Radiomics in CMR

Extracting More Information from Cardiac Images

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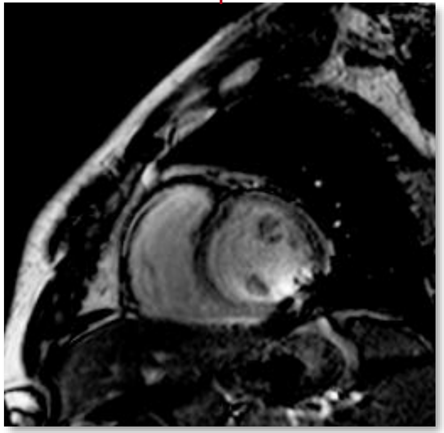
UNIVERSITAT DE BARCELONA

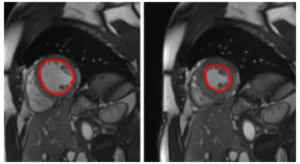
SCMR
Society for Cardiovascular Magnetic Resonance

EACVI
European Association of Cardiovascular Imaging
European Society of Cardiology

1 - Radiomics in CMR: Motivations

Conventional CMR Indices





CMR Indices

Standard CMR indices do not capture:

- Advanced morphological quantification
- Advanced quantification of cardiac remodeling
- Changes in cardiac tissues

(T. H. Marwick,J Am Coll Cardiol. 2018)

CMR radiomics

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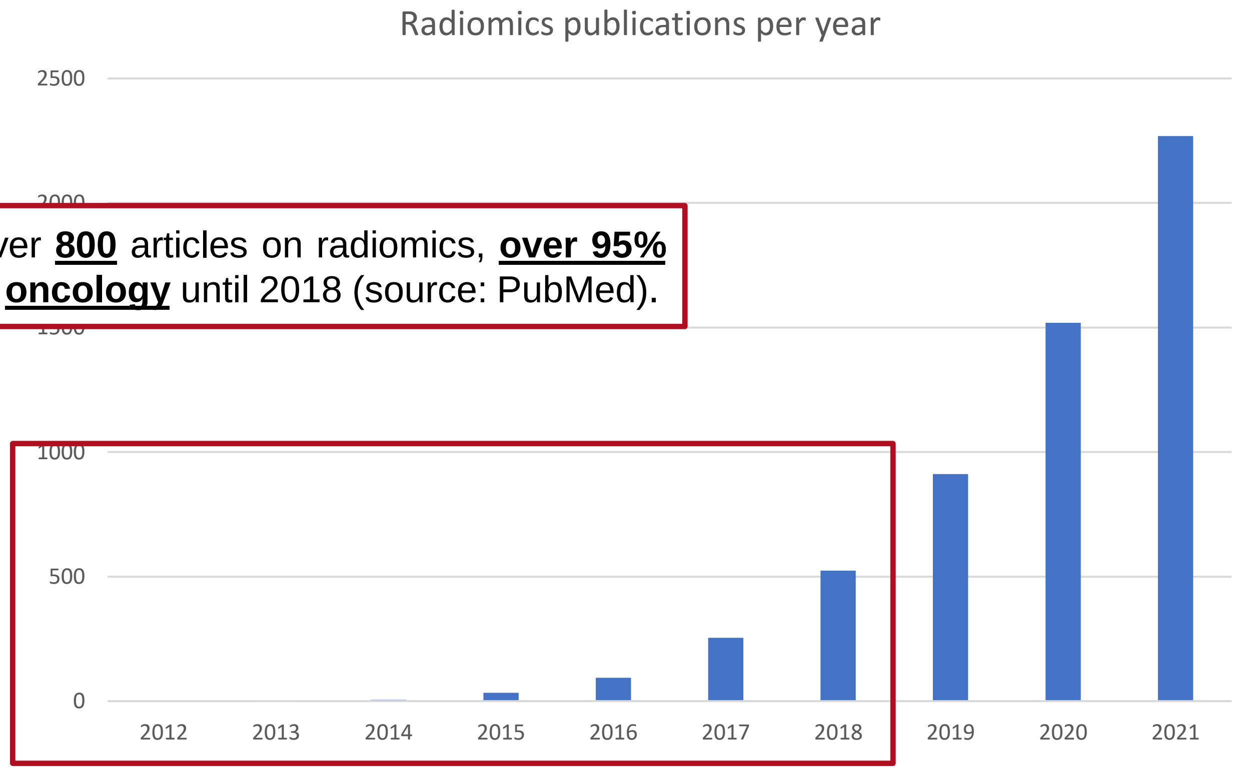
Traditional indices. Myocardial mass, ejection fraction, ED volume, ES volume, stroke volume and the corresponding values indexed to body surface area, height or weight, strain and strain-rates in three directions (radial, circumferential and longitudinal).

Radiomic markers. **Size** radiomics: Diameters, elongations, surface areas, surface to volume ratios. **Shape** radiomics: Sphericity, axes, compactness, flatness, eccentricity. **Boundary** radiomics: Sharpness, regularity, smoothness, etc. **Intensity** radiomics: Mean, standard deviation, skewness, intensity range, entropy, uniformity. **Textural** radiomics: Homogeneity, localised contrast, tissue complexity, structure repeatability, total energy, **fractal dimension**, structure continuity/connectivity, tissue coarseness, directionality, etc.

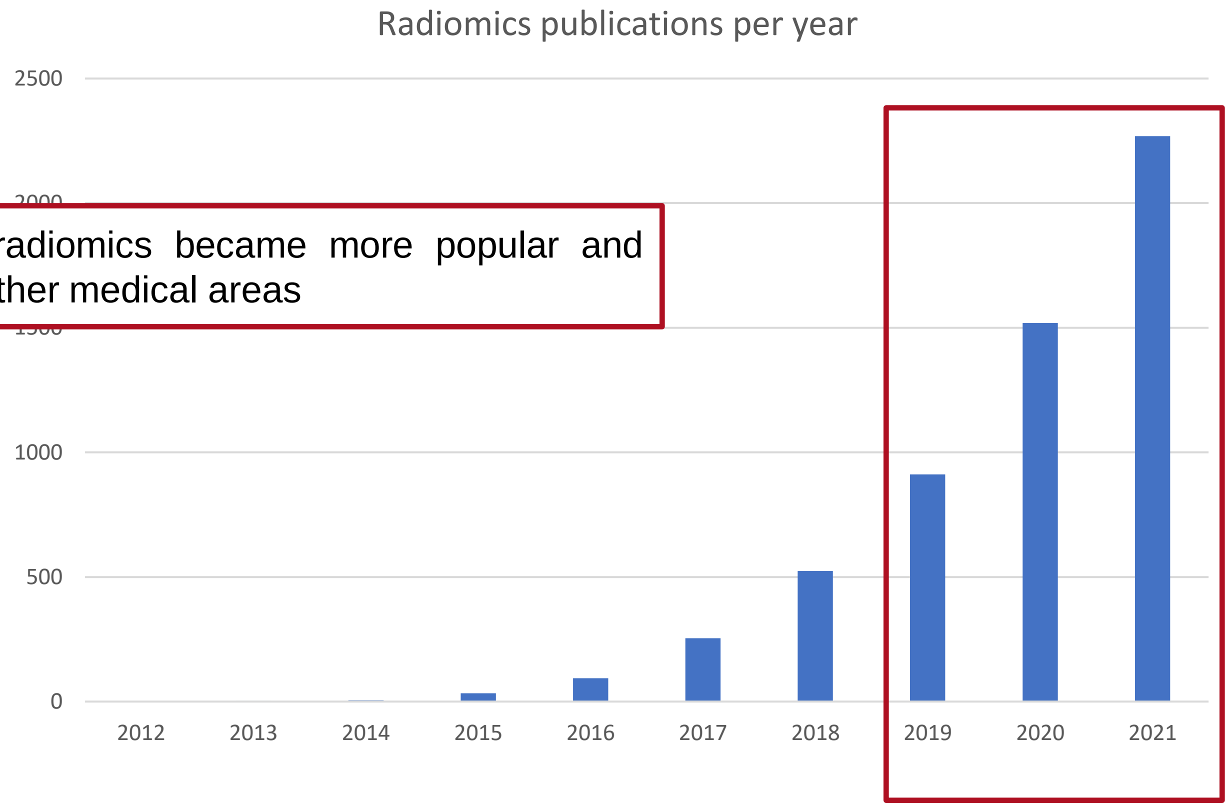
Radiomic transforms. **Wavelets** transform: identifies patterns in different spatial frequencies: **Fourier**: extracts information on periodicity (coarseness/fineness) and directionality of textures; **Laplacian**: Highlights discontinuities and fine tissue changes (e.g. trabeculae); **Logarithmic**: increases dynamic ranges of dark regions (e.g., trabeculae); **Exponential**: Enhances detail in high-value regions; **Histogram of gradients**: Encodes the spatial arrangement of gradients in the image.

