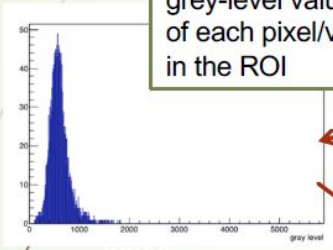
Medical images segmentation

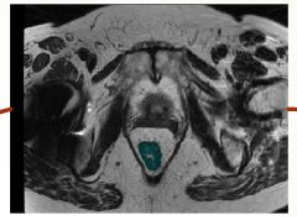
An example application

MARIANNE
(Imaging for stadiation)

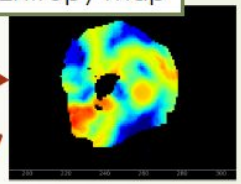
Automatic classification of response to chemoradiotherapy in rectal cancer using 3T T2-w MRI



grey-level value of each pixel/voxel in the ROI

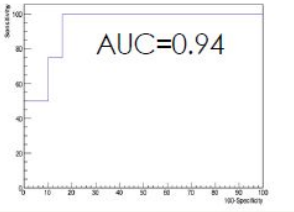


Entropy map



Machine learning algorithm: Random Forest classificator to stratify patient respnce

S. Ciardiello, RF, R. Paramatti, C. Mancini Terracciano, C. Voena, et al …



Avoid surgery to 50% of patients that would not need it

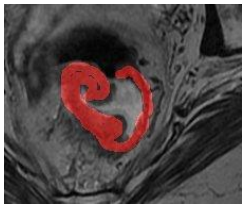
10.1016/j.ejrad.2019.06.013

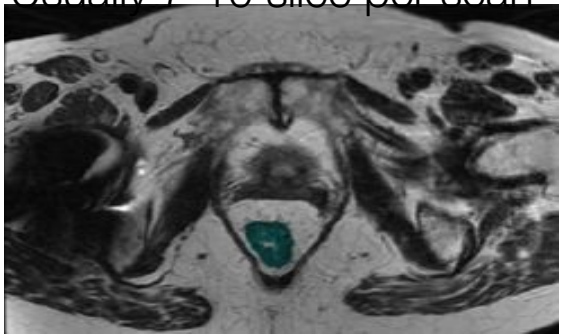
Texture analysis of MR images

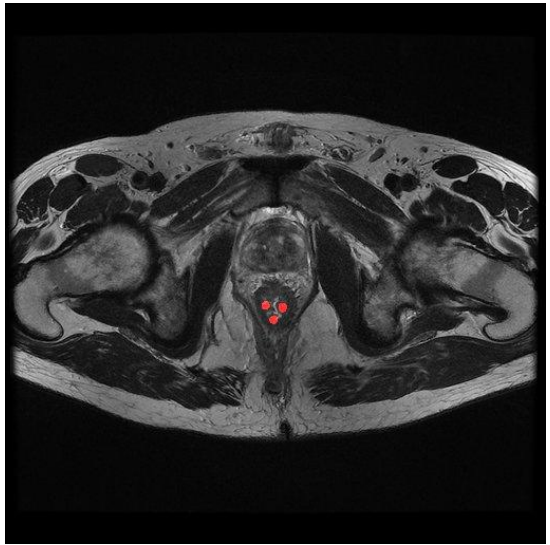
Traditional texture analysis can be improved by automated segmentation of tumoral tissues

The dataset available

- T2-weighted MRI from high field (3T) scanner
- 55 + 36 patients
- ~30 slices along the rectum axis
  Region of interest (ROI)
  drawn by hand by the radiologist
  contains suspect tumor tissue
  Usually 7-10 slice per scan







Recipe to Supervised Learning Method

Supervised methods: Hand coding is used to train statistical models to classify pixels in pre-determined categories (segmentation).

