Sistema Socio Sanitario
Ospedale Niguarda
Regione Lombardia

A SOFTWARE FOR EXTRACTING QUANTITATIVE METRICS AND RADIOMIC FEATURES IN CT IMAGES OF THE LUNG: DEVELOPMENT OF A PRACTICAL TOOL AND CLINICAL APPLICATIONS

L'ESPERIENZA DI OSPEDALE NIGUARDA

L. Berta for the Niguarda COVID-19 WG
S.C. Fisica Sanitaria, ASST NIGUARDA (Milano)

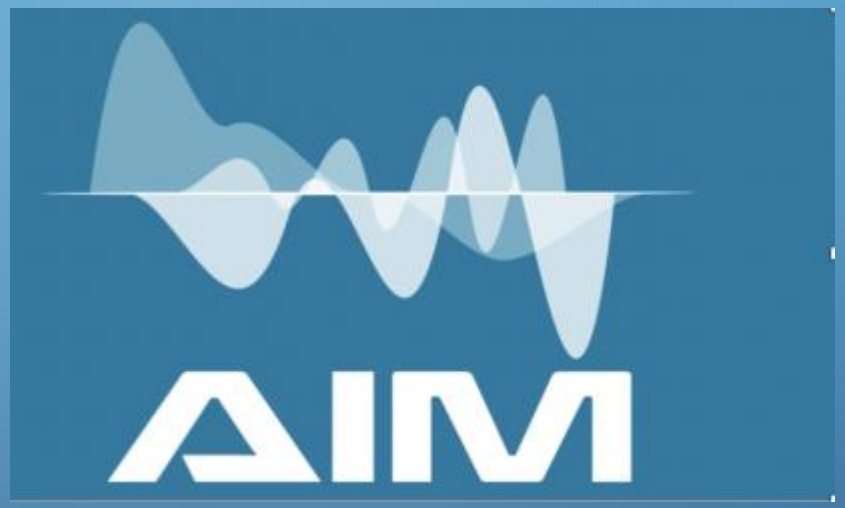
Outline

- Introduction (MPE, quantitative imaging, Niguarda experience)

1. Quantitative Metrics in Lung CT
2. Automatic segmentation
3. AI models for COVID-19
4. Deployment in clinical environment

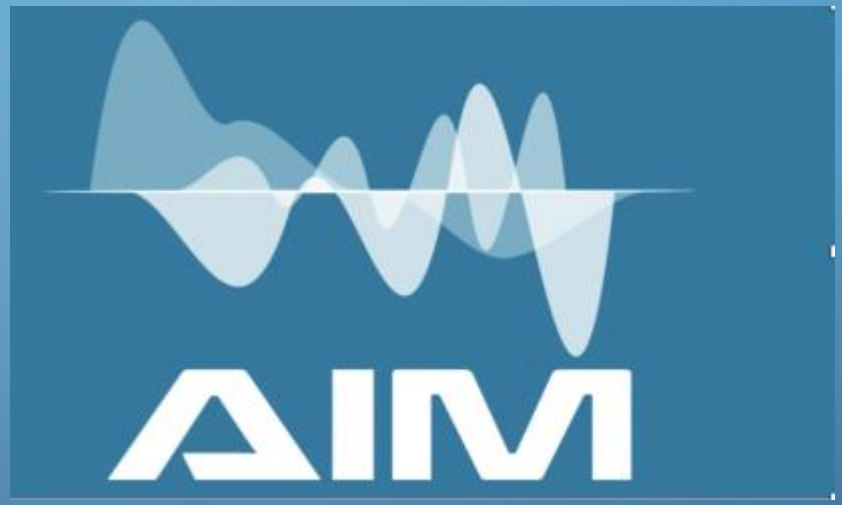
- Work in progress
- Conclusions

Introduction



Introduction

Introduction



The role of Medical Physicist Expert (MPE)

Scientific-Technical Area

Clinical-Medical Area

Matematicians

Techiniques of calculations

Clinical Engineers

Hi-Tech Equipment

Computer/Data Scientists

Image Management and Big-Data

MPE

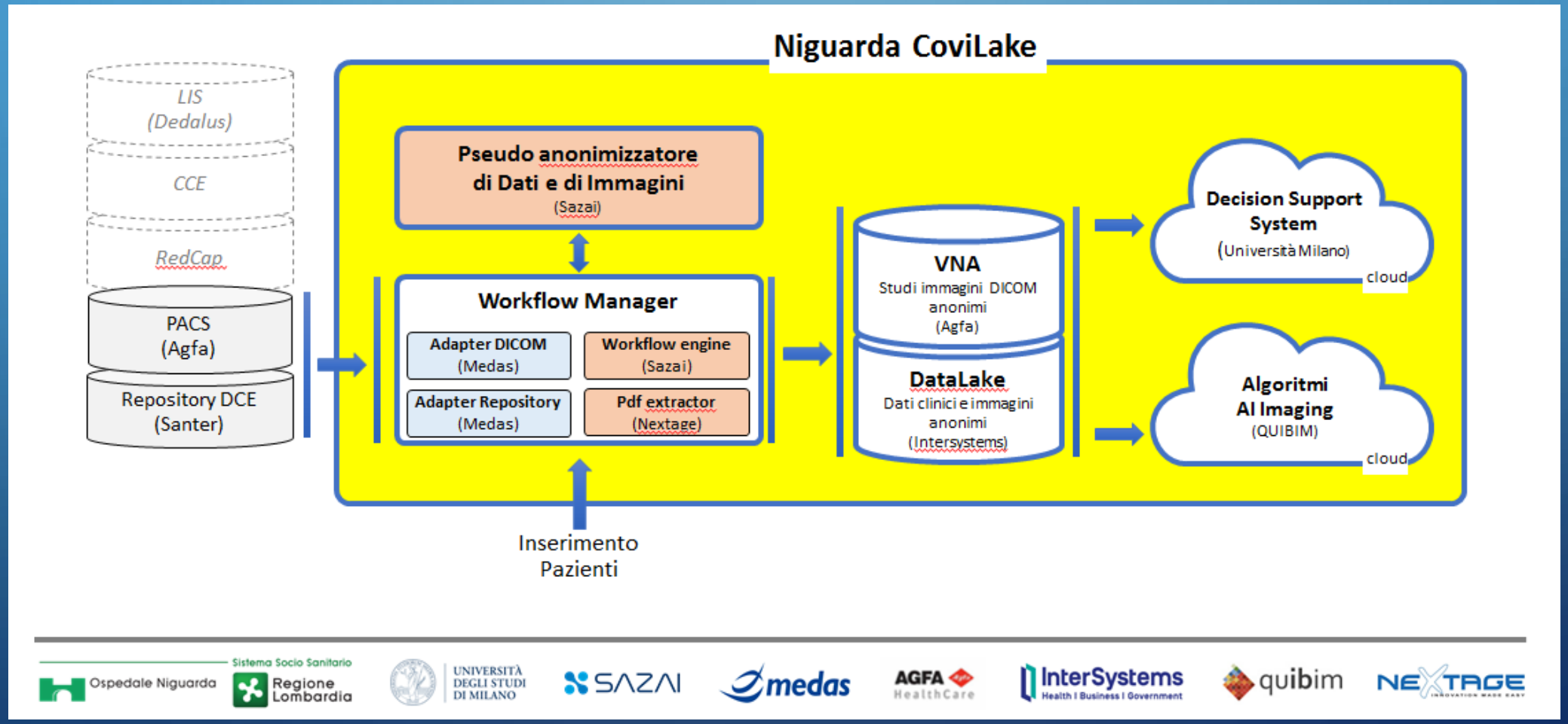
Medical Doctors

Clinical Staff

PATIENTS

Test, Validate, Optimize new technologies (rarely develop)

Datalake Project: a platform for clinical data collection developed during the first wave of COVID (04/20-04/21)



1 - CLINICAL TASK:

CAN WE *QUANTIFY* THE LUNG VOLUME AFFECTED BY THE DISEASE?

