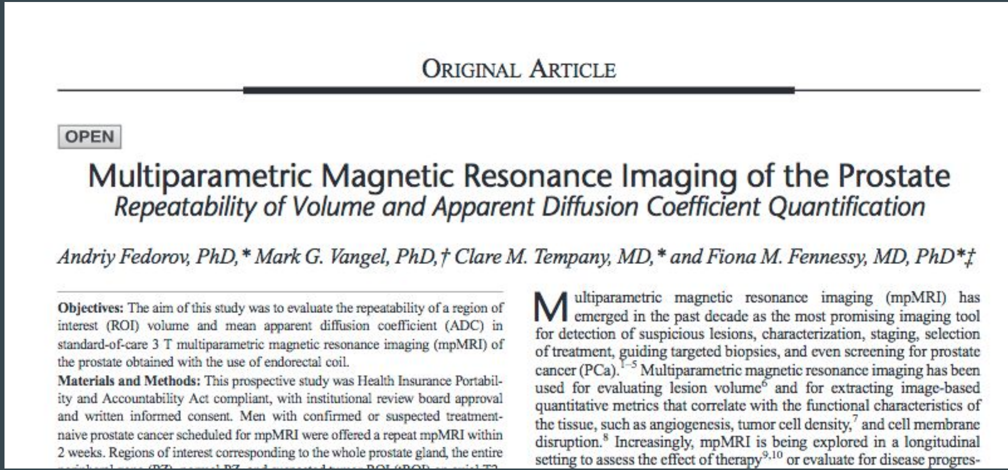
PubMed 27257542





mpMRI - prostate cancer

- Methods paper: Investigative Radiology
  - 15 subjects with test-retest data, segmentations of multiple structures for each time point, segmentation-based quantification
- Data paper: in preparation
- Data: in preparation
  - Final institutional approvals for sharing data secured recently
- Tools: public in dcmqi and 3D Slicer
- QIN project: BWH (PI Fennessy)



ORIGINAL ARTICLE

OPEN

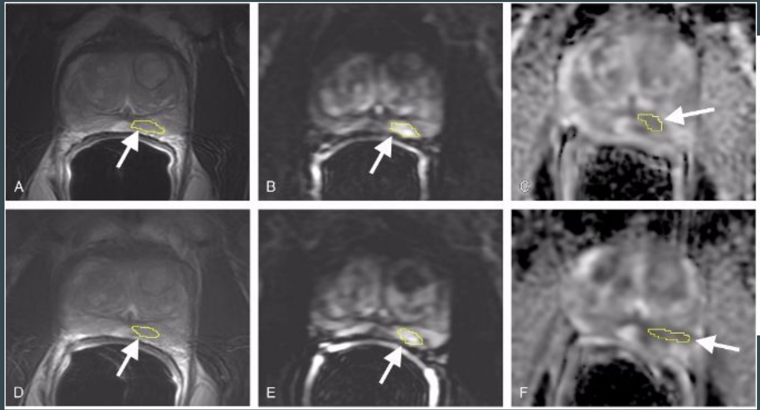
Multiparametric Magnetic Resonance Imaging of the Prostate
Repeatability of Volume and Apparent Diffusion Coefficient Quantification

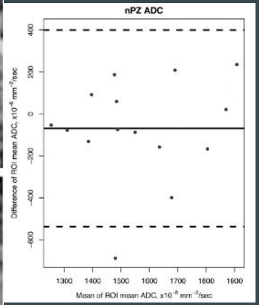
Andriy Fedorov, PhD, Mark G. Vangel, PhD,† Clare M. Tempany, MD,* and Fiona M. Fennessy, MD, PhD*‡*