1) Set of known categories
   - Backgroud, Tissue
   - Tumor / not Tumor

2) Set of hand-labeled images
   - Labeling done by clinicians (defining tumor area)
   - Training Set: ROIs we'll use to learn how to classify pixels
   - Validation Set: ROIs we'll use to learn how well we classify

3) Set of unlabeled images that we want to segment

4) Validate by comparing predicted label to real (hand-coded) label.

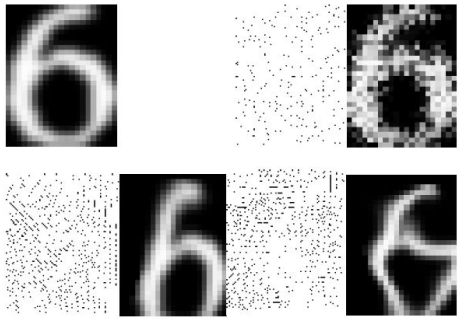
Task: Segmentation

- Identify a portion of an image given the context (attribution of a pixel to a class)
- Simple task for trained humans but hard for algorithms
- Many deep learning applications are about object recognition
- Challenge:
  - **Small dataset**
  - **High variance in the data**
  - **Data sharing and data management**
  - **It is difficult to obtain good quality labels**

(Traditional) Data augmentation

- Essential to teach the network the desired invariance and robustness properties
- Vital when few training samples are available
- Shift and rotation
- Deformations and intensity variations
- Random elastic deformations
- The same transformation is applied to both the image and ROI

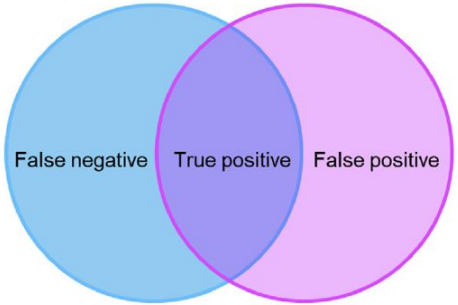
Data augmentation – Elastic deformation



Accuracy vs. DSC

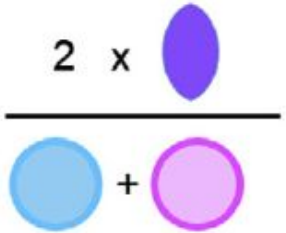
1. The tumor is small. 2% of Total Area
2. An hard coded “no tumor” classifier has 98% accuracy
3. Different cost of Errors?

