Argentine National Cardiac Magnetic Resonance Imaging Registry (RENAREC)

Registro Nacional Argentino de Resonancia Cardíaca (RENAREC)

SANTIAGO L. DEL CASTILLO[1*,], GUILLERMO JAIMOVICH[2,], LUCIANO DESTEFANO[3, MTSAC,], MACARENA DE ZAN[4, MTSAC,], AGUSTINA SCIANCALEPORE[5,], PAZ RICAPITO[5,], JORGE CASAS[6,MTSAC,], FEDERICO CINTORA[7,MTSAC,], MARIANO ESTOFAN[8,].
ON BEHALF OF THE COUNCIL OF COMPUTED TOMOGRAPHY AND CARDIAC RESONANCE, ARGENTINE SOCIETY OF CARDIOLOGY

ABSTRACT

Background: The usefulness of cardiac magnetic resonance imaging (MRI) has greatly increased in the last years. Different international registries have been published on its use; however, there is no data available from Argentina.
Objective: The aim of this study was to evaluate different indications, protocols, safety and therapeutic consequences of cardiac MRI in Argentina.
Methods: A prospective national registry was designed with collection of demographic data, indications for cardiac MRI, associated complications, diagnoses and therapeutic consequences.
Results: A total of 34 centers from 10 provinces of Argentina (85% private and 59% with inpatient capacity) participated in the study, including 1131 patients (mean age 54±18 years and 61% males). The main indications for cardiac MRI were hypertrophic cardiomyopathy (13.9%), and ventricular arrhythmia (12.3%). In 99.7% of cases, no study complications were reported. The most frequent results of cardiac MRI were: normal (31.2%), non-ischemic cardiomyopathy (14.7%), ischemic-necrotic cardiomyopathy (11.6%) and hypertrophic cardiomyopathy (8.9%). Clinical suspicion was confirmed in 23.6% of cases and cardiac MRI generated an unsuspected new diagnosis in 48.7% of cases. The main therapeutic consequences were hospital discharge (31.6%) followed by change in medication (28.1%).
Conclusions: Cardiac MRI is widely used in Argentina, mainly in private centers with a very low incidence of complications. Cardiomyopathies (hypertrophic and dilated) and ventricular arrhythmia are its main indication, and it provides a new unsuspected diagnosis in almost half of the cases. Further studies are required to assess its clinical and therapeutic impact.

Key words: Cardiovascular Magnetic Resonance - Therapeutic implications - Cardiomyopathies - Registries - Argentina

RESUMEN

Introducción: La utilidad de la resonancia magnética cardíaca (RMC) ha crecido ampliamente en los últimos años. En los últimos años se han publicado distintos registros internacionales sobre su uso, pero no contamos con este tipo de información en Argentina.
Objetivo: Evaluar indicaciones, protocolos utilizados, seguridad y consecuencias terapéuticas de la RMC en la República Argentina.
Materiales y métodos: Se diseñó un registro prospectivo a nivel nacional con recolección de datos demográficos, indicaciones de RMC, complicaciones asociadas, diagnósticos y consecuencias terapéuticas.
Resultados: Participaron 34 centros de 10 provincias de Argentina (85% centros privados, 59% centros con internación). Se incluyeron 1131 pacientes (edad 54±18 años, 61% varones). Las principales indicaciones para el estudio de RMC fueron la miocardiopatía hipertrófica (13,9%) y la arritmia ventricular (12,3%). El 99,7% de los estudios fueron reportados sin complicaciones. Los resultados más frecuentes de la RMC fueron: normal (31,2%), miocardiopatía no isquémica (14,7%), miocardiopatía isquémico-necrótica (11,6%) y miocardiopatía hipertrófica (8,9%). La sospecha clínica fue confirmada en el 23,6% de los casos y la RMC generó un diagnóstico nuevo no sospechado en el 48,7% de los casos. Las consecuencias terapéuticas más frecuentes fueron el alta hospitalaria (31,6%) seguida del cambio en la medicación (28,1%).
Conclusiones: La RMC es un estudio ampliamente utilizado en Argentina, principalmente en centros privados, con un número muy bajo de complicaciones. Las principales indicaciones son las miocardiopatías (hipertrófica y dilatada), y provee un diagnóstico nuevo no sospechado en casi la mitad de los casos. Se requieren de otros estudios en el futuro para evaluar las implicancias clínicas y terapéuticas.