Existing Works on Radiomics



There are over **<u>800</u>** articles on radiomics, **<u>over 95%</u>** dedicated to **<u>oncology</u>** until 2018 (source: PubMed).

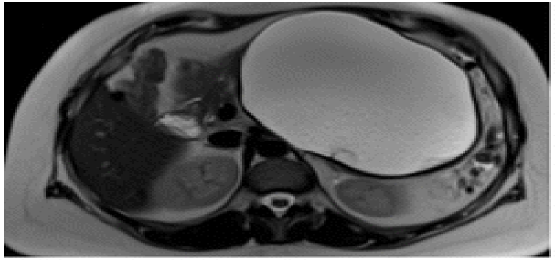
Existing Works on Radiomics



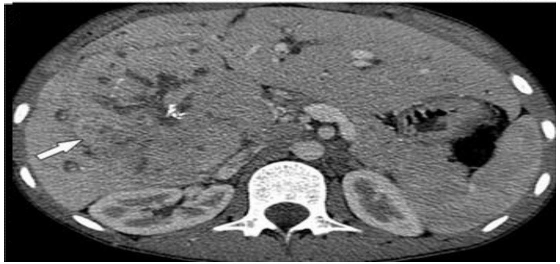
From 2019, radiomics became more popular and extended to other medical areas

Radiomics in Oncology

Diagnosis | **Treatment Planning** | **Prognostication**



Uniform high signal intensity. No lesion is shown

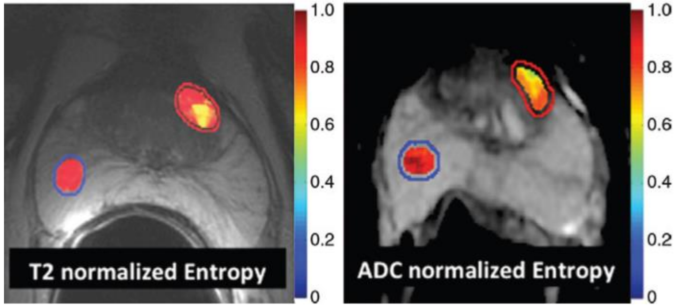


Shows the heterogeneity of a malignant tumor

(J.D.Shur, J Radiograp. 2021)

Radiomics in Oncology

Diagnosis | **Treatment Planning** | Prognostication



Heatmap shows tumour agressiveness

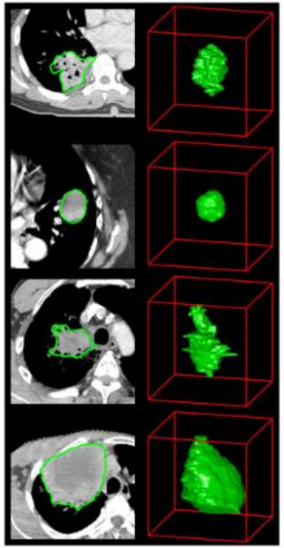
(R.J Gillies et al., J Radiology 2015)