#Estimation #QCT

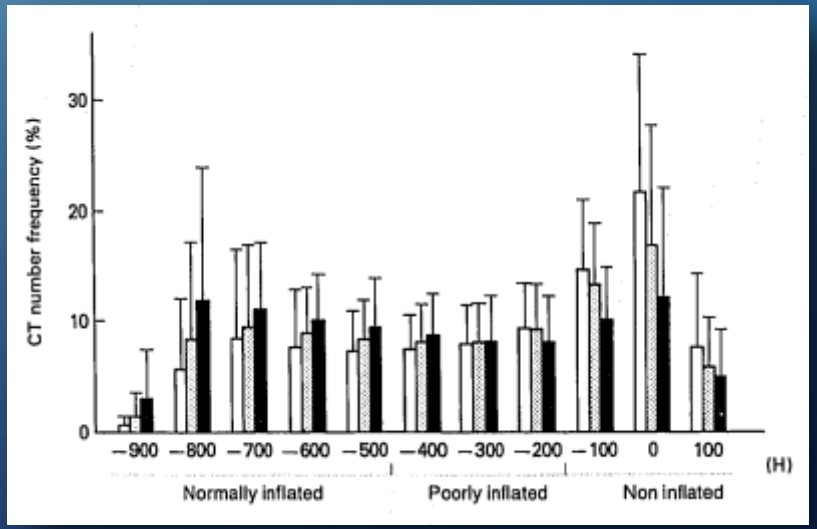
1988

Anesthesiology
69:824–832, 1988

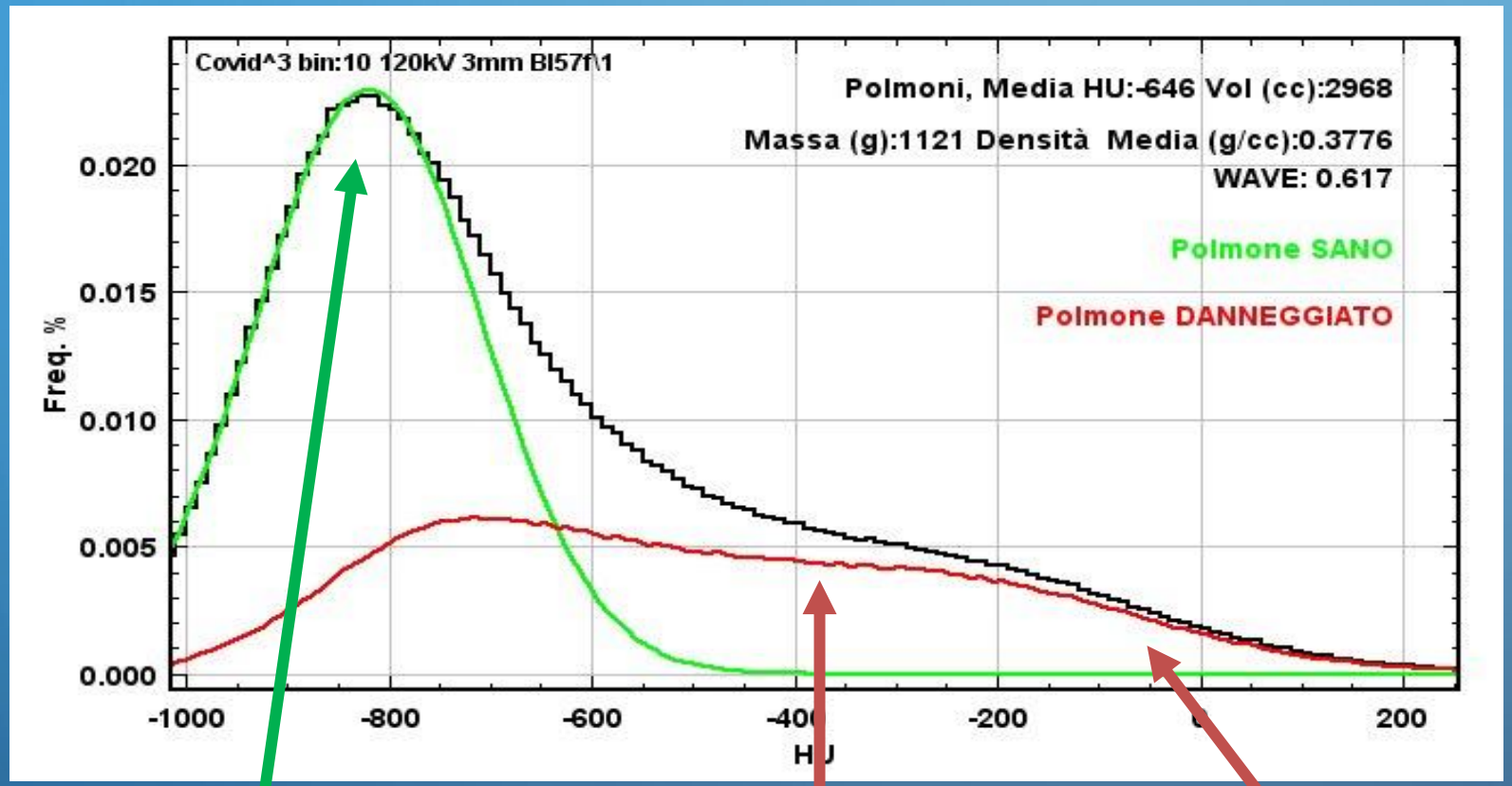
Relationships Between Lung Computed Tomographic Density, Gas Exchange, and PEEP in Acute Respiratory Failure

Luciano Gattinoni, M.D., Antonio Pesenti, M.D.,† Michela Bombino, M.D.,‡ Simone Baglioni, M.D.,‡ Massimo Rivolta, M.D.,‡ Francesca Rossi, M.D.,‡ Gianpiera Rossi, M.D.,§ Roberto Fumagalli, M.D.,§ Roberto Marcolin, M.D.,¶ Daniele Mascheroni, M.D.,¶ Alberto Torresin, Ph.D.***

- Quantitative analysis based on the frequency distribution of the CT numbers (QCT)
- CT numbers represents the linear attenuation coefficient of an x-ray given substance normalized to the linear attenuation coefficient of water



#QCT



HP

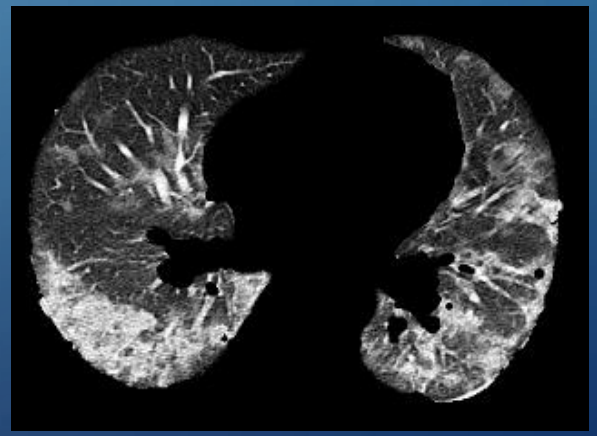
1-Well-Aerated Lung:

Homogenous tissue

Gaussian Distribution

2-Total Lung:

Well-Aerated + Disease + Vessels



Well-Aerated Lung

Ground-Glass Opacity

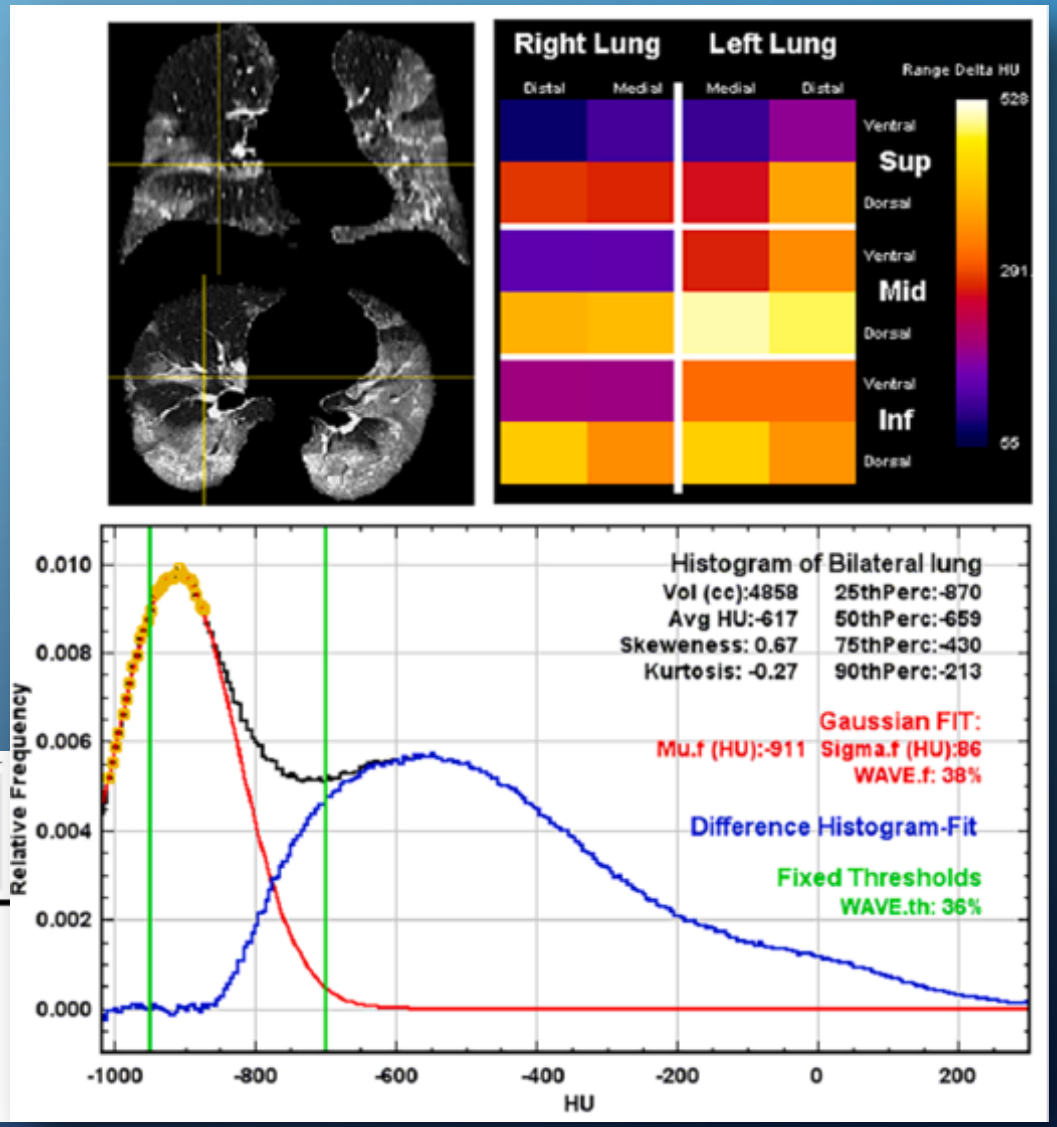
Solids or Fluids

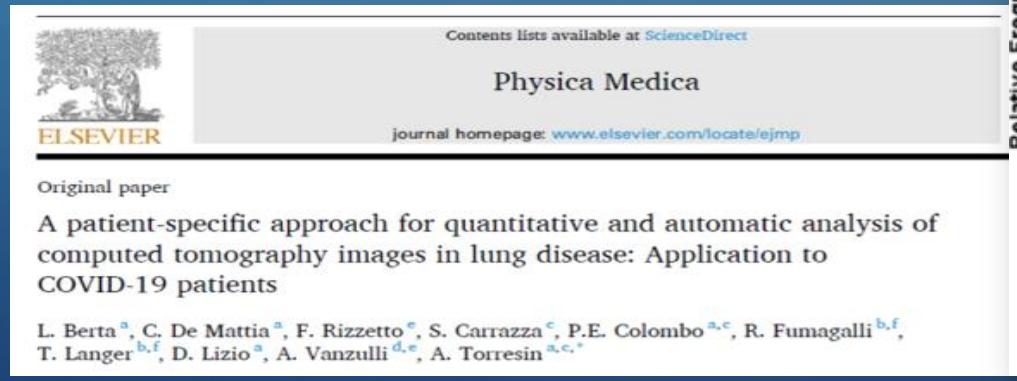
#Estimation #QCT

2020

From Histogram data (first-order RF) we can extract more information about WAVE and density distribution of affected lung