Palabras clave: Resonancia magnética cardíaca - Implicancias terapéuticas- Miocardiopatías - Registros - Argentina

Address for reprints: Santiago del Castillo - E- Mail: santiago.delcastillo@hospitalitaliano.org.ar - Tte Gral J. D.Perón 4190 - C1199ABB Ciudad Autónoma de Buenos Aires. Argentina

[1] Department of Cardiology, Cardiovascular Imaging Division, Hospital Italiano de Buenos Aires. Autonomous City of Buenos Aires, Argentina.
[2] Fundación Científica del Sur, Buenos Aires Province, Argentina
[3] Department of Cardiology, Instituto Cardiovascular San Isidro, Sanatorio Las Lomas, Buenos Aires Province, Argentina.
[4] Instituto de Diagnóstico Maipú, Autonomous City of Buenos Aires, Argentina.
[5] Department of Cardiology, Cardiovascular Imaging Division, Instituto Cardiovascular de Buenos Aires, Autonomous City of Buenos Aires, Argentina
[6] INOVA Diagnóstico, Bahía Blanca, Buenos Aires Province, Argentina
[7] High-Complexity Imaging Institute, Sanatorio Junín, Buenos Aires Province, Argentina
[8] Sanatorio 9 de Julio, San Miguel de Tucumán, Tucumán Province, Argentina

INTRODUCTION

The usefulness of cardiac magnetic resonance imaging (M dow (recommendation IC), when infiltrative cardiomyopathies are suspected (IC) and to identify the ischemic or non-ischemic origin of dilated cardiomyopathies (IIA). (3,4) It is also considered the gold standard to estimate ventricular volumes and function, and due to its great capacity to characterize the myocardium, it provides essential information about the etiology and prognosis of different cardiomyopathies. (5)

Several international registries published in the last years have reported the different indications, quality and clinical impact of cardiac MRI studies in Europe and the United States, but there is no available data for developing countries. (6,7)

Knowledge of the current state of cardiac MRI in the different institutions of our country is crucial at the time of developing standardized and safe study protocols, future research projects and resource planning.

Thus, we consider it is necessary to develop a national cardiac MRI registry that provides information about the different protocols used, complications, indications and clinical impact in different centers at a national level. Based on this premise, the Argentine Society of Cardiology implemented the Argentine National Cardiac Magnetic Resonance Imaging Registry (RENAREC).

METHODS

The Argentine Society of Cardiology Computed tomography and Cardiac magnetic resonance council designed a prospective registry inviting all the professionals and centers of the country. Consecutive patients attending any of the participating centers approved by the steering committee, and who gave their consent for the study, were recruited. The study protocol was approved by the ethics committee of the Argentine Society of Cardiology and incorporated in the centralized registry of research projects of the Autonomous City of Buenos Aires.

Data of interest were collected and sent by digital platform to a central analysis core together with the informed consent. Each physician who performed a cardiac MRI was in charge of filling the study forms. Collected variables were: demographic data, study indication, type of magnetic resonance scanner used, sequences utilized, study complications, diagnoses reached and implications on patient treatment.
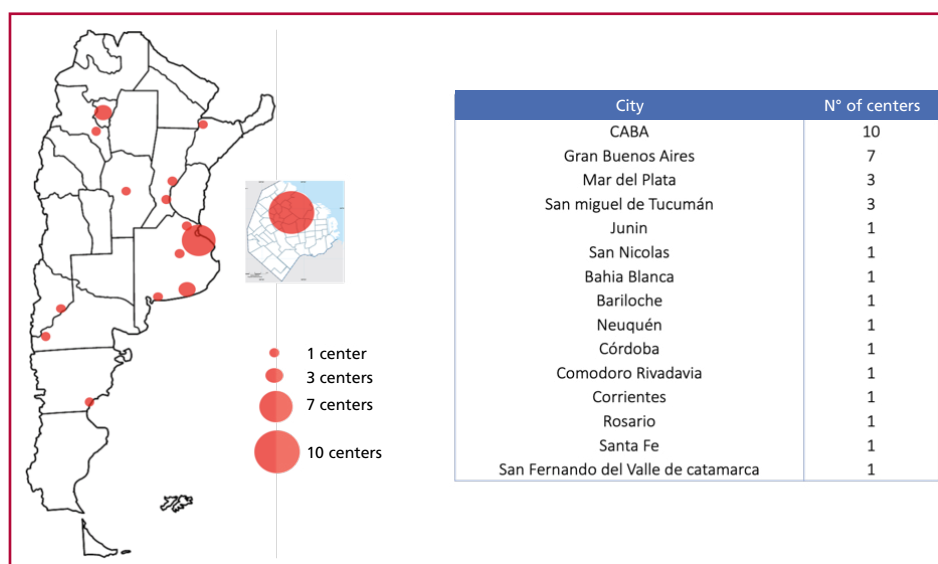
Statistical analysis

