# RISONANZA MAGNETICA: IMPORTANZA DIAGNOSTICA E SVILUPPI FUTURI

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Roma, 7 novembre 2013



# BACKGROUND

European Heart Journal (2005) 26, 325doi: 10.1093/eurheartj/ehi084



Editorial

## Can cardiac pa imaging system

Edward T. Martin\*

Oklahoma Heart Institute, Tulsa



ro Cardiologico

### **Expert Consensus Document**

ACCF/ACR/AHA/NASCI/SCMR 2010 Expert Consensus Document on Cardiovascular Magnetic Resonance A Report of the American College of Cardiology Foundation Task Force on Expert Consensus Documents

Currently, pacemakers available in the United States are labeled as MR unsafe.<sup>362</sup> At present, CMR examination of patients with pacemakers is discouraged and should only be considered at highly experienced centers in cases in which there is a strong clinical indication and where the benefits clearly outweigh the risks. CMR examination of patients with ICDs should not be performed unless the center is highly experienced in both the operation of these devices and in complex CMR procedures in the setting of highly compelling circumstances where the benefits clearly outweigh the risks.



## **PM and CMR: epidemiology**

More than 30 million MRI scan were performed each year in over the world



Between 50 and 75% of patients with device would need an MRI and will not be scanned<sup>1,2</sup>

□ The likelihood of MRI after 65 yo doubles<sup>1</sup>

Kalin R, et al. *Pacing Clin Electrophysiol*. 2005;28:326-328.
Kanal E, et al. *AJR AM J Roentgenol*. 2004;182:1111-1114



1. Magnetic Resonance Imaging (MRI) Equipment – A Global Strategic Business Report, Global Industry Analysts, Inc., San Jose, CA. 2002

2. Roguin A. Europace 2008; 10: 336–346 3. Sakakibara et al., Jpn Heart J 1999



Autore	Rivista	Anno	Paz.	N° MRI	Anatomia	Campo	SAR	PM setup	Effetti principali
Iberer F	Herz	1987	1	1	Torace	1.5	-	Sincrono	Asincrono
Johnson D	PACE	1994	4	-	-	-	-	-	Inibizione
Achenbach S	Z Kardiol	1995	1	1	-	0.5	-	-	Nessuno
Gimbel JR	Pac Clin Electr	1996	4	4	Varie	0.5-1.5	-	OOO (2), DOO (2)	Artefatti Pausa 2 sec
Fontain JM	Pac Clin Electr	1997	1	1	Encefalo	1.5	-	VVI	Pacing Ventricolare
Garcia-Bolao I	lumber	of N	<b>IRI</b> :	scan:	593	1	-	AOO	Asincrono
Sommer T					/	0.5	0.6	AOO (2), VOO (21), DOO (26), VVI (2)	Disattivazione Reed Switch
Valhaus C	Pac Clin Electr	2001	32	32	Varie (2)	0.5	-	AOO (1), VOO (16), DOO (15)	Riduzione batteria Disattivazione Reed Switch
Juratli N	Chest M	RIs	can	• 45 (8	<b>?%</b> )		-	Asincrono	Nessuno
Schmiedel A		111 30	can	0 (0	,,,,	1.5	-	-	Disattvazione Reed Switch
Martin ET	JACC	2004	54	78	Varie (3)	1.5	0.08- 2.0	Sincrono	Alterazione soglia di stimolazione
Del Ojo JL	Pac Clin Electr	2005	13	13	Varie	2	-	DDD	Nessuna
Gimbel JR	Paci Clin Electr	2005	-	11	Varie	1.5	1-2	VOO, DOO	Nessuno
Sommer T	Circulation	2006	82	115	Varie	1.5	1.5	Fc<60 AOO, VOO, DOO Fc≥60 OAO, OVO, ODO	Aumento soglia di cattura PM reset
Nazarian S	Circulation	2006	23	31	Varie (31)	1.5	<2.0	PM dipendenti: VOO, DOO PM indipendenti: VVI, DDI	Attivazione Reed Switch
Goldsher D	Isr Med Assoc	2006	-	3	Encefalo	1.5	3.7	Pacing off, OVO, ODO	Nessuno
Heatlie G	J Cardiovasc Magn Res	2007	-	5	Cuore	0.5	-	000, DDD, VVI, VVIR	Pacing a 100 bpm in modalità VVI
Sierra M	Rev Cardiovasc Med	2008	-	40	-	-	-	000	Nessuno
Naehle CP	Radiology	2008	-	51	Encefalo	3	≤3.2	Fc<60 bpm asincrono Fc≥60 bpm solo sensing	Riduzione batteria PM reset
Gimbel JR	Pac Clin Electr	2008	-	5	Varie	3	≤2.0	PM indipendenti: PM dipendenti	Nessuno
Mollerus M	Pac Clin Electr	2008	-	40	Varie (1)	1.5	2.4	DDI, VVI	Nessuno