WAVE = Well-Aerated Volume Estimation





Contents lists available at ScienceDirect

Physica Medica

journal homepage: www.elsevier.com/locate/ejmp

Original paper

A patient-specific approach for quantitative and automatic analysis of computed tomography images in lung disease: Application to COVID-19 patients

L. Berta [a], C. De Mattia [a], F. Rizzetto [e], S. Carrazza [c], P.E. Colombo [a,c], R. Fumagalli [b,f], T. Langer [b,f], D. Lizio [a], A. Vanzulli [d,e], A. Torresin [a,c,*]

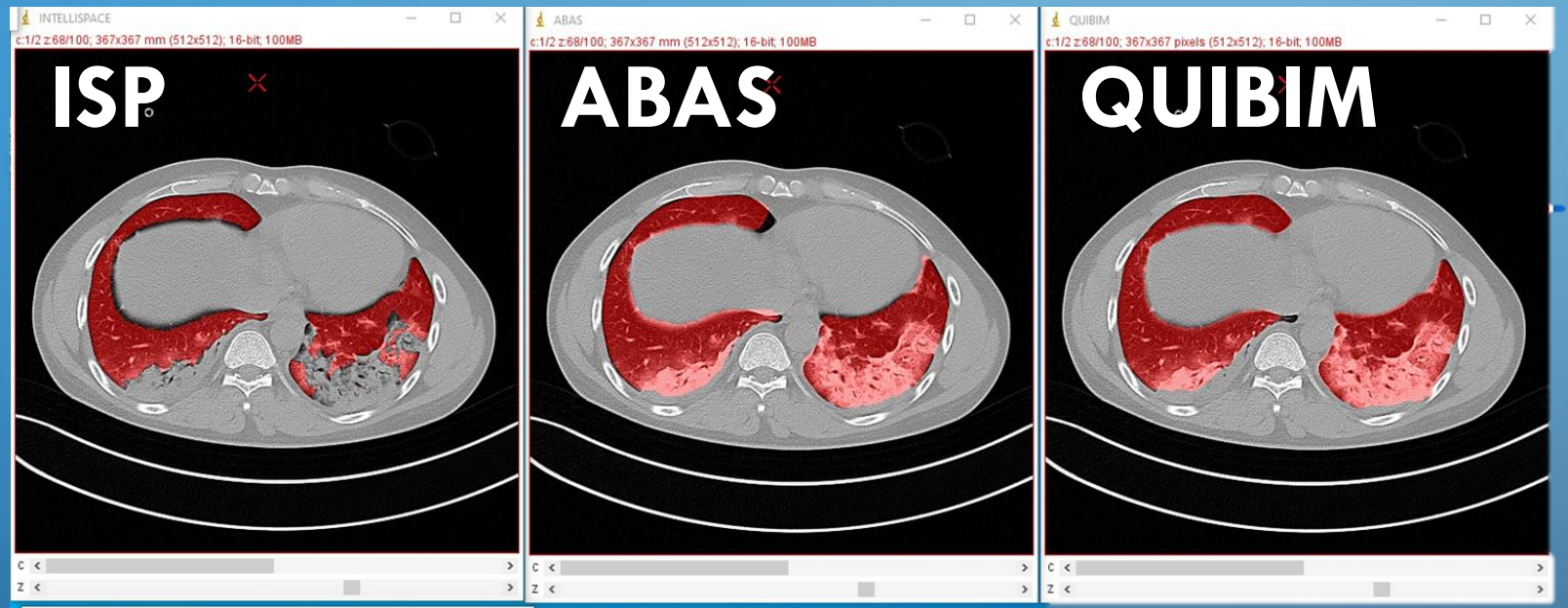
#Estimation #QCT

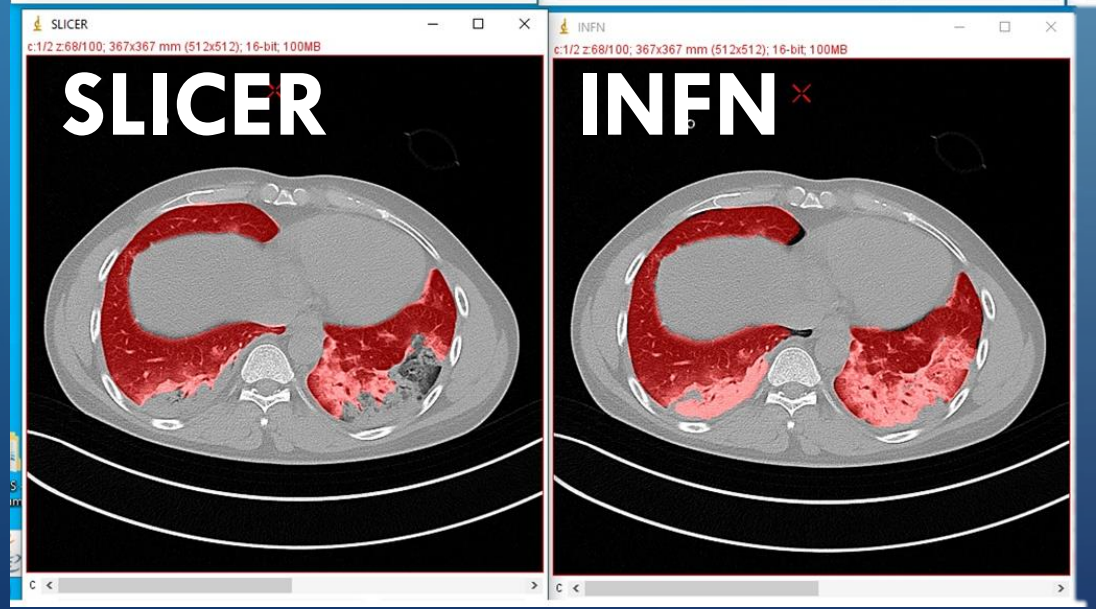
2 - TECHNICAL & LOGISTIC TASK:

CAN WE DEVELOP A PIPELINE STARTING FROM ***AUTOMATIC*** SEGMENTATION?

#Automatization

Example of automatic segmentators



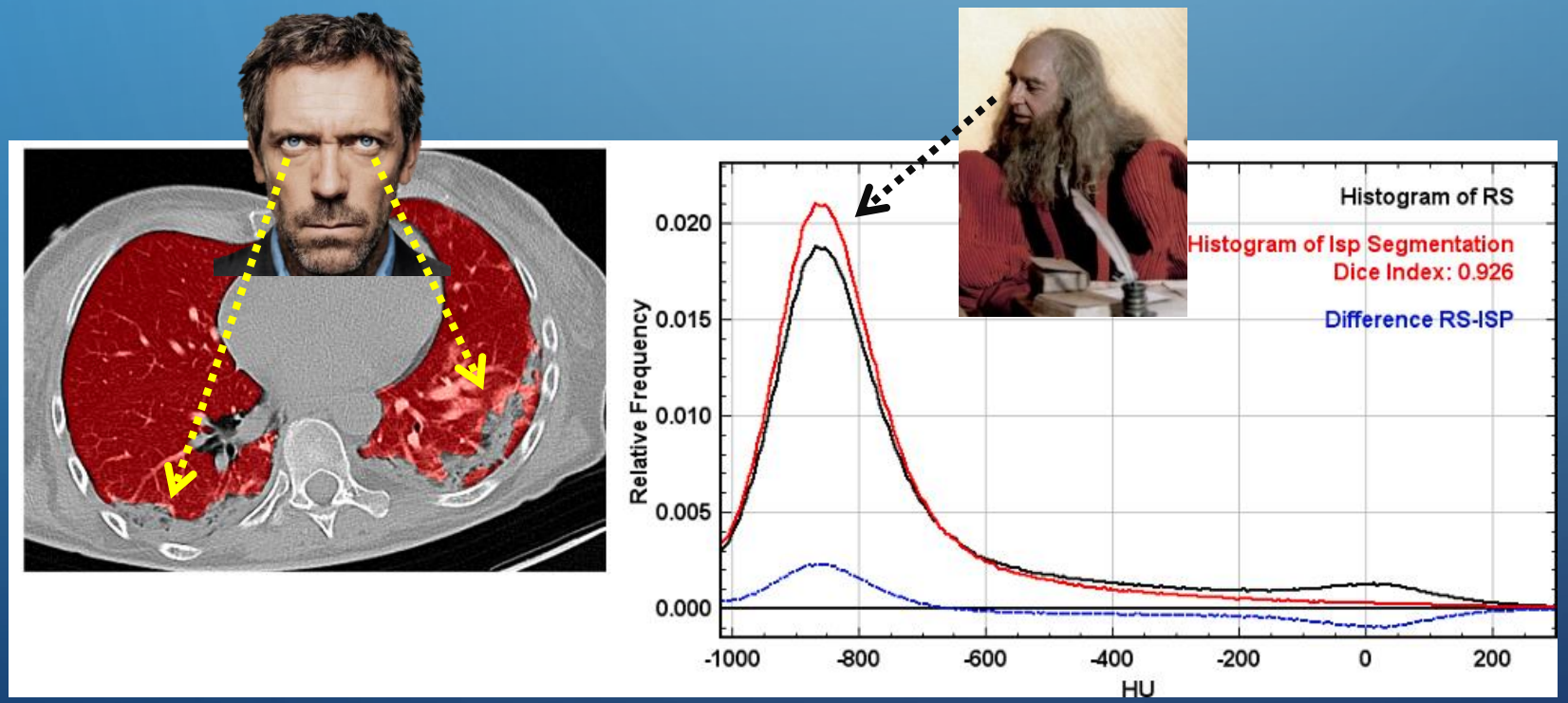


How inaccuracies of automatic segmentations propagate in the calculation of quantitative metrics?

