

11.30 - 12.30**FOCUS ON CARDIOVASCULAR IMAGING**

INTELLIGENZA ARTIFICIALE E CARDIOVASCULAR IMAGING

Mauro Pepi, MD, FESC
Senior Consultant
Centro Cardiologico Monzino, IRCCS,
Milano, ITALY



Centro Cardiologico
Monzino

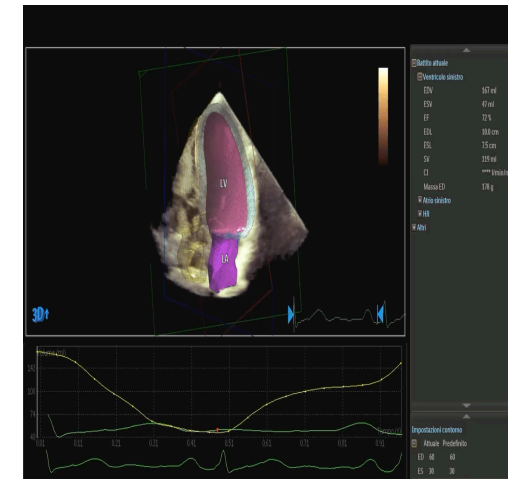


NESSUN CONFLITTO DI INTERESSE

Artificial Intelligence in Cardiovascular Imaging: Current Applications and New Horizons

Andrea Baggiano¹, Saima Mushtaq¹, Laura Fusini¹, Manuela Muratori¹, Gianluca Pontone^{1,2}, Mauro Pepi¹

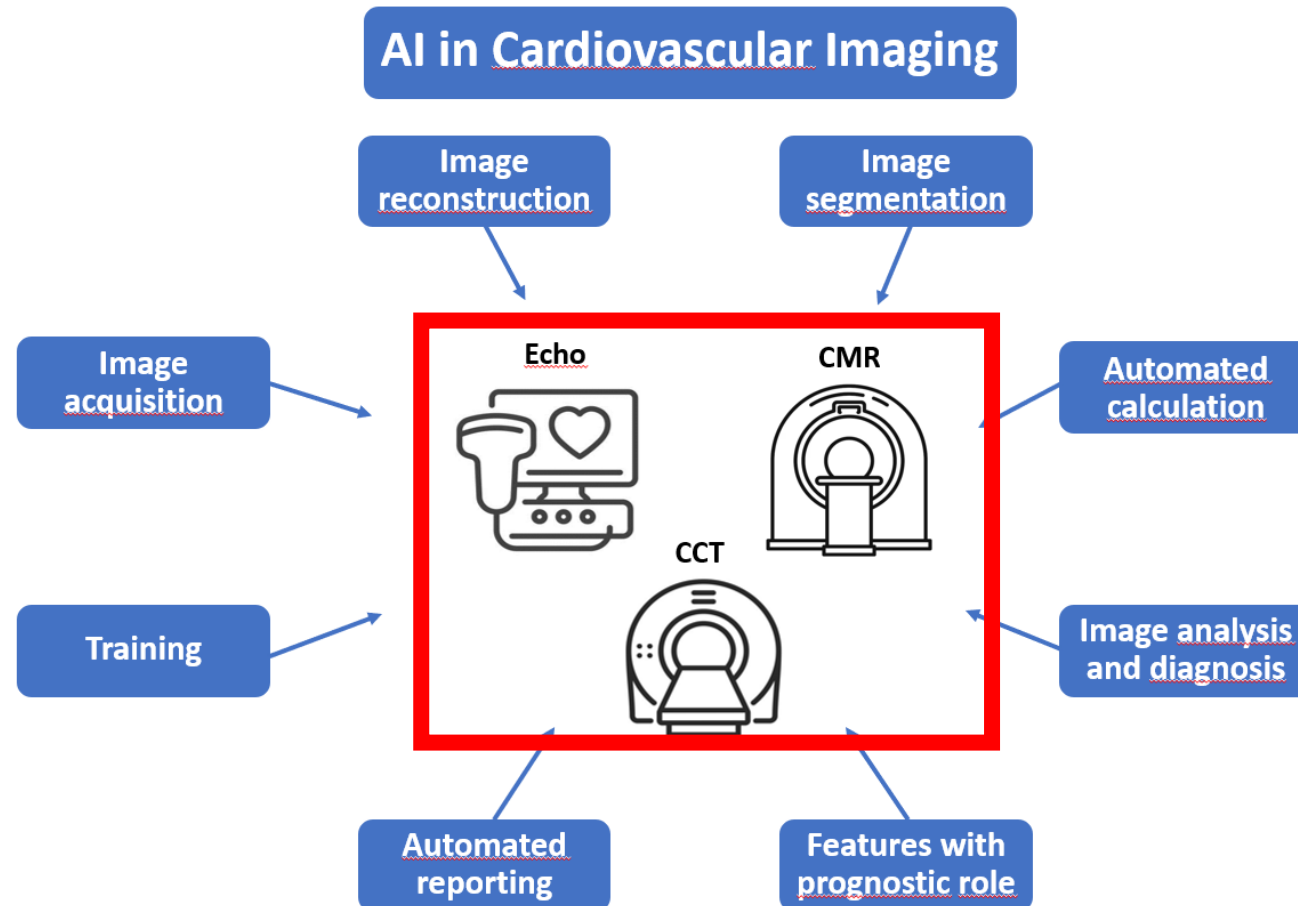
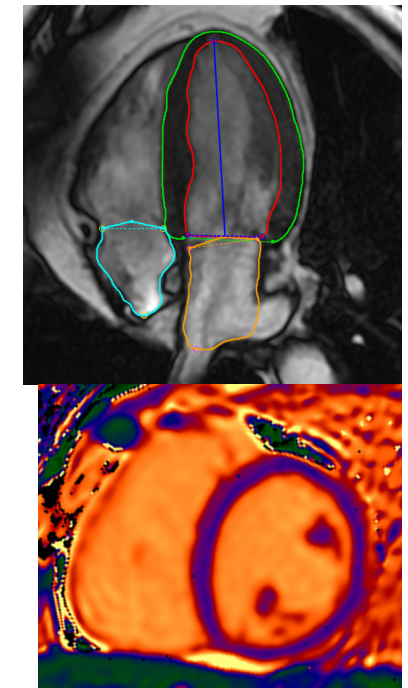
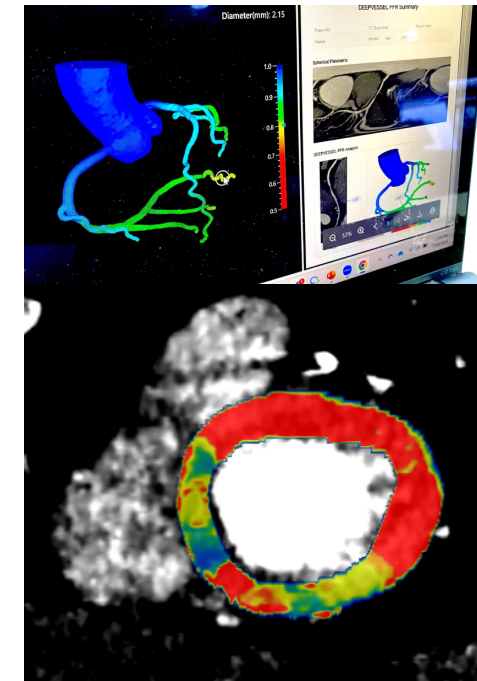
¹Centro Cardiologico Monzino IRCCS, ²Department of Biomedical, Surgical and Dental Sciences, University of Milan, Milan, Italy



ECHO

CT

CMR



Echocardiography

Acquisition

Analysis

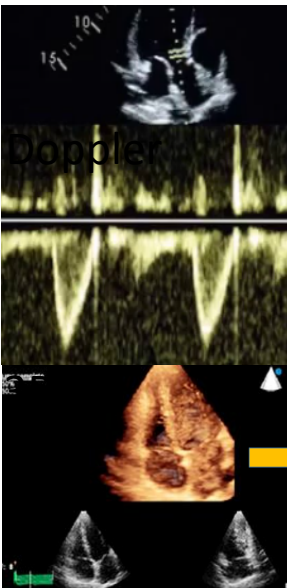
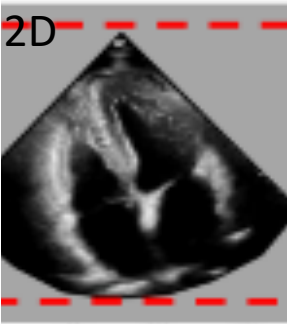
Reporting

Diagnosis

Prognosis

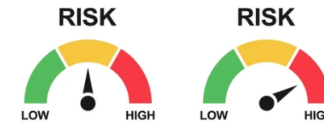
Labeling Structures
Training

Telemedicine
Guidance at a
distance

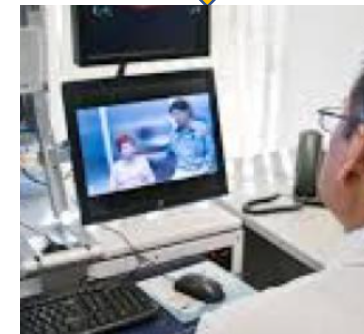
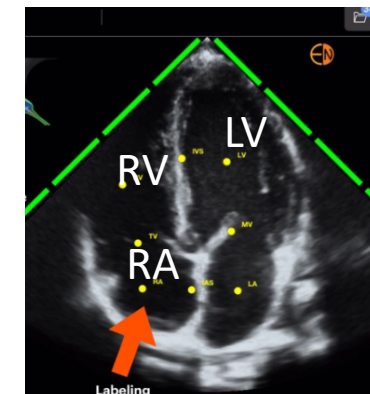
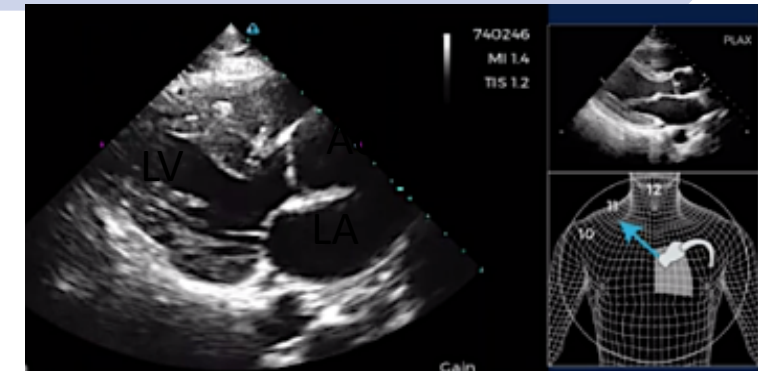


- LV EF
- LV Volumes
- LA Volume
- LV Mass
- RV EF
- RV volumes
- LV, LA, RV Functional Curves
- 2D and Doppler automated measurements

- LV Hypertrophy
- LV and LA dilation
- RV volume and pressure overload
- Restriction
- Constriction
- Diastolic Function
- Cardiomyopathies
- LV wall motion analysis
- Valve disease
- Heart failure



- Echo alone
- Echo and ECG
- Echo and Big Data
- Echo and other Imaging Modalities



ECHOCARDIOGRAPHY

Acquisition

Labeling and
recognition
Of Structures

Guiding ECHO
protocol

Training
Education

Automated
Measure

Telemedicine
Guidance at a distance

AUTOMATED MEASURE

- **NEW** methods that may
- Improve work flow
- Reduce calculation time
- Improve standardization and reproducibility
- Provide automatic diagnosis and prognosis



**< 30 Minutes to perform a
comprehensive echo with a
complete advanced analysis**

Calcoli automatici ecocardiografici e Doppler automatici sono oggi ampiamente integrati sia negli ecografi commerciali di fascia media/alta, sia nei sistemi vendor-neutral / interventor dedicati alla cardiologia interventistica e strutturale.

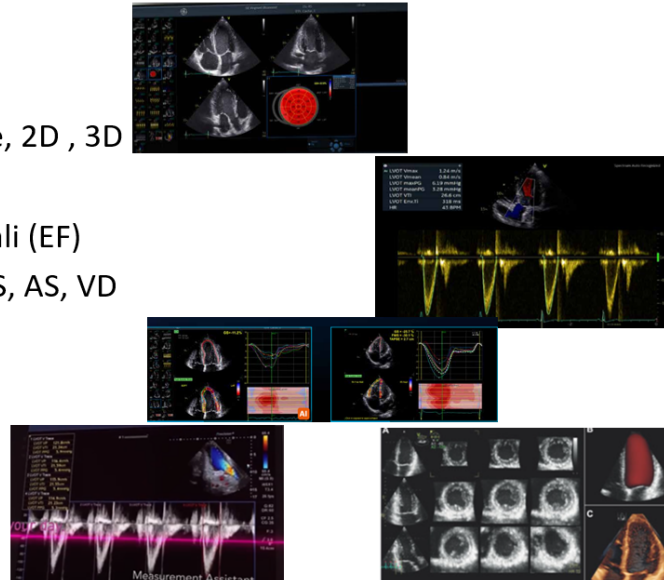
CALCOLI ON-BOARD SINGOLE COMPAGNIE



The majority of ECHO Companies has on board AI measurements

- Calcoli automatici M-mode, 2D , 3D
- Calcoli automatici Doppler
- Calcoli automatici funzionali (EF)
- Calcoli automatici Strain VS, AS, VD

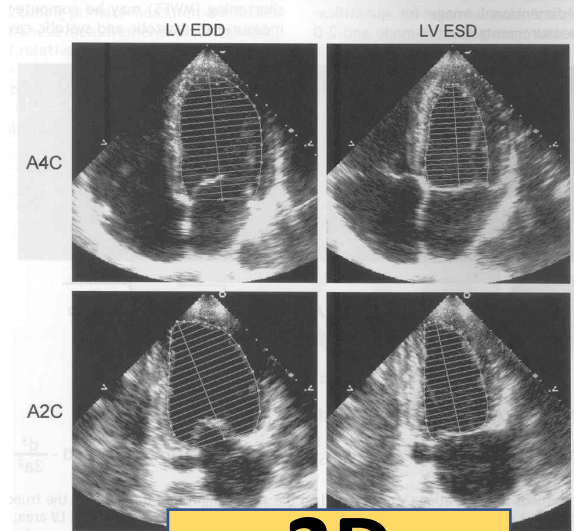
- Ottimizzazione immagini
- Riconoscimento proiezioni



CALCOLI ED ANALISI CON SOFTWARE INTERVENDOR



CALCOLI AUTOMATICI DA IMMAGINI DICOM DI MISURE TRADIZIONALI, CALCOLI DERIVATI COMPLESSI DALLE STESSE IMMAGINI O DIAGNOSI OTTENUTE DA UNA O PIU' PROIEZIONI

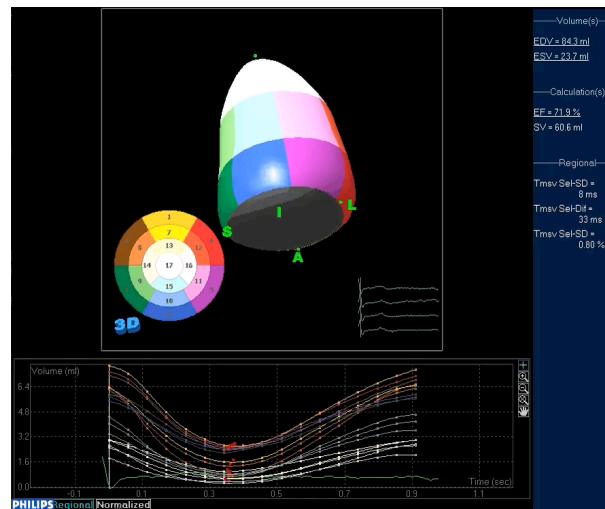


2D

Low reproducibility

**Foreshortening →
volumes
underestimation**

**Time consuming
(multiple
measurements)**

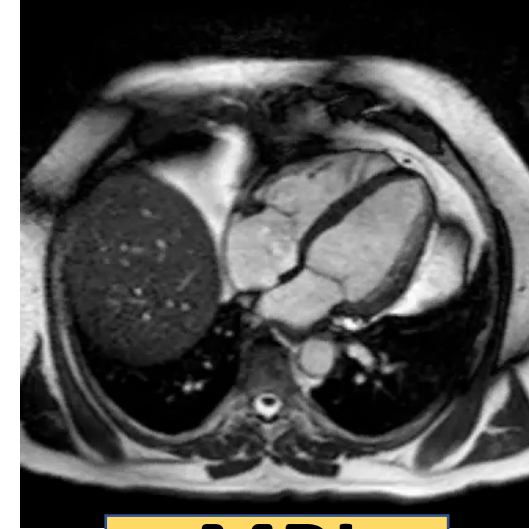


3D

**Higher
reproducibility**

**Than 2D and lower
underestimation
of LV volumes**

**Vs
CMR**



MRI

Gold standard

**Low inter-
observer and
intra-observer
variability**

**VOLUMI/ EF DEL
VENTRICOLO
SINISTRO**

**2D ECHO has
several
limitations in
Accurate
analysis
Volumes and
EF of the left
ventricle**

Chicago University



Roberto Lang

Politecnico MI



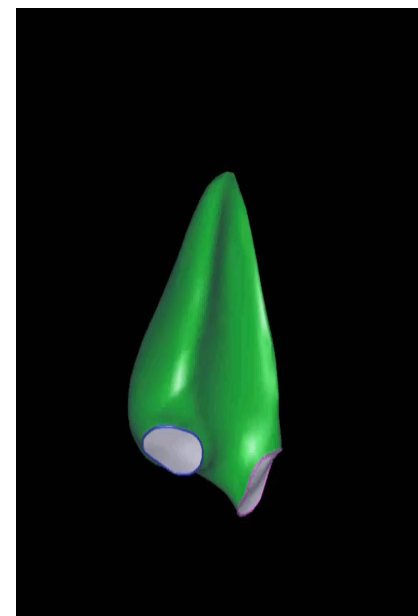
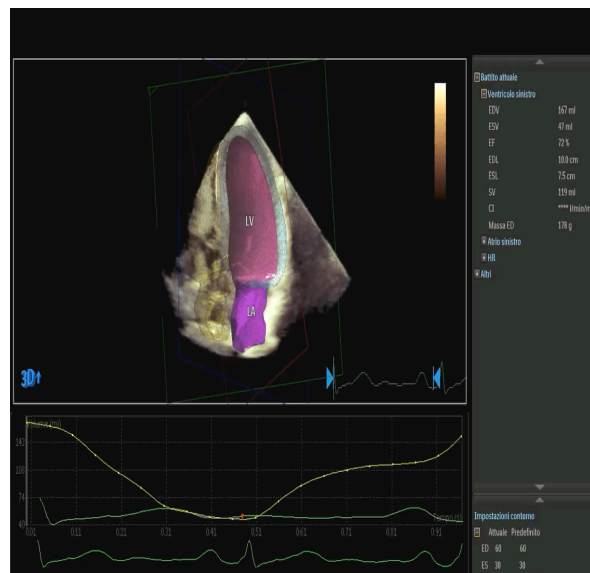
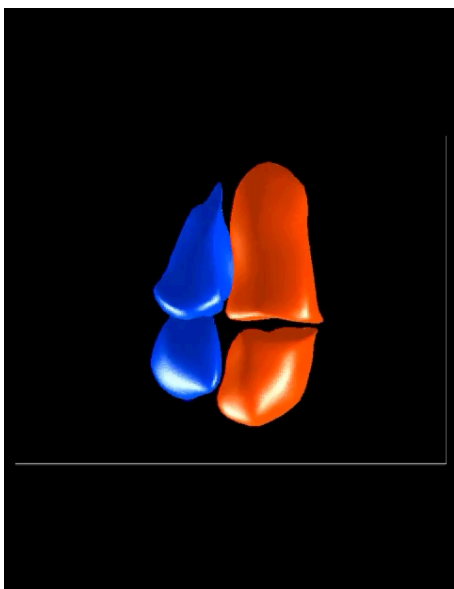
Centro Cardiologico Monzino IRCCS, MI



A «dream» in the year 2000

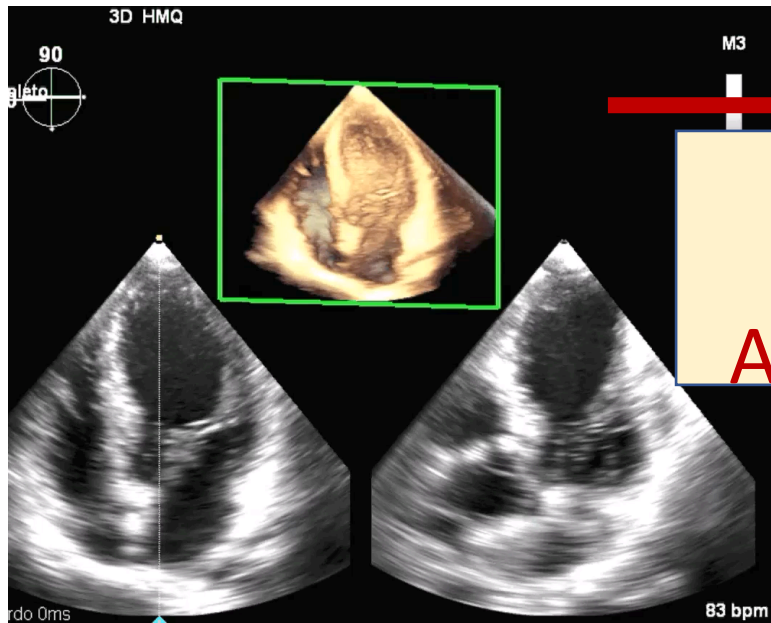
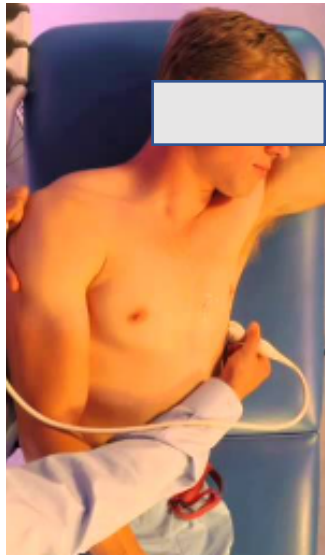