- Accuracy = $\frac{TP+TN}{TP+TN+FP+FN}$



- DICE Sorensen coefficient

$$DSC = \frac{2TP}{2TP + FP + FN}$$



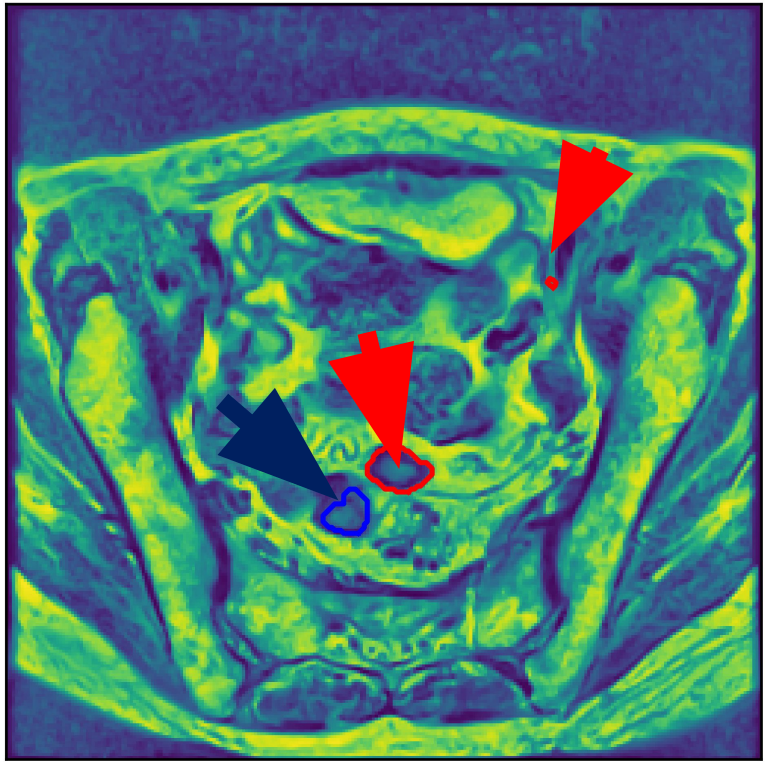
Low Score: separate Areas

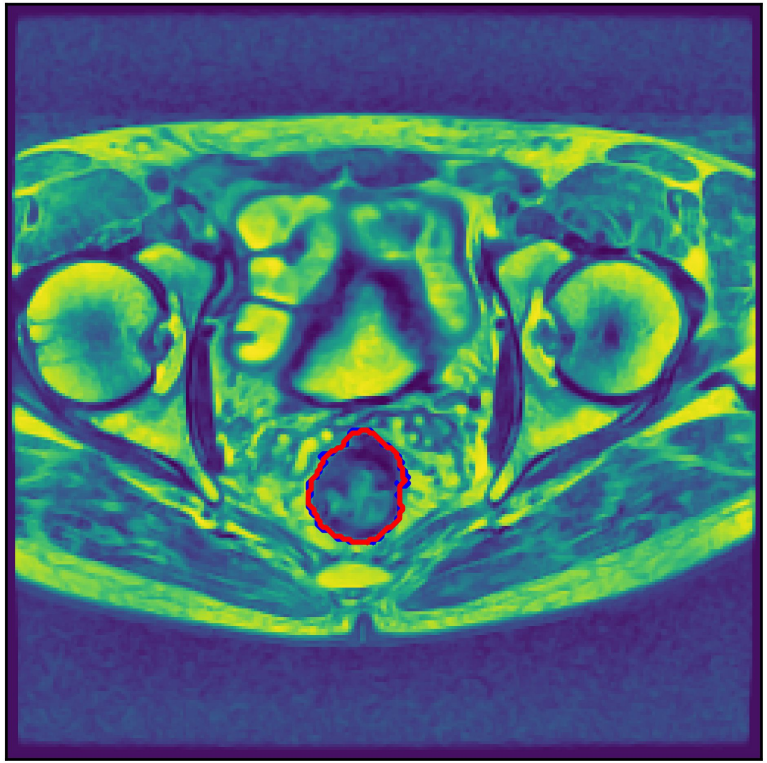
DICE: 0.0

Ground Truth
Prediction

High Score: good intersection

DICE: 0.9





Task: Segmentation

- **Small dataset → Data augmentation, Transfer learning**
- **High variance (acquisition parameters, resolution) → Normalization, geometrical transformation, co-registration**
- **Data sharing and data management → Specialized pipelines**