#Automatization

AUTOMATIC SEGMENTATION ASSESSMENT

- «Automatic» vs «Gold Standard» segmentations -> *QUANTITATIVE*
- Subjective score (5-points scale) by 4 clinicians –> *QUALITATIVE*

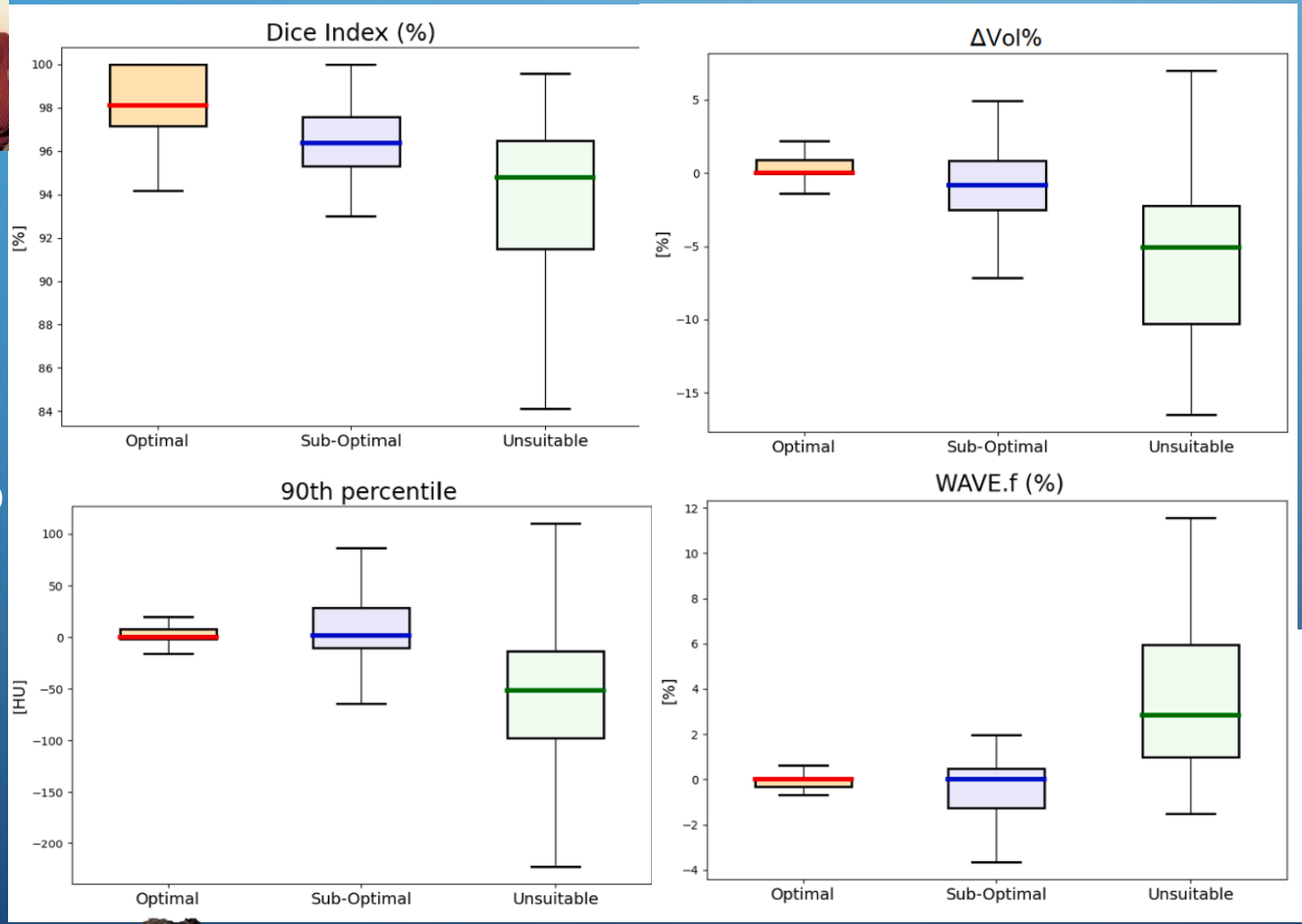


QCT in automatic & reference segmentation

#QA #Automatization #QCT

AUTOMATIC SEGMENTATION ASSESSMENT

Accuracy of QCT metrics with automatic segmentation



Qualitative or quantitative approaches provide both good methods for the assessment of Automatic Segmentation

Original paper

Automatic lung segmentation in COVID-19 patients: Impact on quantitative computed tomography analysis

L. Berta [a], F. Rizzetto [b,c], C. De Mattia [a], D. Lizio [a], M. Felisi [a], P.E. Colombo [a], S. Carrazza [d,e], S. Gelmini [d], L. Bianchi [b,c], D. Artioli [b], F. Travaglini [b], A. Vanzulli [b,f], A. Torresin [a,d,*], on behalf of the Niguarda COVID-19 Working Group

[a] Department of Medical Physics, ASST Grande Ospedale Metropolitano Niguarda, Piazza Ospedale Maggiore 3, 20162 Milan, Italy
[b] Department of Radiology, ASST Grande Ospedale Metropolitano Niguarda, Piazza Ospedale Maggiore 3, 20162 Milan, Italy
[c] Postgraduate School of Diagnostic and Interventional Radiology, Università degli Studi di Milano, via Festa del Perdono 7, 20122, Milan, Italy
[d] Department of Physics, Università degli Studi di Milano, via Giovanni Celoria 16, 20133 Milan, Italy
[e] Department of Physics, INFN Sezione di Milano, via Giovanni Celoria 16, 20133 Milan, Italy
[f] Department of Oncology and Hemato-Oncology, Università degli Studi di Milano, via Festa del Perdono 7, 20122, Milan, Italy

Visual Assessment by Radiologists
(Optimal, Sub-Optimal, Unsuitable)

#QA #Automatization

3 - CLINICAL TASK:

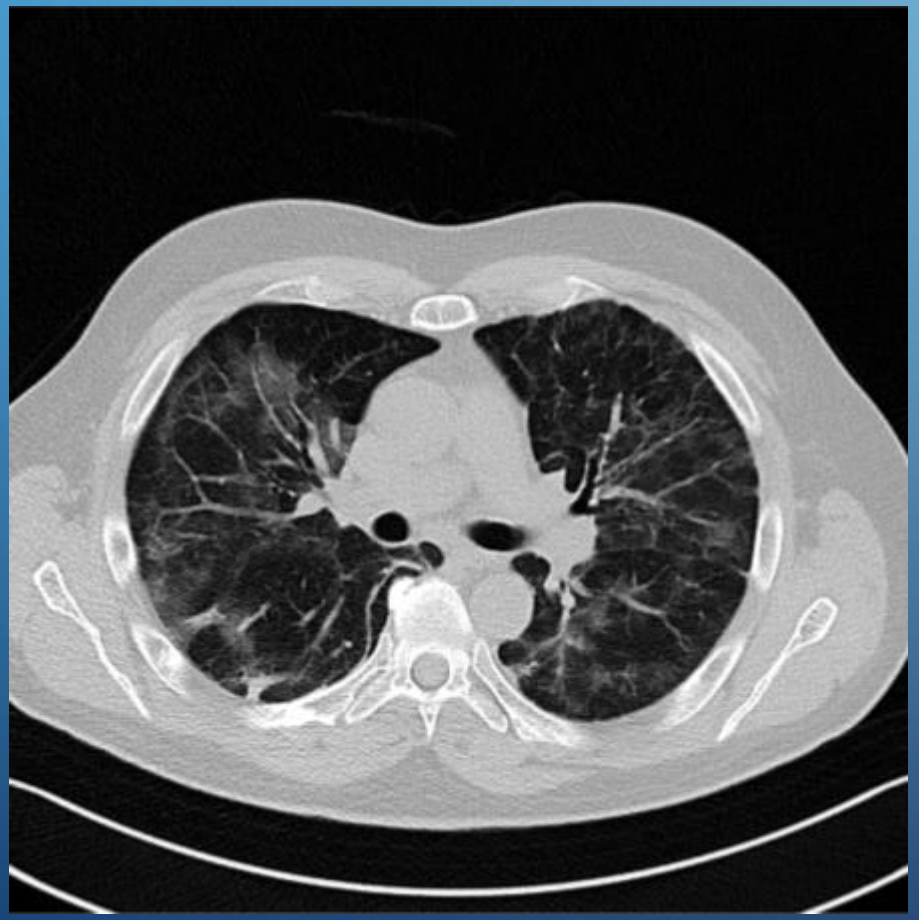
CAN WE USE QCT AND RADIOMICS TOOLS TO ***CLASSIFY*** COVID-19 AND OTHER VIRAL PNEUMONIA FROM CT IMAGES?