Reality in 2024



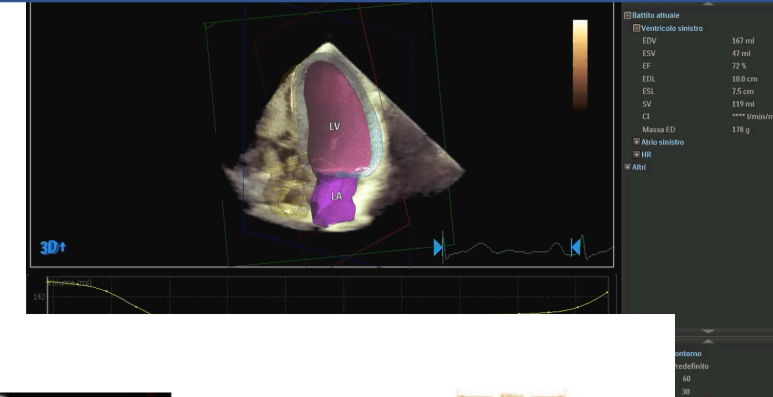
Ing Francesco Maffessanti

From the 4 chamber view we launch Dynamic Heart Model Acquisition

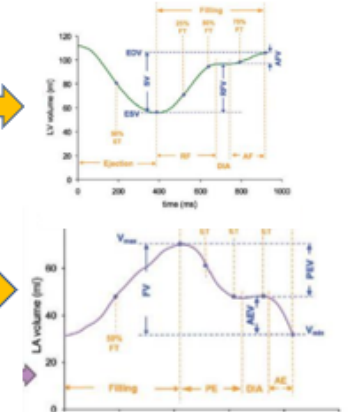
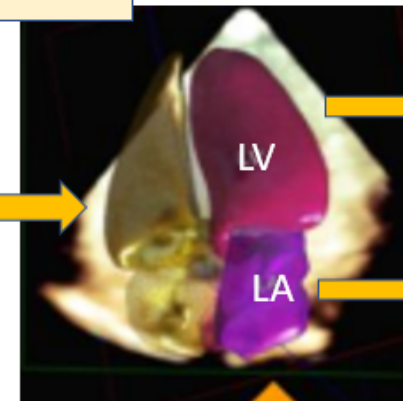
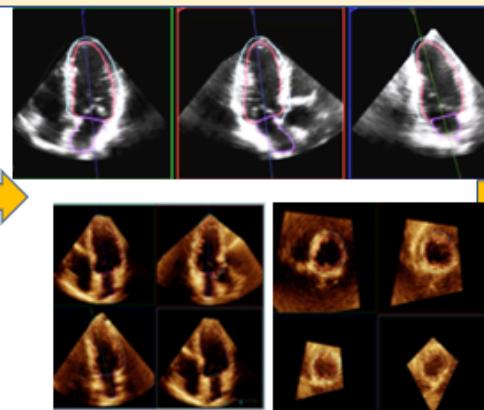
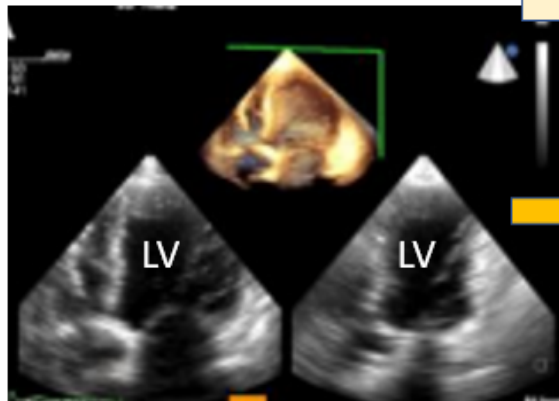


Very
simple
And rapid

VOLUMI e EF del VS
VOLUMI e Funzione dell'ATRIO
SINISTRO
STROKE VOLUME
MASSA VS



29 SECONDS



« Static » Heart Model

JACC: CARDIOVASCULAR IMAGING
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<http://dx.doi.org/10.1016/j.jcmg.2016.08.001>

Transthoracic 3D Echocardiographic Left Heart Chamber Quantification Using an Automated Adaptive Analytics Algorithm

Wendy Tsang, MD, MS,^{a,b} Ivan S. Salgo, MD, MS,^c Diego Medvedofsky, MD,^b Masaaki Takeuchi, MD, PhD,^b David Prater, BS,^c Lynn Weinert, BSc,^b Megan Yamat, RDCS,^b Victor Mor-Avi, PhD,^b Amit R. Patel, MD,^b Roberto M. Lang, MD^b

Feasibility and Accuracy of Automated Software for Transthoracic Three-Dimensional Left Ventricular Volume and Function Analysis: Comparisons with Two-Dimensional Echocardiography, Three-Dimensional Transthoracic Manual Method, and Cardiac Magnetic Resonance Imaging

Gloria Tamborini, MD, Concetta Piazzese, PhD, Roberto M. Lang, MD, Manuela Muratori, MD, Elisa Chiorino, MD, Massimo Mapelli, MD, Laura Fusini, MD, Sarah Ghulam Ali, MD, Paola Gripari, MD, Gianluca Pontone, MD, Daniele Andreini, MD, and Mauro Pepi, MD, *Milan, Italy; and Chicago, Illinois*

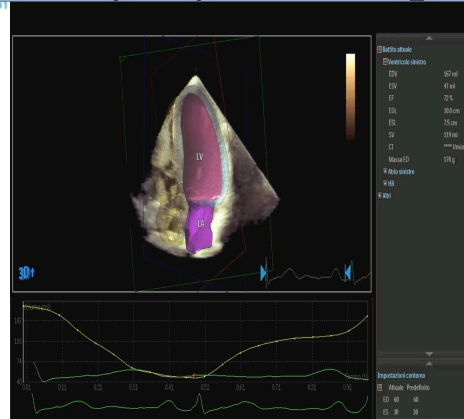


European Heart Journal - Cardiovascular Imaging (2017) 0, 1–12
doi:10.1093/ehjci/ewj328

Three-dimensional echocardiographic quantification of the left-heart chambers using an automated adaptive analytics algorithm: multicentre validation study

Diego Medvedofsky¹, Victor Mor-Avi^{1*}, Mihaela Amzulescu², Covadonga Fernández-Golfín³, Rocío Hinojar³, Mark J. Monaghan⁴, Kyoko Otani⁵, Joseph Reiken⁴, Masaaki Takeuchi⁵, Wendy Tsang⁶, Jean-Louis Vanoverschelde², Mathivathana Indrajith⁴, Lynn Weinert¹, Jose Luis Zamorano³, and Roberto M. Lang^{1†}

Robust 3D quantification of cardiac chambers for everyday clinical practice.



IL METODO AUTOMATICO IN AI DI CALCOLO DELLA FUNZIONE DI VS E AS E' FATTIBILE, RIPRODUCIBILE, RAPIDO E CORRELA CON IL METODO TRADIZIONALE 3D (E CON LA RISONANZA MAGNETICA)

« Dynamic » Heart Model

Dynamic LV and LA volumes and accurately analyse ejection/filling parameters.



ESC
European Society
of Cardiology

European Heart Journal - Cardiovascular Imaging (2018) 0, 1–9
doi:10.1093/ehjci/ey137

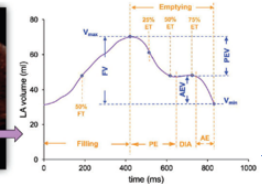
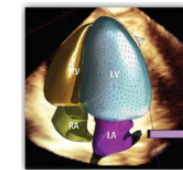
Machine learning based automated dynamic quantification of left heart chamber volumes

Akhil Narang¹, Victor Mor-Avi^{1*}, Aldo Prado², Valentina Volpato^{1,3}, David Prater⁴, Gloria Tamborini³, Laura Fusini³, Mauro Pepi³, Neha Goyal¹, Karima Addetia¹, Alexandra Gonçalves⁴, Amit R. Patel¹, and Roberto M. Lang¹

¹Department of Medicine, University of Chicago Medical Center, 5758 South Maryland Ave, MC 9067 Room 5513, Chicago, IL 60637, USA; ²Centro Privado de Cardiología, Yerba Buena, Virgen de la Merced 550, Tucumán, Argentina; ³Department of Cardiovascular Imaging, Centro Cardiologico Monzino IRCCS, Via Parea 4, 20138 Milan, Italy; and ⁴Philips Healthcare, 3000 Minuteman Road, Andover, 01810 MA, USA

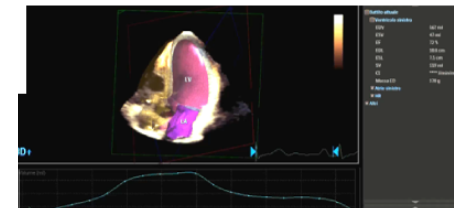
Received 27 July 2018; editorial decision 2 September 2018; accepted 13 September 2018

Dynamic LV and LA volumes and accurately analyse ejection/filling parameters.



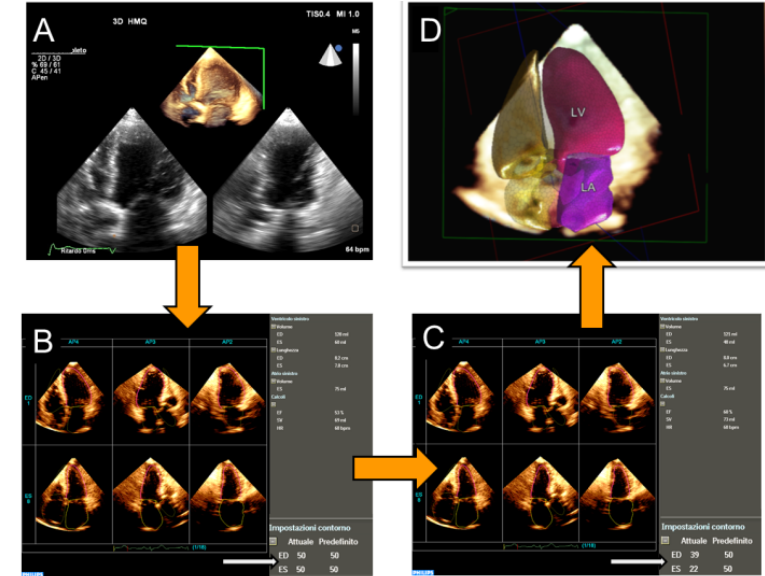
LA volumes and curve

Maximum and minimum volumes (V_{max} , V_{min}) and filling fraction, volume at 50% FT, volumes at 25%, 50%, and 75% emptying time, volume at diastasis, passive emptying volume (PEV), and active emptying volume (AEV)



Feasibility and Accuracy of Automated Software for Transthoracic Three-Dimensional Left Ventricular Volume and Function Analysis: Comparisons with Two-Dimensional Echocardiography, Three-Dimensional Transthoracic Manual Method, and Cardiac Magnetic Resonance Imaging **JASE 2017**

Gloria Tamborini, MD, Concetta Piazzese, PhD, Roberto M. Lang, MD, Manuela Muratori, MD, Elisa Chiorino, MD, Massimo Mapelli, MD, Laura Fusini, MD, Sarah Ghulam Ali, MD, Paola Gripari, MD, Gianluca Pontone, MD, Daniele Andreini, MD, and Mauro Pepi, MD, *Milan, Italy; and Chicago, Illinois*

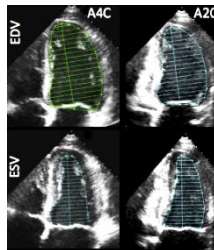


*The study included **194 patients**. LV volumes and EF were obtained with automatic HM and compared to 2DE biplane method (2DBP), 3DE tracings modality (3DFV) and cardiac magnetic resonance (CMR) measurements (90 pts).*

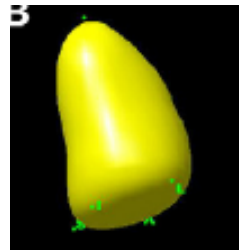
Verso quale (gold ?) standard vogliamo tendere ?????

Versus

2D



3D



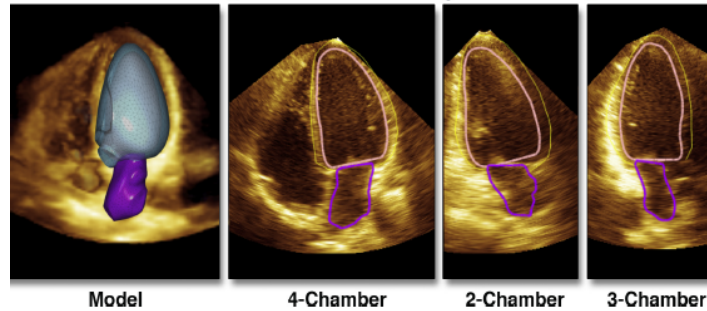
CMR



Acquisition
Reconstruction
29 sec

Ideal sliders ? (first study 50 -50 Diastole-Systole)

LV and LA models are then built by using automatic endocardial surface detection



**Shall we tend towards
ECHO or MRI?
Attualmente ottimizzati
vs MRI**

2D/ 3D standard
volumes

HM
Optimized
39 e 22

The new automated
method may better
compared to
«traditional» 3D TTE
volumes or CMR values
depending on inclusion
or exclusion of
trabeculae (sliders and
setting of border
detection)

MRI standard
volumes

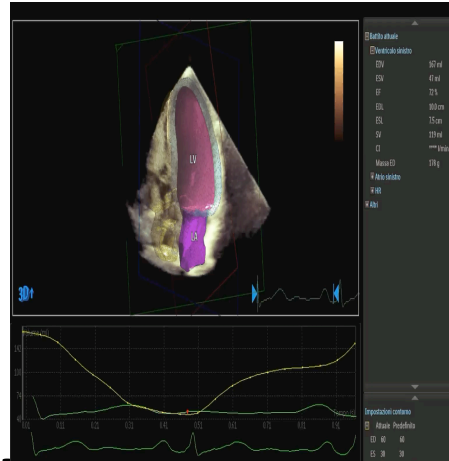
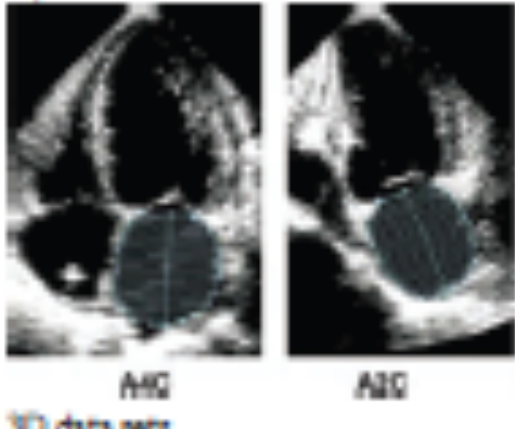
HM
optimized
75 and 57

Tamborini et al
JASE 2017

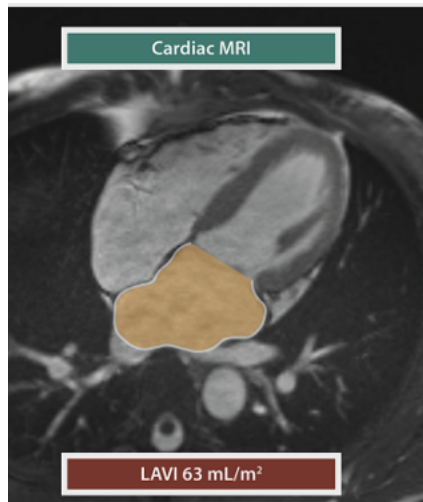
Article

Feasibility and Accuracy of the Automated Software for Dynamic Quantification of Left Ventricular and Atrial Volumes and Function in a Large Unselected Population

Gianpiero Italiano ^{1,*}, Gloria Tamborini ¹, Laura Fusini ¹, Valentina Mantegazza ¹, Marco Doldi ¹, Fabrizio Celeste ¹, Paola Gripari ¹, Manuela Muratori ¹, Roberto M. Lang ² and Mauro Pepi ¹



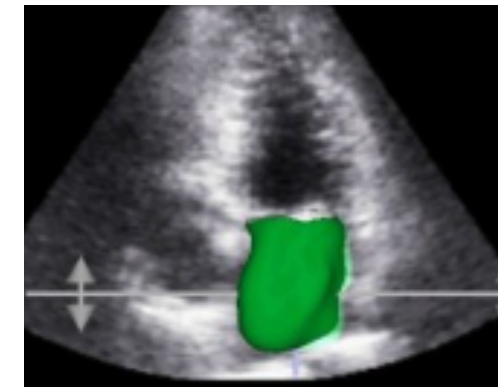
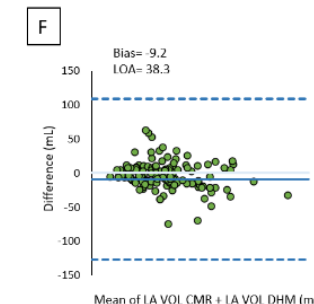
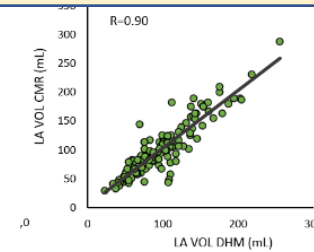
Standard 2DECHO
and Standard MRI
utilize a biplane
method
3DTTE is volumetric



Dynamic Heart Model
**3D LA volume
(volumes)** : excellent
correlation with 2DTTE
and mainly with MRI
(NB Biplane methods)

LA volumes have an important role in
diagnosis and prognosis of several
pathologies. **We have to move from 2D to
3D assessment**

2D TTE : the atrium may be
foreshortened because its
long axis is not necessarily
perfectly aligned with that of
the ventricle.
3DTTE (artificial int.)
and NOT always MRI:
Perfect automated alignment
of the maximal length of the
LA (not in the same axis of
the LV)

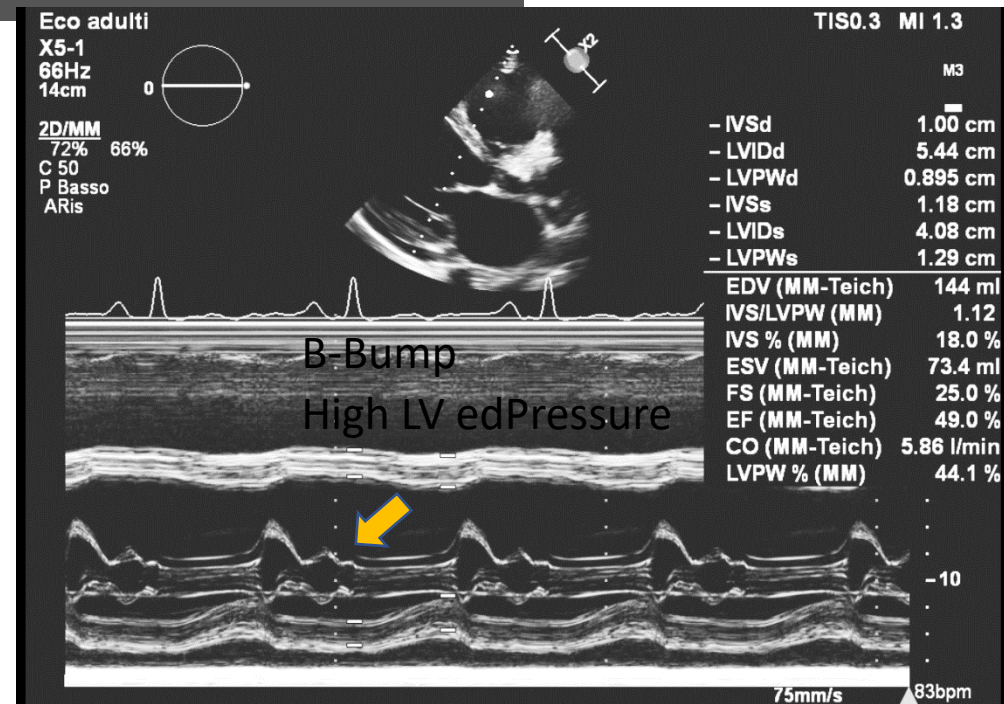


2020

Usefulness in Cardiomyopathies

YOUNG lady

Peripartum dilated CMP:
Heart failure; high LV end-
diastolic pressure; LV EF 30%

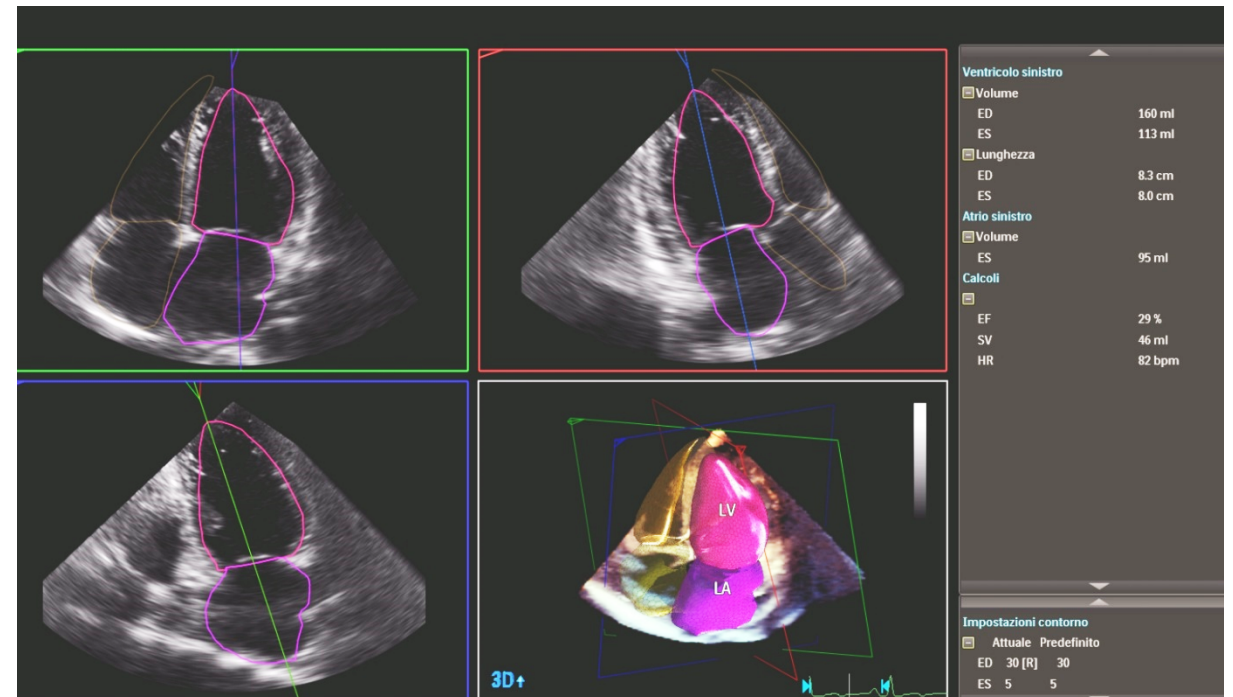
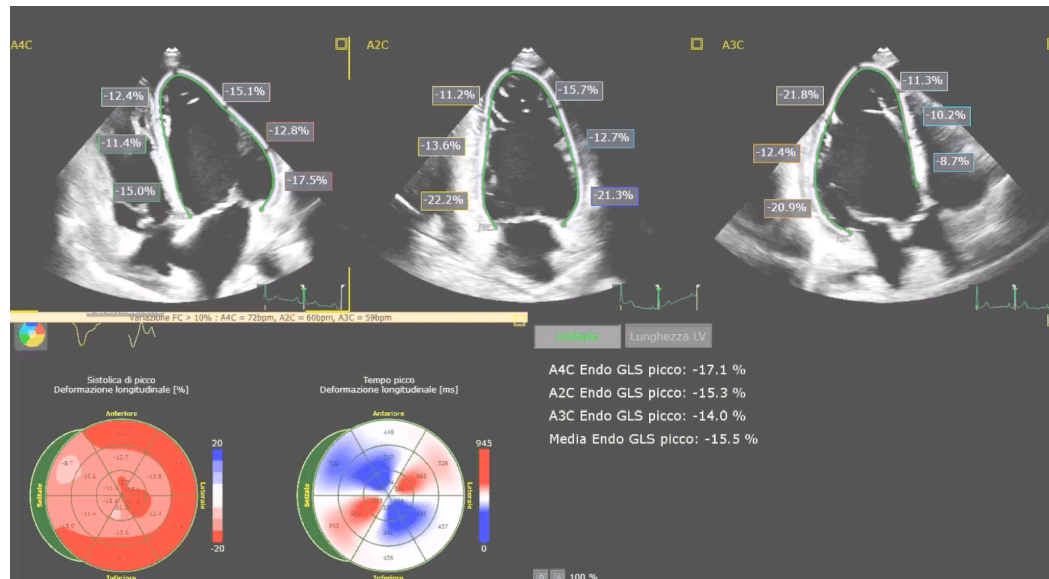
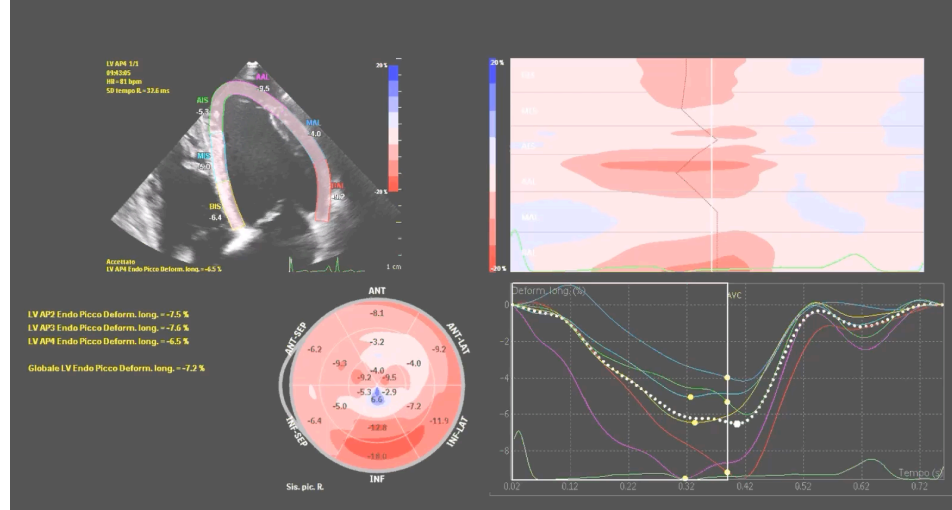