Continuous variables were expressed as mean and standard deviation or median and interquartile range according to their distribution and were compared using Student's t test or the Wilcoxon test, as appropriate. Categorical variables were expressed as frequencies and percentages and were compared with the chi-square test or Fisher's exact test, as appropriate. Statistical significance was established for $p < 0.05$.

RESULTS

Between August 2018 and January 2020, a total of 1131 studies from 34 participating centers distributed in 10 Argentine provinces were included in the study. Figure 1 summarizes the geographical distribution of the centers participating in the registry. Fifty percent of centers corresponded to the metropolitan area of Buenos Aires (10 centers in the Autonomous City of Buenos Aires and 7 centers in the Greater Buenos Aires area). In addition, 3 centers were in Tucuman, 2 in Santa Fe, and 1 in Neuquén, Río Negro, Córdoba, Chubut, Corrientes and Catamarca. The centers involved were mostly private (85%) and 74% had only one cardiac magnetic resonance scanner.

In 59% of cases, the institutions were centers with inpatient facilities and the remaining 41% were ambulatory diagnostic centers. The scanners used were 1.5 Tesla in 97.3% of cases, and the rest 3 Tesla.

City	N° of centers
CABA	10
Gran Buenos Aires	7
Mar del Plata	3
San miguel de Tucumán	3
Junin	1
San Nicolas	1
Bahia Blanca	1
Bariloche	1
Neuquén	1
Córdoba	1
Comodoro Rivadavia	1
Corrientes	1
Rosario	1
Santa Fe	1
San Fernando del Valle de catamarca	1

Fig. 1. Geographic representation of the participating centers. A total of 34 centers from 10 Argentine provinces were included.

CABA: Autonomous City of Buenos Aires. * p = < 0.0001

Mean age of the included patients was 54±18 years and 61% were male. The most frequent reasons for study indication were hypertrophic cardiomyopathy (13.9%), ventricular arrhythmia (12.3%), dilated cardiomyopathy (9%), left ventricular systolic function impairment (7.3%), congenital heart diseases (5.6%), valve diseases (5.2%) and others (Table 1 and Figure 2).

The cardiac MRI study was completed in 98% of cases, and adverse events were only registered in 0.3% of cases: a patient had dipyridamole-induced dyspnea and two patients presented adverse effects related to gadolinium administration, one with minor allergy (rash) and the other with anaphylactic shock.

In 91.8% of cases, there was good image quality, and only 0.2% of studies were considered unsuitable to be reported. The main reasons for poor image quality were the presence of arrhythmias (54.4%) and breath-hold difficulty (42.3%). Most studies (82%) were performed with an acquisition time between 30-60 minutes and only in 10.1% of cases the acquisition was carried out in more than 60 minutes (Table 2).

The sequences used varied according to the reason for the study; the most frequent were cine-sequences (98.5%) and late gadolinium enhancement (89.3%), and the least frequent were those under pharmacological stress (5%) and tagging sequences (4.4%).