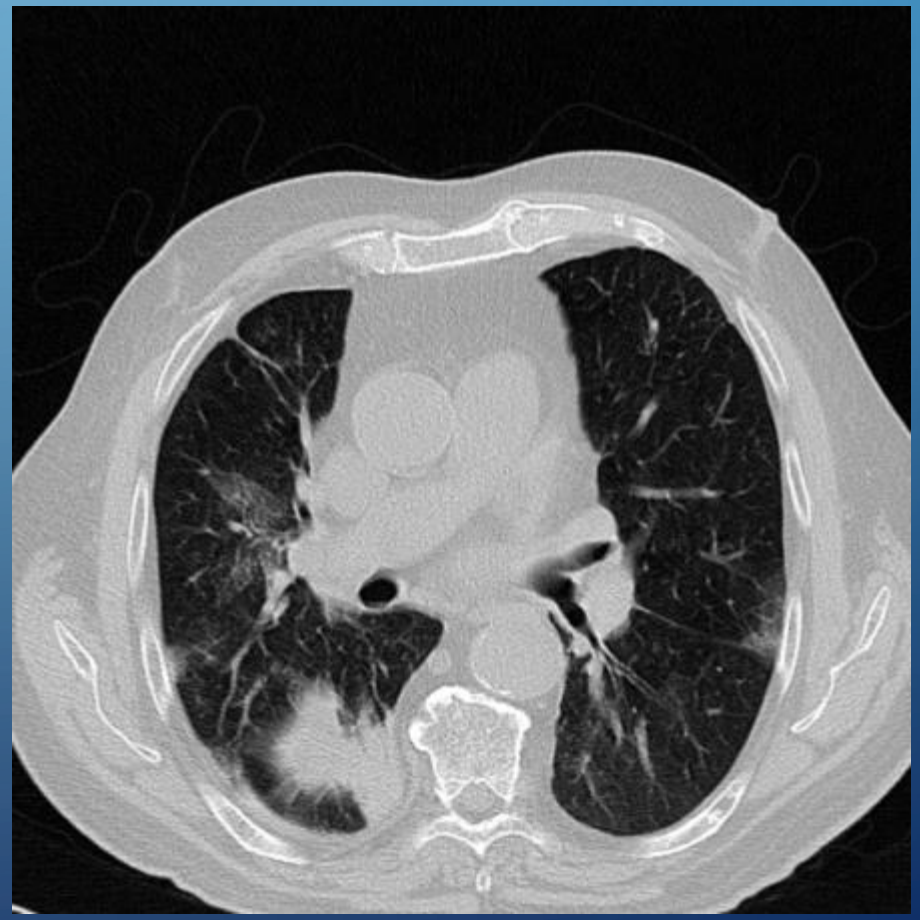
#Classification

COVID-19 PNEUMONIA

VS

VIRAL PNEUMONIA





#Classification

DATASET (from DATALAKE)

PCR-proven!

1031 PATIENTS WITH VIRAL PNEUMONIA EVALUATED WITH CT

647 COVID-19

- $\frac{M}{M+F} = 0.71$
- Median age = 67
- Period: 2020 - 2021

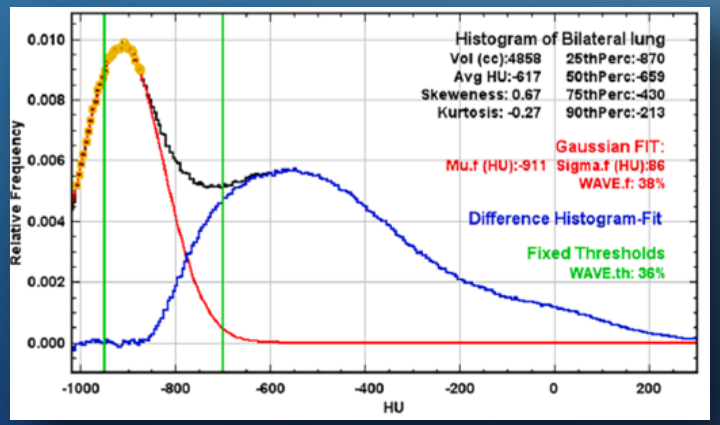
384 non-COVID-19

- $\frac{M}{M+F} = 0.62$
- Median age = 66
- Period: 2018 - 2019

#Clinical Data

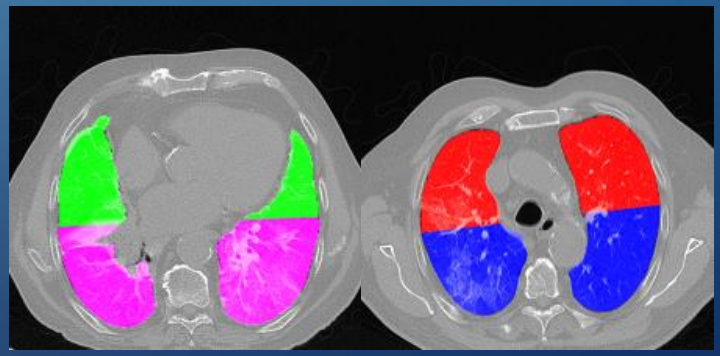
a) QUANTITATIVE METRICS

QUANTITATIVE METRICS
(1° histogram, «WAVE Model»)



Whole LUNG
n = 20

4 GEOMETRICAL SUBDIVISION
n = 80



#QCT

b) RADIOMIC FEATURES (only whole Lung)

pyradiomics

FIRST ORDER FEATURES
RF1 n = 19

→ e.g. skewness, standard deviation, entropy

SECOND ORDER FEATURES
RF2 n = 40

→
- **GLCM n = 24**
  e.g. cluster-shade, correlation
- **GLSZM n = 16**
  e.g. small area emphasis, zone entropy

GLCM = Gray Level Co-occurrence Matrix
GLSZM = Gray Level Size Zone Matrix

#Radiomics

MODELS PERFORMANCE

Table 2 Main properties and results of each artificial intelligence model

Model	Type of features	Number of radiological features[a]	Number of relevant radiological features[a]
Model1	RF1 (2L)	21	10
Model2	QM (2L and 4 GS)	102	26
Model3	RF1 + RF2 (2L)	141	24
Model4	RF1 + QM (2L and 4 GS) + RF2 (2L)	241	32

Zorzi et al. European Radiology Experimental (2023) 7:3
https://doi.org/10.1186/s41747-022-00317-6

European Radiology EXPERIMENTAL
EUROPEAN SOCIETY OF RADIOLOGY

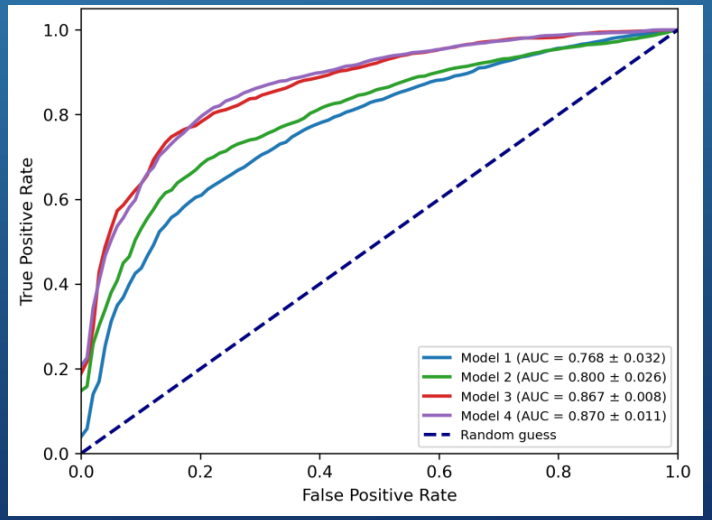
ORIGINAL ARTICLE Open Access

Artificial intelligence for differentiating COVID-19 from other viral pneumonias on CT: comparative analysis of different models based on quantitative and radiomic approaches

Giulia Zorzi[1,2,3], Luca Berta[2*], Francesco Rizzetto[4,5*], Cristina De Mattia[2], Marco Maria Jacopo Felisi[2], Stefano Carrazza[3,6], Silvia Nerini Molteni[7], Chiara Vismara[7], Francesco Scaglione[7,8], Angelo Vanzulli[5,8], Alberto Torresin[2,3,6] and Paola Enrica Colombo[2,6]

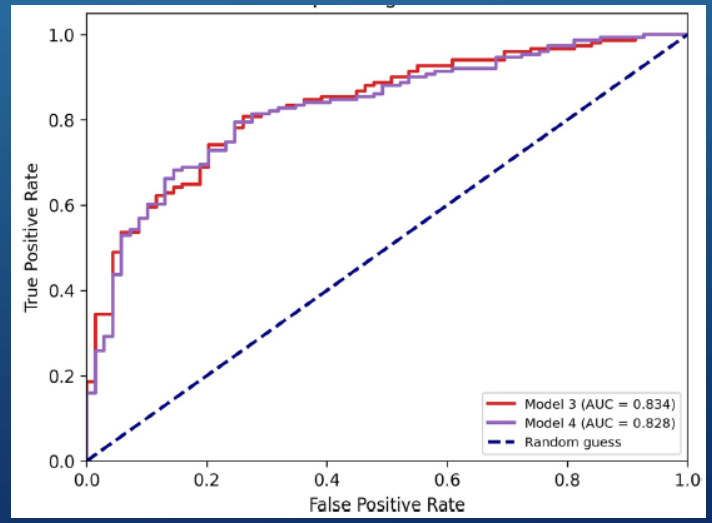
Training-Test

811 CT images, 4fold-CV



Independent Validation

220 CT images



MODEL 3

AUC-Test = 0.87

AUC-IVS = 0.83

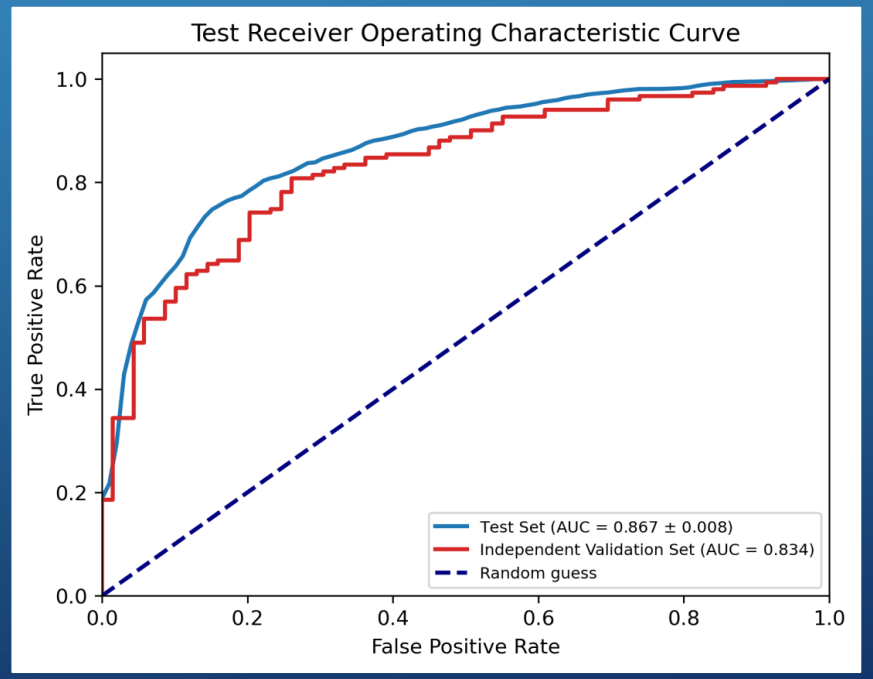
BUILT WITH 1° 2° ORDER RADIOMIC FEATURES on entire lungs (but NOT QCT…)