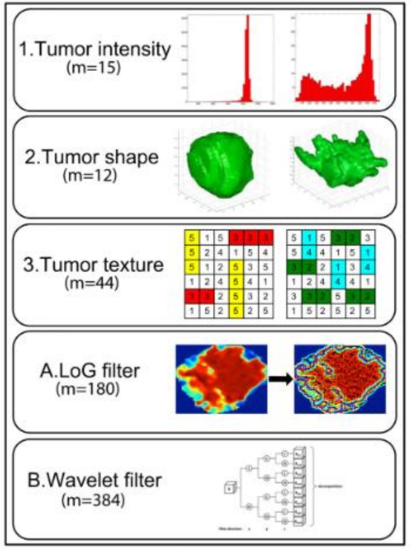
Radiomics in Oncology

Diagnosis

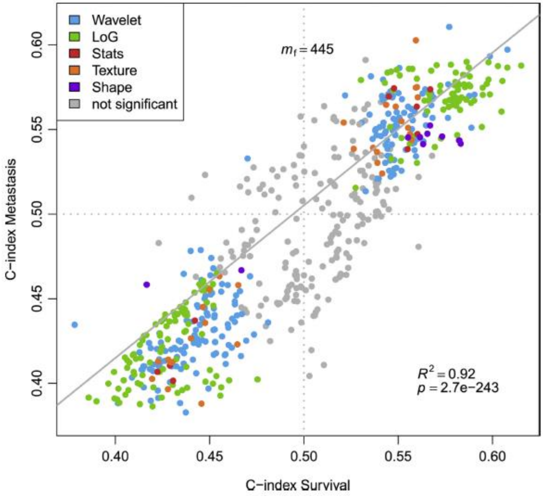
Treatment Planning

Prognostication





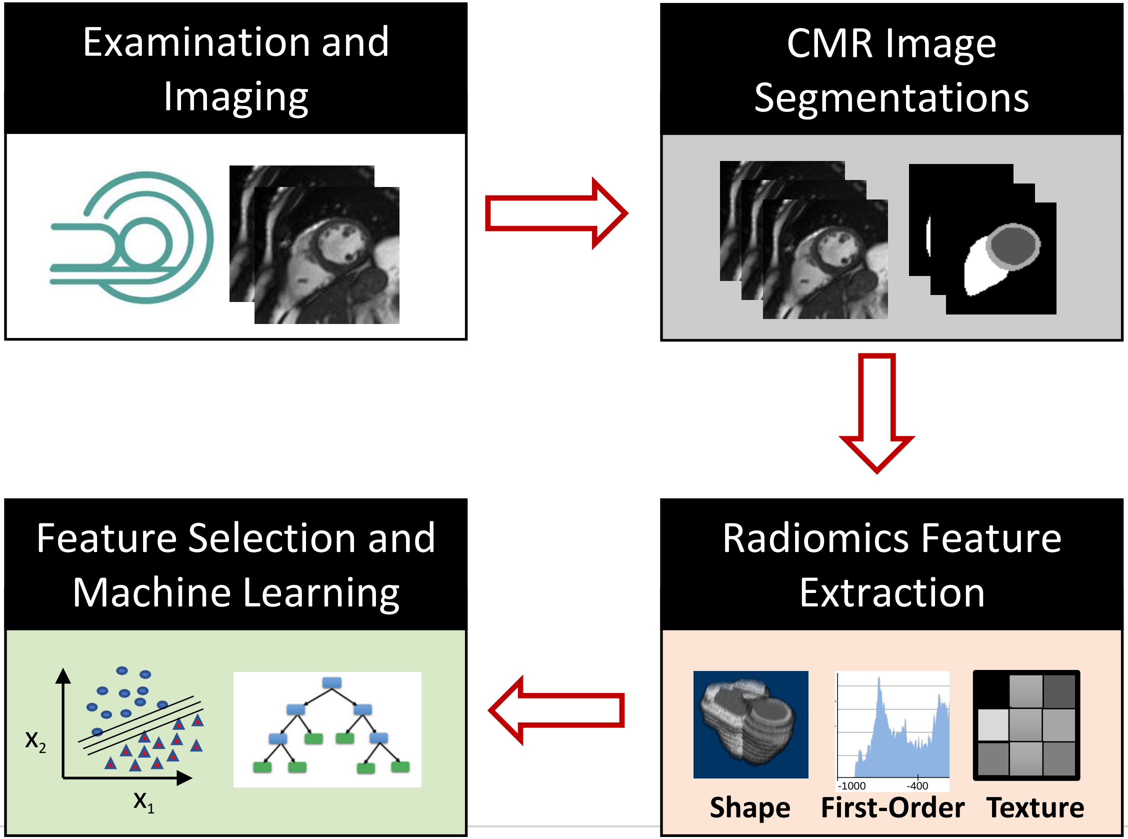
Metastasis prediction



(T.P Coroller et al., Radiother Oncol. 2015)

2 - Radiomics in CMR: Methods

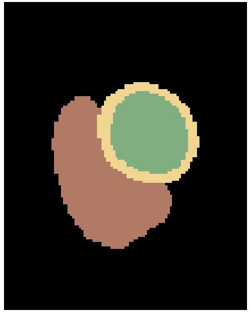
Workflow of Radiomics



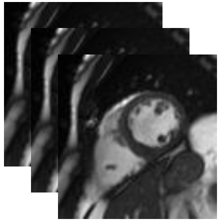
e.g. Pyradiomics library

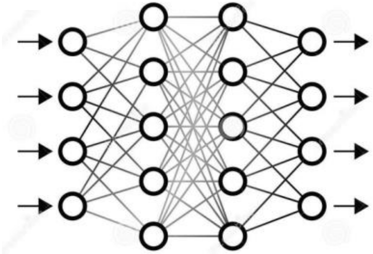
CMR Image Segmentation

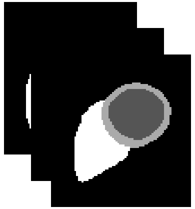
- **Manual segmentation using a commercial software**



- **Automatic segmentation with deep learning techniques**

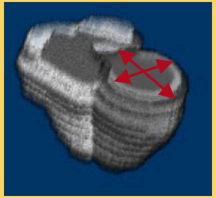






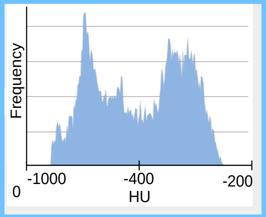
Radiomics Feature Extraction

Shape



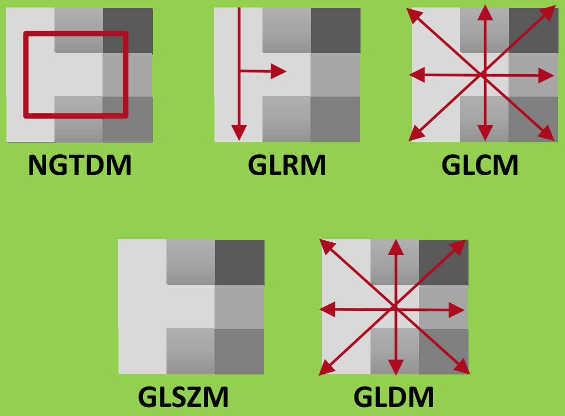
Geometrical properties such as volume, diameter, minor/major axis and sphericity

First-Order



Histogram-based features

Texture

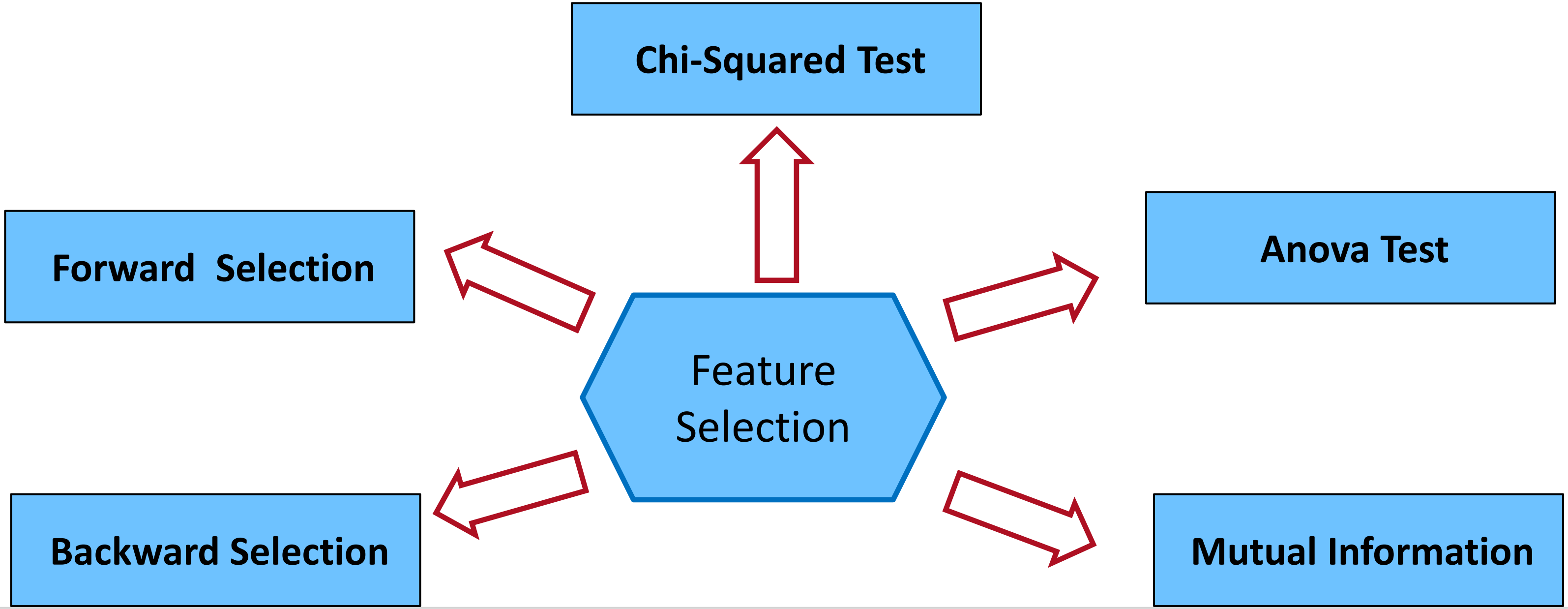


Spatial distribution of the intensity levels

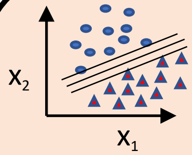
Feature Selection

- **Reduce the number of input variables**

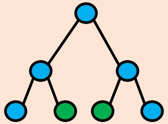
Volume | Minor Axis | [redacted] | … | [redacted] | Major Axis