Among the studies performed, 31.2% were reported as normal, and the most prevalent diseases in the main diagnoses were non-ischemic dilated cardiomyopathy (14.7%), ischemic-necrotic cardiomyopathy (11.6%), hypertrophic cardiomyopathy (8.9%) and heart valve diseases (5.8%) (Table 2). The study was useful to confirm the suspected diagnosis in 23.6% of cases, it could not confirm it in 70% of cases and it was unknown in 6.4% of cases due to the ambiguity of the diagnosis in its request. On the other hand, cardiac MRI generated a relevant unsuspected diagnosis in 48.7% of cases. Nevertheless, in 75.7% of these cases there was no information on whether the study caused changes in the therapeutic conduct. In those cases in which this information was available (24.3%, n=275), the most frequent therapeutic implications were hospital discharge (31.6%), changes in the medication (28.1%), a closer follow-up (18.9%) and avoiding an invasive procedure (12.7%).

DISCUSSION

This is the first registry showing results of cardiac MRI studies performed in different centers of Argentina representing this practice in our country. Firstly, it highlights the degree of representation at a national level, as different centers from 10 provinces of the country participated in the study. Most were private centers (85%), which could interfere with access to this high-complexity study for those patients without social security coverage who receive care in public health centers. It is also interesting that 41% of participating centers were exclusively dedicated to ambulatory diagnosis. Almost all the scanners used were 1.5 Tesla (97.3%)

Table 1. Baseline population characteristics, types of scanner used and main indications for a cardiac magnetic resonance study. (n=1131)

Age (years, SD)	54±18
Male gender, n (%)	691 (61.1)
Body surface area, m2	1.9±0.2
Complete request, n (%)	1067 (94.4)
Scanner used, n (%)	
1.5 T	1100 (97.3)
3 T	31 (2.7)
Scanner brand n (%)	
Siemens	567 (50.2)
Phillips	397 (35.1)
General Electric	152 (13.5)
Toshiba	14 (1.2)
Reason for the study, n (%)	
Hypertrophic CMP	157 (13.9)
Ventricular arrhythmia	139 (12.3)
Dilated CMP	101 (9)
LV systolic function impairment	82 (7.3)
Congenital diseases	63 (5.6)
Heart valve diseases	59 (5.2)
Search for ischemia	55 (4.9)
Viability	53 (4.7)
Myocarditis	53 (4.7)
Masses/thrombus	39 (3.5)
Pericardial diseases	39 (3.5)
MINOCA	34 (3)
Non-compacted CMP	31 (2.8)
Iron overload	26 (2.3)
Amyloidosis	23 (2)
Aortic diseases	23 (2)
Acute infarction	16 (1.4)
Complete LBBB	13 (1.2)
Arrhythmogenic dysplasia	9 (0.8)
Chagas	6 (0.5)
Chemotherapy dysfunction	6 (0.5)
Pulmonary vein anatomy/AF	5 (0.4)
Collagen disease-associated CMP	4 (0.4)
Sarcoidosis	1 (0.1)
Other	90 (8)

SD: Standard deviation, T: Tesla, CMP: Cardiomyopathy, LV: Left ventricular, MINOCA: Myocardial infarction with non-obstructive coronary arteries, LBBB: Left bundle branch block, AF: Atrial fibrillation.

as observed in other international registries. (6,7) All studies were performed by specialists in cardiology, but this data does not seem to be representative due to a
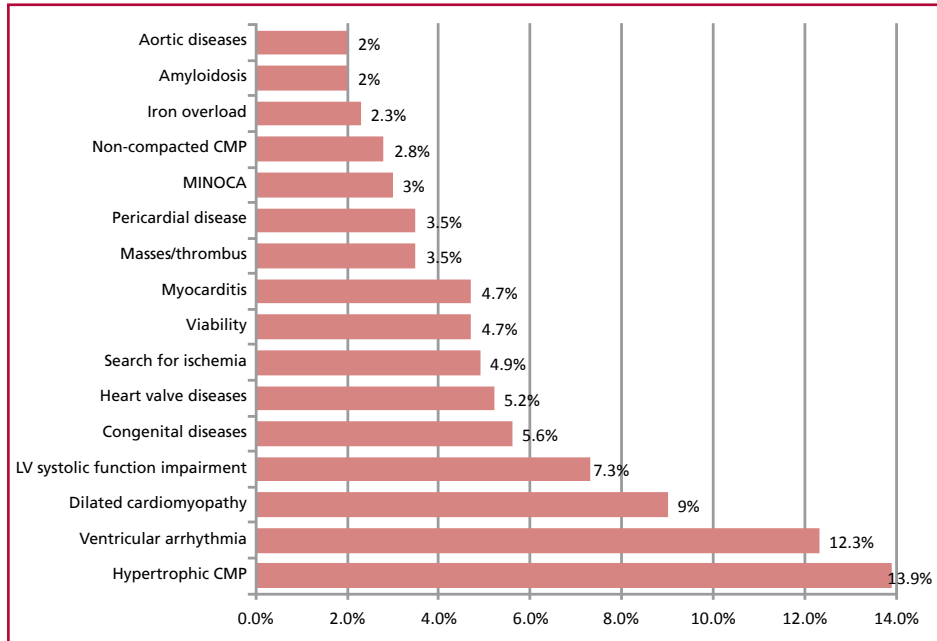
Fig. 2. Main indications for the cardiac MRI study.