Potential complications of CMR under these circumstances Include:

1 damage or movement of the device

- (2) inhibition of the pacing output
- ③ activation of the tachyarrhythmia therapy of the device
- (4) cardiac stimulation

(5) heating of the electrode tips









13 reported deaths of pacemaker patients have been attributed to MRI

EUROPEAN SOCIETY OF

Europace (2005) 7, 353-365

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REVIEW

Do we need pacemakers resistant to magnetic resonance imaging?

Werner Irnich <sup>a,\*</sup>, Burkhard Irnich <sup>b</sup>, Christine Bartsch <sup>a</sup>, Wilhelm Alfred Stertmann <sup>c</sup>, Hubert Gufler <sup>b</sup>, Guenter Weiler <sup>a</sup> Irnich reported already 6 deaths in Germany between 1992 and 2001

	•	•	
Fibrillation	Mag. rate	PM brand/type	MRI/strength
Unknown	100 min <sup>-1</sup>	Vitatron/TX 915	Picker/0.5 T
Yes	65 min <sup>-1</sup>	Medtronic/Minix	Philips/0.5 T
Yes	55 min <sup>-1</sup>	Medtronic/Pasys	Philips/0.5 T
Unknown	100 min <sup>-1</sup>	Siemens/Prolog	Philips/1.5 T
Yes	70 min <sup>-1</sup>	Biotronik/NeosLP	G. E./1.5 T
Unknown	$100  min^{-1}$	Vitatron/Ceryx 3	Siemens/1.0 T
	Fibrillation Unknown Yes Yes Unknown Yes Unknown	Fibrillation     Mag. rate       Unknown     100 min <sup>-1</sup> Yes     65 min <sup>-1</sup> Yes     55 min <sup>-1</sup> Unknown     100 min <sup>-1</sup> Yes     70 min <sup>-1</sup> Unknown     100 min <sup>-1</sup> Yes     70 min <sup>-1</sup>	FibrillationMag. ratePM brand/typeUnknown100 min^{-1}Vitatron/TX 915Yes65 min^{-1}Medtronic/MinixYes55 min^{-1}Medtronic/PasysUnknown100 min^{-1}Siemens/PrologYes70 min^{-1}Biotronik/NeosLPUnknown100 min^{-1}Vitatron/Ceryx 3

Table 4 Cause of death, magnet rate of models and magnetic field strength of MRI units of the six cases of Table 3

Fibrillation means "ventricular fibrillation". PM = pacemaker, Mag. = magnet, MRI = magnetic resonance imaging.



Mortality reports suggest that the heart was not the organ under examination by MR. Although not explicitly stated, it is highly likely that this means that no ECG was being monitored during the MR, and that no measures were taken to reduce the risk of the MR scan.

Several authors have shown that in non-pacemaker dependent patients who have implanted pacemakers, the pacemaker can be turned off for the duration of the scan and the lead set to bipolar mode\

No deaths and no significant complications have resulted from CMR scans being performed in this manner at low field, gradient, and RF sequence settings.