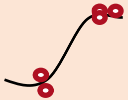
Machine Learning



Support Vector Machine (SVM)



Random Forest (RF)



Logistic Regression (LR)

→ Hyper-parameter optimization

↓ Training tuned algorithms

← Model selection

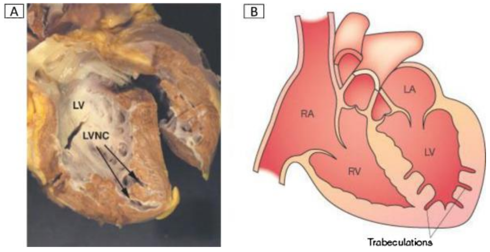
Examples of CMR radiomics applications

Study 1: Diagnosis

Radiomics-Based Classification of Left Ventricular Non-compaction, Hypertrophic Cardiomyopathy, and Dilated Cardiomyopathy in Cardiovascular Magnetic Resonance

Cristian Izquierdo[1], Guillem Casas[2,3,4,5], Carlos Martin-Isla[1], Victor M. Campello[1], Andrea Guala[3,4], Polyxeni Gkontra[1], Jose F. Rodríguez-Palomares[2,3,4,5] and Karim Lekadir[1]*

[1] Artificial Intelligence in Medicine Lab (BCN-AIM), Departament de Matemàtiques i Informàtica, Universitat de Barcelona, Barcelona, Spain, [2] Department of Cardiology, Hospital Universitari Vall d'Hebron, Barcelona, Spain, [3] Vall d'Hebron Institut de Recerca (VHIR), Barcelona, Spain, [4] CIBER-CV, Instituto de Salud Carlos III, Madrid, Spain, [5] Departament de Medicina,



U. Ikeda et al., "Isolated left ventricular non-compaction cardiomyopathy in adults" J. Cardiology, 65(2) 2015.

Sample size: 118

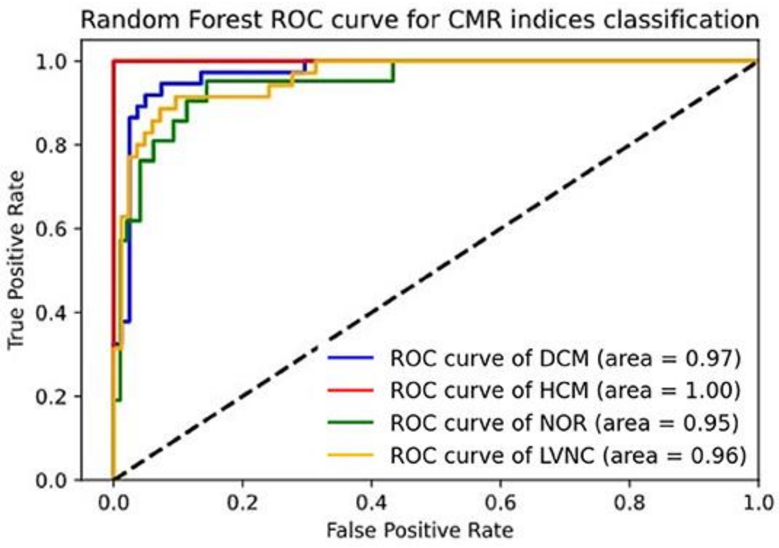
Datasets:

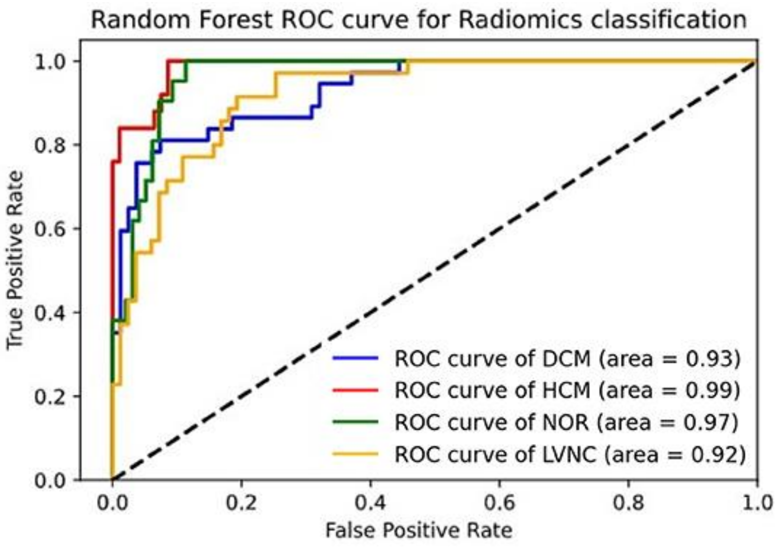
Vall d'Hebron Hospital

Diseases:

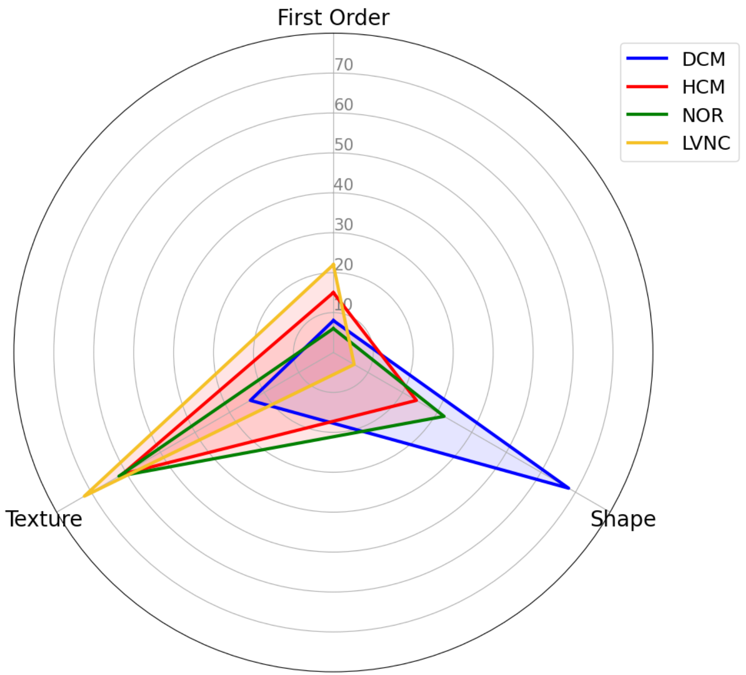
- **Left Ventricular Non-compaction (LVNC) - 35 cases**
- **Hypertrophic Cardiomyopathy (HCM) - 25 cases**
- **Dilated Cardiomyopathy (DCM) - 37 cases**