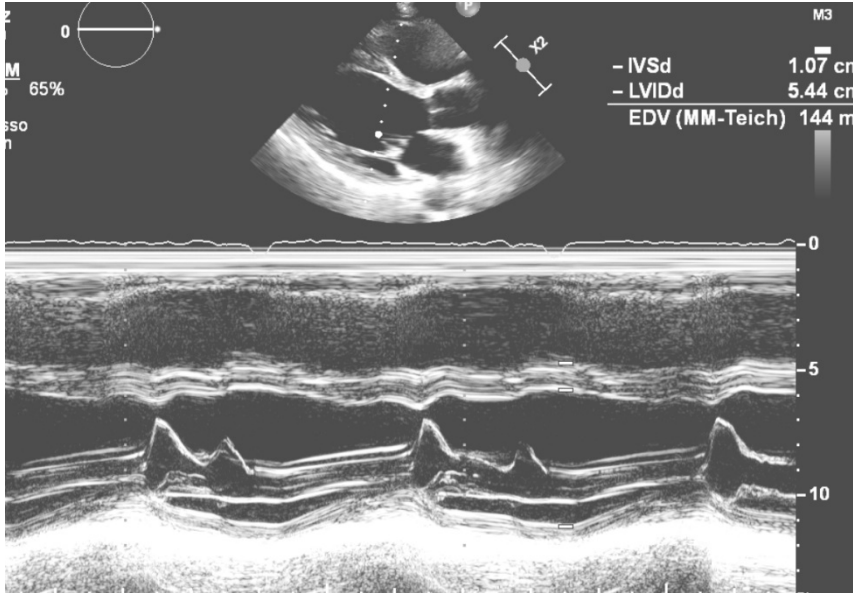
Initial results after therapy

May 2020:

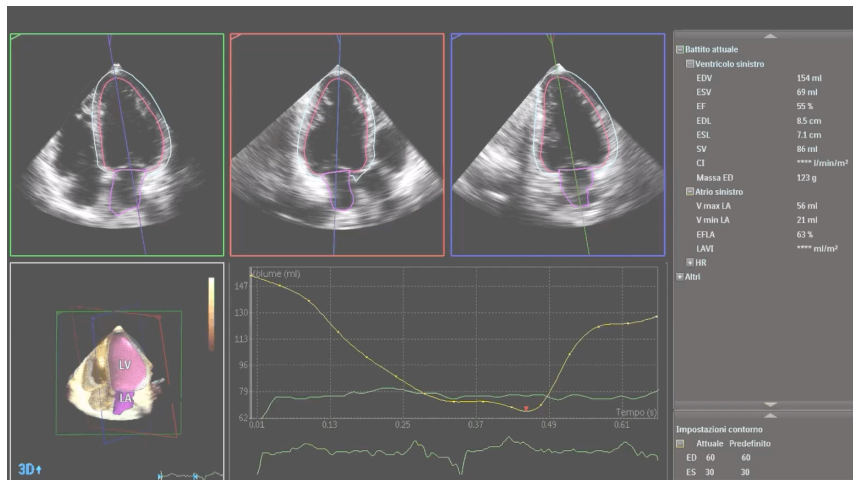
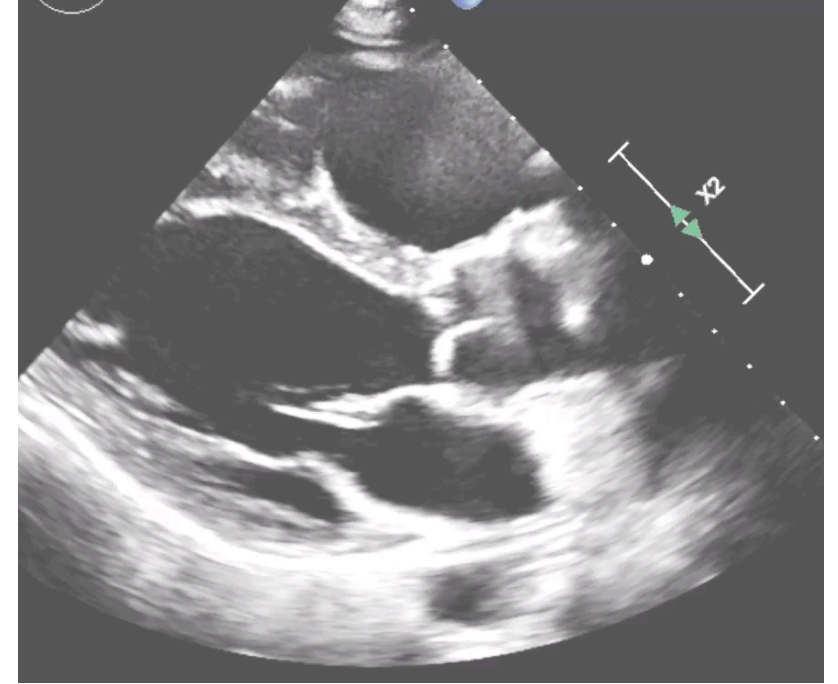
LVEF: 29% ; LV volume 175 ml

Autostrain: GLS: - 13%

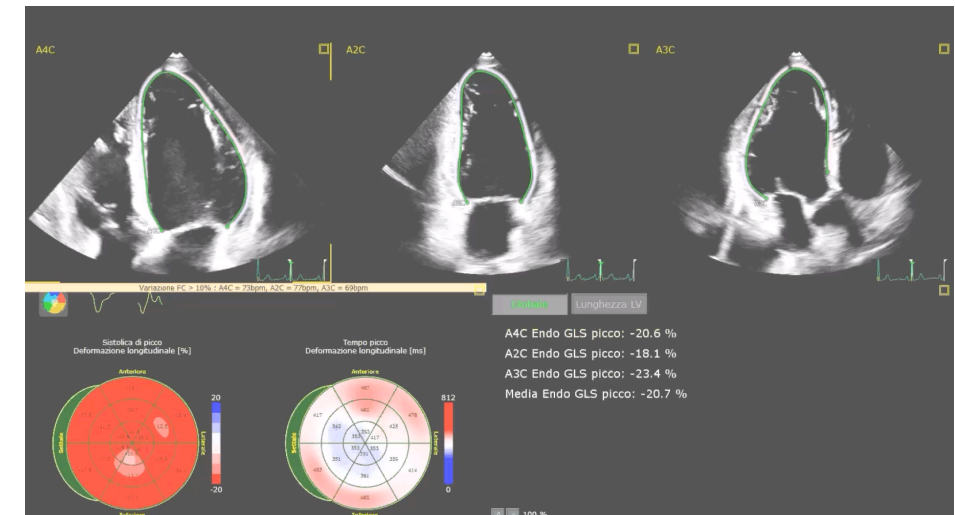




**Optimized
Therapy**
JULY 2020:
LVEF: 55% ;
volume VS
154 ml



Autostrain:
GLS: - 21%



Management of Heart Failure With Improved Ejection Fraction

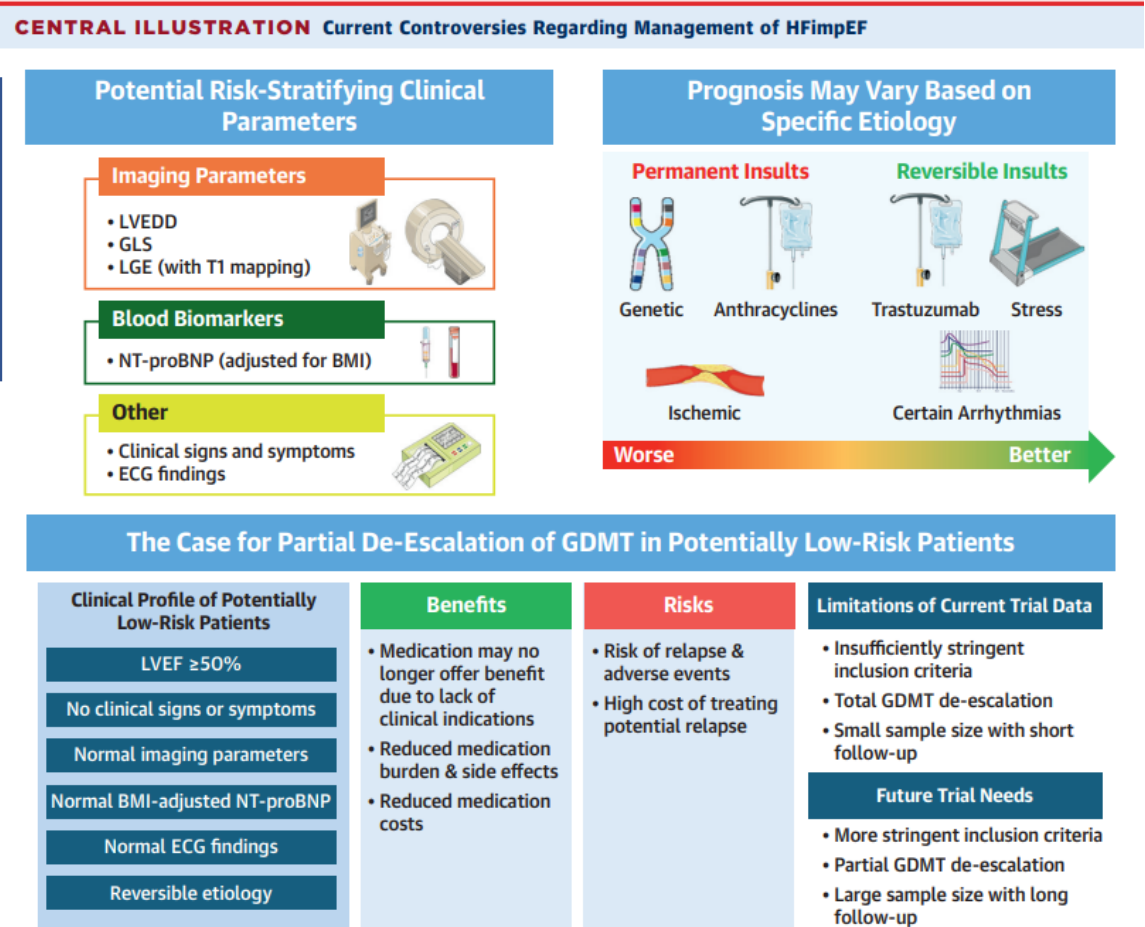
Current Evidence and Controversies

Nandan Kodur, BS,^a W.H. Wilson Tang, MD^{a,b}

INDIPENDENTEMENTE DALLA TERMINOLOGIA E' FONDAMENTALE DOCUMENTARE IL MIGLIORAMENTO FUNZIONALE DEL VENTRICOLO SINISTRO IN MODO ACCURATO

Emerging clinical experience suggests that heart failure arising from acute etiologies **that fully resolve along with complete LVEF recovery may have a favorable prognosis with lower risk of relapse**. Indeed, cohort and case series studies have demonstrated the feasibility of safe de-escalation of GDMT in select patients with specific etiologies, with multiple small trials ongoing

Heart failure with improved ejection fraction (HFimpEF) is defined by **improved left ventricular ejection fraction (LVEF > 10%-40%) among patients who previously had reduced LVEF**. HFimpEF



IMPORTANZA DELLA VALUTAZIONE DEI VOLUMI E DELLA FUNZIONE DEL VENTRICOLO DESTRO IN TUTTE LE CARDIOPATIE

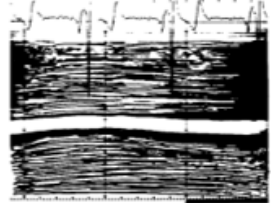
A New Formula For Echo-Doppler Estimation of Right Ventricular Systolic Pressure

Mauro Pepi, MD, Gloria Tamborini, MD, Claudia Galli, MD, Paolo Barbier, MD, Elisabetta Doria, MD, Marco Berti, MD, Marco Guazzi, MD, and Cesare Fiorentini, MD, *Milan, Italy*

JASE 1994

ECHO - DOPPLER

IVCCI = 20 %



CATHETER

RAP = 13 mmHg

V.MAX = 2.4 m/sec
⇒ ΔP = 23 mmHg



M.A = 33 mmHg

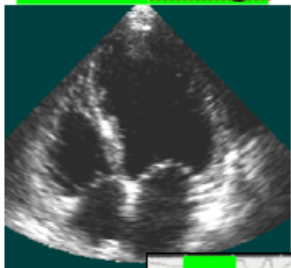
M.B = 39.3 mmHg

M.C = 39 mmHg

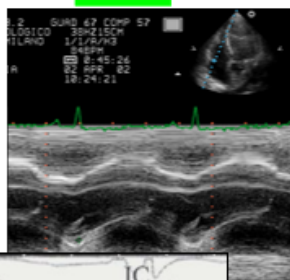
ΔP = 25 mmHg

RVSP = 38 mmHg

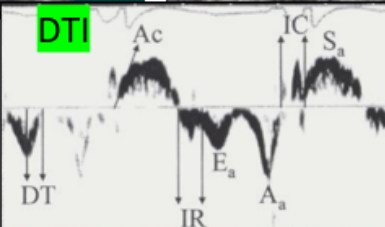
RV area Change



TAPSE



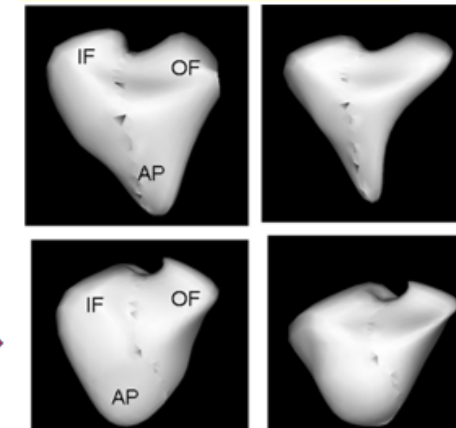
DTI



Feasibility of a New Generation Three-Dimensional Echocardiography for Right Ventricular Volumetric and Functional Measurements

Gloria Tamborini, MD^{a,*}, Denise Brusoni, MD^a, Jorge Eduardo Torres Molina, MD^b, Claudia Agnese Galli, MD^a, Anna Maltagliati, MD^a, Manuela Muratori, MD^a, Francesca Susini, MD^a, Chiara Colombo, MD^a, Francesco Maffessanti, MS^{a,c}, and Mauro Pepi, MD^a

Am J Cardiol 2008

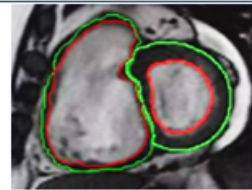


**3D transtoracico
VOLUMI ed EF VD**

2010 - 2020

1980 - 2010

VOLUMI VD e EF SOLO CMR E Nuclear



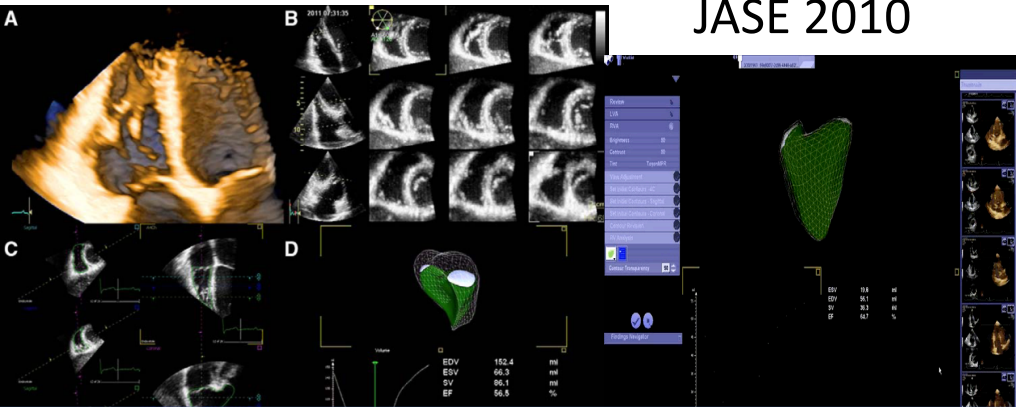
**Dimensioni ed EF solo
qualitative**

**Necessità DATI
QUANTITATIVI**

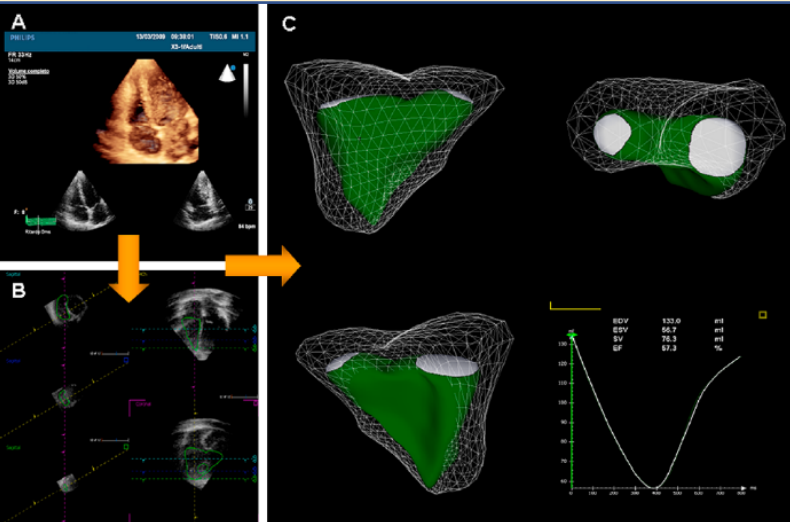
FOCUS TOPIC: RIGHT VENTRICULAR VOLUME AND FUNCTION

Reference Values for Right Ventricular Volumes and Ejection Fraction With Real-Time Three-Dimensional Echocardiography: Evaluation in a Large Series of Normal Subjects

Gloria Tamborini, MD, Nina Ajmone Marsan, MD, Paola Gripari, MD, Francesco Maffessanti, MS, Denise Brusoni, MD, Manuela Muratori, MD, Enrico G. Caiani, PhD, Cesare Fiorentini, MD, and Mauro Pepi, Milan, Italy



Tamborini OFF line Methods FEW minutes
Feasibility 97%; Good-Optimal 85%



Age-, Body Size-, and Sex-Specific Reference Values for Right Ventricular Volumes and Ejection Fraction by Three-Dimensional Echocardiography

A Multicenter Echocardiographic Study in 507 Healthy Volunteers

Francesco Maffessanti, PhD*; Denisa Muraru, MD*; Roberta Esposito, MD; Paola Gripari, MD; Davide Ermacora, MD; Ciro Santoro, MD; Gloria Tamborini, MD; Maurizio Galderisi, MD; Mauro Pepi, MD; Luigi P. Badano, MD

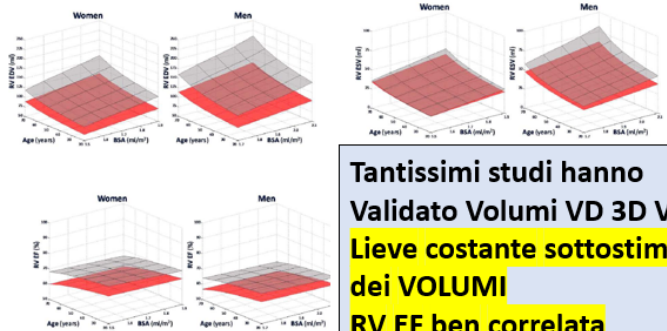
Maffessanti Circulation CV Imaging 2013

EXCELLENT CORRELATION WITH CMR RV
Ejection Fraction
Slight Underestimation of RV Volumes

Normative equations for RV parameters (N=507) Maffessanti, Muraru et al. Circ Imag. 2013

	RV EDV, mL		RV ESV, mL		RV SV, mL		RV EF, %	
	β (95% CI)	R^2	β (95% CI)	R^2	β (95% CI)	R^2	β (95% CI)	R^2
Normative equations (ASBa)								
Women	$120.4 \cdot \text{Age}^{-0.24} \cdot \text{BSA}^{1.02}$		$66.2 \cdot \text{Age}^{-0.39} \cdot \text{BSA}^{1.23}$		$55.2 \cdot \text{Age}^{-0.14} \cdot \text{BSA}^{0.94}$		$45.9 \cdot \text{Age}^{0.10}$	
Men	$134.9 \cdot \text{Age}^{-0.24} \cdot \text{BSA}^{1.02}$		$79.3 \cdot \text{Age}^{-0.39} \cdot \text{BSA}^{1.23}$		$59.0 \cdot \text{Age}^{-0.14} \cdot \text{BSA}^{0.94}$		$43.8 \cdot \text{Age}^{0.10}$	

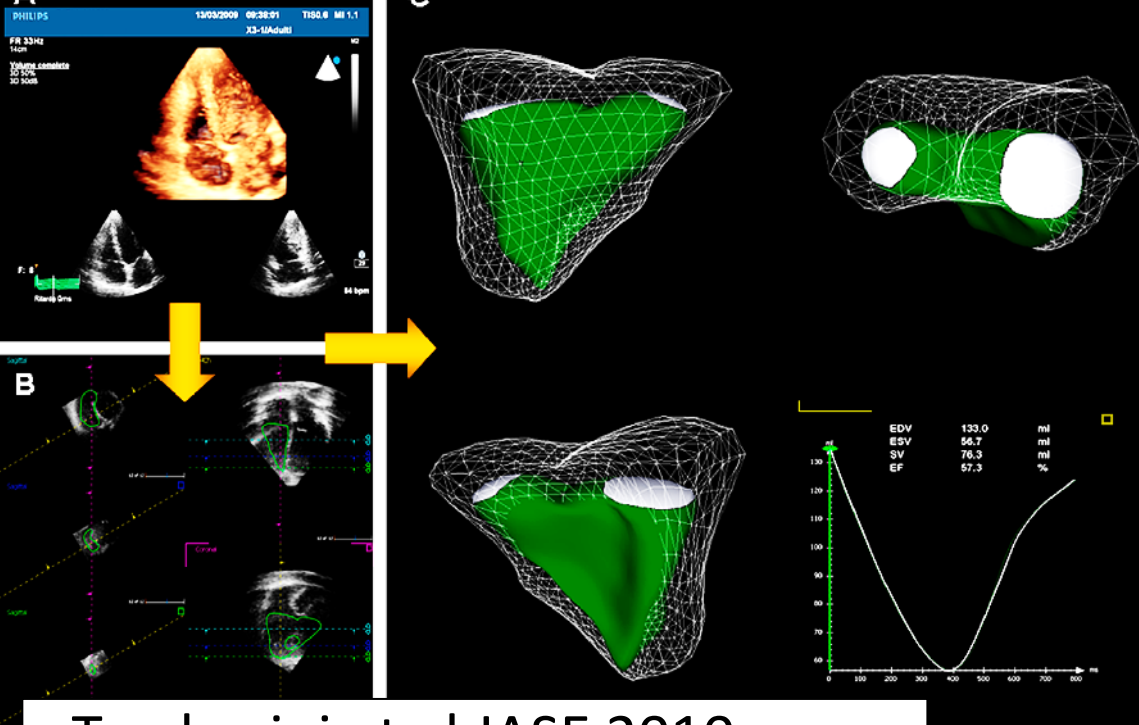
3D echo
MRI



Tantissimi studi hanno
Validato Volumi VD 3D Vs RMN
Lieve costante sottostima
dei VOLUMI
RV EF ben correlata

Normative equations for RV parameters (N=441)*

pp ^{RV} mass _{AHW}		pp ^{RVEDV} _{AHW}		pp ^{RVEF} _{AHW}	
RV Index					
Women	$\text{RV mass (g)} / (10.59 \cdot \text{Age}^{-0.320} \cdot \text{Ht}^{1.135} \cdot \text{Wt}^{0.315})$		$\text{RVEDV (mL)} / (27.94 \cdot \text{Age}^{-0.258} \cdot \text{Ht}^{1.582} \cdot \text{Wt}^{0.382})$		$\text{RVEF (\%)} / (75.19 \cdot \text{Age}^{0.0706} \cdot \text{Ht}^{-0.00771} \cdot \text{Wt}^{-0.0782})$
Men	$\text{RV mass (g)} / (11.25 \cdot \text{Age}^{-0.320} \cdot \text{Ht}^{1.135} \cdot \text{Wt}^{0.315})$		$\text{RVEDV (mL)} / (31.50 \cdot \text{Age}^{-0.258} \cdot \text{Ht}^{1.582} \cdot \text{Wt}^{0.382})$		$\text{RVEF (\%)} / (71.52 \cdot \text{Age}^{0.0706} \cdot \text{Ht}^{-0.00771} \cdot \text{Wt}^{-0.0782})$



Tamborini et al JASE 2010

SISTEMI off line (7
Minuti..)