Faris OW PACE 2009: FDA viewpoint on MRI and PM

"... while FDA recognize that there are pacemaker and ICD patients for whom, on a-case-by-case basis, the diagnostic benefit from MRI otweights the presumed risks, we believe that those risks have not yet been chracaterized and mitigated sufficiently to justify the routine use of MRI in those population ... "

## **Researchers Seek MRI-Safe Pacemakers**

JAMA, February 4, 2009-Vol 301, No. 5 (Reprinted)



Although MRI is indicated for up to 75% of patients with this cardiac device, only those who have certain types of pacemakers might be eligible for the procedure—and even then, MRI for patients with such pacemakers remains controversial because it is not approved



□ CMR images can be acquired throughout the body in any tomographic plane without limitations imposed by body habitus.

□ Ability to quantify with relatively high spatial and temporal resolution meaningful measures of cardiovascular structure with a voxel sizes up to 1x1x3 cm in a 1.5 T scanner and with frame rates up to 20 - 40 msec.

□ CMR is a flexible imaging modality that allows assessment of multiple different parameters of cardiovascular anatomy and function. As mentioned, CMR can define cardiovascular anatomy and structure, characterize tissue composition(including myocardial viability), measure function in terms of heart wall motion or blood flow, assess metabolism with spectroscopic techniques, visualize and quantify myocardial perfusion.



## **ADVANTAGES OF CMR: radiation exposure issue**

### Scientists Say F.D.A. Ignored Radiation Warnings

By GARDINER HARRIS Published: March 28, 2010

WASHINGTON — Urgent warnings by government experts about the risks of routinely using powerful CT scans to screen patients for <u>colon cancer</u> were brushed aside by the <u>Food and Drug</u> <u>Administration</u>, according to agency documents and interviews with agency scientists.

SIGN IN TO RECOMMEND
TWITTER
E-MAIL
SEND TO PHONE

#### Calif. governor signs medical radiation bill into law

By <u>Eric Barnes</u> AuntMinnie.com staff writer September 30, 2010

Gov. Arnold Schwarzenegger of California on Wednesday signed a medical radiation protection bill into law, paving the way for implementation of the first state law in the U.S. aimed at protecting patients from excessive radiation exposure received during CT scans and radiation therapy procedures.

SB 1237, which the governor signed without comment along with scores of other bills, will impose strict new procedures and reporting requirements to protect patients from medical radiation overdoses when it becomes effective July 1, 2012. The bill also provides an accreditation mandate for CT scanners that will take effect January 1, 2013, six months after the other provisions.

The bill requires that radiation dose be recorded on the scanned image and in a patient's health records, and that radiation overdoses be reported to patients, treating physicians, and the state Department of Public Health (DPH). It requires the same level of monitoring for therapeutic radiation used to treat cancer.



Centro Cardiologico Monzino

## **ADVANTAGES OF CMR: radiation exposure issue**

Table 1: Radiation doses and estimated cancer risk from common radiological examinations and isotope scans

Type of test	Effective radiation dose (mSv)	Equivalent period of natural background radiation	Lifetime additional risk of cancer/examination	Lost life expectancy	Equivalent n. of chest x-rays
Chest radiograph	0.01	A few days	Negligible risk	2 minutes	I
Skull radiograph	0. i	A few weeks	Minimal risk (1 in 100,000 to 1 in1,000,000)	20 minutes	5
Lung isotope scan		A few months to a year	Very low risk (1 in 10,000 to 1 in 100,000)	3 hrs	50
Cardiac gated study	10	A few years (4 years)	Low risk (1 in 2,000)	2 days	500
Thallium scan	20	(8 years)	(1 in 1,000)	4 days	1000

#### Picano E Cardiovasc Ultrasound 2006

Radiation Protection of Patients Undergoing Cardiac Computed Tomographic Angiography

LAR (F, 20 y): 0.7%

1 pts in 143

Andrew J. Einstein

JAMA. 2009;301(5):545-547 (doi:10.1001/jama.2009.53)

http://jama.ama-assn.org/cgi/content/full/301/5/545

LAR (M, 80 y):

0.075%

1 pts in 1338



Online article and related content current as of August 3, 2009.