Study 1: Results





Study 1: Results



Study 2: Diagnosis

Prediction of incident cardiovascular events using machine learning and CMR radiomics

Esmeralda Ruiz Pujadas*[1], Zahra Raisi-Estabragh*[2,3], Liliana Szabo*[2,3], Celeste McCracken[4], Cristian Izquierdo Morcillo[1], Víctor M. Campello[1], Carlos Martín-Isla[1], Angelica M. Atehortua[1], Hajnalka Vago[5], Bela Merkely[5], Pal Maurovich-Horvat[6], Nicholas C. Harvey[7,8], Stefan Neubauer[4], Steffen E. Petersen†[2,3,9,10], Karim Lekadir†[1]

[1] Departament de Matematiques i Informatica, Universitat de Barcelona, Artificial Intelligence in Medicine Lab (BCN-AIM), Barcelona, Spain

[2] William Harvey Research Institute, NIHR Barts Biomedical Research Centre, Queen Mary University of London, Charterhouse Square, London, EC1M 6BQ, UK

Sample size: 32115

Datasets:

biobank uk

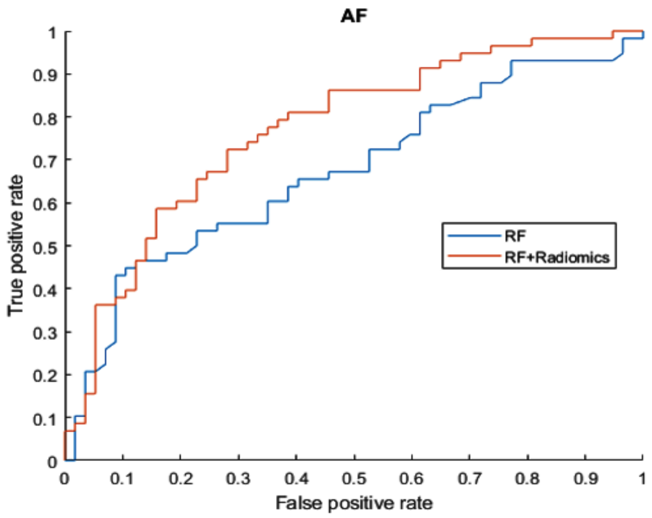
Diseases:

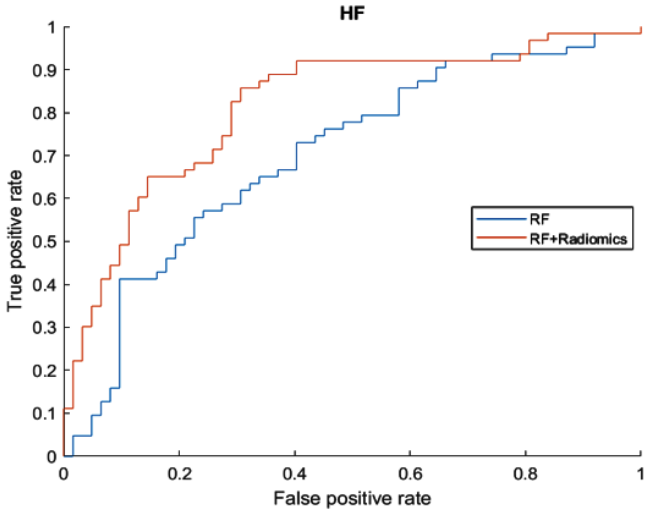
- **Atrial Fibrillation (AF) – 193 cases**
- **Heart Failure (HF) – 209 cases**

Method for classification:

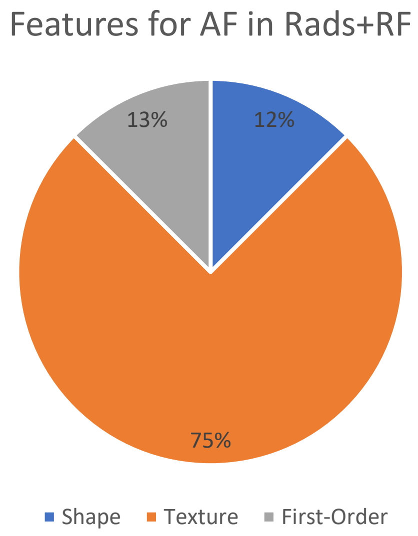
SVM

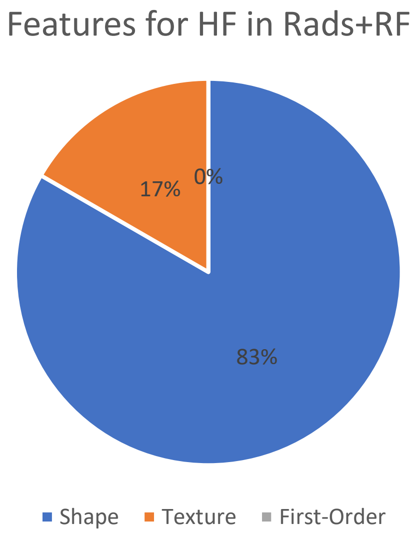
Study 2: ROC Curves





Study 2: Feature Distribution





CMR radiomics applications:
Knowledge extraction

Study 3: Radiomics of Risk Factors

Radiomics Signatures of Cardiovascular Risk Factors in Cardiac MRI: Results From the UK Biobank

Irem Cetin[1], Zahra Raisi-Estabragh[2,3], Steffen E. Petersen[2,3], Sandy Napel[4], Stefan K. Piechnik[5], Stefan Neubauer[5], Miguel A. Gonzalez Ballester[1,6], Oscar Camara[1] and Karim Lekadir[7*]*

[1] BCN MedTech, Department of Information and Communication Technologies, Universitat Pompeu Fabra, Barcelona, Spain, [2] William Harvey Research Institute, NIHR Barts Biomedical Research Centre, Queen Mary University of London, London, United Kingdom, [3] Barts Heart Centre, St. Bartholomew's Hospital, Barts Health NHS Trust, London, United Kingdom, [4] Department of Radiology, Stanford University, Stanford, CA, United States, [5] Division of Cardiovascular Medicine, Radcliffe Department of Medicine, University of Oxford, Oxford, United Kingdom, [6] Catalan Institution for Research and Advanced Studies (ICREA), Barcelona, Spain, [7] Departament de Matematiques i Informatica, Universitat de Barcelona, Artificial Intelligence in Medicine Lab (BCN-AIM), Barcelona, Spain

Sample size: 32115

Datasets: biobank uk

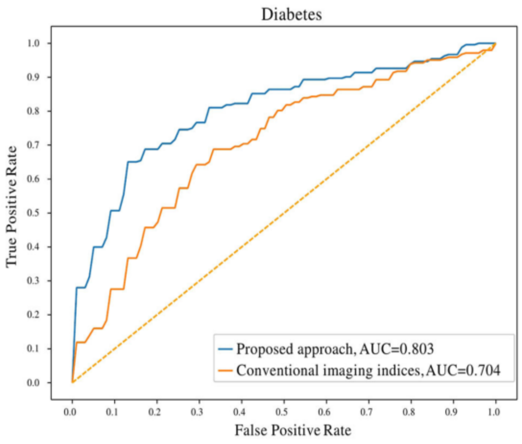
Diseases:

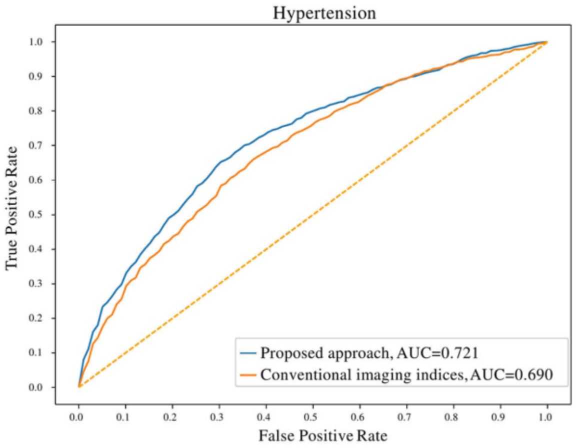
- **Diabetes (N=243)**
- **Hypertension (N= 1934)**
- **High cholesterol (N= 779)**

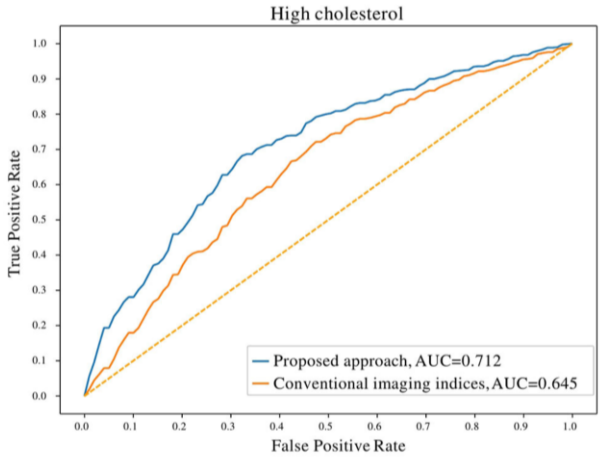
Machine Learning methods:

1. **SVM**
2. **LR**
3. **RF**

Study 3: Results







Radiomics challenges:
Image variability across scans

Study 4: Repeatability of CMR Radiomics

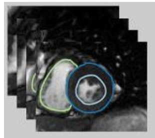
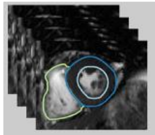
SCMR Society for Cardiovascular Magnetic Resonance

EACVI European Association of Cardiovascular Imaging

Repeatability of Cardiac Magnetic Resonance Radiomics: A Multi-Centre Multi-Vendor Test-Retest Study

Zahra Raisi-Estabragh[1,2], Polyxeni Gkontra[3], Akshay Jaggi[3], Jackie Cooper[1], João Augusto[2,4], Anish N. Bhuva[2,4], Rhodri H. Davies[2,4], Charlotte H. Manisty[2,4], James C. Moon[2,4], Patricia B. Munroe[1], Nicholas C. Harvey[5,6], Karim Lekadir[3] and Steffen E. Petersen[1,2]*

[1] NIHR Barts Biomedical Research Centre, William Harvey Research Institute, Queen Mary University of London, London, United Kingdom, [2] Barts Heart Centre, St Bartholomew's Hospital, Barts Health NHS Trust, London, United Kingdom, [3] Departament de Matemàtiques i Informàtica, Universitat de Barcelona, Barcelona, Spain, [4] Institute of Cardiovascular Science, University College London, London, United Kingdom, [5] MRC Lifecourse Epidemiology Unit, University of Southampton, Southampton, United Kingdom, [6] NIHR Southampton Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust, Southampton, United Kingdom

Test  Retest 

Sample size: 110 subjects

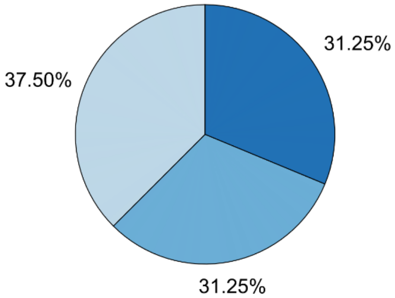
Dataset: "VOLUME" resource of 5 UK research centres

Statistical Analysis:

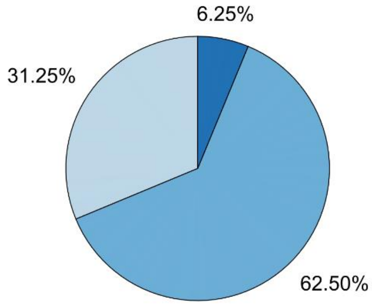
1. **Intra-class correlation**
2. **Coefficient of variation (%)**
3. **Mean relative difference (%)**