CMP: Cardiomyopathy, MINOCA: Myocardial infarction with non-obstructive coronary arteries, LV: Left ventricular.

bias, as it was a study launched and carried out by the Argentine Society of Cardiology.

The main reasons for requesting a cardiac MRI were cardiomyopathies and ventricular arrhythmia, and the search for ischemia (4.9%) by cardiac MRI

with stress and perfusion technique was infrequent. This was the main difference when comparing these findings with other international registries, as the search for ischemia was the first indication for cardiac MRI in the EuroCMR registry (n=27 781) and
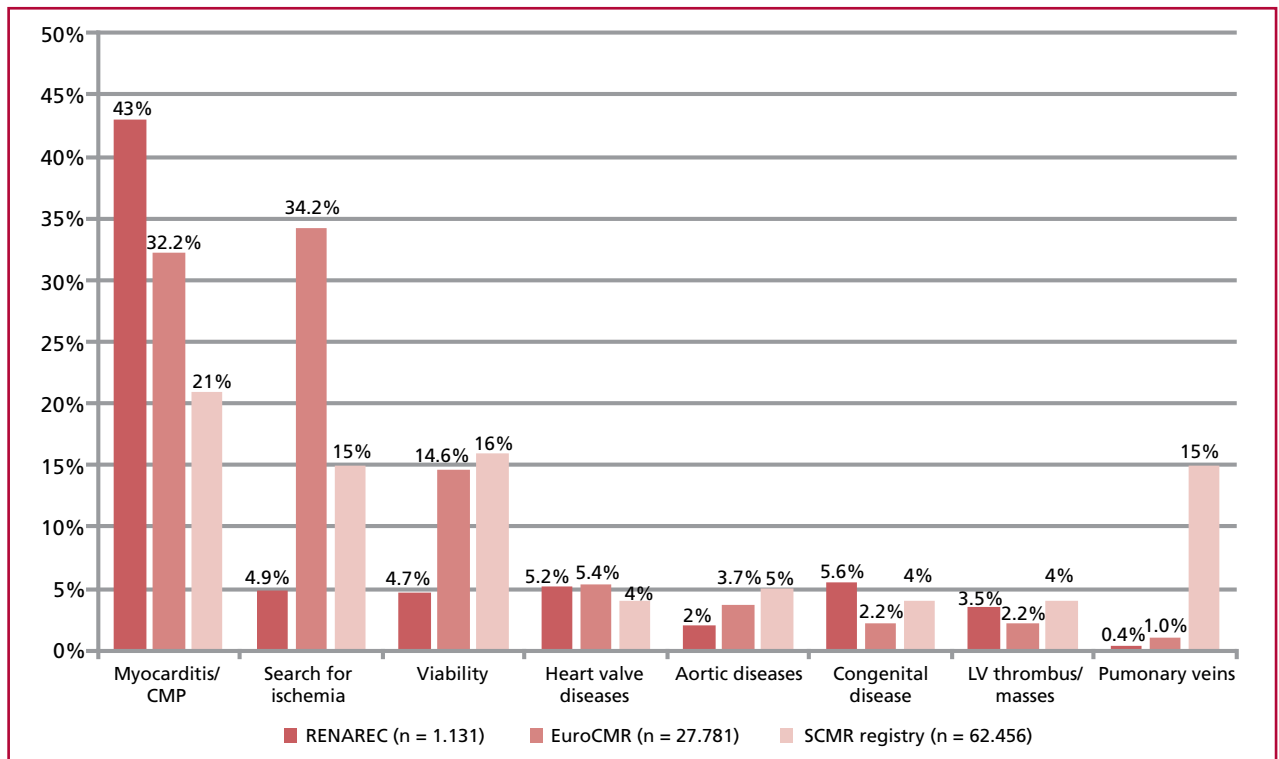
CMP: Cardiomyopathy, LV: Left ventricular