Clinical Change	Echo (SD/N)	MRI (SD/N)	Reduction in sample size (%)
EDV, 10 ml	23.8/121	7.4/12	90
ESV, 10 ml	15.8/53	6.5/10	81
EF, 3%	6.6/102	2.5/15	85
Mass, 10 gr	36.4/273	6.4/9	97

Bellinger NG J Cardiovasc Magn Reson 2000



# CAD

## **ADVANTAGES OF CMR**

□ Regional myocardial function may be assessed using CMR Tagging. In this method, specialized radiofrequency pulses are applied prior to the beginning of the cine CMR pulses sequence. These additional pulses result in alteration of the magnetic properties of the heart, typically in a grid stripe pattern.

### 2D Tagging (FGRE)

224 x 192 / 8 vps 7 mm slice thickness 35 cm FOV 12° flip angle TE/TR = 1.7/4.3ms Tag spacing: 5 pixels





Valutazione della perfusione del mdc nel miocardio:

- velocità acquisizione ( elevato frame/rate )
- massima copertura (8 fette / 2 intervalli R-R)
- sincronizzazione cardiaca
- multifasica, fortemente T1 pesata
- massima soppressione basale del miocardio

### **FIESTA Time Course**

### Asset Te 1.2ms TR 2.8ms flip°36 Tl 119ms 0.5Nex 125kHz FOV 40 128x128 thk 8mm 4 slices/1 R-R 60 phases Rest phase : 20ml DTPA at 5ml





CAD



Journal of the American College of Cardiology © 2007 by the American College of Cardiology Foundation Published by Elsevier Inc. Vol. 50, No. 14, 2007 ISSN 0735-1097/07/\$32.00 doi:10.1016/Ltace.2007.06.030 1 Cardiac In IWMA 8. **Diagnostic Performance of Stress** .6 **Cardiac Magnetic Resonance Imaging** in the Detection of Coronary Artery Disease .4 IWMA A Meta-Analysis .2 Kiran R. Nandalur, MD,\* Ben A. Dwamena, MD,\*† Asim F. Choudhri, MD,‡ 0 Mohan R. Nandalur, MD, § Ruth C. Carlos, MD, MS\* 2 ß Ann Arbor, Michigan; Charlottesville, Virginia; and Washington, DC Prior Probability Figure 3

A meta-analysis of all CMR perfusion studies demonstrated a sensitivity of 91% and specificity of 81% for the diagnosis of CAD on a per-patient level.







Three-year event-free survival has been reported at 99.2% for patients with normal stress perfusion CMR or DS CMR and 83.5% for those with abnormal stress perfusion or DS CMR. Ischemia suggested by stress perfusion CMR or DS CMR is predictive of cardiac events over the 3-year time period with hazard ratios of 12.5 and 5.4, respectively,

# CAD

## **ADVANTAGES OF CMR**

The Lancet, Early Online Publication, 23 December 2011 doi:10.1016/S0140-6736(11)61335-4 Cite or Link Using DOI

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#### Findings

In the 752 recruited patients, 39% had significant CHD as identified by x-ray angiography. For multiparametric CMR the sensitivity was 86-5% (95% CI 81-8-90-1), specificity 83-4% (79-5-86-7), positive predictive value 77-2%, (72-1-81-6) and negative predictive value 90-5% (87-1-93-0). The sensitivity of SPECT was 66-5% (95% CI 60-4-72-1), specificity 82-6% (78-5-86-1), positive predictive value 90-5% (87-1-93-0). The sensitivity of SPECT was 66-5% (95% CI 60-4-72-1), specificity 82-6% (78-5-86-1), positive predictive value 71-4% (65-3-76-9), and negative predictive value 79-1% (74-8-82-8). The sensitivity and negative predictive value of CMR and SPECT differed significantly (p<0-0001 for both) but specificity and positive predictive value did not (p=0-916 and p=0-061, respectively).