SISTEMI ON BOARD : 4
Minuti

Ora con metodi di
INTELLIGENZA ARTIFICIALE

2008

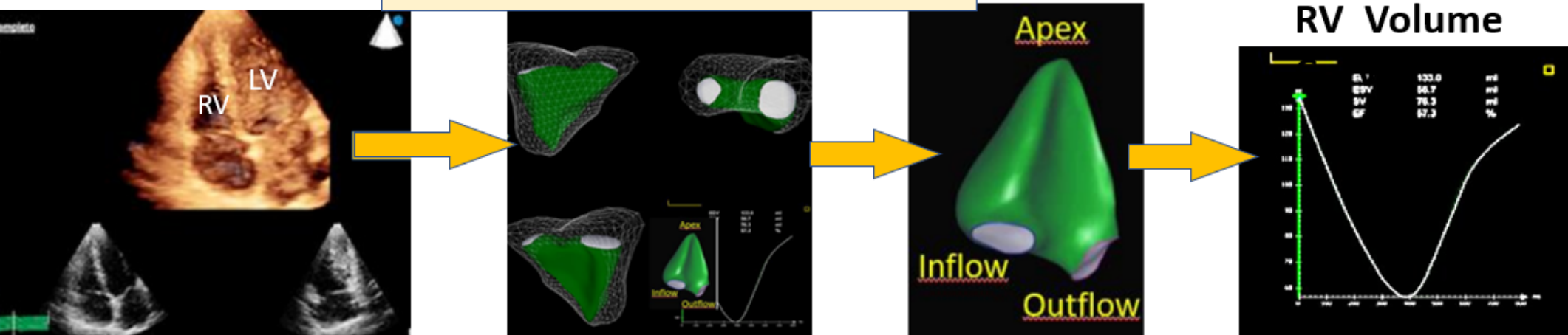
2025:

Lieve
sottostima

Volumi;

Buona
correlazione
EF

18 SECONDS



Superati problemi di valutazioni OFF-line

Article

Head-to-Head Comparison between Automatic and Semiautomatic System for the 3D Echocardiographic Multiparametric Evaluation of RV Function and Dimension

Marco Penso^{1,2,*}, Remo Antonio Ranalletta¹, Mauro Pepi¹, Anna Garlaschè¹, Sarah Ghulam Ali¹, Laura Fusini^{1,2}, Valentina Mantegazza¹, Manuela Muratori¹, Riccardo Maragna¹ and Gloria Tamborini¹

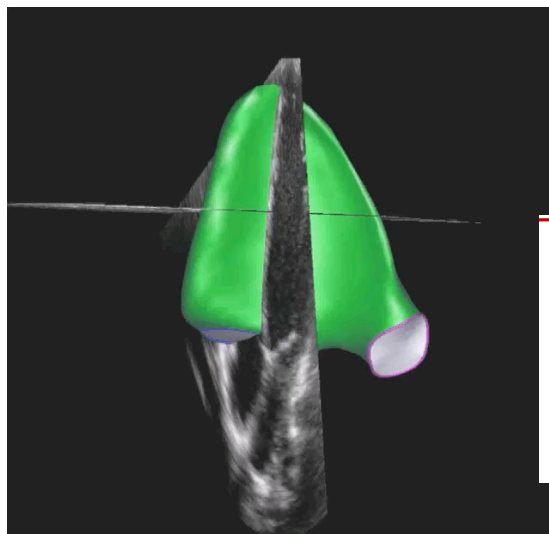
15 SECONDI

Article

Comparison between Automatic and Semiautomatic System for the 3D Echocardiographic Multiparametric Evaluation of RV Function and Dimension

Marco Penso^{1,2,*}, Remo Antonio Ranalletta¹, Mauro Pepi¹, Anna Garlaschè¹, Sarah Ghulam Ali¹, Laura Fusini^{1,2}, Valentina Mantegazza¹, Manuela Muratori¹, Riccardo Maragna¹ and Gloria Tamborini¹

- Fattibilità 95%
- Accuratezza dei volumi e della frazione d'eiezione vs sistema semiautomatico
- Accuratezza delle misure derivate (tapse, fac, strain) vs le misure bidimensionali tradizionali



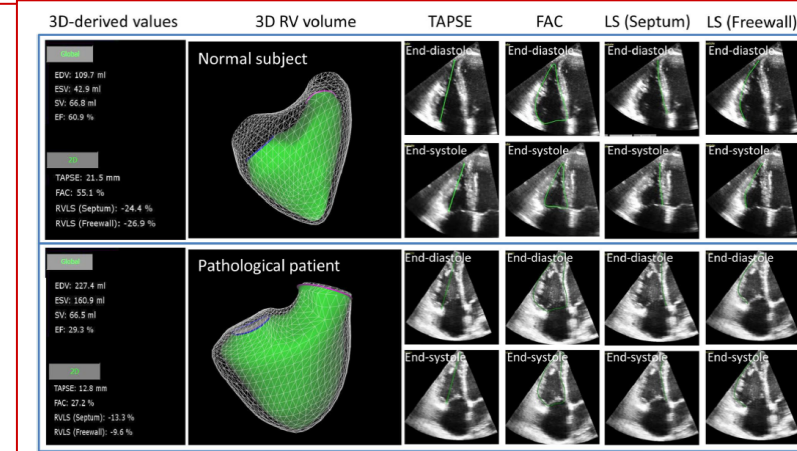
ORIGINAL PAPER



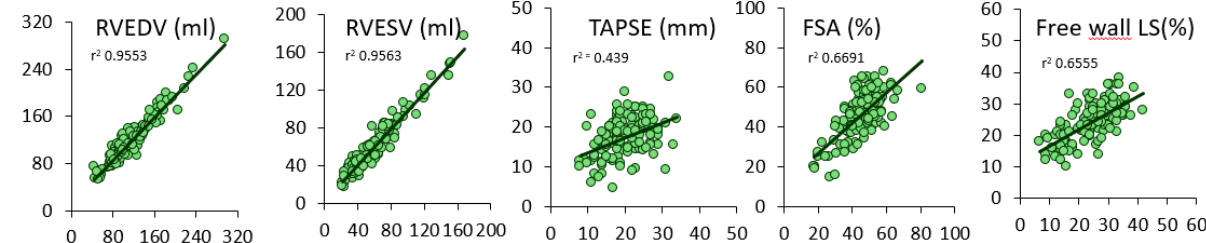
Multi-parametric “on board” evaluation of right ventricular function using three-dimensional echocardiography: feasibility and comparison to traditional two-and three dimensional echocardiographic measurements

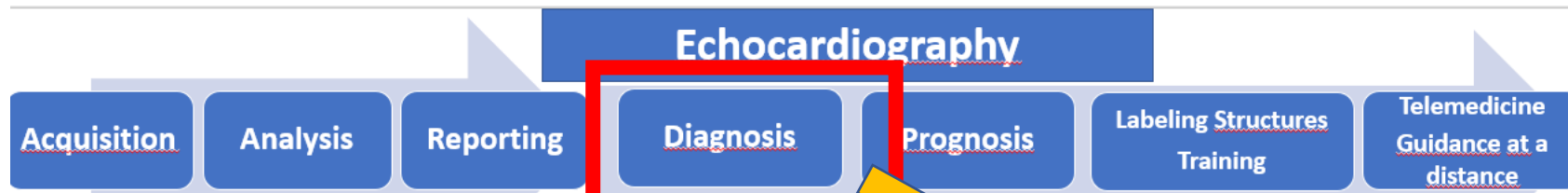
Gloria Tamborini¹, Claudia Cefalù¹, Fabrizio Celeste¹, Laura Fusini¹, Anna Garlaschè¹, Manuela Muratori¹, Sarah Ghulam Ali¹, Paola Gripari¹, Giovanni Berna¹, Mauro Pepi¹

Dati 2D, e DTI estratti in AI dal 3D



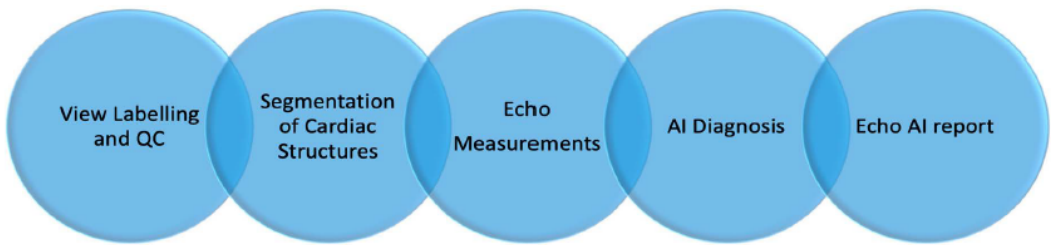
TAPSE; FSA; FREE WALL STRAIN





Automated Echo Interpretation

Akkus et al 2021

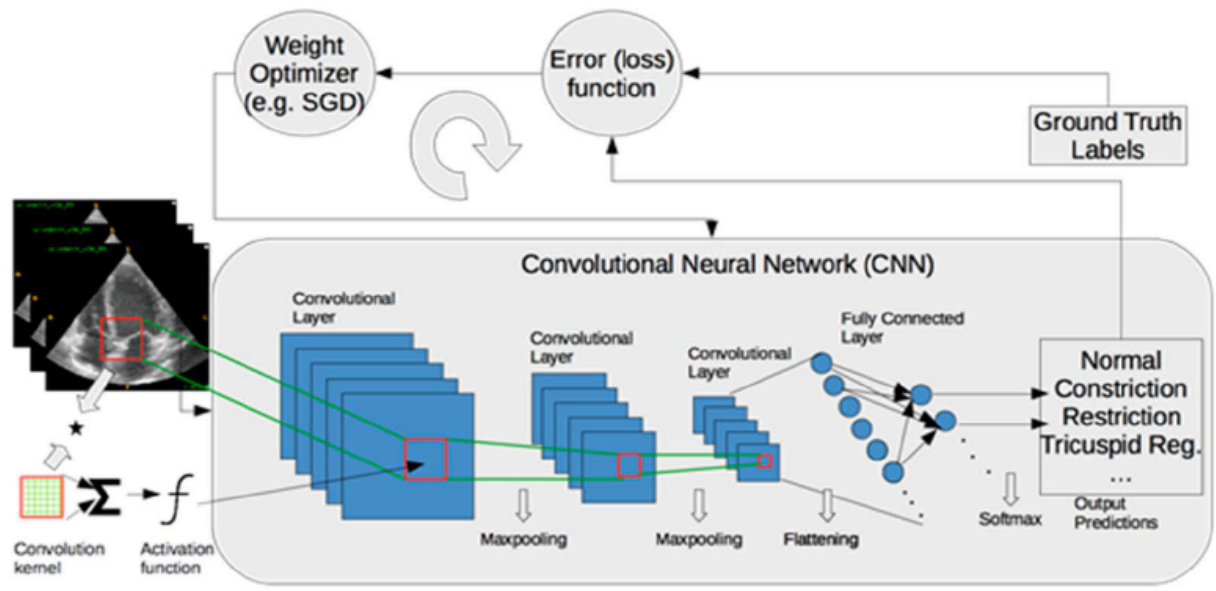


**Classify
DIAGNOSIS**

Classify:

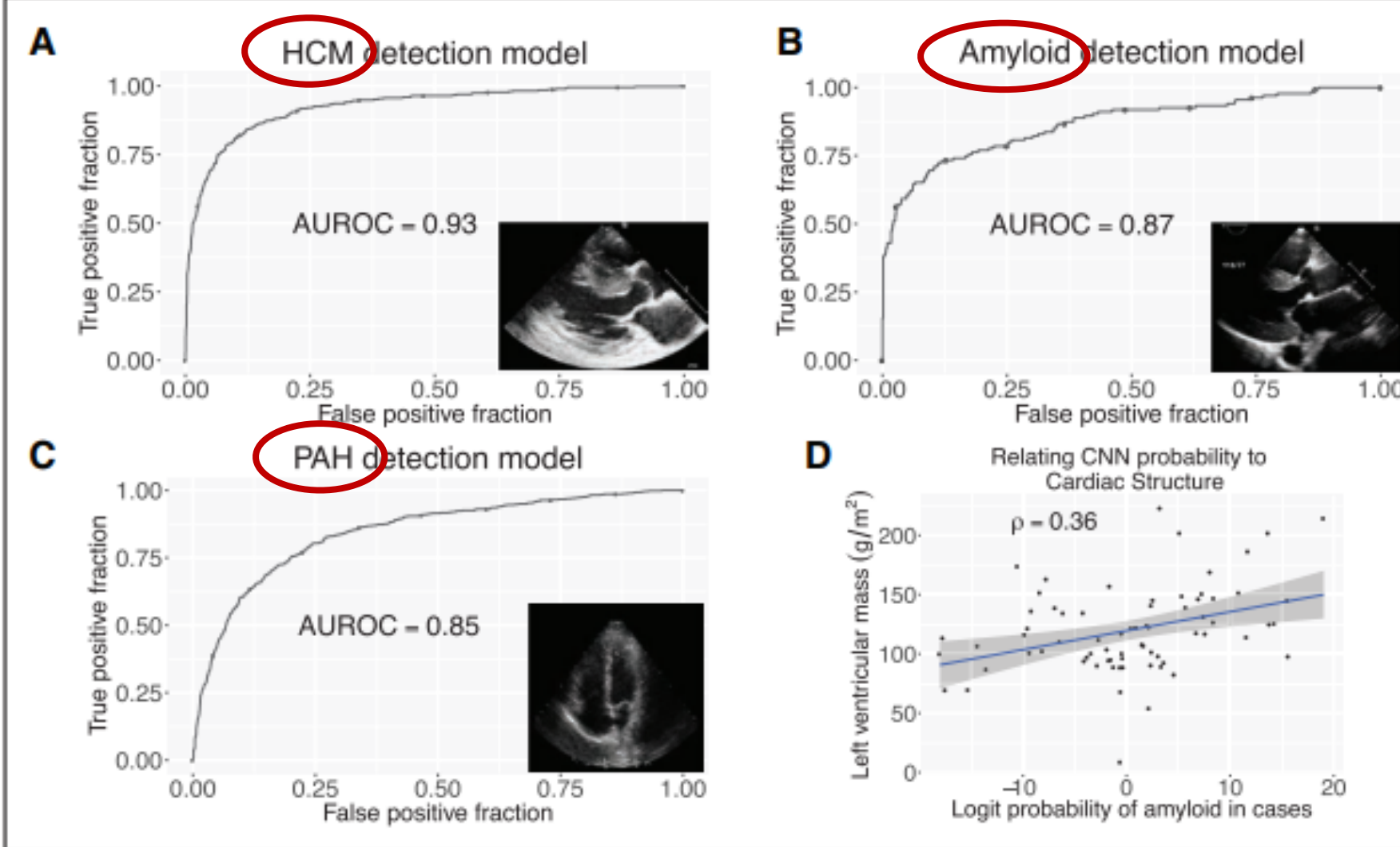
Normality
Restriction
Constriction
etc

Figure 5. The flowchart of automated artificial-intelligence-empowered echo (AI-Echo) interpretation pipeline using a chain approach. QC: Quality Control.



Deep-learning
model for
classification of
myocardial
diseases

Figure 3. A framework of training a deep-learning model for classification of myocardial diseases. Operations between layers are shown with arrows. SGD: Stochastic Gradient Descent.



Hypertrophic
CMP

Amiloydosis

Pulmonary
Hypertension

Figure 7. CNNs enable detection of abnormal myocardial diseases.

A through **C**, Receiver operating characteristic curves for hypertrophic cardiomyopathy (**A**), cardiac amyloid (**B**), and pulmonary arterial hypertension (**C**) detection. **D**, Relationship of probability of amyloid with left ventricular mass. Blue line indicates linear regression fit, with 95% CI indicated by gray shaded area. AUROC indicates area under the receiver operating characteristic curve; CNN, convolutional neural network; HCM, hypertrophic cardiomyopathy; and PAH, pulmonary arterial hypertension.

OPEN Differential diagnosis of common etiologies of left ventricular hypertrophy using a hybrid CNN-LSTM model

In-Chang Hwang^{1,2,4,5}, Dongjun Choi^{1,4}, You-Jung Choi⁴, Lia Ju¹, Myeongju Kim³, Ji-Eun Hong², Hyun-Jung Lee^{2,5}, Yeonyee E. Yoon^{1,2}, Jun-Beom Park^{2,5}, Seung-Pyo Lee^{2,5}, Hyung-Kwan Kim^{2,5}, Yong-Jin Kim^{2,5} & Goo-Young Cho^{1,2}

Differential diagnosis of left ventricular hypertrophy (LVH) is often challenging because of the

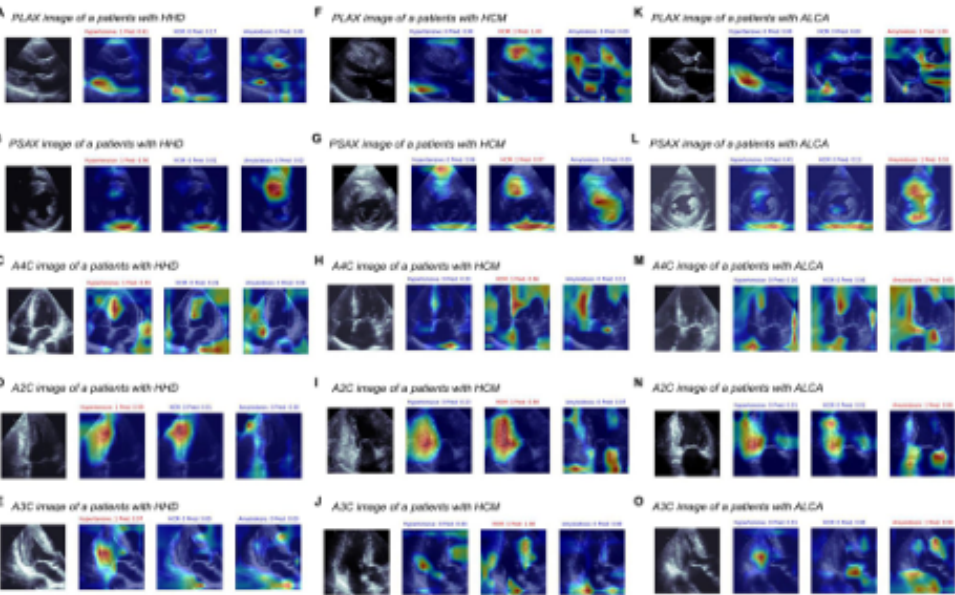
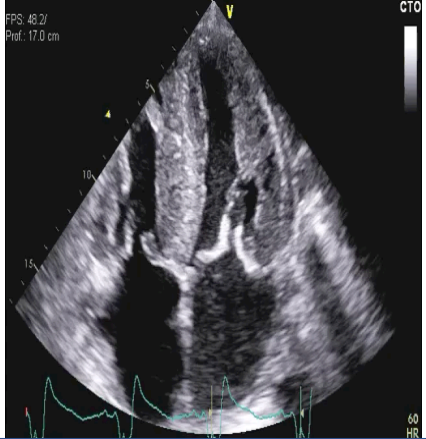


Figure 3. Representative figures in the class activation mapping. Typical class activation maps of patients with HHD (A–E), HCM (F–J), or ALCA (K–O), are presented. AUC area under the ROC curve, CI confidence interval, ALCA light-chain cardiac amyloidosis, HCM hypertrophic cardiomyopathy, HHD hypertensive heart disease, ROC receiver operating characteristic curve.