Objectives: The aim of this study was to evaluate the repeatability of a region of interest (ROI) volume and mean apparent diffusion coefficient (ADC) in standard-of-care 3 T multiparametric magnetic resonance imaging (mpMRI) of the prostate obtained with the use of endorectal coil.
Materials and Methods: This prospective study was Health Insurance Portability and Accountability Act compliant, with institutional review board approval and written informed consent. Men with confirmed or suspected treatment-naive prostate cancer scheduled for mpMRI were offered a repeat mpMRI within 2 weeks. Regions of interest corresponding to the whole prostate gland, the entire

Multiparametric magnetic resonance imaging (mpMRI) has emerged in the past decade as the most promising imaging tool for detection of suspicious lesions, characterization, staging, selection of treatment, guiding targeted biopsies, and even screening for prostate cancer (PCa).[1–5] Multiparametric magnetic resonance imaging has been used for evaluating lesion volume[6] and for extracting image-based quantitative metrics that correlate with the functional characteristics of the tissue, such as angiogenesis, tumor cell density,[7] and cell membrane disruption.[8] Increasingly, mpMRI is being explored in a longitudinal setting to assess the effect of therapy[9,10] or evaluate for disease progres-

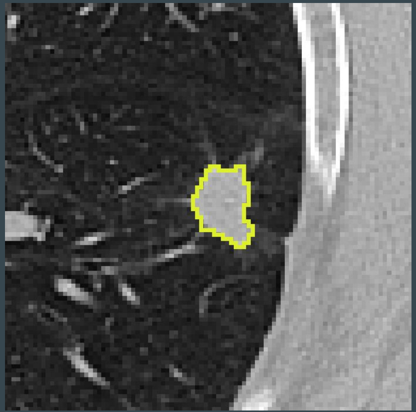
Fedorov et al. 2017. Multiparametric Magnetic Resonance Imaging of the Prostate: Repeatability of Volume and Apparent Diffusion Coefficient Quantification. Investigative radiology DOI: 10.1097/RLI.0000000000000382.

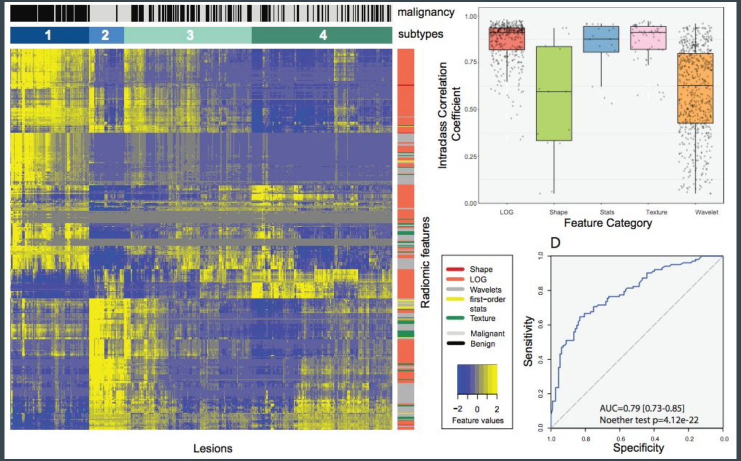




CT - lung cancer

- Methods paper: radiomics for lung nodule malignancy grading, under review
  - Chest CT for 302 subjects, segmentations of 1 or more nodules, radiomics features
- Data paper: in preparation
- Data: public on TCIA
  - TCIA LIDC-IDRI collection
- Tools: public in *pyradiomics, dcmqi* and *3D Slicer*
- QIN project: DFCI (PI Aerts)



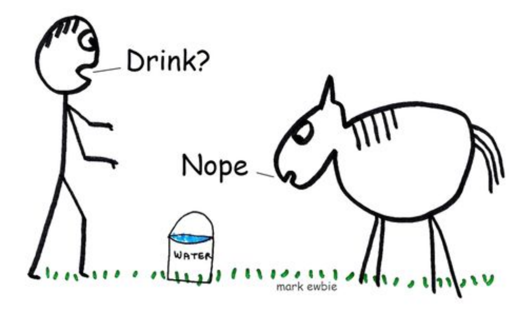


https://www.radiomics.io/pyradiomics.html

Van Griethuysen et al. Computational radiomics system decoding the radiographic phenotype. Cancer Research - under review