# CAD

## **ADVANTAGES OF CMR**

Early after the first pass of Gd, a significant fraction of the injected Gd enters the interstitial space. Several minutes

after intravenous administr distribution available in r results in a higher conce what is present in viable referred to as "delayed gadolinium enhancement" myocardial scars as defir recovery after revasculariz





Kim RJ Circulation 1997 Fieno DS JACC 2000 Rehwald WG Circulation 2002



Impact of Unrecognized Myocardial Scar Detected by Cardiac Magnetic Resonance Imaging on Event-Free Survival in Patients Presenting With Signs or Symptoms of Coronary Artery Disease

Raymond Y. Kwong, MD, MPH; Anna K. Chan, MBBS; Kenneth A. Brown, MD; Carmen W. Chan. MBBS: H. Glenn Revnolds, MSc; Sui Tsang, BS; Roger B. Davis, ScD



*Conclusions*—Among patients with a clinical suspicion of coronary artery disease but without a history of MI, LGE involving a small amount of myocardium carries a high cardiac risk. In addition, LGE provides incremental prognostic value to MACE and cardiac mortality beyond common clinical, angiographic, and functional predictors. (*Circulation*. 2006;113:2733-2743.)





Incremental Prognostic Significance of Combined Cardiac Magnetic Resonance Imaging, Adenosine Stress Perfusion, Delayed Enhancement, and Left Ventricular Function Over Preimagin



value for prediction of adverse events over pre-CMR data and can be combined to further enhance prognostication. Normal combined CMR confers a low risk of subsequent cardiac events. (*Circulation*. 2011;123:1509-1518.)



## ADVANTAGES OF CMR: clinical case 1

#### History

.

305 B plano 3E Plurimi episodi febbrili. Ad Rx torace cardiomegalia. Eco TT del 10/02 mostrava VS dilatato con alterazioni della cinesi in sede inferiore e posterolaterale con FE del 20%. Settore destro dilatato con TAPSE normale



CAD

ED: 1.8 mSv



## ADVANTAGES OF CMR: clinical case 2



55-year-old man admitted with pulmonary edema severe LV enlargement and dysfunction and evidence of 3-vessels diseas at ICA.

	1				
1M	post CABG	3M post	7	6M	post
120	LV Function	Pre	1M	3M	6M
Lenc.	EDV (ml) ESV (ml)	450 375	350 255	207 110	200 105
	SV (ml) EF (%)	75 17	95 27	97 47	95 47.5



## ADVANTAGES OF CMR: clinical case 3



## 51-year-old man with suspected CAD









### Hypertrophic Cardiomyopathy

### **ADVANTAGES OF CMR**



Figure 4. (A and B) Patterns of hyperenhancement in hypertrophic cardiomyopathy by cardiovascular magnetic resonance. The patterns of hyperenhancement are grouped into diffuse or confluent type (upper rows: long-axis, vertical, or horizontal; lower rows: shown. The different patterns may have clinical or prognostic significance, and this qualitative classification may complement the overall quantification of hyperenhancement. RV = right ventricular.

...

## **Clinical case 1**

### Hypertrophic Cardiomyopathy

#### History

REPARTO 1A - LETTO 104

Paziente di 37 anni, dal 2007 nota cardiomiopatia ipertrofica ostruttiva. Da 3 mesi dispnea ingravescente ed astenia (NYHA III). ECO TT SIV/ PP 22/17, SAM del LAM, gradiente sistolico 66 mmHg, IM moderata. Holter: una sola tripletta di BEV.







Characteristics of ARVD include global or regional dilatation and dysfunction of the RV (and in some cases, the LV) myocardium. Furthermore, fatty and/or fibrous replacement may be found. Morphological and functional targets for CMR include regional or global wall motion abnormalities, aneurysms, and segmental or global dilation, as well as global hypokinesis, with quantitative analysis of RV volume and function



### Myocarditis

### **ADVANTAGES OF CMR**

Journal of the American College of Cardiology © 2005 by the American College of Cardiology Foundation Published by Elsevier Inc. Vol. 45, No. 11, 2005 ISSN 0735-1097/05/\$30.00 doi:10.1016/j.jacc.2004.11.069