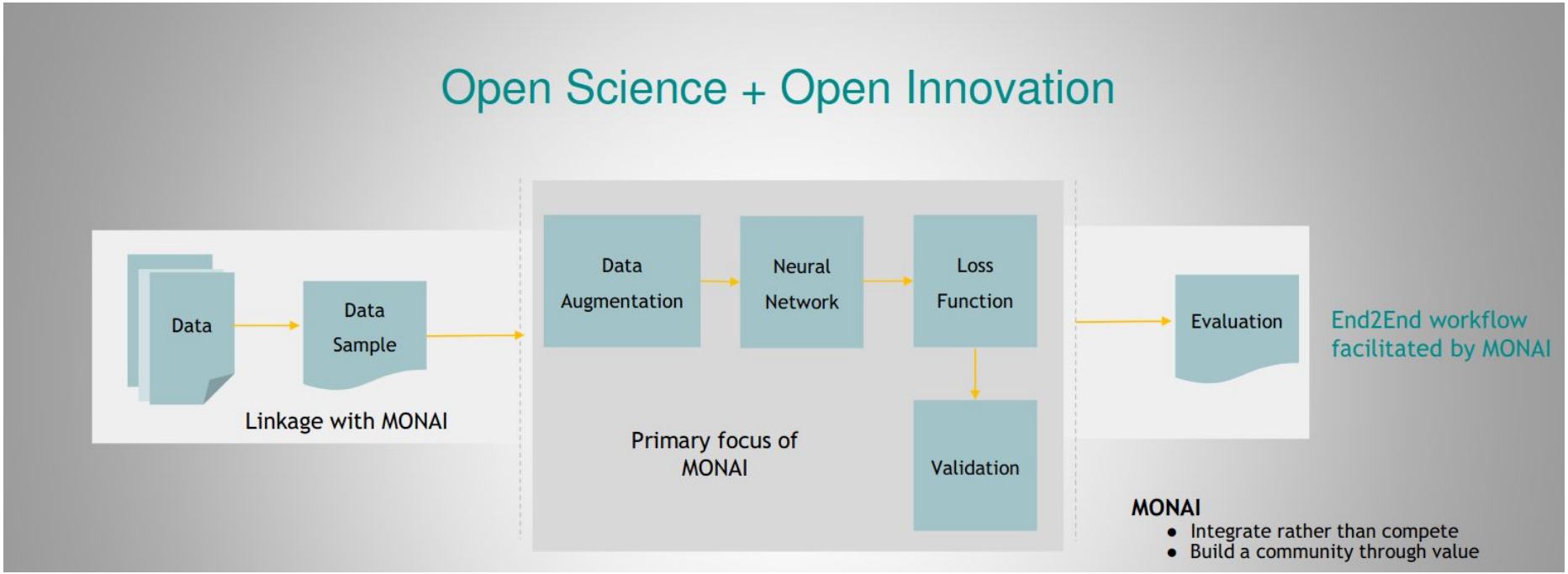
  (data conversion, dataloaders, losses, metrics,...)
- **It is difficult to obtain good quality labels→ ?**

A Specialized package to build pipelines for Medical Images

- Freely available (Open-source code)
- Provides easy access to key public datasets (Open-access data)
- Community-supported (Open innovation)
- Optimized for medical imaging and reproducibility
- Reference implementation of best practices