Several studies showed that Ai may classify different etiologies and patterns of LV hypertrophy: Hypertrophic CMP, Hypertension, Infiltrative CMP athletic heart, etc



Detection of Cardiac Amyloidosis with Us2.ai –Now FDA cleared and CE marked

JUL 7, 2025

Amyloidosis Uncovered

Under development as part of FDA TAP Program

EchoGo™
AMYLOIDOSIS

Detects Cardiac Amyloidosis (CA) from a single 4-chamber view

funded by
janssen
Pfizer

Release: Q2 2024
*Pending FDA Submission

Powered by AI

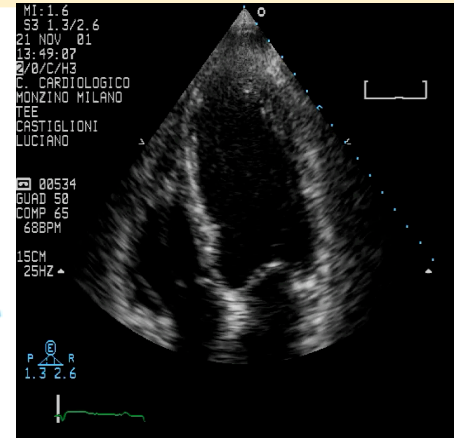
ECHO AI diagnosis of Amyloidosis from a single 4 –chamber view

Segmental LV function in baseline and during Stress

NEW RESEARCH PAPER

Automated Echocardiographic Detection of Severe Coronary Artery Disease Using Artificial Intelligence

Ross Upton, PhD,^{a,b} Angela Mumith, PhD,^{a,*} Arian Beqiri, PhD,^{a,*} Andrew Parker, PhD,^{a,*} William Hawkes, PhD,^{a,*} Shan Gao, PhD,^a Mihaela Porumb, PhD,^a Rizwan Sarwar, MD,^b Patricia Marques, BSc,^a Deborah Markham, PhD,^a Jake Kenworthy, BSc,^a Jamie M. O'Driscoll, PhD,^{a,c} Neelam Hassanali, PhD,^a Kate Groves, PhD,^a Cameron Dockerill, BSc,^b William Woodward, BSc,^b Maryam Alsharqi, MSc,^b Annabelle McCourt, MSc,^b Edmund H. Wilkes, PhD,^a Stephen B. Heitner, MD,^d Mrinal Yadava, MD,^d David Stojanovski, MEng,^e Pablo Lamata, PhD,^e Gary Woodward, PhD,^a Paul Leeson, MB, BChir, PhD^{a,b}

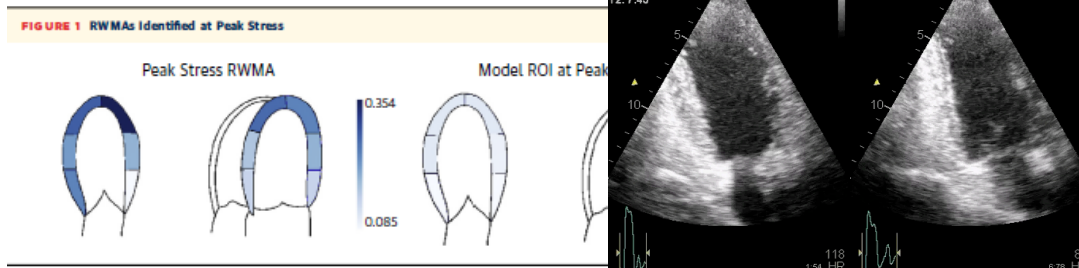


Circulation

ORIGINAL RESEARCH ARTICLE

Fully Automated Echocardiogram Interpretation in Clinical Practice Feasibility and Diagnostic Accuracy

Analisi automatica Segmenti VS durante stress



Artificial Intelligence and Echocardiography: A Primer for Cardiac Sonographers

Ashlee Davis, BS, ACS, RDCS, FASE, Kristen Billick, BS, ACS, RDCS, FASE, Kenneth Horton, ACS, RCS, RCIS, FASE, Madeline Jankowski, BS, RDCS, FASE, Peg Knoll, RDCS, RCS, FASE, Jane E. Marshall, BS, RDCS, FASE, Alan Paloma, RDCS, Richie Palma, BS, ACS, RDCS, FASE, and David B. Adams, ACS, RCS, RDCS, FASE, *Durham, North Carolina; La Jolla, Irvine, and Stanford, California; Salt Lake City, Utah; Chicago, Illinois; and Boston, Massachusetts*

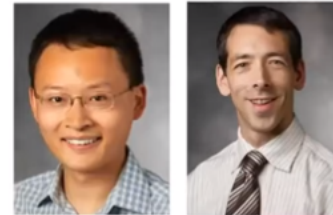
Article | Published: 25 March 2020

Video-based AI for beat-to-beat assessment of cardiac function

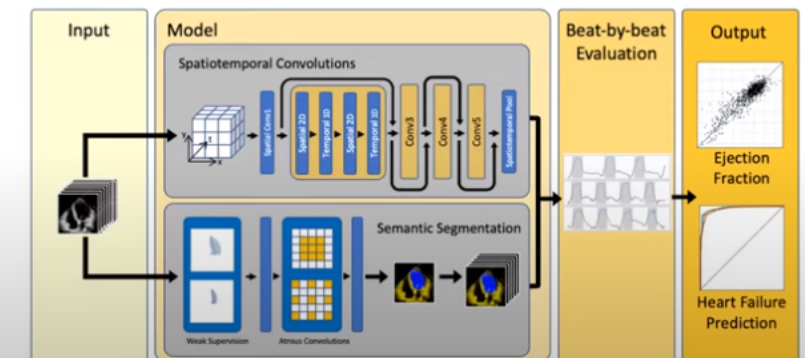
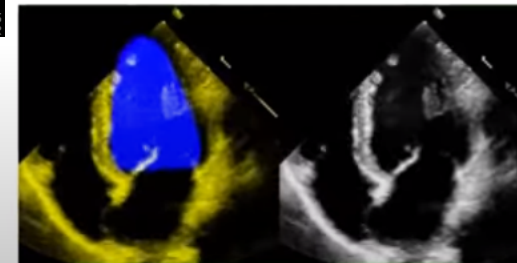
David Ouyang , Bryan He, Amirata Ghorbani, Neal Yuan, Joseph Ebinger, Curtis P. Langlotz, Paul A. Heidenreich, Robert A. Harrington, David H. Liang, Euan A. Ashley & James Y. Zou 

Nature 580, 252–256 (2020) | [Cite this article](#)

16k Accesses | 58 Citations | 167 Altmetric | [Metrics](#)



NATURE 2020



AI and Valve Diseases (few examples) NB more than 900 references



Journal of the American Society of
Echocardiography

Available online 23 December 2022

In Press, Corrected Proof [What's this?](#)



Prediction of Coronary Artery Calcium Using Deep Learning of Echocardiograms

Neal Yuan MD^{a, b}, Alan C. Kwan MD^{c, e}, Grant Duffy^c, John Theurer^c,
Jonathan H. Chen MD, PhD^f, Koen Nieman MD, PhD^{f, g}, Patrick Botting MSPH^c,
Damini Dey PhD^e, Daniel S. Berman MD^c, Susan Cheng MD, MPH, MSc^c, David Ouyang MD^{c, d}

MACHINE LEARNING DETECTION OF AORTIC STENOSIS

Automated Detection of Aortic Stenosis Using Machine Learning



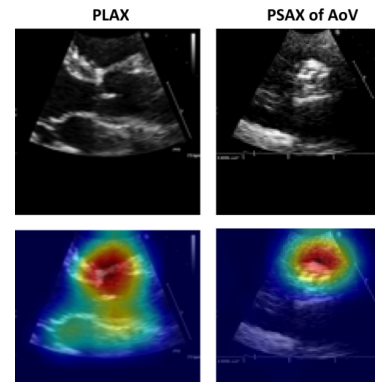
Benjamin S. Wessler, MD, Zhe Huang, MS, Gary M. Long, Jr, MS, Stefano Pacifici, MD, Nishant Prashar, MD, Samuel Karmiy, MD, Roman A. Sandler, PhD, Joseph Z. Sokol, Daniel B. Sokol, MS, Monica M. Dehn, RDCS, Luisa Maslon, RDCS, Eileen Mai, RDCS, Ayan R. Patel, MD, and Michael C. Hughes, PhD, *Boston, Medford, and Dorchester, Massachusetts; and Los Angeles, California*

JAMA Cardiology | **Original Investigation**

Automated Deep Learning Phenotyping of Tricuspid Regurgitation in Echocardiography

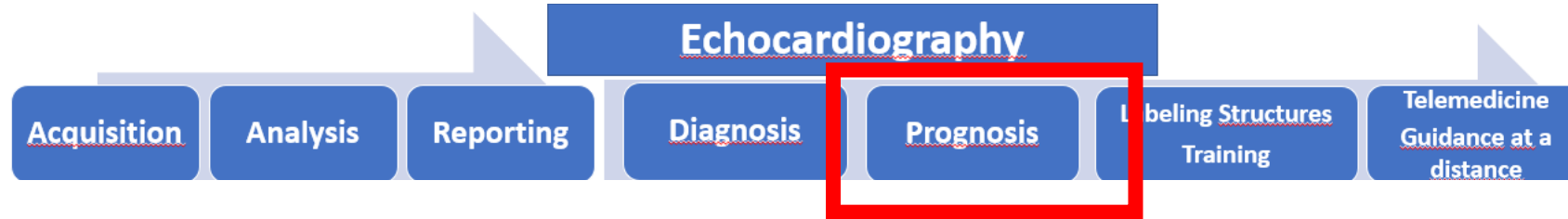
Amey Vrudhula, MD; Milos Vukadinovic, BS; Christiane Haeffele, MD; Alan C. Kwan, MD; Daniel Berman, MD; David Liang, MD, PhD; Robert Siegel, MD; Susan Cheng, MD, MMSc, MPH; David Ouyang, MD

Il modello (ECO parasternale) predice il Calcium score (presenza di alti livelli di calcio) a livello coronarico con una elevata accuratezza.



Detection of Aortic Stenosis and also bicuspid valve

**Identification of Significant TR Data from:
4 Chamber and other echo-views (both with and without color Doppler information).**



ESC

European Society
of Cardiology

European Heart Journal - Imaging Methods and Practice (2024) 2, qyae136
<https://doi.org/10.1093/ehjimp/qyae136>

INVITED REVIEW

Advancements and applications of artificial intelligence in cardiovascular imaging: a comprehensive review

Federico Fortuni ^{1,*}, Giuseppe Ciliberti², Benedetta De Chiara³,
Edoardo Conte ⁴, Luca Franchin ⁵, Francesca Musella ⁶, Enrica Vitale⁷,
Francesco Piroli⁸, Stefano Cangemi⁹, Stefano Cornara¹⁰, Michele Magnesa¹¹,
Antonella Spinelli¹², Giovanna Geraci ¹³, Federico Nardi¹⁴, Domenico Gabrielli¹⁵,
Furio Colivicchi ¹², Massimo Grimaldi¹⁶, and Fabrizio Oliva^{17,18,19}

DATA INTEGRATION

Clinical Data, Big data → Prognosis
ECG, ECHO, CMR, CT

ELIAS, JACC 2024

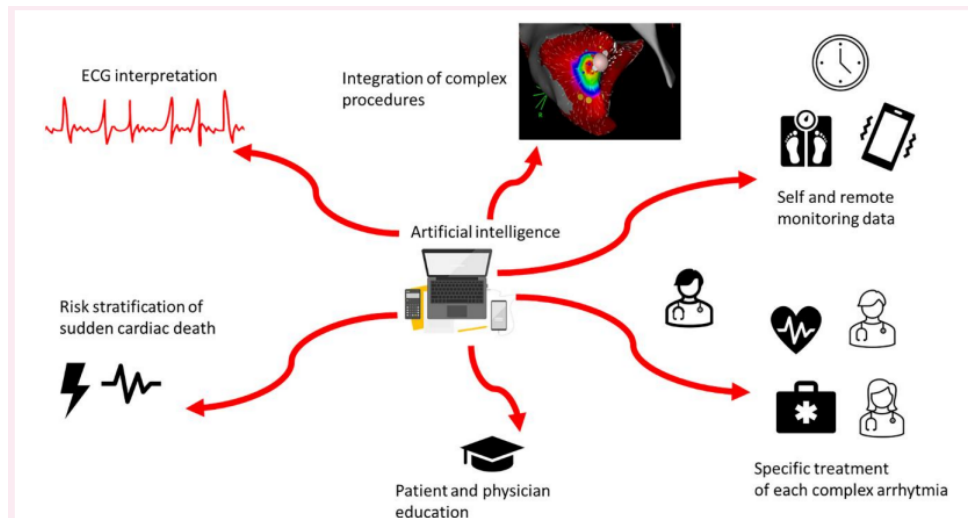
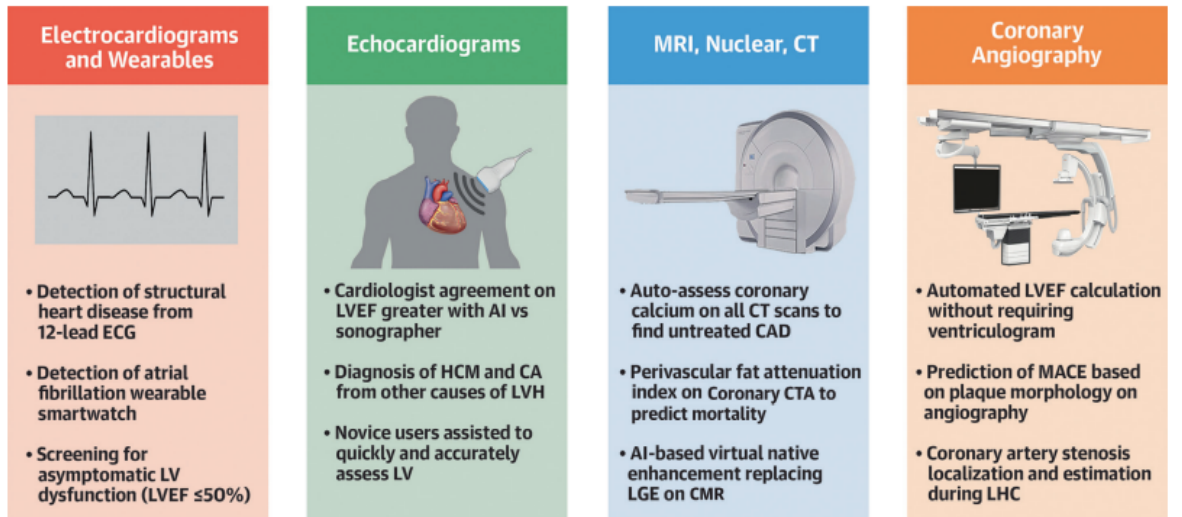


Figure 6 AI applications in the imaging field of EP. The figure highlights AI's role in data integration, risk stratification, procedural guidance, automatic ECG interpretation, treatment optimization, and education in the field of EP.

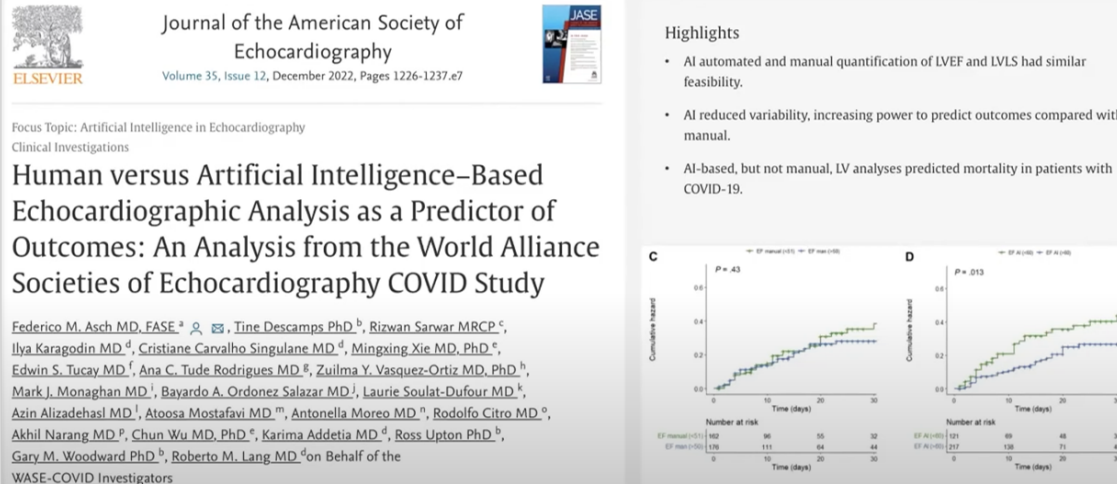
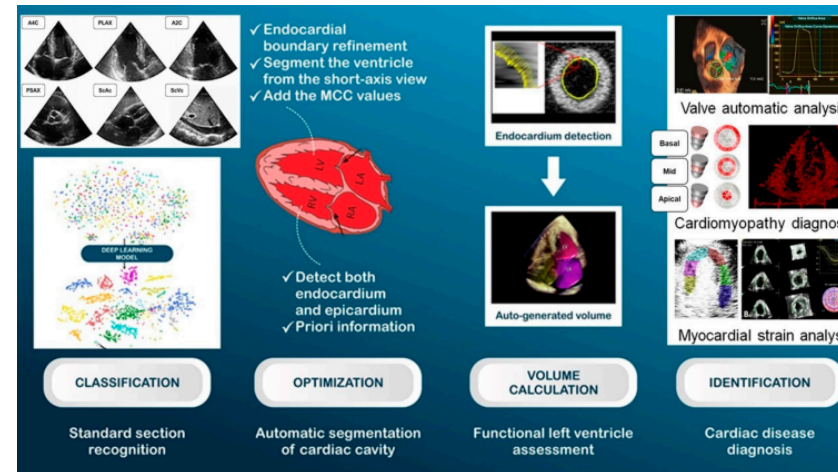
CENTRAL ILLUSTRATION Key Studies in Cardiovascular Artificial Intelligence by Imaging Modality



Elias P, et al. J Am Coll Cardiol. 2024;83(24):2472-2486.

Clinical data
ECG
CT / MRI
Biological
Markers
Other

+

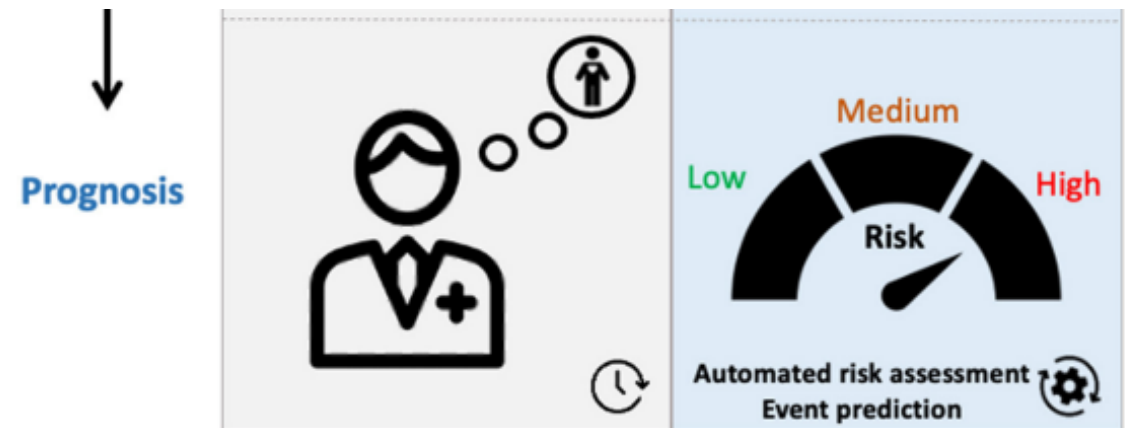


PROGNOSIS: SPECIFIC VARIABLES OR LOW-MEDIUM-HIGH RISK EVENT PREDICTION

Predicting Long-Term Mortality in TAVI Patients Using Machine Learning Techniques

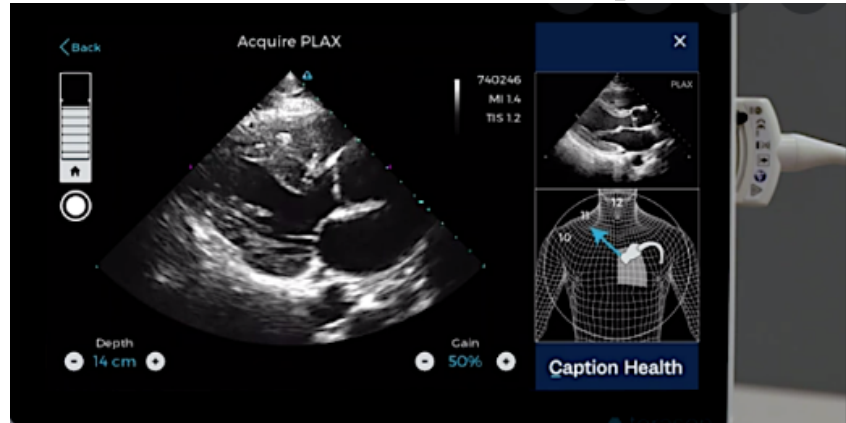
Marco Penso^{1,*}, Mauro Pepi¹, Laura Fusini¹, Manuela Muratori¹, Claudia Cefalù¹, Valentina Mantegazza¹, Paola Gripari¹, Sarah Ghulam Ali¹, Franco Fabbicchi¹, Antonio L. Bartorelli^{1,2}, Enrico G. Caiani³ and Gloria Tamborini¹

Mortality in TAVI: 14 potential predictors were identified with the **organic mitral regurgitation** (myxomatous or calcific degeneration of the leaflets and/or annulus) which showed the **highest impact on 5 years mortality**.



Altri aspetti di grande prospettiva dell'IA

- guiding of beginners toward a technically correct image with a DL technique (several new equipments)



Collaborative AI

TRAINING
TELEMEDICINE- GUIDANCE
ROBOTICS



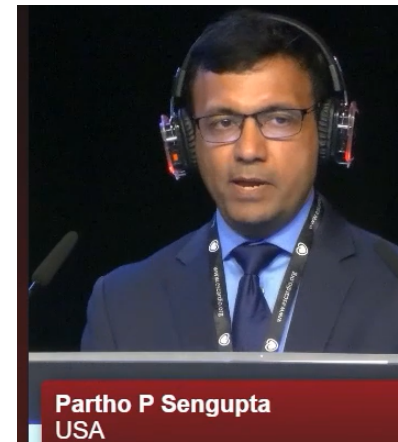
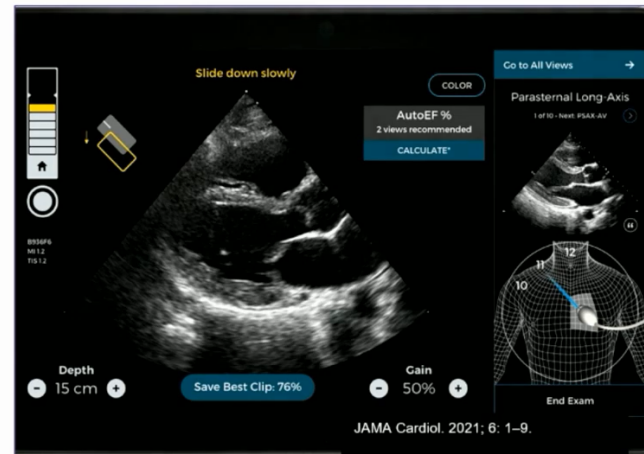
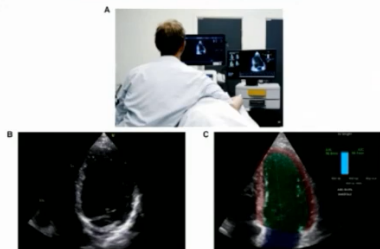
ESC European Heart Journal - Imaging Methods and Practice (2021) 1, 1-9
ORIGINAL ARTICLE
European Society of Cardiology

Real-time guiding by deep learning during echocardiography to reduce left ventricular foreshortening and measurement variability

Sigbjørn Sabo¹, Hakon Neergaard Pettersen^{1,2}, Erik Smistad^{1,3}, David Padeloup¹, Stian Bergseng Stølen⁴, Bjørnar Leangen Grenne^{1,4}, Lasse Lovstakken¹, Espen Holte^{1,4}, and Havard Dalen^{1,4,5,6}

¹Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, NTNU, Box 9001, 7001 Trondheim, Norway
²Department of Imaging Medicine, Kristiansund Hospital, Thore and Sonja Hospital Trust, Thore and Sonja, 6508 Kristiansund, Norway
³Sørland Hospital, Box 4760 Torshov, 4765 Trondheim, Norway
⁴State of Cardiology, St. Olav University Hospital, Box 1200 Torshov, 7006 Trondheim, Norway
⁵Department of Internal Medicine, Lævanger Hospital, Nord-Trøndelag Hospital Trust, Kariakgt 2, 7601 Lævanger, Norway

Received 12

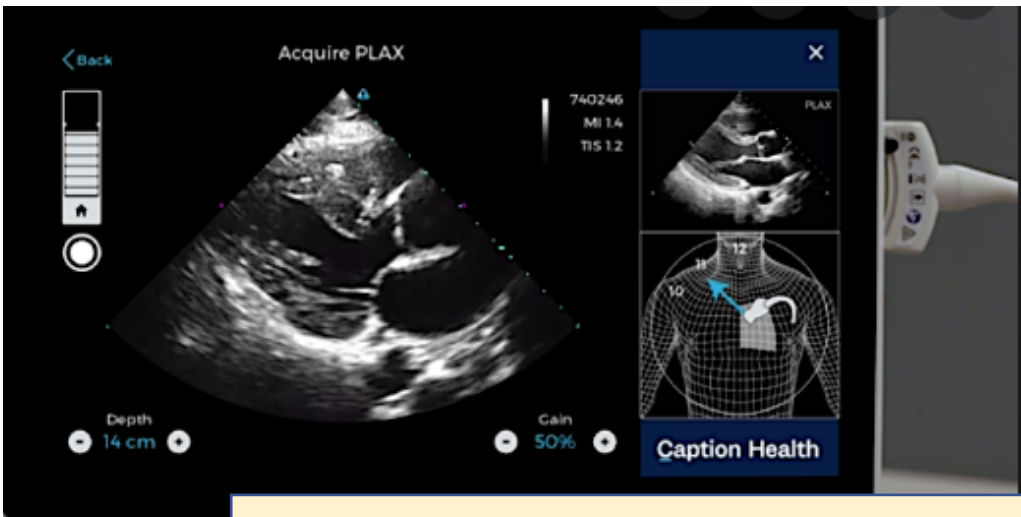


COLLABORATIVE
AI

The application of artificial intelligence (AI) in echocardiography has shown tremendous growth in the past decade, with the exciting potential **for standardization, reducing variability**, automating measurements, and recognizing uncommon diseases.