Study 4: Results

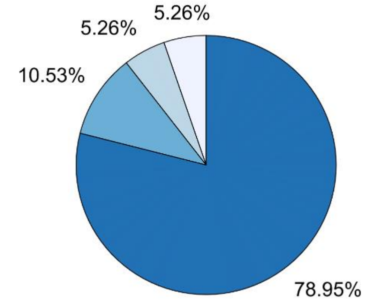
Shape radiomics LV myocardium



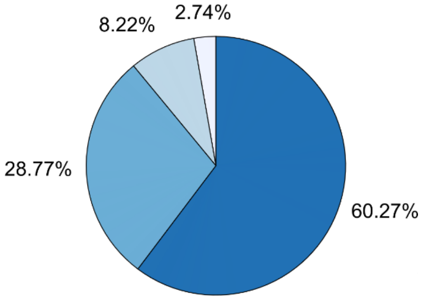
Shape radiomics RV

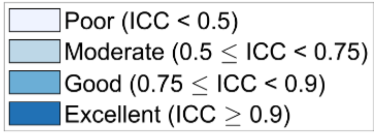


Intensity radiomics LV myocardium



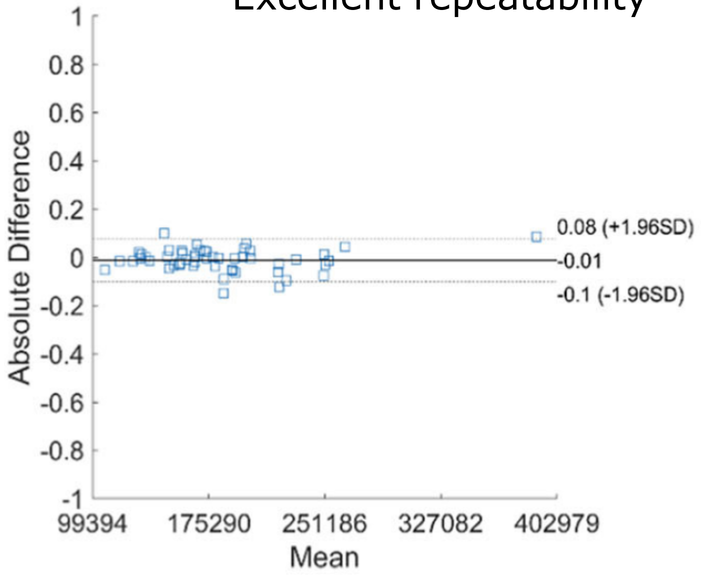
Texture radiomics RV



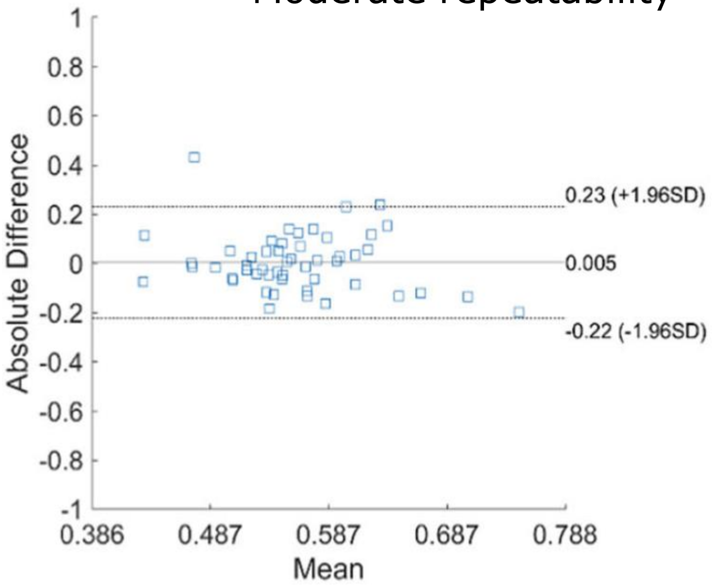


Study 4: Analysis of Shape Features

Volume
Excellent repeatability

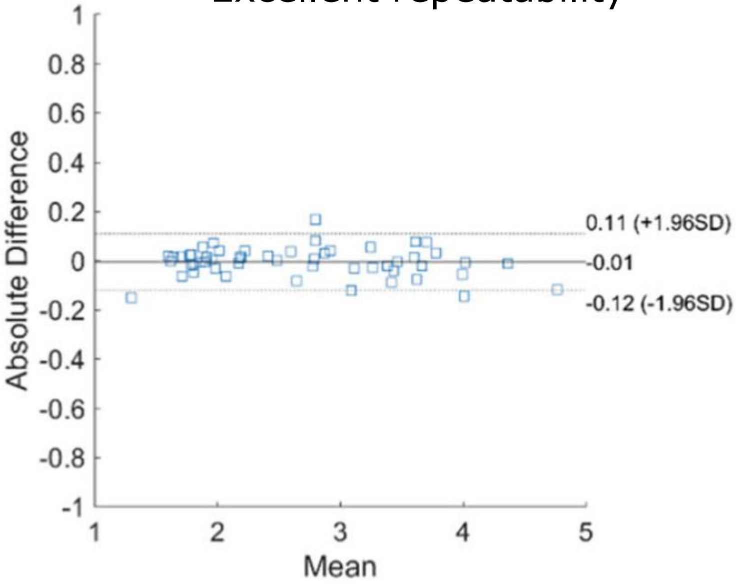


Flatness
Moderate repeatability

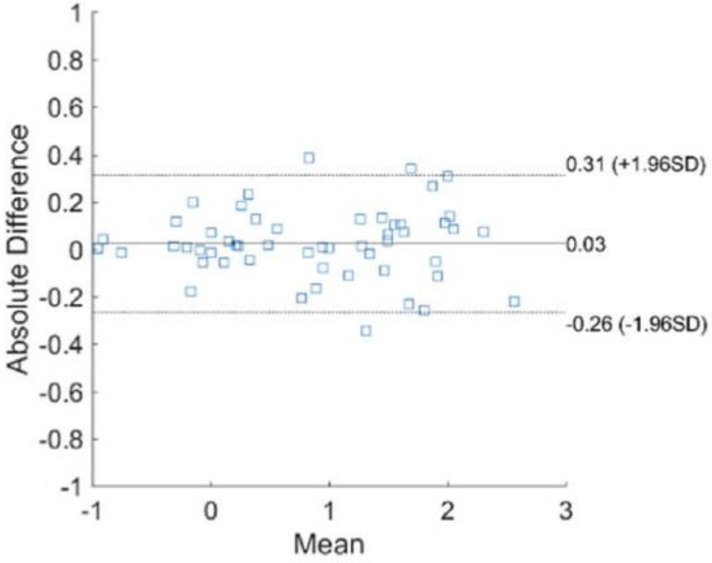


Study 4: Analysis of Intensity Features

Entropy
Excellent repeatability



Skewness
Good repeatability



Study 5: Radiomics Normalisation

Minimising multi-centre radiomics variability through image normalisation: A pilot study

Víctor M. Campello[1,*], Carlos Martín-Isla[1], Cristian Izquierdo[1], Andrea Guala[2,3], José F. Rodríguez Palomares[2,3,4], David Viladés[5], Martín L. Descalzo[5], Mahir Karakas[6,7], Ersin Çavuş[6,7], Zahra Raisi-Estabragh[8,9], Steffen E. Petersen[8,9,10,11], Sergio Escalera[1,12], Santi Seguí[1], and Karim Lekadir[1]

[1] *Artificial Intelligence in Medicine Lab (BCN-AIM), Barcelona, Spain*
[2] *Vall d'Hebron Institut de Recerca (VHIR), Barcelona, Spain*
[3] *CIBER-CV, Instituto de Salud Carlos III, Madrid, Spain*
[4] *Department of Cardiology, Hospital Universitari Vall d'Hebron, Barcelona, Spain*
[5] *Cardiac Imaging Unit, Cardiology Service, Hospital de la Santa Creu i Sant Pau, Universitat Autonoma de Barcelona, Barcelona, Spain*
[6] *Dept. of Cardiology, University Heart & Vascular Center Hamburg, Hamburg, Germany*
[7] *DZHK (German Center for Cardiovascular Research), Germany*

Sample size: 218 subjects

Datasets:

MICCAI

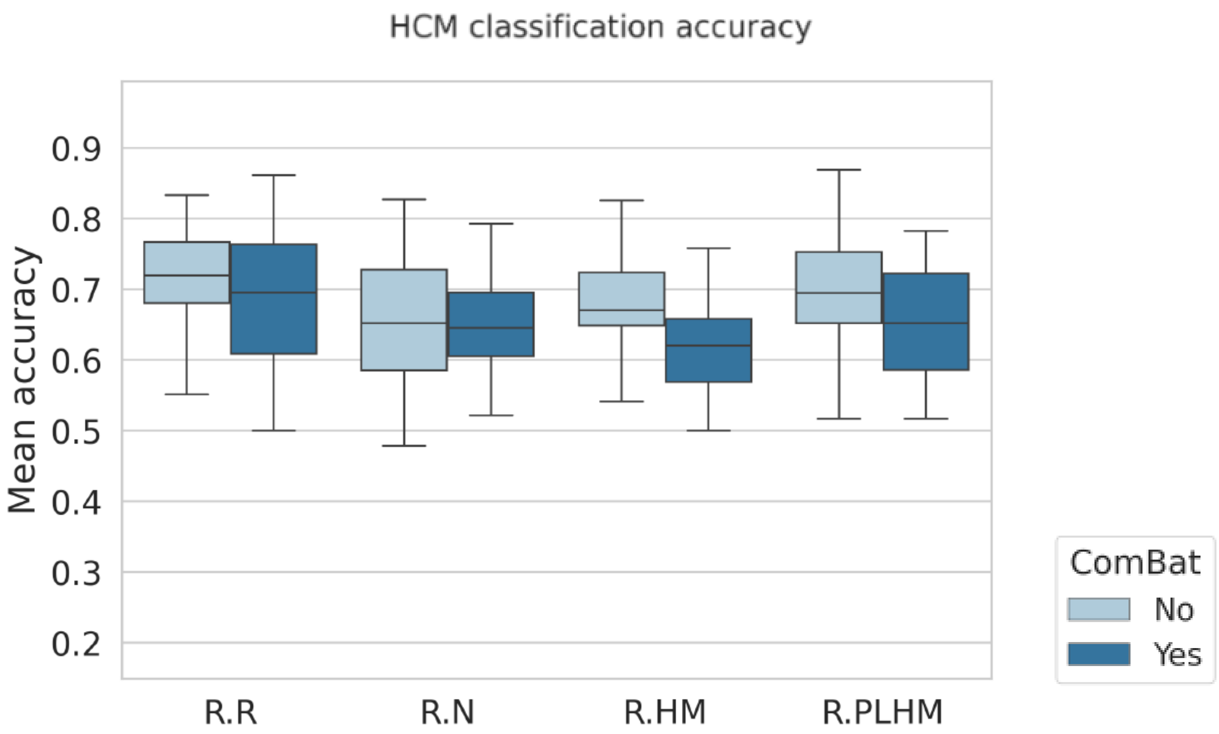
Diseases:

- **Hypertrophic Cardiomyopathy (HCM) – 106 cases**

Methods for normalisation:

1. **Combat**
2. **Intensity rescaling (R)**
3. **Intensity normalisation (N)**
4. **Histogram normalisation (HN)**
5. **Piecewise normalisation (PHN)**

Study 5: Results



Future of Radiomics in CMR: Opportunities & Challenges

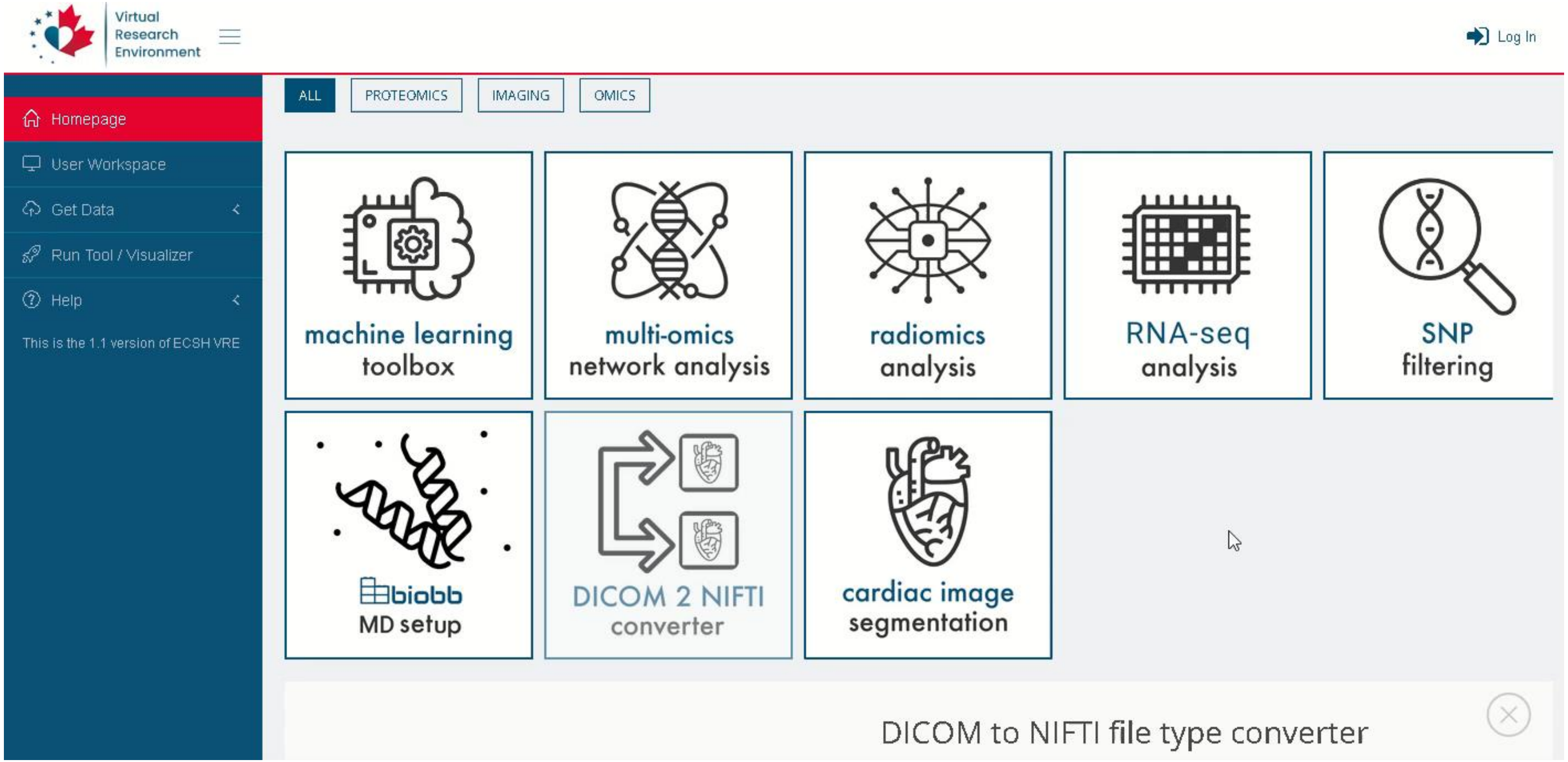
Other Works in CMR Radiomics

SCMR
Society for Cardiovascular Magnetic Resonance

EACVI
European Association of Cardiovascular Imaging

Myocarditis	Cardiac MRI Texture Analysis of T1 and T2 Maps in Patients with Infarctlike Acute Myocarditis
Hypertrophic Cardiomyopathy	Radiomic Analysis of Myocardial Native T_1 Imaging Discriminates Between Hypertensive Heart Disease and Hypertrophic Cardiomyopathy
Ischemic Heart Disease	New Imaging Signatures of Cardiac Alterations in Ischaemic Heart Disease and Cerebrovascular Disease Using CMR Radiomics
Myocardial Infarction	Texture analysis of cardiac cine magnetic resonance imaging to detect nonviable segments in patients with chronic myocardial infarction

euCanSHare


Virtual
Research
Environment
Log In
ALL
PROTEOMICS
IMAGING
OMICS
Homepage
User Workspace
Get Data
Run Tool / Visualizer
Help
This is the 1.1 version of ECSH VRE
machine learning
toolbox
multi-omics
network analysis
radiomics
analysis
RNA-seq
analysis
SNP
filtering
biobb
MD setup
DICOM 2 NIFTI
converter
cardiac image
segmentation
DICOM to NIFTI file type converter

Acknowledgments

SCMR Society for Cardiovascular Magnetic Resonance

EACVI European Association of Cardiovascular Imaging

Thank you

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Disclosure

SCMR
Society for Cardiovascular Magnetic Resonance

EACVI
European Association of Cardiovascular Imaging

- No conflict to declare