https://monai.io/

Overview of MONAI



https://monai.io/

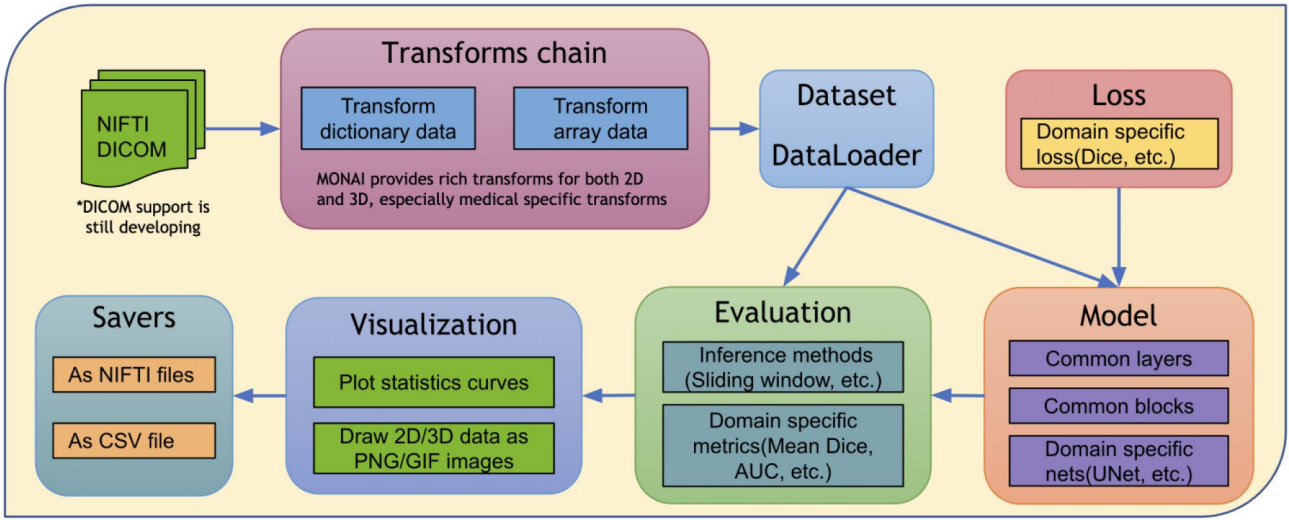
A brief introduction to MONAI

What we will cover:

- Data support
- Normalization
- Model implementations

What we will not cover:

- MONAI is a complex package that also helps with apps deployment, data sharing, annotations …



The tutorial are taken from the official MONAI bootcamp
https://github.com/Project-MONAI/MONAIBootcamp2021

The DICOM file format (.dcm)

DICOM® — Digital Imaging and Communications in Medicine — is *the* international standard for medical images and related information. It defines the formats for medical images that can be exchanged with the data and quality necessary for clinical use.

DICOM groups information into data sets. For example, a file of a chest x-ray image may contain the patient ID within the file, so that the image can never be separated from this information by mistake. This is similar to the way that image formats such as JPEG can also have embedded tags to identify and otherwise describe the image.

A DICOM data object consists of a number of attributes, including items such as name, ID, etc., and also one special attribute containing the image pixel data (i.e. logically, the main object has no "header" as such, being merely a list of attributes, including the pixel data). A single DICOM object can have only one attribute containing pixel data.

https://www.dicomstandard.org/about

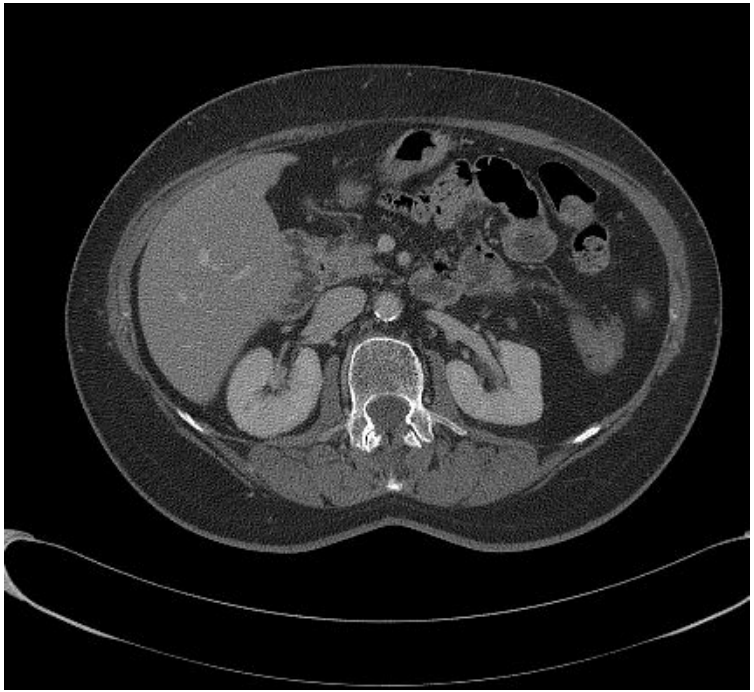
Example of a DICOM header from a CT

File Edit Font

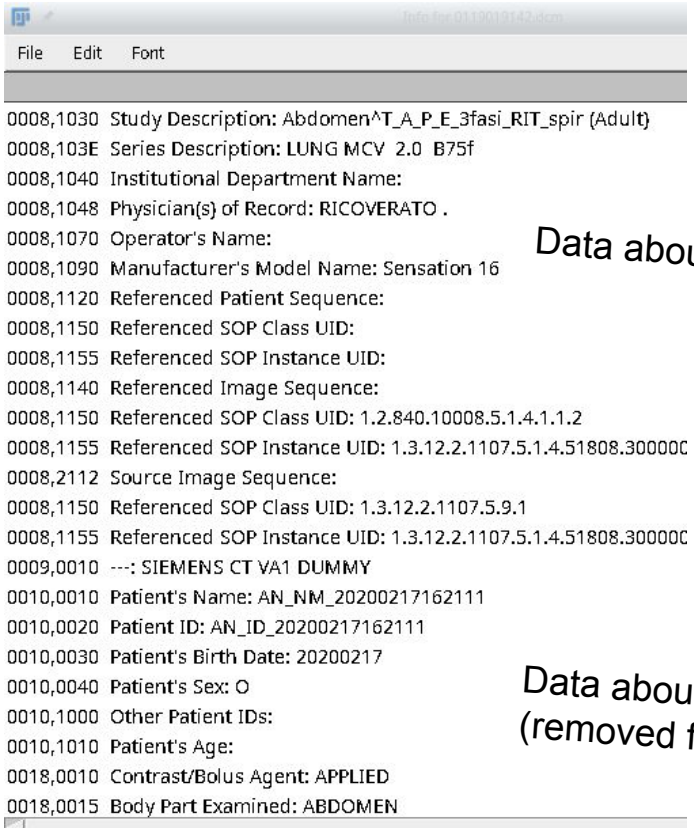
0002,0000 ---: 200
0002,0002 Media Storage SOP Class UID: 1.2.840.10008.5.1.4.1.1.2
0002,0003 Media Storage SOP Inst UID: 1.3.12.2.1107.5.1.4.51808.30
0002,0010 Transfer Syntax UID: 1.2.840.10008.1.2
0002,0012 Implementation Class UID: 1.2.410.200010.99.3.5
0002,0013 Implementation Version Name: INF_4.5
0002,0016 Source Application Entity Title: TAC2DEA
0008,0005 Specific Character Set: ISO_IR 100
0008,0008 Image Type: ORIGINAL\PRIMARY\AXIAL\CT_SOM5 SPI
0008,0016 SOP Class UID: 1.2.840.10008.5.1.4.1.1.2
0008,0018 SOP Instance UID: 1.3.12.2.1107.5.1.4.51808.30000019022
0008,0020 Study Date: 20190227
0008,0021 Series Date: 20190227
0008,0022 Acquisition Date: 20190227
0008,0023 Image Date: 20190227
0008,0030 Study Time: 152951.500000
0008,0031 Series Time: 155215.046000
0008,0032 Acquisition Time: 154601.119322
0008,0033 Image Time: 154601.119322
0008,0050 Accession Number: 20200217162111
0008,0060 Modality: CT
0008,0070 Manufacturer: SIEMENS
0008,0080 Institution Name:
0008,0081 Institution Address:
0008,0090 Referring Physician's Name:

Data about the exam

Information of the machine used



Example of a DICOM header from a CT



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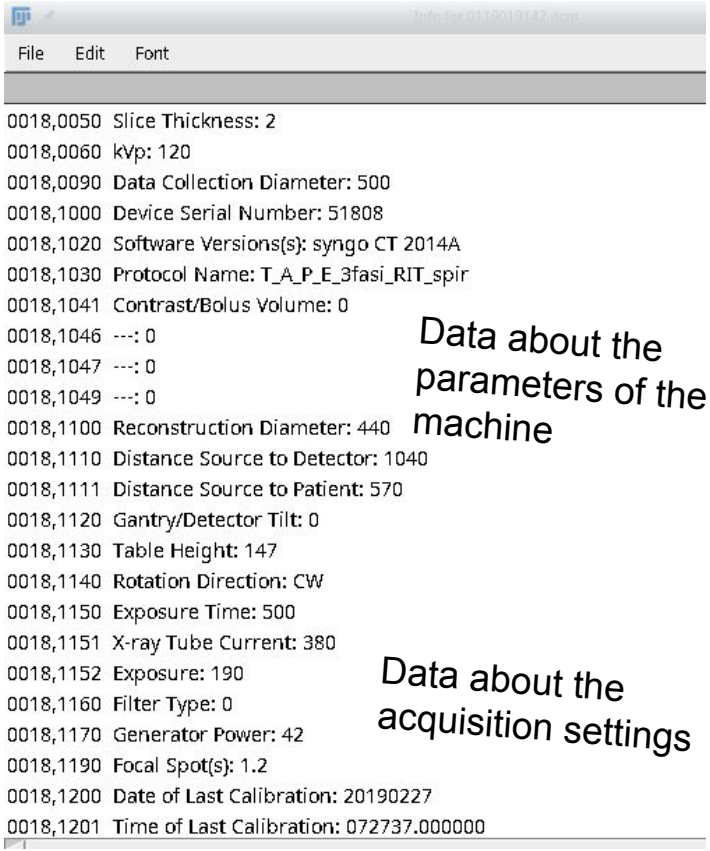
0008,1030 Study Description: Abdomen^T_A_P_E_3fasi_RIT_spir (Adult)
0008,103E Series Description: LUNG MCV 2.0 B75f
0008,1040 Institutional Department Name:
0008,1048 Physician(s) of Record: RICOVERATO .
0008,1070 Operator's Name:
0008,1090 Manufacturer's Model Name: Sensation 16
0008,1120 Referenced Patient Sequence:
0008,1150 Referenced SOP Class UID:
0008,1155 Referenced SOP Instance UID:
0008,1140 Referenced Image Sequence:
0008,1150 Referenced SOP Class UID: 1.2.840.10008.5.1.4.1.1.2
0008,1155 Referenced SOP Instance UID: 1.3.12.2.1107.5.1.4.51808.300000
0008,2112 Source Image Sequence:
0008,1150 Referenced SOP Class UID: 1.3.12.2.1107.5.9.1
0008,1155 Referenced SOP Instance UID: 1.3.12.2.1107.5.1.4.51808.300000
0009,0010 ---: SIEMENS CT VA1 DUMMY
0010,0010 Patient's Name: AN_NM_20200217162111
0010,0020 Patient ID: AN_ID_20200217162111
0010,0030 Patient's Birth Date: 20200217
0010,0040 Patient's Sex: O
0010,1000 Other Patient IDs:
0010,1010 Patient's Age:
0018,0010 Contrast/Bolus Agent: APPLIED
0018,0015 Body Part Examined: ABDOMEN

Data about the exam

Data about the patient (removed for privacy)



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0018,0050 Slice Thickness: 2
0018,0060 kVp: 120
0018,0090 Data Collection Diameter: 500
0018,1000 Device Serial Number: 51808
0018,1020 Software Versions(s): syngo CT 2014A
0018,1030 Protocol Name: T_A_P_E_3fasi_RIT_spir
0018,1041 Contrast/Bolus Volume: 0
0018,1046 ---: 0
0018,1047 ---: 0
0018,1049 ---: 0
0018,1100 Reconstruction Diameter: 440
0018,1110 Distance Source to Detector: 1040
0018,1111 Distance Source to Patient: 570
0018,1120 Gantry/Detector Tilt: 0
0018,1130 Table Height: 147
0018,1140 Rotation Direction: CW
0018,1150 Exposure Time: 500
0018,1151 X-ray Tube Current: 380
0018,1152 Exposure: 190
0018,1160 Filter Type: 0
0018,1170 Generator Power: 42
0018,1190 Focal Spot(s): 1.2
0018,1200 Date of Last Calibration: 20190227
0018,1201 Time of Last Calibration: 072737.000000

Data about the parameters of the machine

Data about the acquisition settings

And many, many more. See https://www.dicomlibrary.com/dicom/dicom-tags/