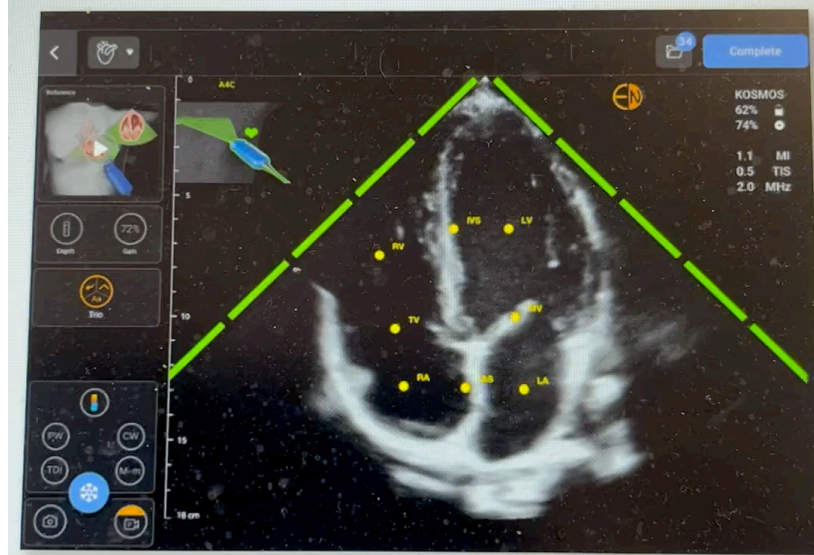
To GUIDE USERS

Education and Point of CARE
(COVID...)
Automated Measurements
Reports

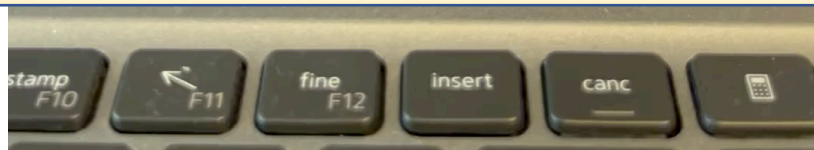


Guiding operators remotely

**Riconoscimento Automatico
struttura con labeling**
Rosso: Immagine non corretta
Verde Immagine Corretta
Calcoli Automatici EF



**TABLET con sonda CUORE, POLMONE
ADDOME
POCUS con AI**



Cardiac Computed Tomography

Patient Selection and screening

Acquisition

Images analysis and interpretation

Ischaemia (FFR-CT, CTP)

Reporting

Cardiac Structure Segmentation

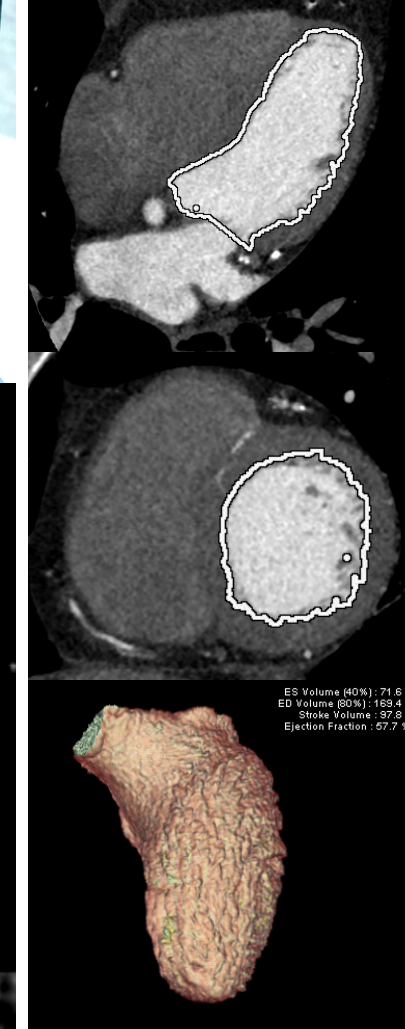
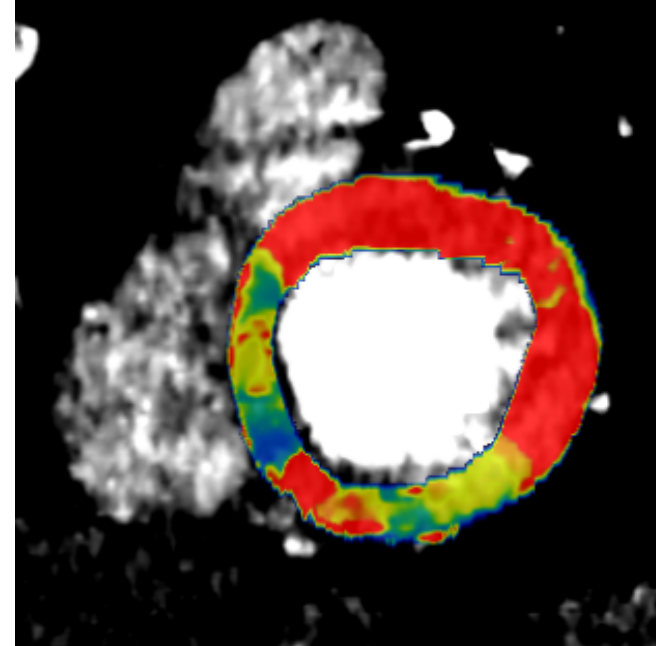
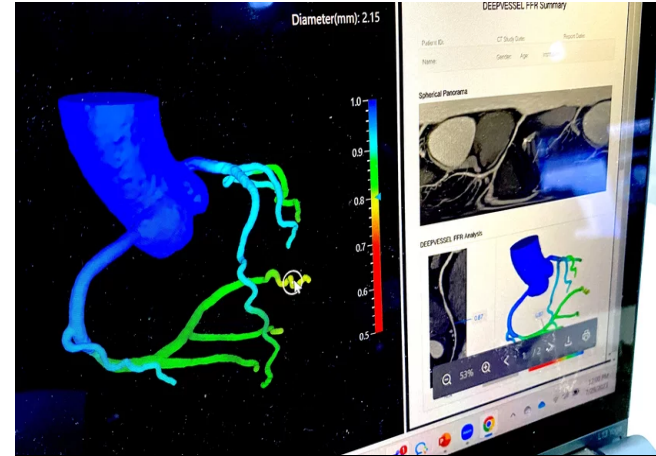
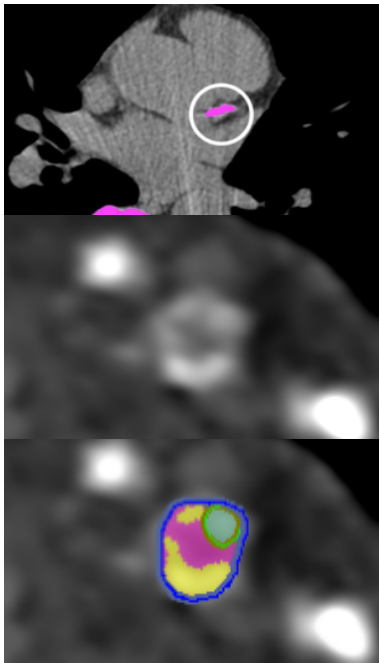
Other findings



- CT protocol selection
- Patient positioning
- Scanning parameters
- Correction of motion artifacts



- Identify calcium
- Detection and quantification of stenosis
- Atherosclerosis burden
- Plaque analysis

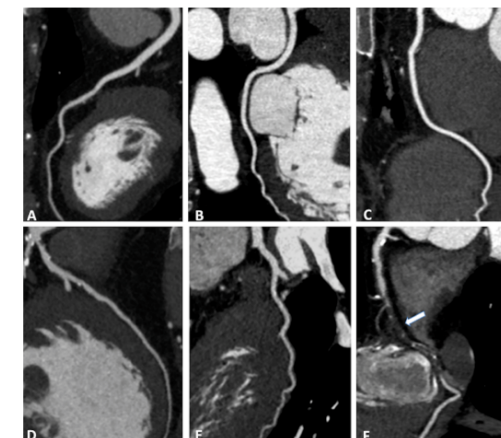
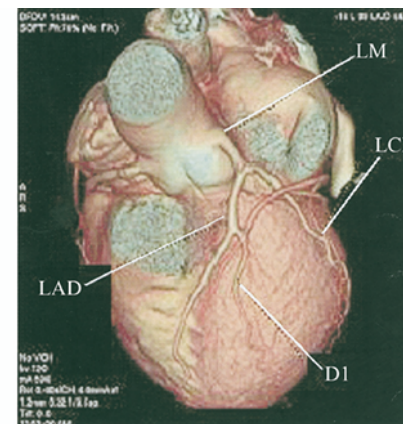
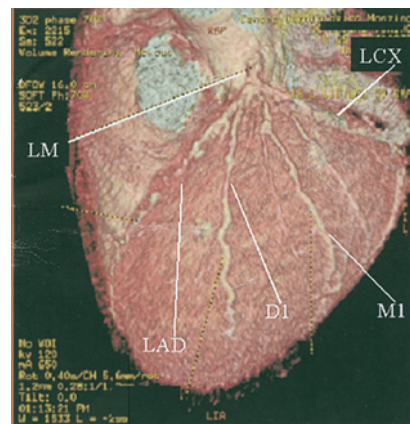


Baggiano et al
J Cardiovasc
Echography 2025

2009

Sixty-Four Slice Multidetector Computed Tomography: An Accurate Imaging Modality for the Evaluation of Coronary Arteries in Dilated Cardiomyopathy of Unknown Etiology

Daniele Andreini, Gianluca Pontone, Antonio L. Bartorelli, Piergiuseppe Agostoni, Saima Mushtaq, Erika Bertella, Daniela Trabattoni, Gaia Cattadori, Sarah Cortinovis, Andrea Annoni, Alice Castelli, Giovanni Ballerini and Mauro Pepi
Circ Cardiovasc Imaging 2009;2:199-205; originally published online Mar 24, 2009;



Multidetector computed tomography is feasible, safe, and accurate for identification of idiopathic versus ischemic DCM, and may represent an alternative to coronary angiography.

Journal of the American College of Cardiology
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ISSN 0735-1097/07/\$32.00
doi:10.1016/j.jacc.2007.01.086

JACC 2007

Cardiac Imaging

Diagnostic Accuracy of Multidetector Computed Tomography Coronary Angiography in Patients With Dilated Cardiomyopathy

Daniele Andreini, MD, Gianluca Pontone, MD, Mauro Pepi, MD, Giovanni Ballerini, MD, Antonio L. Bartorelli, MD, FACC, Alessandra Magini, MD, Carlo Quaglia, MD, Enrica Nobili, MD, Piergiuseppe Agostoni, MD, PhD
Milan, Italy

2026: ANALISI AUTOMATICA QUADRO CORONARICO CON DEEP LEARNING

Performance of a deep learning algorithm for the evaluation of CAD-RADS classification with CCTA

^{1,*}Giuseppe Muscogiuri, MD, PhD, FSCCT, ^{1,*}Mattia Chiesa, MSc, PhD, ²Michela Trotta, MSc, ³Marco Gatti, MD ⁴Vitanio Palmisano, MD, ⁵Serena Dell'Aversana, MD, ⁶Francesca Baessato, MD ⁷, Annachiara Cavaliere, MD, ⁸Gloria Cicala, MD, ⁹Antonella Loffreno, MD, ⁷Giulia Rizzon, MD, ¹Marco Guglielmo, MD, FSCCT, ¹Andrea Baggiano, MD, ¹Laura Fusini, MD, ⁴Luca Saba, MD, ^{1,10}Daniele Andreini, MD, PhD, FESC, FSCCT, ¹Mauro Pepi, MD, FESC, ^{11,12}Mark G. Rabbat, MD, ¹³Andrea I. Guaricci, MD, PhD, FESC, ¹⁴Carlo N. De Cecco, MD, PhD, ¹Gualtiero Colombo, MD ¹Gianluca Pontone MD, PhD, FESC, FSCCT

AI-Driven Quantitative Coronary CT Angiography in Suspected Coronary Artery Disease

Multicenter CONFIRM2 Registry

JACC
Adv2025



Alexander van Rosendael, MD, PhD,^a Rine Nakanishi, MD, PhD,^b Jeroen J. Bax, MD, PhD,^a Gianluca Pontone, MD, PhD,^c Saima Mushtaq, MD,^d Ronny R. Buechel, MD,^e Christoph Gräni, MD, PhD,^f Gudrun Feuchtnr, MD,^g Pietro G. Lacaita, MD,^h Amit R. Patel, MD,^h Cristiane C. Singulane, MD,^h Andrew D. Choi, MD,ⁱ Mouaz Al-Mallah, MD, MSc,^j Daniele Andreini, MD, PhD,^k Ronald P. Karlsberg, MD,^{l,m,n} Geoffrey W. Cho, MD,^{l,m,n} Carlos E. Rochitte, MD,^o Mirvat Alasnag, MD,^p Ashraf Hamdan, MD,^{q,r} Filippo Cademartiri, MD, PhD,^s Erica Maffei, MD,^t Hugo Marques, MD, PhD,^t Pedro de Araújo Gonçalves, MD, PhD,^{t,u} Himanshu Gupta, MD,^v Martin Hadamitzky, MD,^w Omar Khalique, MD,^x Dinesh Kalra, MD,^y James D. Mills, MD,^z Nick S. Nurmohamed, MD, PhD,^{aa,bb} Paul Knaapen, MD, PhD,^{aa} Matthew Budoff, MD,^{cc} Kashif Shaikh, MD,^{dd} Enrico Martin, MD, PhD,^{ee} David M. German, MD, MPH,^{ff} Maros Ferencik, MD, PhD,^{ff} Andrew C. Oehler, MD,^{gg} Roderick Deaño, MD, MPH,^{hh} Prashant Nagpal, MD,ⁱⁱ Marly van Assen, MD,^{jj} Carlo N. De Cecco, MD, PhD,^{jj} Vasileios Kamperidis, MD, PhD,^{kk} Borek Foldyna, MD, PhD,^{ll} Jan M. Brendel, MD,^{ll} Victor Y. Cheng, MD,^{mm} Kelley R. Branch, MD, MSc,ⁿⁿ Marcio Bittencourt, MD, MPH, PhD,^{oo} Sabha Bhatti, MD,^{pp} Venkateshwar Polsani, MD,^{qq} George Wesbey, MD,^{rr} Rhanderson Cardoso, MD,^{ss} Ron Blankstein, MD,^{ss} Augustin Delago, MD,^{tt,uu} Amit Pursnani, MD,^{vv,ww} Amro Alsaïd, MD,^{xx} Stephen Bloom, MD,^{yy} Melissa Aquino, MSc,^{zz} Ibrahim Danad, MD, PhD^{aaa}

Noncalcified plaque burden and increment in stenosis severity as the most powerful predictors of MACE (CONFIRM 2 3551 Patients)

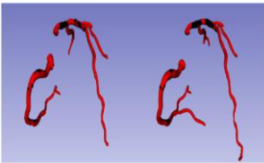
Quantificazione automatica della placca coronarica da TC

Le applicazioni più mature riguardano la coronaro-TC. Nuovi algoritmi di AI permettono di **quantificare automaticamente volume, composizione e caratteristiche della placca aterosclerotica**, identificando pazienti a rischio elevato anche in presenza di stenosi non severe. **Il burden aterosclerotico totale può essere un predittore più importante degli eventi cardiovascolari rispetto al solo grado di stenosi.**

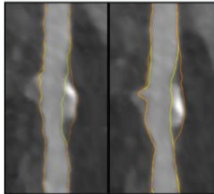
PlaqueViT: A Vision Transformer Model for Fully Automatic Vessel and Plaque Segmentation in Coronary Computed Tomography

Can this deep learning model segment coronary arteries and plaques from coronary CT angiography (CCTA)?

- CCTA image data from the Swedish CardioPulmonary BioImage Study
- Customized 3D vision transformer model used for voxelwise classification
- Segmentation and plaque detection on par with expert readers



3D visualization of a coronary tree segmentations.



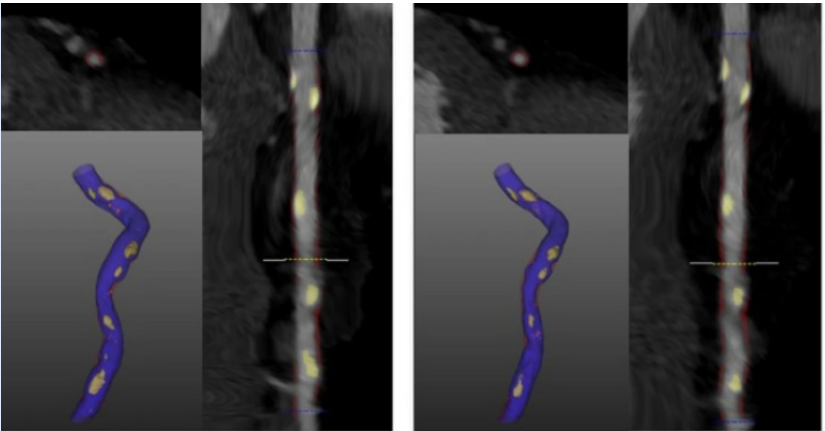
Left: Image from QAngio CT software of manually annotated CCTA examination. Right: Fully automatic segmentation of the same examination by PlaqueViT.

PlaqueViT is a promising tool for fully automatic plaque detection and segmentation in CCTA, useful for clinical decision support and large population studies.

Eur Radiol (2025) Alvén J, Petersen R, Hagerman D, et al.; DOI: 10.1007/s00330-025-11410-w



European Society of Radiology
European Radiology



a

Systolic phase

b

Diastolic phase

c

Quantitative plaque measurements

Measurement	Systolic phase	Diastolic phase
Total Plaque Volume (mm ³)	102.0	107.9
NCP Volume (mm ³)	82.0	89.9
LD NCP Volume (mm ³)	2.4	2.3
CP Volume (mm ³)	20.0	18.0
Plaque Length (mm)	51.4	53.4
Diameter Stenosis (%)	30.4	28.3

Artificial intelligence-guided quantitative coronary CT assessment to rule-in or rule-out myocardial ischaemia

Putri Annisa Kamila^{1,2*}, Nick S. Nurmohamed^{3,4}, Ibrahim Danad⁵, Ruurt A. Jukema³, Pieter G. Raijmakers⁶, Roel S. Driessen³, Michiel J. Bom³, Pepijn van Diemen³, Gianluca Pontone^{7,8}, Daniele Andreini⁹, Hyuk-Jae Chang¹⁰, Richard J. Katz¹¹, Andrew D. Choi¹¹, Paul Knaapen³, Jeroen J. Bax^{1,12}, and Alexander van Rosendael¹³, on the behalf of the CREDENCE and PACIFIC-1 Investigators[†]

This study demonstrates that a simplified framework combining three quantitative CCTA metrics (diameter stenosis, percent atheroma volume (PAV) and average lumen area (ALA) can enhance myocardial ischaemia risk stratification.

AI-Guided Quantitative CCTA to Stratify Myocardial Ischemia Risk

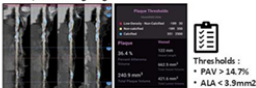
CREDENCE and PACIFIC-1 studies

Patients underwent CCTA with AI-QCT analysis and invasive FFR.