DICOM4QI: DICOM for Quantitative Imaging

- Demonstration and connectathon at the annual Radiological Society of North America (RSNA) meeting
- Goals:
  - Promote adoption of the DICOM standard for Quantitative Imaging applications
  - Develop best practices for storing QI analysis data using DICOM
  - Understand and lower adoption barriers
- Educate vendors so they adopt standards
- Educate customers so they demand standards

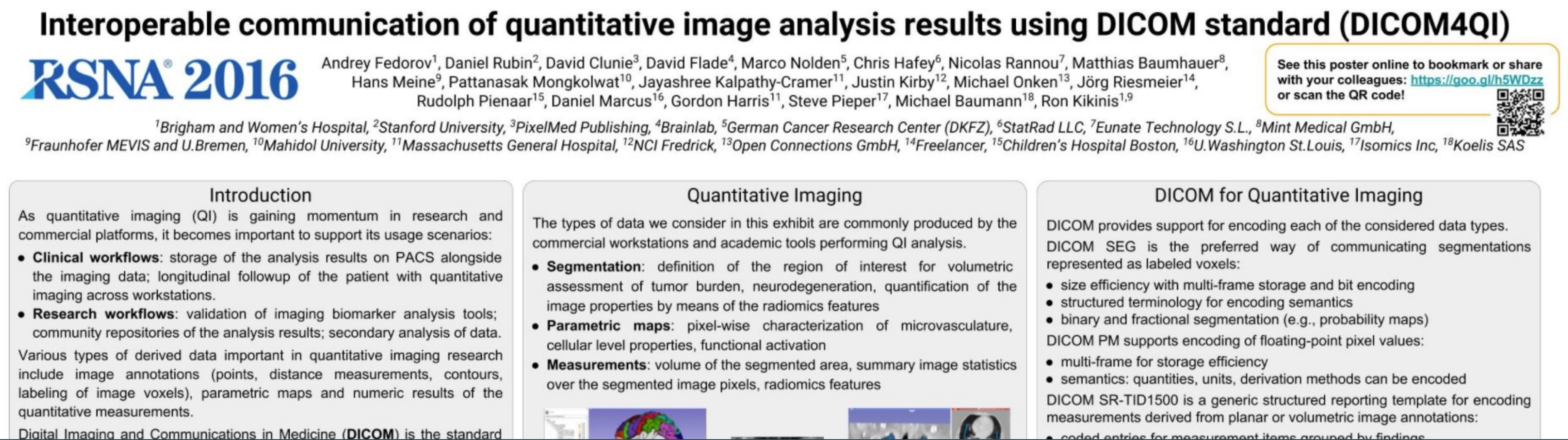


You can lead a horse to the water, but you can't make it drink
http://markewbie.weebly.com/proverbs.html

** This is not an official IHE or DICOM connectathon. We use the word "connectathon" to describe the essence of the activity, and not our affiliation to official connectathons that are already established in the field.*

https://qiicr.gitbooks.io/dicom4qi

- RSNA QIRR exhibit 2015 and 2016
- RSNA 2016
  - 3 types of QI DICOM objects (segmentations, parametric maps, volumetric measurements SR)
  - 11 platforms evaluated (including 5 commercial)



Interoperable communication of quantitative image analysis results using DICOM standard (DICOM4QI)

RSNA® 2016

Andrey Fedorov[1], Daniel Rubin[2], David Clunie[3], David Flade[4], Marco Nolden[5], Chris Hafey[6], Nicolas Rannou[7], Matthias Baumhauer[8], Hans Meine[9], Pattanasak Mongkolwat[10], Jayashree Kalpathy-Cramer[11], Justin Kirby[12], Michael Onken[13], Jörg Riesmeier[14], Rudolph Pienaar[15], Daniel Marcus[16], Gordon Harris[11], Steve Pieper[17], Michael Baumann[18], Ron Kikinis[1,9]