Fig. 3. Comparison of cardiac MRI indications between RENAREC and EuroCMR and SCMR registries.(5,6)

Table 2. Adverse effects, quality and main diagnoses of cardiac MRI (n=1131)

Completed the study, n (%)	
No	23 (2)
Yes	1108 (98)
Adverse effects n (%)	
Not present	1016 (89.8)
Minor allergy (Skin rash)	1 (0.1)
Mayor allergy (Shock)	1 (0.1)
Dipyridamole-induced dyspnea	1 (0.1)
Does not apply (study without contrast)	112 (9.9)
Quality of the study, n (%)	
Good	1038 (91.8)
Fair	91 (8)
Not reportable	2 (0.2)
Reason for bad quality, n (%)	
Arrhythmia	49/90 (54.4)
Breath-hold inability	38/90 (42.3)
Poor LGE inversion	2/90 (2.2)
Metallic artifact	1/90 (1.1)
Cardiac MRI diagnosis, n (%)	
Normal study	349 (31.2)
Non ischemic-necrotic cardiomyopathy	167 (14.7)
Ischemic-necrotic cardiomyopathy	130 (11.6)
Hypertrophic cardiomyopathy	100 (8.9)
Heart valve disease	66 (5.8)
Congenital diseases	53 (4.7)
Myocarditis sequelae	46 (4.1)
Pericardial disease	38 (3.4)
Aortic disease	32 (2.9)
Amyloidosis	21 (1.9)
Acute myocarditis	19 (1.6)
Non-compacted cardiomyopathy	17 (1.5)
Primary tumor	14 (1.3)
Arrhythmogenic dysplasia	8 (0.7)
LV thrombus	7 (0.6)
Other	48 (5.1)

LGE: Late gadolinium enhancement; MRI: Magnetic resonance imaging, LV: Left ventricular.

the second in the Global SCMR registry (n=62 456) (5,6) (Figure 3). In the latest guidelines on chest pain management, stress cardiac MRI looking for ischemia is on the same level of recommendation than stress echocardiogram, single photon emission computed tomography (SPECT) and positron emission tomog-raphy (PET) for patients at intermediate ischemic risk and without known coronary lesions in the acute condition (recommendation IB), and for patients with intermediate-high risk chronic pain without known coronary lesions, both for the diagnosis of coronary heart disease as for stratification of major cardiovas-cular events risk (recommendation IB). (7) Consider-ing that CMR with dobutamine has been shown to have greater diagnostic accuracy than dobutamine stress echocardiography, and to be a safe procedure, we believe that the costs and the impossibility of per-forming stress with exercise are the main limitations to its application. (9-12) This method to look out for ischemia is expected to grow in the next years.

The complications associated with the study of cardiac MRI were infrequent (0.3%) and only one pa-tient (0.08%) presented a severe adverse effect associ-ated with gadolinium administration. Although in our study the type of gadolinium used was not available, these findings are in agreement with the safety data of contrast agents with gadolinium observed in large international registries. (13-18)

In most cases, physicians performing the study interpreted image quality as good (91.8%) and only 0.2% could not report the study due to poor acquisi-tion quality; two main causes for this difficulty were marked presence of arrhythmia and breath-hold in-ability. New sequence technologies and protocols should lead to solve these problems. On the other hand, most registry studies demanded 30-60-minute acquisition time. The current cardiac MRI acquisition protocols' guideline published a few months after this registry ended, includes fast acquisition protocols for follow-up in certain clinical scenarios as hypertensive or hypertrophic cardiomyopathy, viability and cardio-toxicity. (19,20) The incorporation of these protocols to clinical practice will certainly decrease the acquisi-tion times in the near future.