#### Diagnostic Performance of Cardiovascular Magnetic Resonance in Patients With Suspected Acute Myocarditis

#### Comparison of Different Approaches

Hassan Abdel-Aty, MD,\* Philipp Boyé, MD,\* Anja Zagrosek, MD,\* Ralf Wassmuth, MD,\* Andreas Kumar, MD,\* Daniel Messroghli, MD,\* Petra Bock, MD,\* Rainer Dietz, MD,\* Matthias G. Friedrich, MD, FESC,\*† Jeanette Schulz-Menger, MD\*

Berlin, Germany; and Calgary, Alberta, Canada



Figure 5. Diagnostic performance of T2, late gadolinium enhancement (LGE), and global relative enhancement (GRE) as compared to the "any-two" approach. Spotted bars = sensitivity; diagonal striped bars = specificity; solid bars = diagnostic accuracy.



1) A combined CMR approach using T2-weighted imaging, early and late gadolinium enhancement, provides a high diagnostic accuracy in the diagnosis and assessment of patients with suspected acute myocarditis.





### ATRIAL FIBRILLATION



## Pre – RFCA characterization of LA



### ATRIAL FIBRILLATION

## **ADVANTAGES OF CMR**



### ATRIAL FIBRILLATION

### **ADVANTAGES OF CMR**



## **REGISTRO ITALIANO CMR**

Centri Arruolati 38: GENNAIO 2011 – GIUGNO 2011

### ► Centri attivi 36 (all' 8-3-2011)

Ascoli Piceno, Avellino, Bassano del Grappa, Bologna, Cagliari, Campobasso, Lamezia Terme, Chieti, Como, Firenze, Ferrara, Genova, Guastalla(RE), L'Aquila, Messina, Milano 6, Modena, Palermo, Pozzuoli (Na), Rimini, Roma 5, Rovigo, Trento, Torino, Trieste, Schio (Vi), Varese.





# **PM and CMR: possible solutions**

### **EnRhythm MRI trial**

Magnetic resonance imaging in patients with a pacemaker system designed for the magnetic resonance environment

Bruce L. Wilkoff, MD, FHRS, CCDS,\* David Bello, MD,<sup>†</sup> Milos Taborsky, MD, PhD, FESC,<sup>‡</sup> Josef Vymazal, MD, PhD,<sup>‡</sup> Emanuel Kanal, MD, FACR, FISMRM,<sup>§</sup> Hubertus Heuer, MD,<sup>||</sup> Katrin Hecking, MD,<sup>||</sup> W. Ben Johnson, MD, CCDS,<sup>¶</sup> William Young, MD,<sup>¶</sup> Brian Ramza, MD, PhD,<sup>\*\*</sup> Naveed Akhtar, MD,<sup>\*\*</sup> Bernhard Kuepper, MD,<sup>††</sup> Peter Hunold, MD,<sup>††</sup> Roger Luechinger, PhD,<sup>‡‡</sup>

JAMA 2011

Mike Mitka

2011

## First MRI-Safe Pacemaker Receives Conditional Approval From FDA

□ The approval, announced February 8, limits the device's use in MRIs to certain patients (not- depended, implanted more than 6 weeks) imaging of certain parts of the body (neck and abdomen), under certain scanning parameters (Magnetic Field 1.5 T; SAR ≤ 2 W/kg; Slew Rate < 200



# THANK YOU FOR YOUR ATTENTION



Centro Cardiologico Monzino Department of Cardiovascular Sciences and Community Health, University of Milan Prof. Cesare Fiorentini

Area of Cardiovascular Imaging Dr. Mauro Pepi

Cardiovascular MR Unit Gianluca Pontone, MD

Radiology Unit Enrica Nobili, MD

Cardiovascular CT Unit Daniele Andreini, MD

Cardiologist Paola Gripari, MD Erika Bertella, MD Saima Mushtaq. MD

Radiologist Andrea Annoni, MD Alberto Formenti, MD Maria Petulla, MD

Fellows: Monica Loguercio, Chiara Segurini, Andrea Baggiano, Edoardo Conte, Virginia Beltrama.