[1]Brigham and Women's Hospital, [2]Stanford University, [3]PixelMed Publishing, [4]Brainlab, [5]German Cancer Research Center (DKFZ), [6]StatRad LLC, [7]Eunate Technology S.L., [8]Mint Medical GmbH, [9]Fraunhofer MEVIS and U.Bremen, [10]Mahidol University, [11]Massachusetts General Hospital, [12]NCI Fredrick, [13]Open Connections GmbH, [14]Freelancer, [15]Children's Hospital Boston, [16]U.Washington St.Louis, [17]Isomics Inc, [18]Koelis SAS

See this poster online to bookmark or share with your colleagues: https://goo.gl/h5WDzz or scan the QR code!

Introduction

As quantitative imaging (QI) is gaining momentum in research and commercial platforms, it becomes important to support its usage scenarios:

- **Clinical workflows**: storage of the analysis results on PACS alongside the imaging data; longitudinal followup of the patient with quantitative imaging across workstations.
- **Research workflows**: validation of imaging biomarker analysis tools; community repositories of the analysis results; secondary analysis of data.

Various types of derived data important in quantitative imaging research include image annotations (points, distance measurements, contours, labeling of image voxels), parametric maps and numeric results of the quantitative measurements.

Digital Imaging and Communications in Medicine (**DICOM**) is the standard

Quantitative Imaging

The types of data we consider in this exhibit are commonly produced by the commercial workstations and academic tools performing QI analysis.

- **Segmentation**: definition of the region of interest for volumetric assessment of tumor burden, neurodegeneration, quantification of the image properties by means of the radiomics features
- **Parametric maps**: pixel-wise characterization of microvasculature, cellular level properties, functional activation
- **Measurements**: volume of the segmented area, summary image statistics over the segmented image pixels, radiomics features

DICOM for Quantitative Imaging

DICOM provides support for encoding each of the considered data types.

DICOM SEG is the preferred way of communicating segmentations represented as labeled voxels:

- size efficiency with multi-frame storage and bit encoding
- structured terminology for encoding semantics
- binary and fractional segmentation (e.g., probability maps)

DICOM PM supports encoding of floating-point pixel values:

- multi-frame for storage efficiency
- semantics: quantities, units, derivation methods can be encoded

DICOM SR-TID1500 is a generic structured reporting template for encoding measurements derived from planar or volumetric image annotations:

Tutorial at MICCAI 2017 http://qiicr.org/dicom4miccai

DICOM4MICCAI

21st Century DICOM for Quantitative Imaging Research: Why, What, and How

DICOM4MICCAI is a tutorial satellite event to MICCAI 2017.

This page is work in progress to organize materials for this tutorial. Stay tuned for updates!

Register for this tutorial here!

Scope

The objective of this tutorial is to introduce MICCAI community to the capabilities of the DICOM standard related to the storage of the data typically produced in the process of quantitative image analysis.

Digital Imaging and Communications in Medicine (DICOM) is both the format most commonly used (by the manufacturers of the medical imaging equipment) and probably most commonly despised (by the medical imaging researchers).

In this tutorial we will attempt the impossible: to convince the attendees that DICOM can, and perhaps should, be used for storing your processing results such as segmentations, parametric maps, volumetric measurements and more!

Our tutorial will consist of the presentations followed by hands-on activities using open source tools.

In conclusion

If you are doing image analysis, and plan to share your analysis results - please check out our tools and talk to us!

- andrey.fedorov@gmail.com
- http://qiicr.org
- https://github.com/QIICR/dcmqi

"We need that big data to be accessible. It's not enough to say that we are in a big data era for cancer. We also need to be in a big data access era."

Francis Collins, PhD, MD, director of the NIH