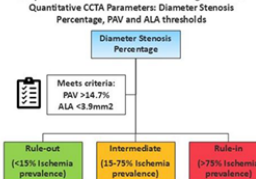
Three quantitative parameters are used: diameter stenosis percentage, percent atheroma volume (PAV) and average lumen area (ALA)

Design and Framework Development

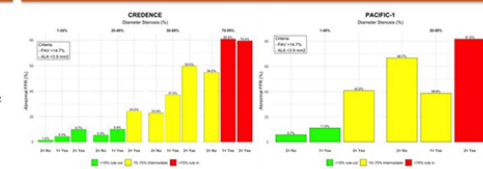
AI-QCT Processing Image



Simplified Ischemia Risk Stratification Using AI-Guided Quantitative CCTA Parameters: Diameter Stenosis Percentage, PAV and ALA thresholds



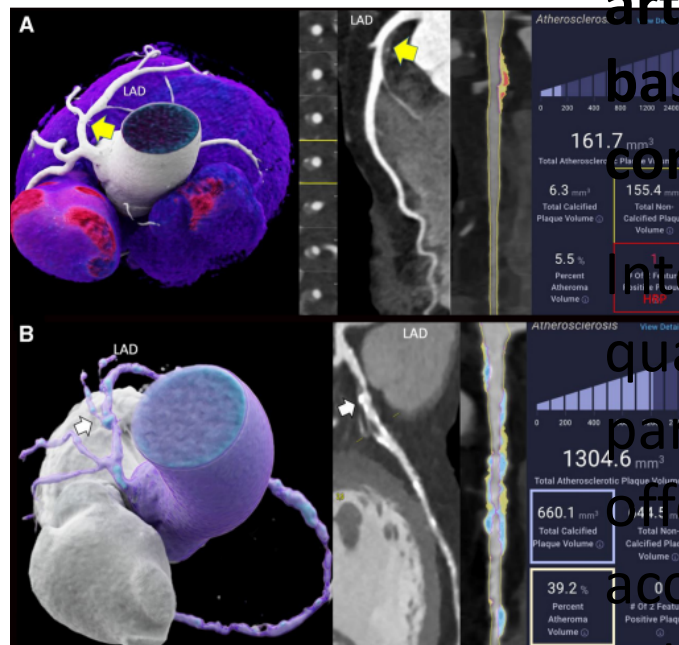
Main Results



- Confidently ruled out ischemia in majority of non-obstructive vessels.
- Identified a subset of non-obstructive lesions with high-risk features that may warrant further evaluation or management.
- Reliable ruled in ischemia in most of high-grade stenoses.
- The framework supports routine integration of quantitative plaque and lumen assessment to improve ischemia risk assessment

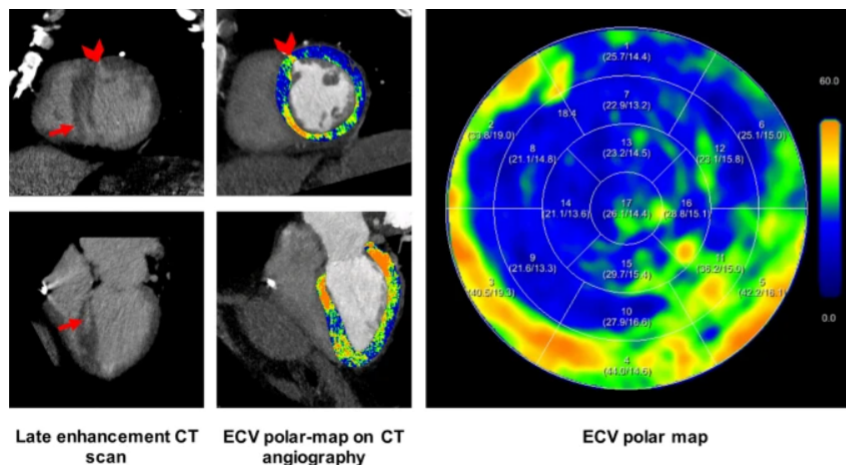
AI-Quantitative CT Coronary Plaque Features Associate With a Higher Relative Risk in Women: CONFIRM2 Registry

Gudrun M. Feuchtner¹, MD, Pietro G. Lacaita, MD; Jeroen J. Bax², MD, PhD; Fatima Rodriguez³, MD, MPH; Rine Nakanishi⁴, MD; Gianluca Pontone⁵, MD, PhD; Saima Mushtaq⁶, MD; Ronny R. Buechel⁷, MD; Christoph Gräni⁸, MD, PhD; Amit R. Patel⁹, MD; Cristiane C. Singulane¹⁰, MD; Andrew D. Choi, MD, MsC; Mouaz Al-Mallah¹¹, MD, MsC; Daniele Andreini, MD, PhD; Ronald P. Karlsberg¹², MD; Geoffrey Cho¹³, MD; Carlos E. Rochitte¹⁴, MD; Mirvat Alasnag, MD; Ashraf Hamdan, MD; Filippo Cademartiri¹⁵, MD, PhD; Erica Maffei¹⁶, MD; Hugo Marques, MD, PhD; Pedro M. Gonçalves Pereira¹⁷, MD, PhD; Himanshu Gupta¹⁸, MD; Martin Hadamitzky, MD; Omar Khalique¹⁹, MD; Dinesh Kalra²⁰, MD; James D. Mills²¹, MD; Nick S. Nurmohamed²², MD; Paul Knaapen²³, MD, PhD; Matthew Budoff²⁴, MD; Kashif Shaikh, MD; Enrico Martin, MD, PhD; David M. German, MD, MPH; Maros Ferencik²⁵, MD, PhD; Andrew C. Oehler²⁶, MD; Roderick Deaño²⁷, MD, MPH; Prashant Nagpal²⁸, MD; Marly Van Assen²⁹, MD; Carlo Nicola De Cecco³⁰, MD, PhD; Borek Foldyna³¹, MD, PhD; Jan Michael Brendel³², MD; Victor Y. Cheng, MD; Kelley Branch³³, MD, MS; Marcio Bittencourt³⁴, MD, MPH, PhD; Sabha Bhatti, MD; Venkateshwar Polsani³⁵, MD; George Wesbey, MD; Rhanderson Cardoso, MD; Ron Blankstein³⁶, MD; Augustin Delago, MD; Amit Pursnani³⁷, MD; Amro Alsaïd³⁸, MD; Stephen Bloom, MD; Vasileios Kamperidis³⁹, MD; Fabian Barbieri⁴⁰, MD, PhD; Melissa Aquino; Ibrahim Danad, MD[†]; Alexander van Rosendael, MD, PhD^{*}



artificial intelligence–based quantitative computed tomography integrating quantitative AI-QCT parameters offers a more accurate risk estimate in women

Cardiac CT with delayed enhancement (DE-CT) is an emerging, effective alternative to MRI for identifying left ventricular (LV) scars



MRI



European Heart Journal (2005) 26, 1461–1474
doi:10.1093/eurheartj/ehi258

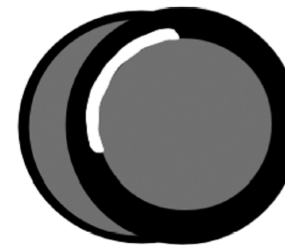
Delayed enhancement cardiovascular magnetic resonance assessment of non-ischaemic cardiomyopathies

Heiko Mahrholdt^{1*}, Anja Wagner², Robert M. Judd², Udo Sechtem¹, and Raymond S.

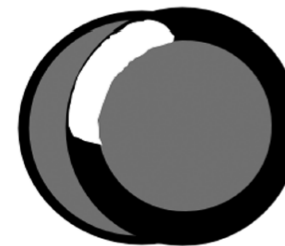
HYPERENHANCEMENT PATTERNS

Ischemic

A. Subendocardial Infarct

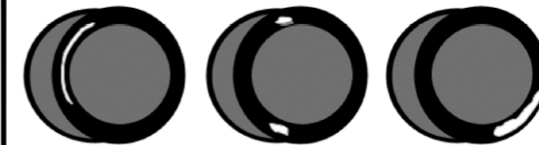


B. Transmural Infarct



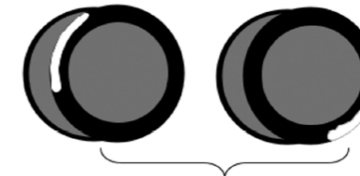
Nonischemic

A. Mid-wall HE



- Idiopathic Dilated Cardiomyopathy
- Myocarditis
- Hypertrophic Cardiomyopathy
- Right ventricular pressure overload (e.g. congenital heart disease, pulmonary HTN)
- Sarcoidosis
- Myocarditis
- Anderson-Fabry
- Chagas Disease

B. Epicardial HE



- Sarcoidosis, Myocarditis, Anderson-Fabry, Chagas Disease

C. Global Endocardial HE



- Amyloidosis, Systemic Sclerosis, Post cardiac transplantation

Cardiac Magnetic Resonance

Baggiano et al
J Cardiovasc
Echography 2025

Image
Acquisition

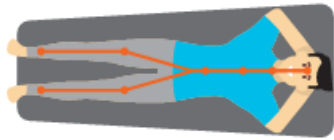
Image
Reconstruction

Image
Segmentation

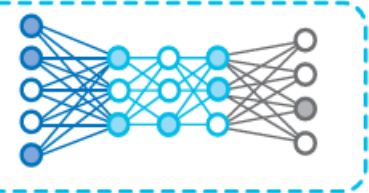
Image
Analysis

Prognosis

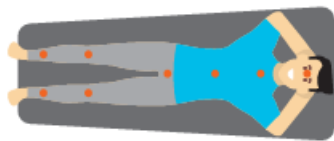
Report
Generation



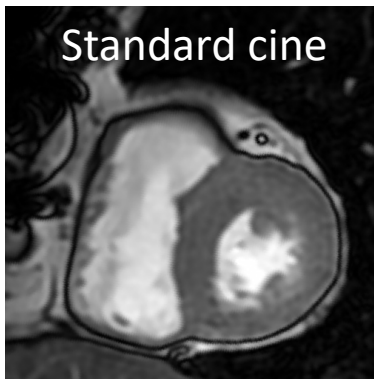
RGB images



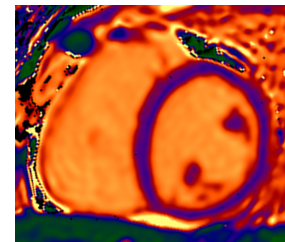
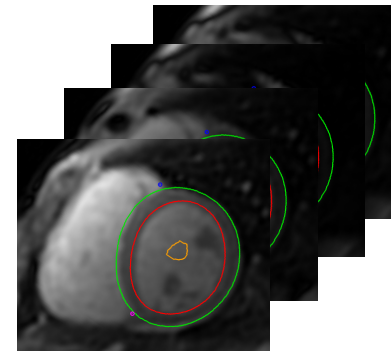
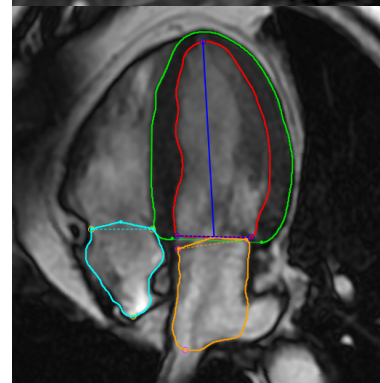
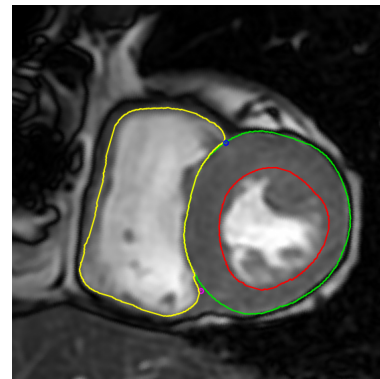
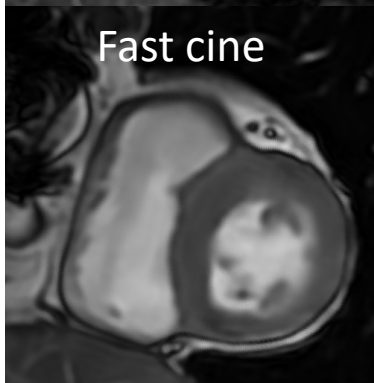
RGBLandmarkNet



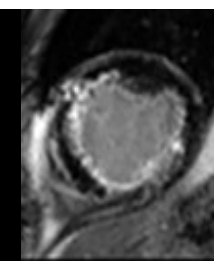
Standard cine



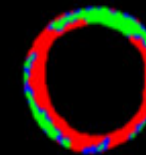
Fast cine



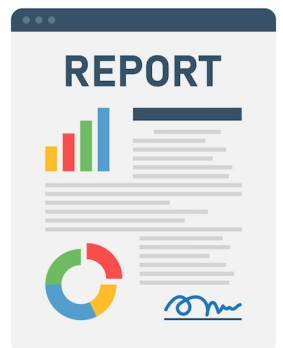
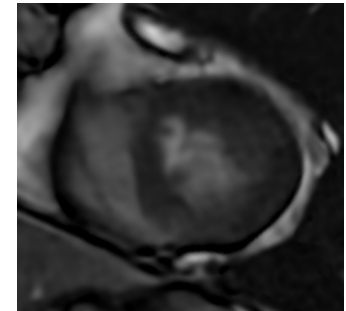
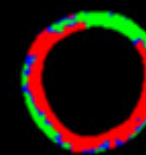
LGE
visualization



LGE
quantification
by human



LGE
quantification
by ML



MRI One single Exam >>>> DIAGNOSIS



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REVIEW

Role of multimodality imaging in the diagnosis and management of cardiomyopathies

Rôle de l'imagerie multimodale dans le diagnostic et la gestion des cardiomyopathies

Stéphane Ederhy^{a,b}, Nicolas Mansencal^{c,d},
Patricia Réant^e, Nicolas Piriou^f,
Gilles Barone-Rochette^{g,h,i,*}

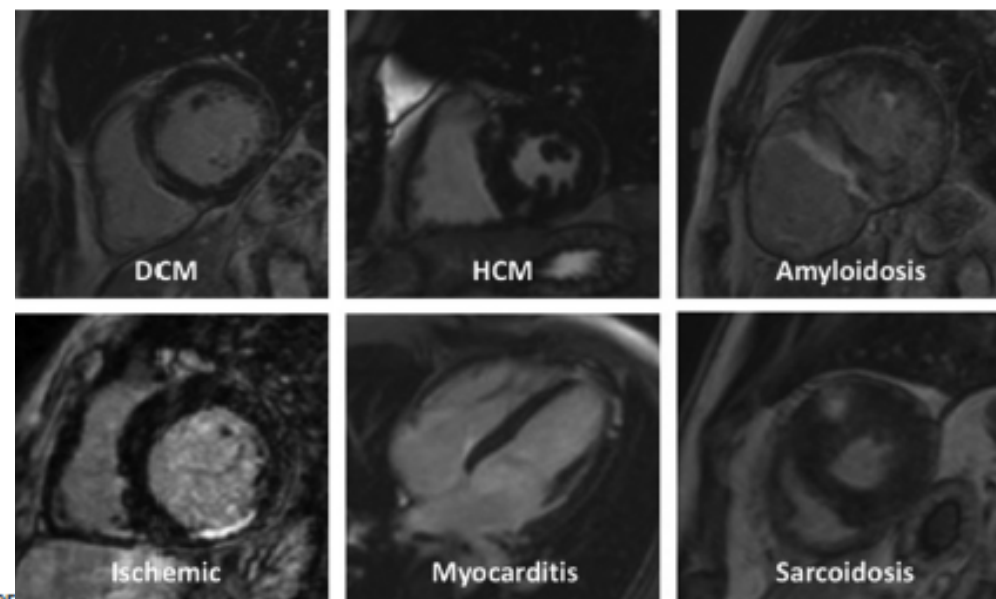
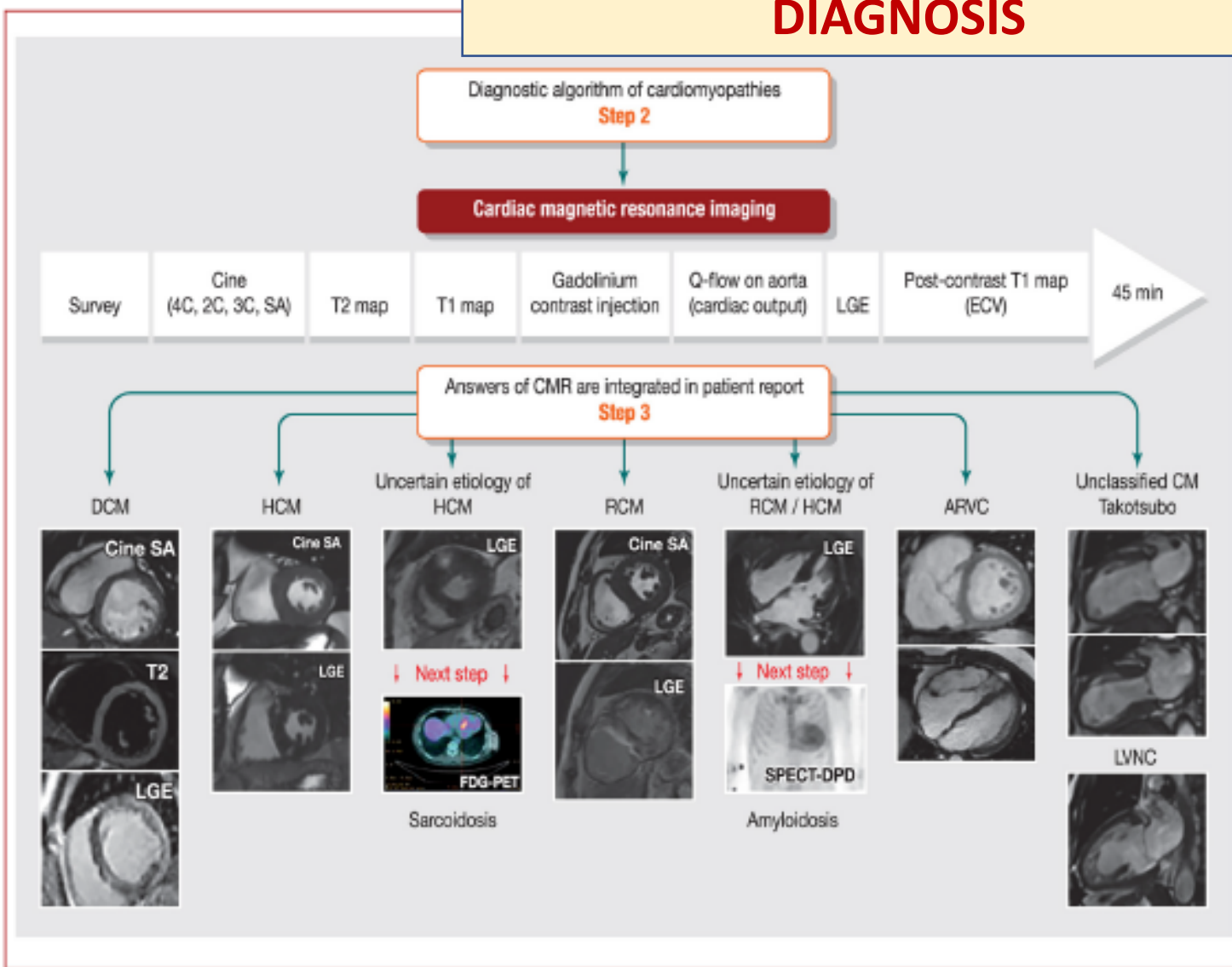


Figure 2. Steps 2 and 3 of the diagnostic algorithm for cardiomyopathies. 2C: two-chamber; 3C: three-chamber; 4C: four-chamber; ARVC: arrhythmogenic right ventricular cardiomyopathy; CM: cardiomyopathy; CMR: cardiac magnetic resonance imaging; DCM: dilated cardiomyopathy; DPD: diphosphono-1,2-propanodicarboxylic acid; ECV: extracellular volume; FDG: fluorodeoxyglucose; HCM: hypertrophic cardiomyopathy; LGE: late gadolinium enhancement; LVNC: left ventricular non-compaction; PET: positron emission tomography; RCM: restrictive cardiomyopathy; SA: short axis; SPECT: single-photon emission computed tomography.

RESEARCH

Open Access



Cardiovascular magnetic resonance images with susceptibility artifacts: artificial intelligence with spatial-attention for ventricular volumes and mass assessment

Marco Penso^{1,2*} , Mario Babbaro¹, Sara Moccia³, Marco Guglielmo¹, Maria Ludovica Careri^{1,4}, Carlo Maria Giacari¹, Mattia Chiesa^{1,2}, Riccardo Maragna¹, Mark G. Rabbat^{5,6}, Andrea Barison⁷, Nicola Martini⁷, Mauro Pepi¹, Enrico G. Caiani^{2,8†} and Gianluca Pontone^{1†}

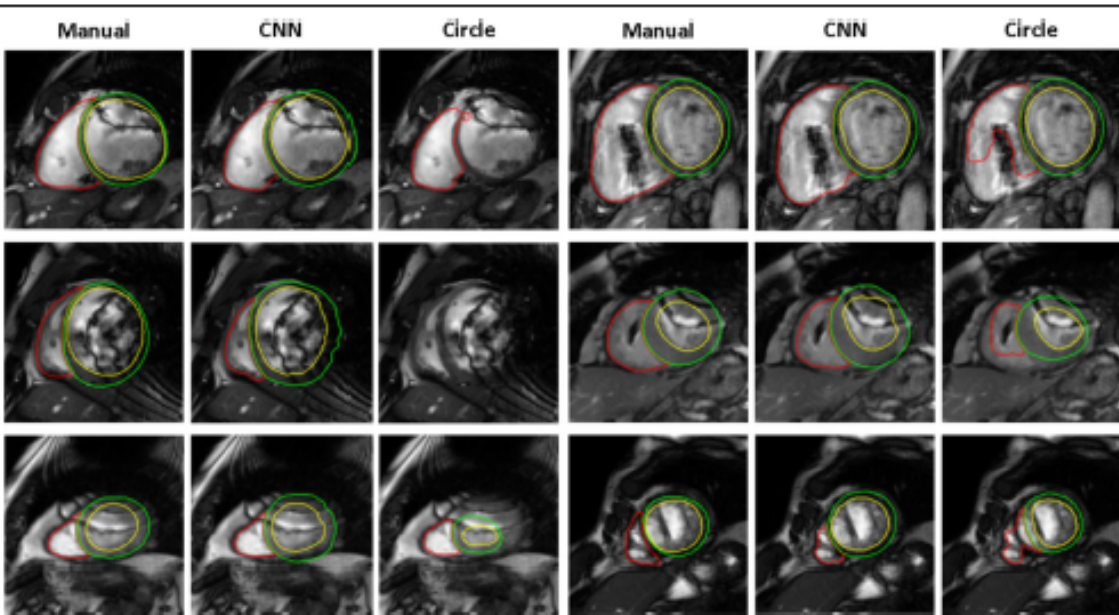


Fig. 4 Example of segmentation results obtained from short-axis CMR images affected by susceptibility artifacts using the developed CNN vs commercial CMR software (cvi42) compared to the manually traced gold standard at different slice locations (LV blood-pool: yellow; RV blood-pool: red; myocardium: green)

In this multicenter study, a novel deep CNN for automatic segmentation of cardiac structures in CMR images affected by magnetic susceptibility artifacts was developed and tested.

The developed method was able to obtain accurate image segmentation, matching expert physician performance and clinical measurement accuracy in both artifacts and artifacts-free cine CMR images.

This allows for automatic and faster segmentation of cardiac anatomy than manual tracing.

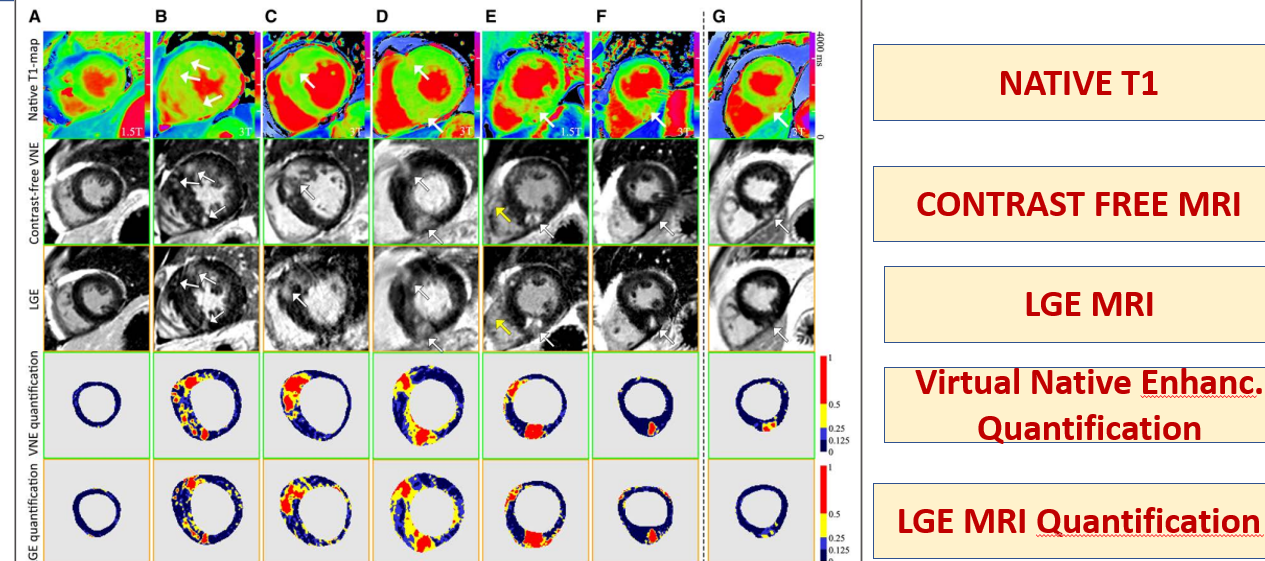
ORIGINAL RESEARCH ARTICLE

Toward Replacing Late Gadolinium Enhancement With Artificial Intelligence Virtual Native Enhancement for Gadolinium-Free Cardiovascular Magnetic Resonance Tissue Characterization in Hypertrophic Cardiomyopathy

Qiang Zhang¹, PhD; Matthew K. Burrage², MBBS; Elena Lukaschuk, MSc; Mayooran Shanmuganathan³, MBBS, MRCP; Iulia A. Popescu⁴, DPhil; Chrysovalantou Nikolaidou⁵, MD; Rebecca Mills, BSc; Konrad Werys⁶, PhD; Evan Hann⁷, DPhil; Ahmet Barutcu, MD; Suleyman D. Polat⁸, MD; Hypertrophic Cardiomyopathy Registry (HCMR) Investigators†; Michael Salerno, MD, PhD; Michael Jerosch-Herold⁹, PhD; Raymond Y. Kwong¹⁰, MD, MPH; Hugh C. Watkins¹¹, MD, PhD; Christopher M. Kramer, MD; Stefan Neubauer, MD; Vanessa M. Ferreira, MD, DPhil*; Stefan K. Piechnik¹², DSc, PhD*

Virtual Native Enhancement (VNE) is a new CMR technology that resembles conventional LGE but without the need for contrast administration.