Cardiac MRI indicated a new unsuspected diagno-sis in almost half of the studies (48.7%). Since a large number of studies was performed in ambulatory diag-nostic centers, it is logical that in more than 75% of cases we have no information on the clinical impact of the cardiac MRI result. However, it is very inter-esting to highlight the data of those studies in which this information was acquired (24.3%, n=275). The main therapeutic changes brought up by cardiac MRI were hospital discharge in 31.6% of cases, a change in medication in 28.1% and a closer follow-up in 18.9%. It should also be pointed out that cardiac MRI avoided an invasive procedure in 12.7% of cases. These data are similar to the EuroCMR Registry, mainly regard-ing the change in medication observed in that registry (25%). One of the main differences encountered was that cardiac MRI led to an invasive procedure in 16% of cases in the European registry, while it only did so in 4% of our studies, a difference that is probably ex-plained by the high cardiac MRI indication searching for ischemia in Europe. (6,7)

CONCLUSIONS

Cardiac MRI is a national widespread study in Argentina, mainly in private healthcare centers. It is a safe practice with a very low number of complications. Its main indication is the study of cardiomyopathies and ventricular arrhythmia, and it provides a new unsuspected diagnosis in nearly half of cases. Future studies are required to evaluate the clinical and therapeutic implications of this study.

Conflicts of interest

None declared.

(See authors' conflict of interests forms on the web/Additional material.)

Financing

None.

REFERENCES

1. Kawel-Boehm N, Hetzel SJ, Ambale-Venkatesh B, Captur G, Francois CJ, Jerosch-Herold M, et al. Reference ranges ("normal values") for cardiovascular magnetic resonance (CMR) in adults and children: 2020 update. J Cardiovasc Magn Reson 2020;22:87. https://doi.org/10.1186/s12968-020-00683-3. Erratum in: J Cardiovasc Magn Reson 2021;23:114.

2. Abbasi SA, Ertel A, Shah RV, Dandekar V, Chung J, Bhat G, et al. Impact of cardiovascular magnetic resonance on management and clinical decision-making in heart failure patients. J Cardiovasc Magn Reson 2013;15:89. https://doi.org/10.1186/1532-429X-15-89.

3. McDonagh TA, Metra M, Adamo M, Gardner RS, Baumbach A, Böhm M, et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J 2021;42:3599–726. https://doi.org/

4. Heidenreich PA, Bozkurt B, Aguilar D, Allen LA, Byun JJ, Colvin MM, et al. 2022 AHA/ACC/HFSA Guideline for the Management of Heart Failure: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation 2022;145:e895-e1032. https://doi.org/10.1161/CIR.0000000000001063.

5. Patel AR, Kramer CM. Role of Cardiac Magnetic Resonance in the Diagnosis and Prognosis of Nonischemic Cardiomyopathy. JACC Cardiovasc Imaging 2017;10:1180–93. https://doi.org/ 10.1016/j.jcmg.2017.08.005.

6. Global Cardiovascular Magnetic Resonance Registry (GCMR) Investigators, Kwong RY, Petersen SE, Schulz-Menger J, Arai AE, Bingham SE, Chen Y, et al. The global cardiovascular magnetic resonance registry (GCMR) of the society for cardiovascular magnetic resonance (SCMR): its goals, rationale, data infrastructure, and current developments. J Cardiovasc Magn Reson 2017;19:23. https://doi.org/10.1186/s12968-016-0321-7.

7. Bruder O, Wagner A, Lombardi M, Schwitter J, van Rossum A, Pilz G, et al. European cardiovascular magnetic resonance (EuroCMR) registry – multi national results from 57 centers in 15 countries. J Cardiovasc Magn Reson 2013;15:9. https://doi.org/10.1186/1532-429X-15-9.