#Classification

CLASSIFICATION: AI vs RADIOLOGISTS

INDEPENDENT VALIDATION SET
220 PATIENTS

MODEL 3



READERS

- 3 radiologists: >10-y experience
- 1 resident: 3-y experience

CO-RADS score:

- Score = 1 or 3: non-COVID-19
- Score= 3-5: COVID-19

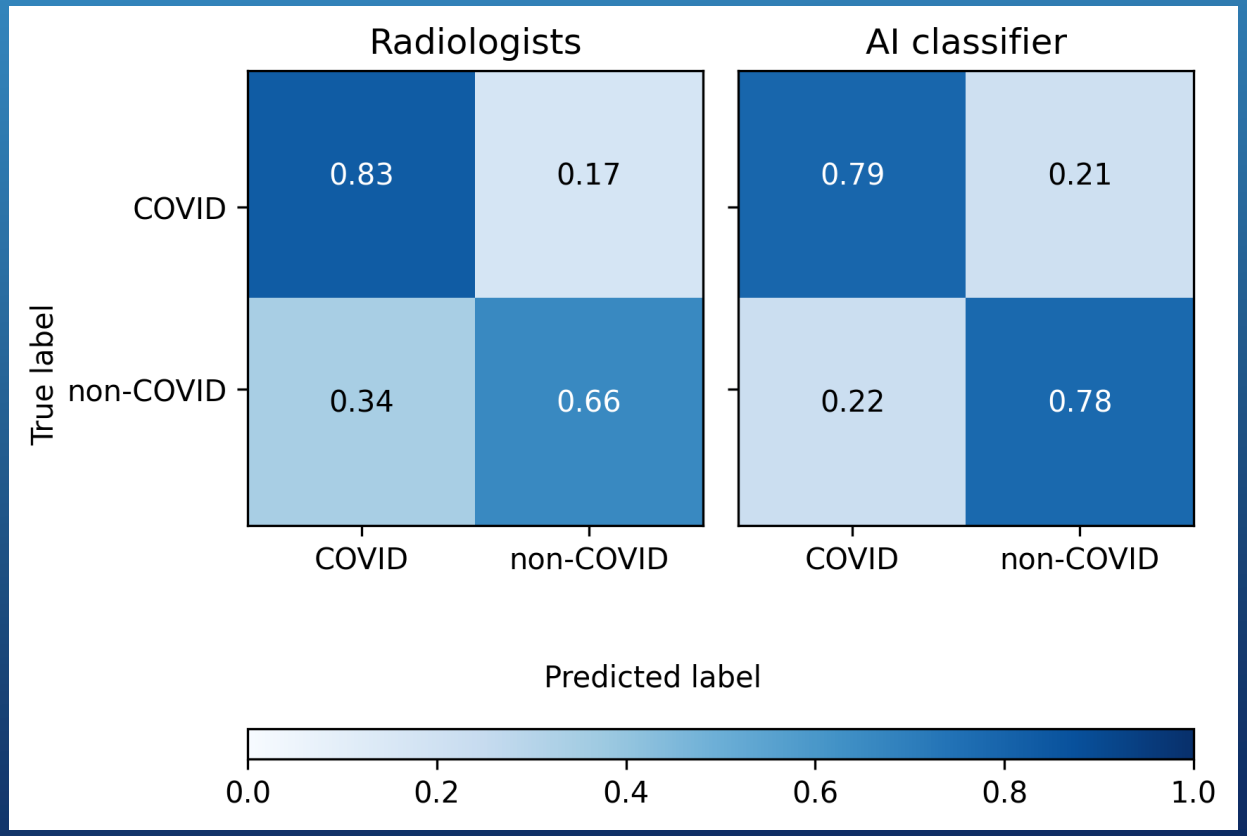
#Classification

RESULTS

ACCURACY:

→ AI = 79%

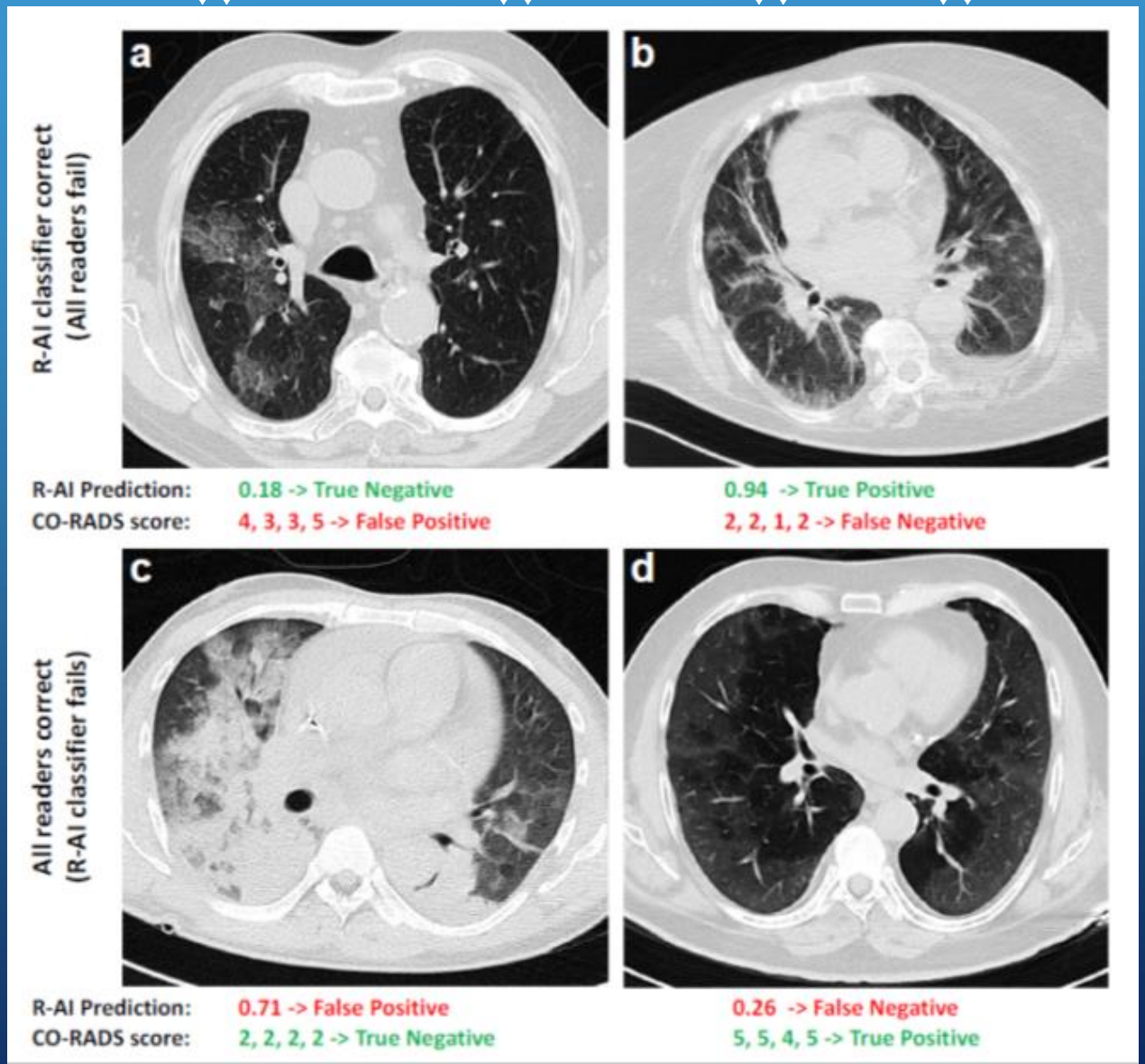
→ RADIOLOGISTS = 78%



#Classification

RESULTS

↓↓NON-COVID↓↓ ↓↓COVID↓↓



tomography MDPI

Article

Diagnostic Performance in Differentiating COVID-19 from Other Viral Pneumonias on CT Imaging: Multi-Reader Analysis Compared with an Artificial Intelligence-Based Model

Francesco Rizzetto [1,2,*], Luca Berta [3], Giulia Zorzi [3,4], Antonino Cincotta [1,2], Francesca Travaglini [1], Diana Artioli [1], Silvia Nerini Molteni [5], Chiara Vismara [5], Francesco Scaglione [5,6], Alberto Torresin [3,7], Paola Enrica Colombo [3,7], Luca Alessandro Carbonaro [1,6] and Angelo Vanzulli [1,6]

→ AI Correct, all readers fail

→ All readers correct, AI fails

#Classification

CHALLENGING CASES

- CO-RADS 3 score assigned by 2 or more radiologists
- Difference between CO-RADS score assigned ≥ 3

	220 VALIDATION CASES		59 CHALLENGING CASES	
	AI	RADIOLOGISTS	AI	RADIOLOGISTS
Accuracy	79%	78%	75% ✓	55% ✗
Specificity	78%	66%	78%	34%
Sensitivity	79%	83%	72%	69%

#Classification

4 - TECHNICAL AND LOGISTIC TASK:

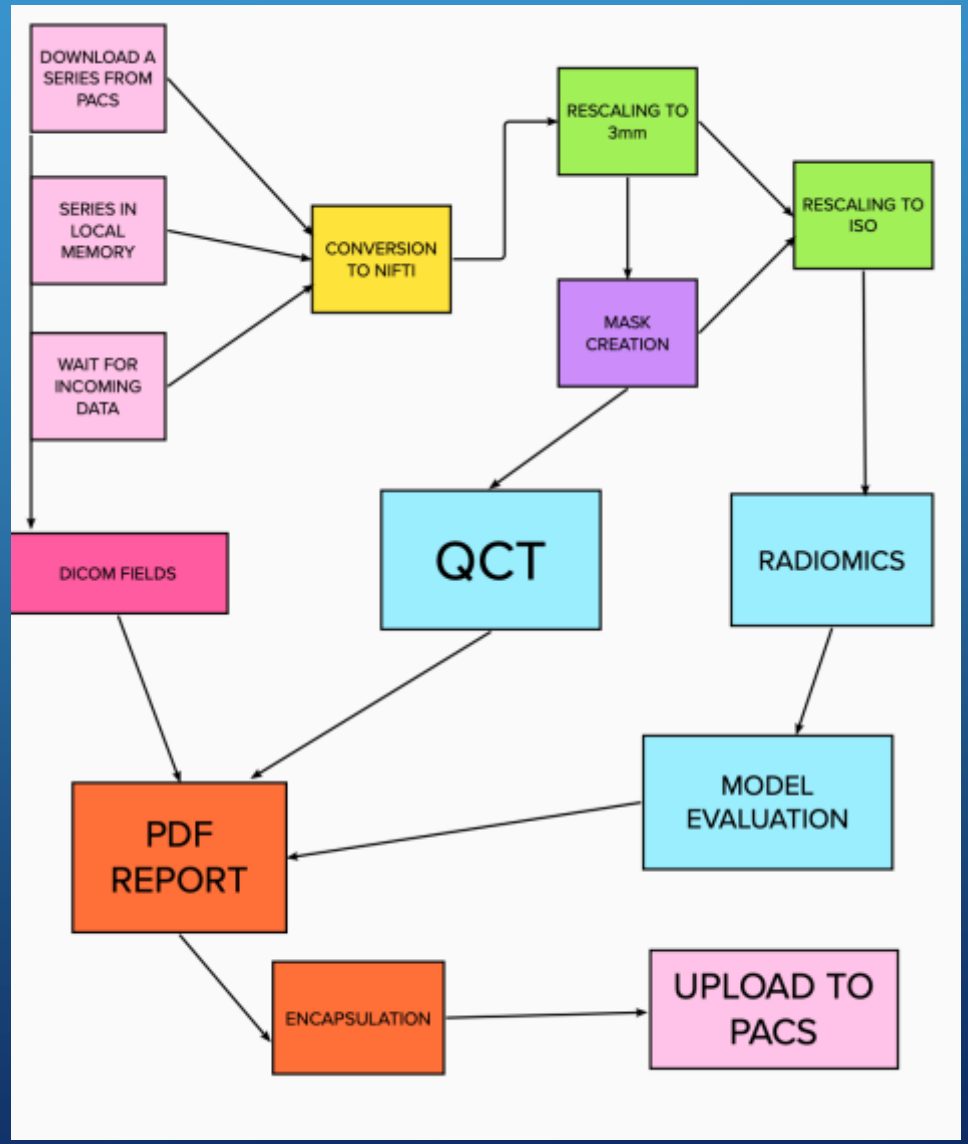
CAN WE IMPLEMENT THIS MODEL IN THE «*REAL*» CLINICAL PRACTICE?

#Deployment

CLEARLUNG

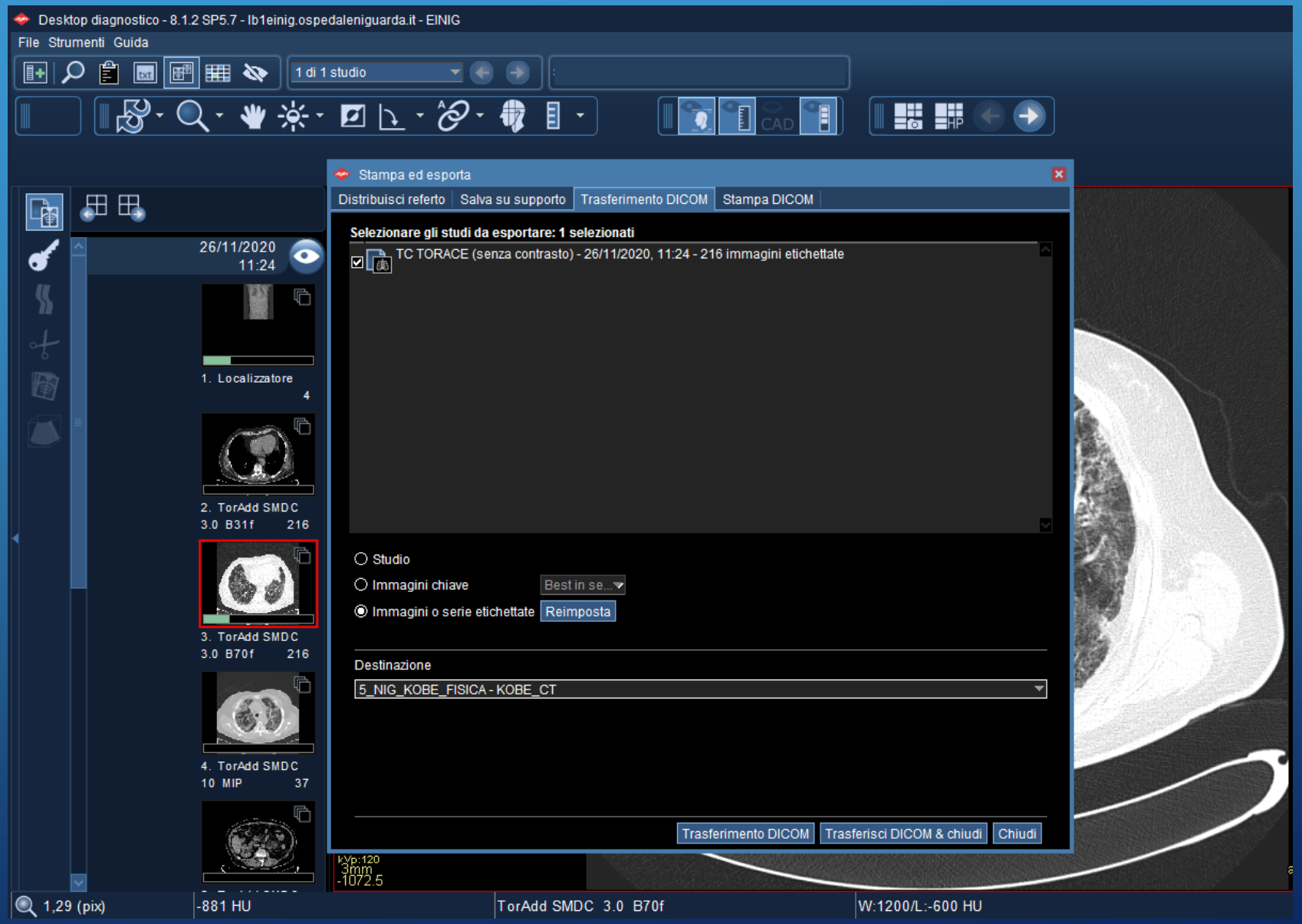
CLEARLUNG
Clinical Extraction And Radiomics on LUNGs

- Framework for quantitative analysis and radiomics on lung CT scans
- COVID-19 AI diagnosis
- Real-time analysis and prediction thanks to PACS connection



#Deployment

PACS CONNECTION



#Deployment

1 minute and 29 seconds!!!

#Deployment

RESULT OF THE AUTOMATIC ANALYSIS

Sistema Socio Sanitario
Ospedale Niguarda | Regione Lombardia

CLEARLUNG
Clinical Extraction And Radiomics on LUNGs

DIPARTIMENTO DEI SERVIZI
Struttura Complessa: Fisica Sanitaria
email: fisica.diagnostica@ospedaleniguarda.it

Piazza Ospedale Maggiore 3
20162 Milano (MI)

MEDICAL PHYSICS REPORT
QUANTITATIVE ANALYSIS - LUNG CT

PATIENT DATA

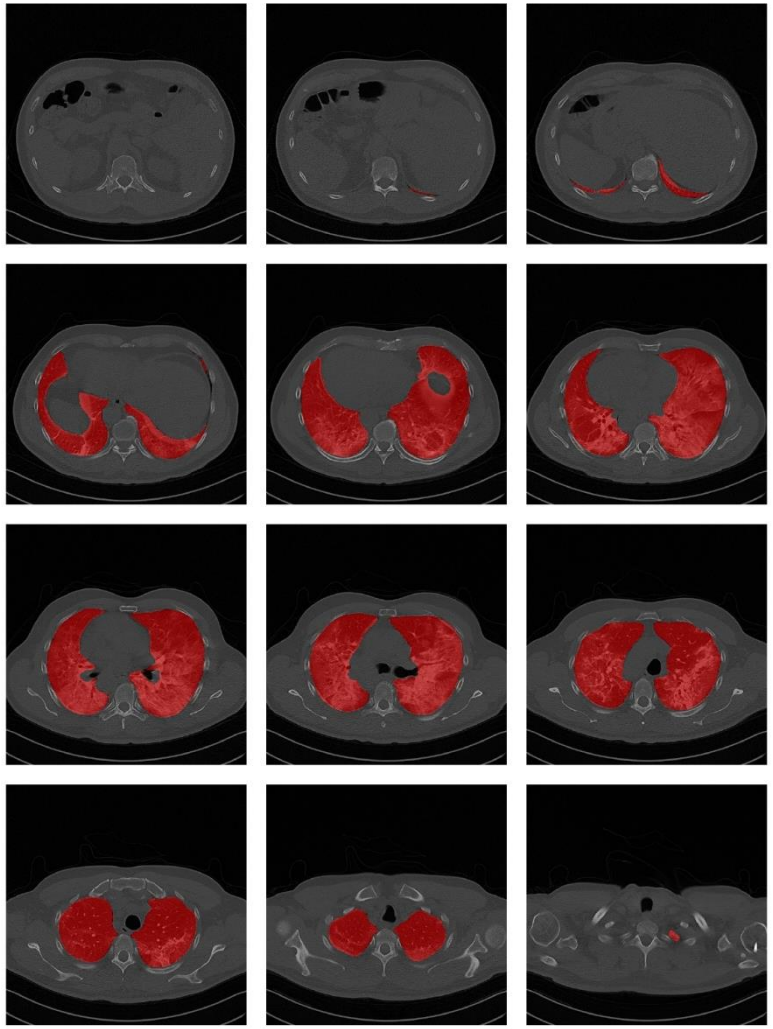
Accession number: 103990569	Analysis date 22/12/2022
Age: 59	CT study date: 20/03/2020
Sex: M	CT series description: Torace3.0BI571