VNE achieved high agreement with LGE in the distribution and quantification of lesions, with significantly better image quality



The VNE technology has the potential to change the current paradigm for CMR imaging, as it may allow significantly **faster, lower-cost, and contrast free CMR scans**, enabling frequent monitoring of myocardial tissue changes.



ESC

European Society
of Cardiology

Europace (2021) 23, 1072–1083

doi:10.1093/europace/evaa401

PROGNOSI: NON ISCHAEMIC DILATED CMP; ICD ?

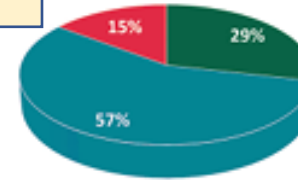
CarDiac magnEtic Resonance for prophylactic Implantable-cardioVerter defibrillAtor ThErapy in Non-Ischaemic dilated CardioMyopathy: an international Registry

Andrea Igoen Guaricci^{1†}, Pier Giorgio Masci^{2†}, Giuseppe Muscogiuri^{3‡},
Marco Guglielmo^{3‡}, Andrea Baggiano^{3‡}, Laura Fusini³, Valentina Lorenzoni⁴,
Chiara Martini^{5§}, Daniele Andreini^{3‡}, Anna Giulia Pavon⁶, Giovanni D. Aquaro⁷,
Andrea Barison⁷, Giancarlo Todiere⁷, Mark G. Rabbat⁸, Emily Tat⁸,
Claudia Raineri⁹, Adele Valentini¹⁰, Akos Varga-Szemes¹¹, U. Joseph Schoepf¹¹,
Carlo N. De Cecco^{11,12}, Jan Bogaert¹³, Monica Dobrovie¹³, Rolf Symons¹³,
Marta Focardi¹⁴, Annalaura Gismondi¹⁴, Jordi Lozano-Torres¹⁵,
José F. Rodriguez-Palomares^{15,16}, Chiara Lanzillo¹⁷, Mauro Di Roma¹⁷,
Claudio Moro¹⁸, Gabriella Di Giovine¹⁹, Davide Margonato¹⁹, Manuel De Lazzari²⁰,
Martina Perazzolo Marra²⁰, Alberto Nese²¹, Grazia Casavecchia²²,
Matteo Gravina²³, Francesca Marzo²⁴, Samuela Carigi²⁴, Silvia Pica²⁵,
Massimo Lombardi²⁵, Stefano Censi²⁶, Angelo Squeri²⁶, Alessandro Palumbo⁵,
Nicola Gaibazzi²⁷, Giovanni Camastra²⁸, Stefano Sbarbati²⁹, Patrizia Pedrotti³⁰,
Ambra Masi³⁰, Nazario Carrabba³¹, Silvia Pradella³², Mauro Timpani³³,
Gloria Cicala^{5§}, Cristina Presicci^{5§}, Sara Puglisi^{5§}, Nicola Sverzellati^{5§},
Vincenzo Ezio Santobuono¹, Mauro Pepi³, Juerg Schwitler^{6,34†}, and
Gianluca Pontone^{3,*,†,‡}

A composite clinical and CMR-based risk score provides incremental prognostic value beyond Standard Of Care evaluation, which may have impact on the indication of implantable cardioverter-defibrillator implantation.

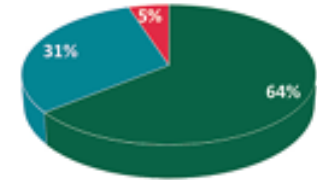
TTE-LVEF≤35%

Distribution of scores

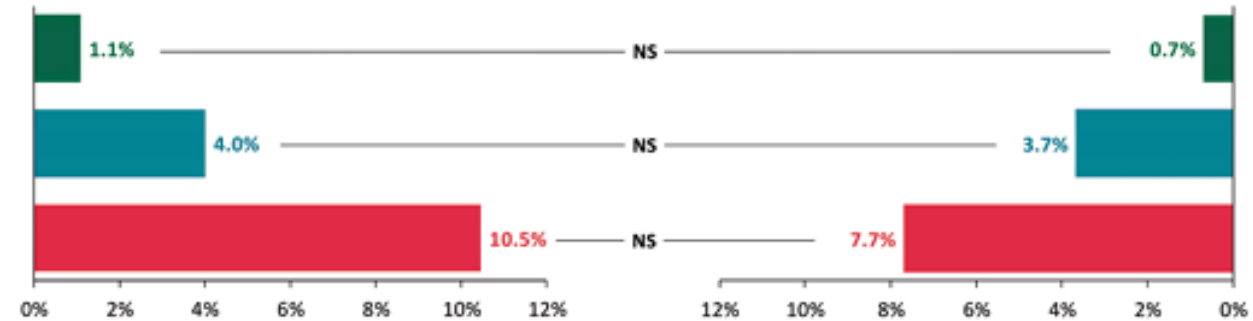


TTE-LVEF>35%

Distribution of scores



MAACE: event rate per 100 person-year

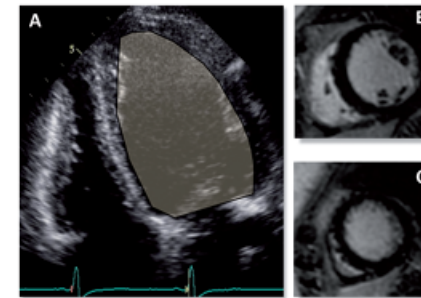


■ Composite Risk Score ≤2

■ 2< Composite Risk Score ≤5

■ Composite Risk Score >5

PATIENT A

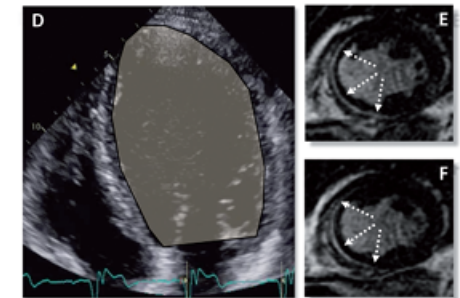


♀, 65 years
TTE-LVEF ≤35%
CMR LVEDVi ≤120.5 mL/m²
midwall LGE ≤3 myocardial segment

Composite Risk Score = 0

NO events

PATIENT B



♂, 45 years
TTE-LVEF >35%
CMR LVEDVi >120.5 mL/m²
midwall LGE >3 myocardial segment

Composite Risk Score = 7

Sudden Cardiac Death

Machine Learning in Hypertrophic Cardiomyopathy

Nonlinear Model From Clinical and CMR Features Predicting Cardiovascular Events

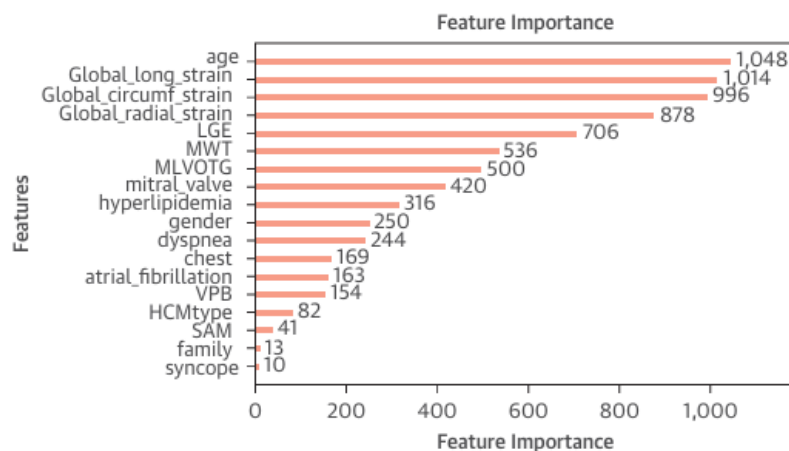
Kankan Zhao, PhD,^{a,b} Yanjie Zhu, PhD,^a Xiuyu Chen, MD,^c Shujuan Yang, MD,^c Weipeng Yan, BS,^c Kai Yang, MD,^c Yanyan Song, MD,^c Chen Cui, MD,^c Xi Xu, PhD,^c Qingyong Zhu, PhD,^a Zhuo-Xu Cui, PhD,^a Gang Yin, BS,^c Huaibin Cheng, MD,^a Minjie Lu, MD,^a Dong Liang, PhD,^a Ke Shi, MD,^d Lei Zhao, MD,^e Hui Liu, MD,^f Jiayin Zhang, MD,^g Liang Chen, MD,^c Sanjay K. Prasad, MD,^{h,i} Shihua Zhao, MD, PhD,^c Hairong Zheng, PhD^a

TABLE 1 Factors Used for Feature Selection

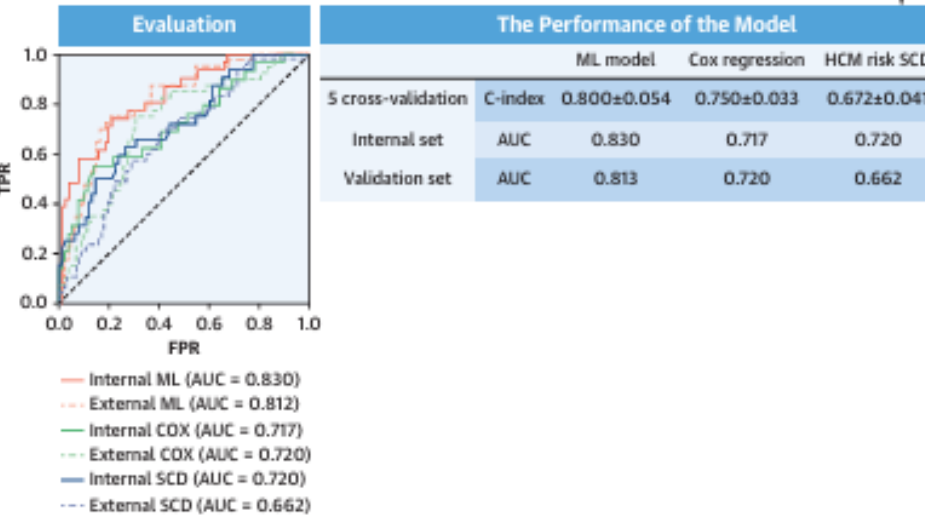
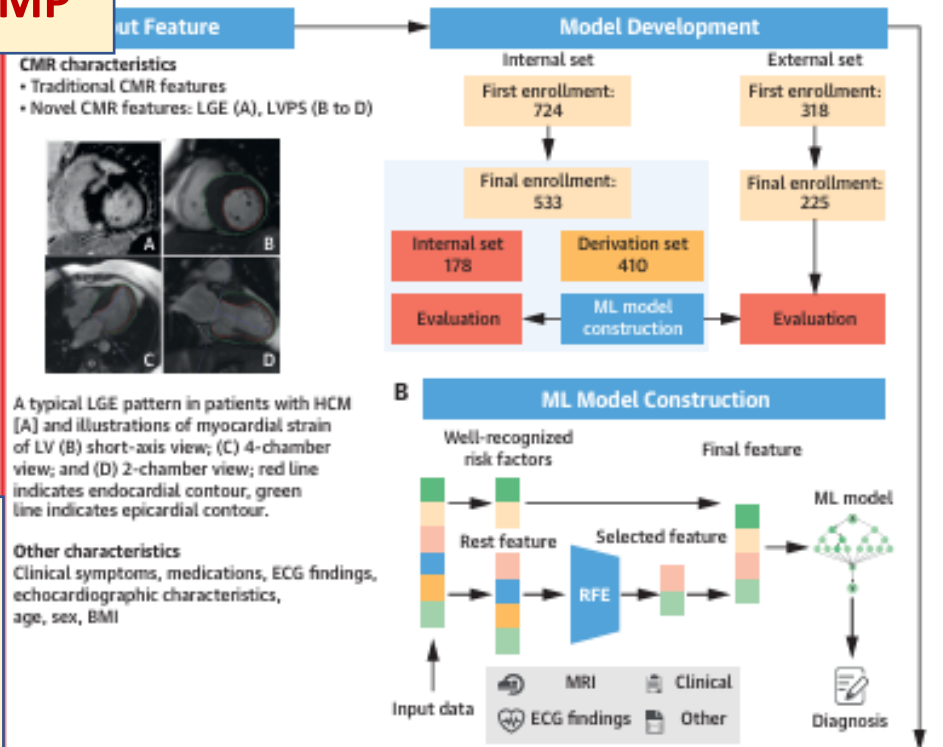
Category	Variables
Important risk factors	MWT, LAD, MLVOTG, family history of SCD, NSVT, syncope, age, LGE extent, LGE location, GRS, GCS, GLS
Other factors	SAM, atrial fibrillation, dyspnea, chest discomfort, palpitation, LVOT obstruction, VPB, LVEF, hypertension, LVEDD, LVEDVI, CI, hyperlipidemia, gender, NYHA functional class, mitral valve, diabetes, LBBB, LV aneurysm, BMI, LVESVI, SVT, HR, HCM type, family history of HCM

BMI = body mass index; CI = cardiac index; CMR = cardiac magnetic resonance; GCS = global circumferential strain; GLS = global longitudinal strain; GRS = global radial strain; HCM = hypertrophic cardiomyopathy; HR = heart rate; LAD = left atrial diameter; LBBB = left bundle branch block; LGE = late gadolinium enhancement; LV = left ventricular; LVEDD = left ventricular end-diastolic diameter; LVEDVI = left ventricular end-diastolic volume index; LVEF = left ventricular ejection fraction; LVESVI = left ventricular end-systolic volume index; LVOT = left ventricular outflow tract; MLVOTG = maximal left ventricular outflow tract gradient; MWT = maximum wall thickness; NSVT = nonsustained ventricular tachycardia; SAM = systolic anterior motion; SCD = sudden cardiac death; SVT = supraventricular tachycardia; VPB = ventricular premature beat.

FIGURE 3 Factors Used for the Models



The ML-derived risk stratification approach performs better than the top of the usual risk stratification approaches (HCM Risk-SCD model).



Editorial

Artificial Intelligence in Cardiology: Why So Many Great Promises and Expectations, but Still a Limited Clinical Impact?

Gian Luigi Nicolosi 

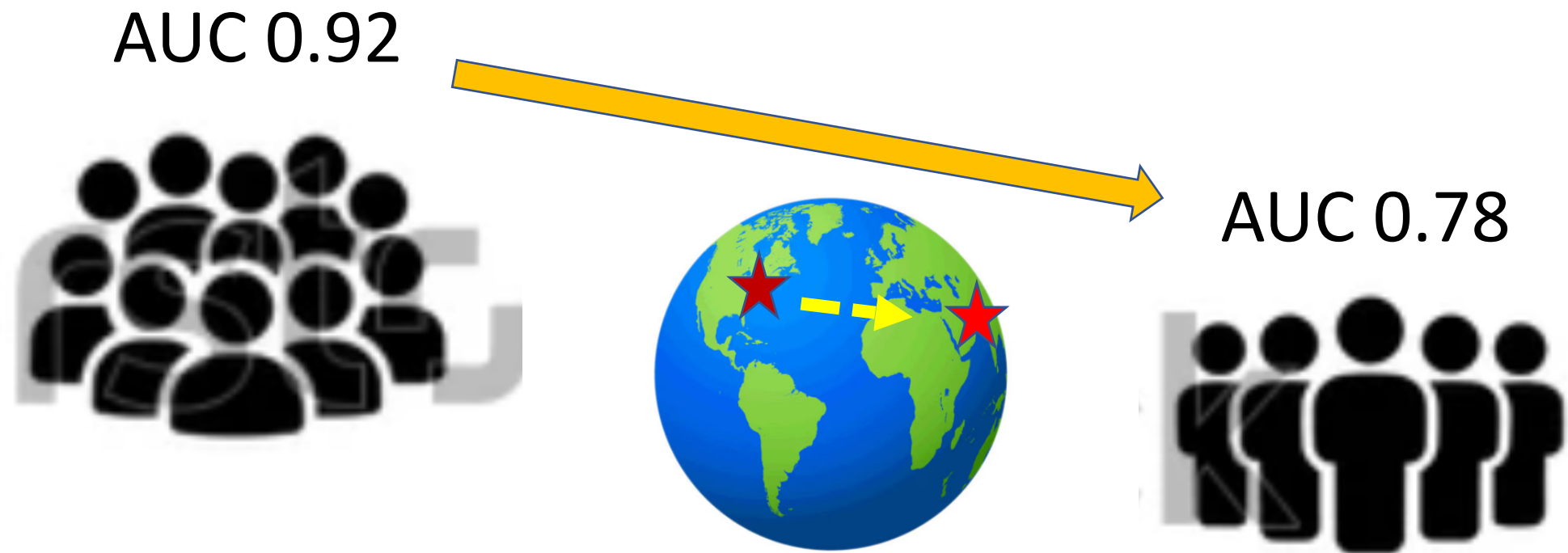
Division of Cardiology, Policlinico San Giorgio, 33170 Pordenone, Italy; gianluigi.nicolosi@gmail.com

Despite this apparent tremendous potential, the impact of AI in current clinical cardiology practice is still limited

Some difficulties seem to derive from the apparent relative “isolation” of several AI experiences:

Some of these problems are related to the certification of AI products as medical devices, to the privacy protection, to legislative and legal and responsibility issues in the case of derived wrong medical decisions, to the transparency and the physiological plausibility of AI results

Applying an Artificial Intelligence (AI) medical device to a new population —often called **covariate shift** or **data drift**—carries significant risks. Algorithms trained on data from one demographic or hospital can experience **severe performance drops when used on different patient groups**, threatening diagnostic accuracy and patient safety.



AI CONTRADDIZIONI SUL CONCETTO DI SUPERVISIONE



- La trasparenza è un elemento chiave per garantire il controllo dei dati personali. Il Garante Privacy e il Regolamento europeo sull'IA (AI Act, art. 14) sottolineano che l'uso di sistemi di IA in ambito sanitario deve prevedere sempre una **supervisione umana qualificata da parte di professionisti medici**.



MA.....

- DATI AUTOMATICI:

- «ESPERIENZA»



In PASSATO MISURE
DEGLI OPERAI
DIRETTE AD ESEMPIO
CON FILO A PIOMBO

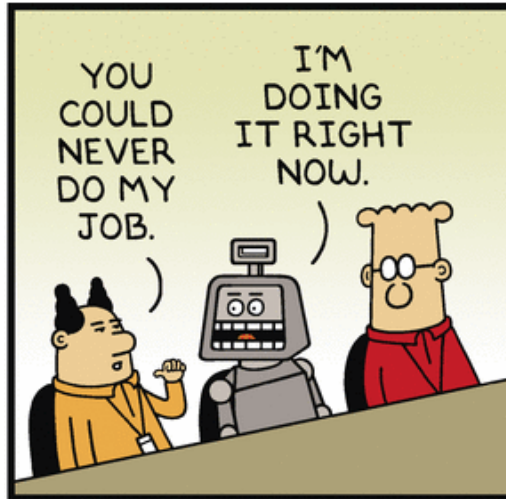


2026:
MISURE CON LASER
QUALCUNO CONTROLLA
SE IL DATO E' ACCURATO ?

Contraddizione SUL concetto di SUPERVISIONE



In ... positivo però...



Source: Dilbert

Review

Beyond Computer-Aided Diagnosis: Artificial Intelligence as a “Digital Mentor” for POCUS Image Acquisition and Quality Assurance: A Narrative Review

Hyub Huh¹ and Jeong Jun Park^{2,*} 

**A La diffusione de:
devices (Ecografi)
può limitare la
mentorship >>>>
RIDUZIONE
QUALITA' E RISCHI
POTENZIALI**

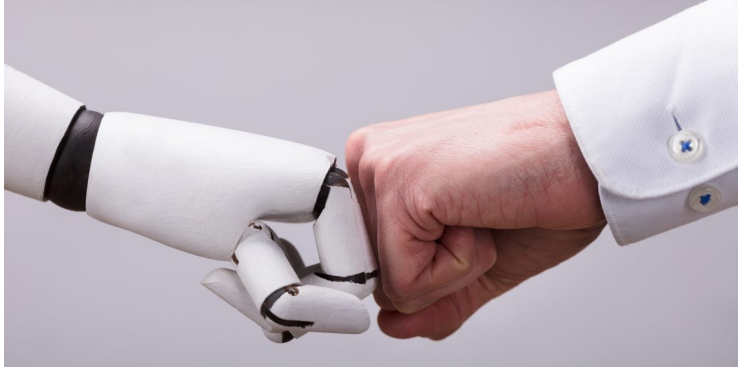


**B: L'AI , CON
ACQUISIZIONI
GUIDATE E
FEEDBACK DI
ESPERTI CIRCA LA
QUALITA' DEGLI
ESAMI PUO' EVITARE
TALI RISCHI**

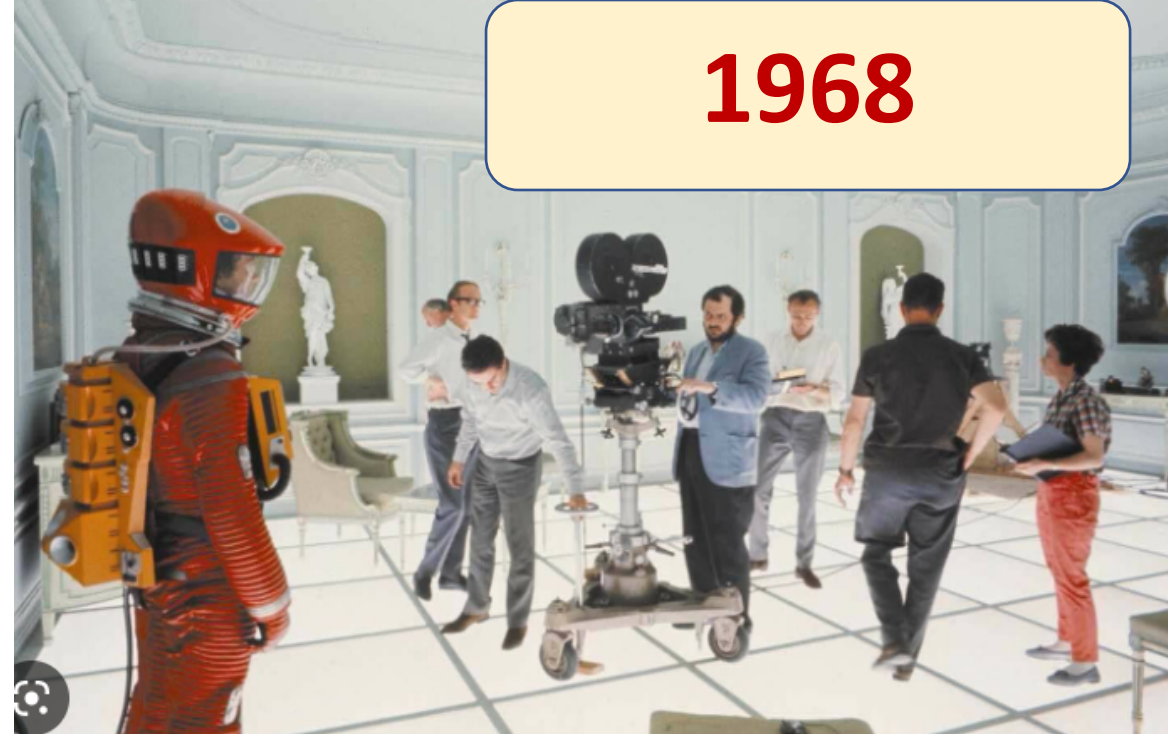


Stanley Kubrick

“I remember [Spielberg] described the movie as mostly being about your responsibility to intelligence,”



Technology plays a crucial role, raising the question of how technology influences mankind. Is man really in control of his tools, or is he rather enslaved by his machines and their growing complexities?



1968