8. Writing Committee Members, Gulati M, Levy PD, Mukherjee D, Amsterdam E, Bhatt DL, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: Executive Summary: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. J Am Coll Cardiol 2021;78:2218–61. https://doi.org/10.1016/j.jacc.2021.07.052

9. Gaemperli O, Kaufmann PA. PET and PET/CT in cardiovascular disease. Ann N Y Acad Sci 2011;1228:109–36. https://doi.org/10.1111/j.1749-6632.2011.06030.x.

10. Nagel E, Lehmkuhl HB, Bocksch W, Klein C, Vogel U, Frantz E, et al. Noninvasive diagnosis of ischemia-induced wall motion abnormalities with the use of high-dose dobutamine stress MRI: comparison with dobutamine stress echocardiography. Circulation 1999;99:763–70. https://doi.org/10.1161/01.cir.99.6.763.

11. Wahl A, Paetsch I, Gollesch A, Roethemeyer S, Foell D, Gebker R, et al. Safety and feasibility of high-dose dobutamine-atropine stress cardiovascular magnetic resonance for diagnosis of myocardial ischaemia: experience in 1000 consecutive cases. Eur Heart J 2004;25:1230–6. https://doi.org/ 10.1016/j.ehj.2003.11.018

12. Hendel RC, Friedrich MG, Schulz-Menger J, Zemmrich C, Bengel F, Berman DS, et al. CMR First-Pass Perfusion for Suspected Inducible Myocardial Ischemia. JACC Cardiovasc Imaging 2016;9:1338–48. https://doi.org/ 10.1016/j.jcmg.2016.09.010

13. Bruder O, Schneider S, Pilz G, van Rossum AC, Schwitter J, Nothnagel D, et al. 2015 Update on Acute Adverse Reactions to Gadolinium based Contrast Agents in Cardiovascular MR. Large Multi-National and Multi-Ethnical Population Experience With 37788 Patients From the EuroCMR Registry. J Cardiovasc Magn Reson. 2015;17:58. https://doi.org/10.1186/s12968-015-0168-3

14. Uhlig J, Lücke C, Vliegenthart R, Loewe C, Grothoff M, Schuster A, et al. Acute adverse events in cardiac MR imaging with gadolinium-based contrast agents: results from the European Society of Cardiovascular Radiology (ESCR) MRCT Registry in 72,839 patients. Eur Radiol 2019;29:3686–95. https://doi.org/10.1007/s00330-019-06171-2

15. Wagner A, Bruder O, Schneider S, Nothnagel D, Buser P, Pons-Lado G, et al. Current variables, definitions and endpoints of the European Cardiovascular Magnetic Resonance Registry . J Cardiovasc Magn Reson 2009;11:43. https://doi.org/10.1186/1532-429X-11-43.

16. Bruder O, Schneider S, Nothnagel D, Pilz G, Lombardi M, Sinha A, et al. Acute adverse reactions to gadolinium-based contrast agents in CMR: multicenter experience with 17,767 patients from the EuroCMR Registry. JACC Cardiovasc Imaging 2011;4:1171–6. https://doi.org/ 10.1016/j.jcmg.2011.06.019

17. Prince MR, Zhang H, Zou Z, Staron RB, Brill PW. Incidence of immediate gadolinium contrast media reactions. AJR Am J Roentgenol 2011 Feb;196:W138–43. https://doi.org/ 10.2214/AJR.10.4885.

18. Hunt CH, Hartman RP, Hesley GK. Frequency and severity of adverse effects of iodinated and gadolinium contrast materials: retrospective review of 456,930 doses. AJR Am J Roentgenol 2009;193:1124–7. https://doi.org/ 10.2214/AJR.09.2520

19. Kramer CM, Barkhausen J, Bucciarelli-Ducci C, Flamm SD, Kim RJ, Nagel E. Standardized cardiovascular magnetic resonance imaging (CMR) protocols: 2020 update. J Cardiovasc Magn Reson 2020;22:17. https://doi.org/10.1186/s12968-020-00607-1.

20. Menacho Medina K, Seraphim A, Katekaru D, Abdel-Gadir A, Han Y, Westwood M, et al. Noninvasive rapid cardiac magnetic resonance for the assessment of cardiomyopathies in low-middle income countries. Expert Rev Cardiovasc Ther 2021;19:387–98. https://doi.org/ 10.1080/14779072.2021.1915130