DISCLAIMERS

This report is automatically generated by CLEARLUNG, a python software developed at the Medica Physics Department at Ospedale Niguarda. The pipeline performs both radiomic and clinical analysis on lung CT scans. Moreover, it is capable of receiving CTs from PACS in real time, and to send results in PDF format onto PACS after the analysis is finished. The clinical analysis was performed on CTs rescaled at 3.0 mm, while the radiomic analysis was performed on CTs rescaled at 1.15 mm.

The lung CT was subjected to a quantitative analysis of radiomic features with a neural network model trained to distinguish COVID-19 pneumonia cases from other viral pneumonias (model covid_0922). The classifier indicated a 26.1% probability of pneumonia originating from COVID-19. It should be noted that, in the training phase, the algorithm correctly classified about 80% of lung CT scans.

AUTOMATIC SEGMENTATION EVALUATION

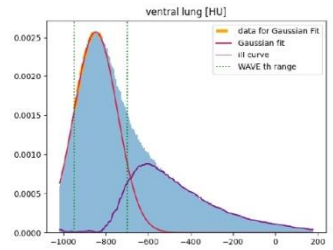


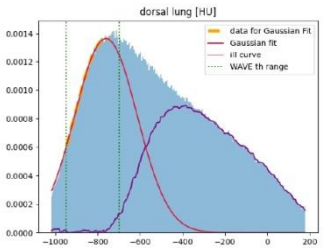
CLINICAL FEATURES - VENTRAL LUNG

Lung volume (cc):	1503		
Mean HU:	-699	Std dev HU:	231
Overinflated (-1000, -900) HU:	15%	Normally aerated (-900, -500) HU:	65%
Non aerated (-500, -100) HU:	15%	Consolidated (-100, 100) HU:	2%
WAVE fit:	0.626%	WAVE.th (-950, -700) HU:	54%
Mean ILL HU:	-470	Std dev ILL HU:	210

CLINICAL FEATURES - DORSAL LUNG

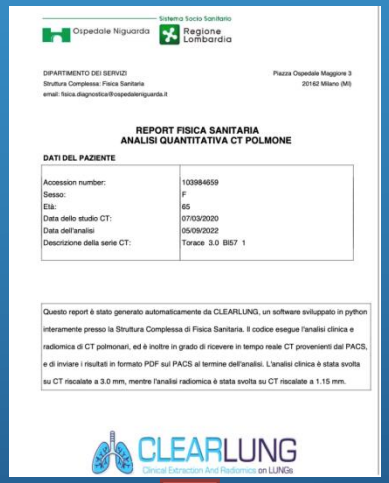
Lung volume (cc):	1906		
Mean HU:	-515	Std dev HU:	287
Overinflated (-1000, -900) HU:	6%	Normally aerated (-900, -500) HU:	50%
Non aerated (-500, -100) HU:	33%	Consolidated (-100, 100) HU:	9%
WAVE fit:	0.482%	WAVE.th (-950, -700) HU:	29%
Mean ILL HU:	-302	Std dev ILL HU:	215





#Report

W.I.P. 1: «AI in Clinical Practice»



Ospedale Niguarda — Sistema Socio Sanitario Regione Lombardia

DIPARTIMENTO DEI SERVIZI
Struttura Complessa: Fisica Sanitaria
email: fisica.diagnostica@ospedaleniguarda.it

Piazza Ospedale Maggiore 3
20162 Milano (MI)

REPORT FISICA SANITARIA
ANALISI QUANTITATIVA CT POLMONE

DATI DEL PAZIENTE

Accession number:	103984659
Sesso:	F
Età:	65
Data dello studio CT:	07/03/2020
Data dell'analisi	05/09/2022
Descrizione della serie CT:	Torace 3.0 B67 1

Questo report è stato generato automaticamente da CLEARLUNG, un software sviluppato in python interamente presso la Struttura Complessa di Fisica Sanitaria. Il codice esegue l'analisi clinica e radiomica di CT polmonari, ed è inoltre in grado di ricevere in tempo reale CT provenienti dal PACS, e di inviare i risultati in formato PDF sul PACS al termine dell'analisi. L'analisi clinica è stata svolta su CT riscalate a 3.0 mm, mentre l'analisi radiomica è stata svolta su CT riscalate a 1.15 mm.

CLEARLUNG
Clinical Extraction And Radiomics on LUNGs

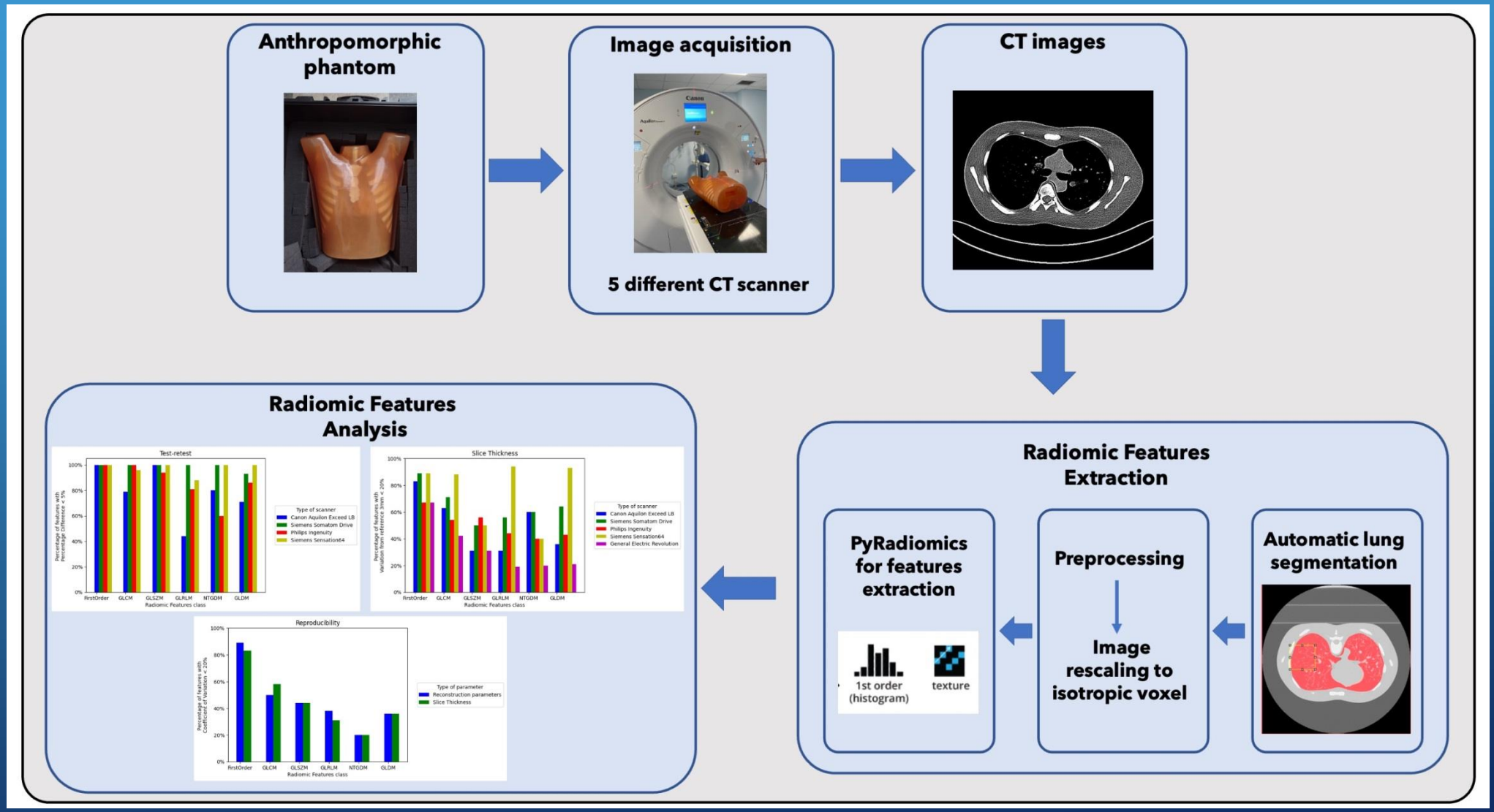
CORADS = 3

AI
Prediction: 0.78

CORADS = 4

Discuss Δ-Time and Δ-accuracy

W.I.P. 2: «Antrhopomorphic Phantom»



#Radiomics #QA

CONCLUSIONS

- Structured Data and QA is mandatory to develop robust and automatic pipelines: this can be done only by humans
- Artificial intelligence modeling is «feasible» in clinical environment
- Clinical validation with independent data and medical doctors is mandatory
- Interdisciplinary approach leads to results applicable in the clinical setting

Thanks!

Niguarda Team: