

## Original Research

## The Future of Cardiovascular Magnetic Resonance in Greece: Expectations and Reality

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**Introduction:** The latest advances in cardiovascular magnetic resonance (CMR) have established this technique as the gold standard imaging modality for many cardiac diseases. However, cardiologists seem to be reluctant to use CMR in their everyday clinical practice.

**Methods:** In an attempt to identify some of the reasons for this discrepancy, we conducted a survey employing a written questionnaire completed by 60 trained cardiologists in the third most populated region of Greece.

**Results:** Cardiologists would refer patients for CMR rarely (71.6%) or never (28.3%). The most frequent indications for CMR were congenital heart disease (46.7%) and aortography (28.3%). Only 13.3% were familiar with cardiac computed tomography and 8.3% with CMR. Participants would like CMR to be able to clarify coronary artery anatomy (81.3%). Only 3% answered correctly all the questions regarding contraindications of CMR. The main reasons for not referring a patient for CMR were non-availability (75%), lack of familiarity (60%), and high cost (55%). The most appropriate physician for conducting/interpreting a CMR examination is a cardiologist (31.7%), radiologist (10%), both (51.7%), or not important (6.7%). The method is going to expand a lot (41.6%), moderately (46.7%), or not at all (1.2%) in the future.

**Conclusions:** A complex interplay between the lack of trained physicians and technicians, non-availability of scanners for CMR, high costs, and lack of adequate education of cardiologists, leads to a vicious circle with the final odds against CMR. Actions to bypass these issues are required on behalf of all scientists involved in CMR imaging. Training of more physicians and technicians, establishment of dedicated CMR programs, and in-depth education of cardiologists regarding the indications and advantages of CMR over other imaging modalities, will be required if CMR is to become established in everyday clinical practice.

**D**uring the last 20 years, major advancements occurred in the field of cardiovascular magnetic resonance (CMR), and there has been an exponential growth in the number of relevant publications.<sup>1</sup> CMR has become the gold standard imaging modality for many cardiac diseases.<sup>2</sup> Its major advantage is that it is non-invasive, does not involve ionising radiation, allows unrestricted access to the chest and is highly reproducible.<sup>3</sup> The main contraindications are implanted pacemakers/defibrillators, some kinds of metallic

implants, and severe claustrophobia.<sup>4-6</sup> Most of the artificial valves, as well as coronary or large vessel stents, do not constitute a contraindication, whereas some metallic implants near the viewing field may produce severe artefacts; however, they do not constitute a contraindication *per se*.<sup>4,6</sup>

CMR is a versatile imaging modality. A variety of magnetic resonance sequences deliver a remarkably wide spectrum of imaging and functional information regarding the heart. Spin echo sequences (black blood) produce excellent images of

the heart and blood vessels, allowing clarification of cardiac anatomy. Gradient echo sequences (white blood) allow the study of myocardial and valvular function and flow dynamics. Flow sequences allow very accurate calculations of cardiac output and regurgitant fractions. Gadolinium-based sequences allow for very accurate non-invasive angiography (MRA), whereas more sophisticated sequences, such as late gadolinium enhancement (LGE), aid in studying myocardial viability.<sup>7,8</sup> Finally, cardiac perfusion and stress imaging are becoming a reality.<sup>3,9,10</sup> Novel technological advancements and development of 3 Tesla magnets are broadening the spectrum of CMR applications further.<sup>11</sup> All these applications lead the enthusiasts in the field to dream about the so called 'one stop shop' examination, with a great deal of information on the heart's anatomy, function, perfusion and viability acquired in one CMR session.<sup>10</sup>

Despite these advances, CMR is not implemented in everyday clinical practice.<sup>1,12</sup> Most cardiologists would agree that CMR is an excellent tool for studying complex congenital heart disease,<sup>13-15</sup> cardiac tumours, and other rare and specialised heart conditions; however, they seem to be reluctant to refer patients for other more common indications of CMR.<sup>12,16</sup> This may be related to the non-availability of scanners, high costs, and/or lack of education regarding CMR's capabilities.<sup>16</sup> Indeed, usage of CMR is restricted to large medical centres and there is a lack of interest in training and involvement in cardiac MRI among young cardiologists. In Greece there are only a few dedicated CMR scanners, most of them located in the capital, Athens.

The aim of this report is to examine the practice of cardiologists regarding CMR in the third most populated region of Greece, located 200 km away from Athens, and to expose the reasons for any possible reluctance of cardiologists to use the method.

## Methods

A written questionnaire regarding CMR usage was distributed to 60 trained cardiologists (hospital practitioners and cardiologists practicing privately) in the city of Patras, Achaia, Greece. This is a region in the southwest of Greece, 200 km from the capital Athens, and is considered the third most populated region in Greece after Athens and Thessaloniki. The questionnaire included 14 questions that aimed to explore cardiologists' opinions regarding indications, contraindications, advantages and disadvantages of CMR, as

well as their perspective on how this imaging modality should be used efficiently by the cardiological community in everyday clinical practice. It was written, distributed and collected by the authors of this report. Data for each question answered were recorded in Microsoft Excel 2003® (Microsoft Corporation, Seattle, WA). Frequency distributions are presented as percentages, as appropriate.

## Results

Sixty cardiologists completed the questionnaire. Cardiologists would generally refer their patients for a CMR examination rarely (71.6%) or never (28.3%). The most frequent indications for CMR that cardiologists recalled – no multiple choice answers – were congenital heart disease (46.7%) and aortography (28.3%) (Table 1). Cardiologists were then asked to choose for which out of 6 specific indications of CMR they had ever referred a patient. The most frequent indications for CMR referral were anatomy (41.7%), aortography (20%), viability (20%), and myocardial ischaemia (18.3%) (Table 2).

When asked which other imaging modality, compared to CMR, would reveal equally accurate information about the condition they had in mind (and for which they would order a CMR), cardiologists replied echocardiography (55%), catheterisation (46.6%), and cardiac computed tomography (CT) (23.3%).

The next question referred to the imaging modality with which cardiologists were most accustomed and felt that they would arrive at the correct diagnosis when viewing films or videos of the examination. Echocardiography (88.3%) and catheterisation (51.7%) were the

**Table 1.** Answers to the question: Which indications for cardiac magnetic resonance imaging do you happen to know?

Indication	No. of cardiologists	Percentage (%)
Congenital heart disease	28	46.7
Aortography	17	28.3
Cardiomyopathies/myocarditis	14	23.3
Myocardial viability	11	18.3
Myocardial ischaemia	11	18.3
Tumours	4	6.6
Constrictive pericarditis	4	6.6
ARVD	3	5
Valvular function	3	5
Cooley's disease	1	1.6

ARVD – arrhythmogenic right ventricular dysplasia.

**Table 2.** Answers to the question: If you have ever referred a patient for cardiac magnetic resonance imaging, for which of the 6 indications listed have you done that?

Indication	No. of cardiologists	Percentage (%)
Myocardial anatomy	25	41.7
Aortography	12	20
Myocardial viability	12	20
Myocardial ischaemia	11	18.3
Myocardial function	10	16.7
Valvular function	4	6.7

most frequent answers. Only 13.3% of the cardiologists replied cardiac CT and 8.3% CMR.

When asked what they consider to be the main advantages of CMR, image quality (55%), non-invasiveness (36.6%), and non-involvement of ionising radiation (23.3%) were the most frequent answers. Regarding any disadvantages of the method, cardiologists replied high costs (58.3%), not being able to image the coronary arteries (16.7%), bad image quality related to patient movement (6.7%), and claustrophobia (1.7%). They also answered non-availability of scanners (25%), and lack of education and training in CMR (21.7%); however, these answers do not refer to the method *per se*.

When asked what kind of information they would consider useful from a new non-invasive imaging modality like CMR, they replied coronary artery anatomy (81.3%), cardiac anatomy (36.6%), cardiac function (35%), myocardial perfusion (13.3%), myocardial viability (8%), and valvular function (1.6%).

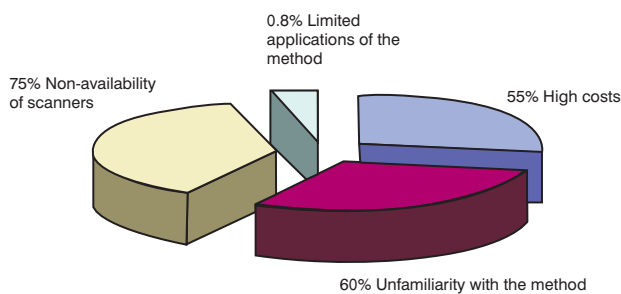
Most cardiologists replied that pacemakers are a contraindication for CMR (75%); however, answers were balanced regarding metallic valves, non-ferromagnetic metallic implants and stents (Table 3).

When asked for which of 4 reasons they would hesitate to refer a patient for a CMR examination, the most frequent answers were non-availability (75%), lack of familiarity with the method (60%), and high costs (55%). Less than 1% would think that the method has restricted and rare applications (Figure 1).

**Table 3.** Answers to the question: Which of the following is a contraindication for cardiac magnetic resonance imaging?

Contraindication	Yes	No	Don't know
Pacemakers/ICDs	45 (75%)	7 (11.7%)	8 (13.3%)
Metallic valves	32 (53.3%)	18 (30%)	10 (16.7%)
Stents	13 (21.7%)	29 (48.3%)	18 (30%)
Metallic implants*	27 (45%)	18 (30%)	15 (25%)

\*Non-ferromagnetic. Wrong answers are shown in bold italics.



**Figure 1.** When asked for which of 4 reasons cardiologists would hesitate to refer a patient for a CMR examination, the most frequent answers were non-availability (75%), lack of familiarity with the method (60%) and high costs (55%). Less than 1% thought that the method has limited and rare applications.

Most cardiologists have heard about CMR from congresses (70%), internet (43.3%), or from a colleague (30%). They think that if the method is to expand, better access (78.3%), education and training (78.3%), and cost reduction (60%) are necessary.

When asked who is the most appropriate physician for conducting/interpreting a CMR examination, they replied the cardiologist (31.7%), radiologist (10%), both (51.7%), or not important (6.7%).

When asked if CMR is more or less relatively unnecessary for their practice at the moment, they replied yes (28.3%), no (60%), and “I don’t know yet” (11.7%). Finally, they believe that the method is going to expand a lot (41.6%), moderately (46.7%), or not at all (1.2%) in the future.

### Discussion

The aim of this questionnaire was to approach the practice of trained cardiologists (practicing in hospitals or privately), serving a population of about 1 million in an area of Greece outside Athens, regarding CMR usage. Our survey concluded that cardiologists in this area rarely refer patients for CMR (71.7%). It is significant that 28.3% have never referred a patient for CMR thus far. In contrast, data from a tertiary referral CMR centre in the capital (Athens), published recently in this journal, show an increasing number of clinical CMR examinations during the last five years.<sup>17</sup> One could speculate that cardiologists who participated in this survey think that the method is either not important for their practice, and/or are unaware of the indications for CMR. It might also be that high costs and non-availability of scanners in this region are additional reasons and this would explain the discrepancy between the in-

creasing clinical practice in Athens and the total absence of scanners dedicated to CMR 200 km to the southwest.<sup>17</sup> Both speculations were confirmed in the answers that were obtained.

The two most frequent indications for CMR which cardiologists recalled – without specific multiple choice answers given – were congenital heart disease (46.7%), and ascending aortography (28.3%). In total, the cardiologists mentioned most of the current indications of CMR,<sup>9</sup> however, this was done only by a small minority (10%). When asked which were the specific indications for which they had ever referred a patient for CMR – answers given in the form of 6 multiple choices – anatomy (41.7%), aortography (20%) and viability (20%), were the most frequent answers. It seems that cardiologists are aware of one of the most important applications of CMR, namely congenital heart disease (CHD).<sup>9,13</sup> However, general cardiologists rarely follow up adults with CHD, because these patients are uncommon and are followed up in specialised centres. The next most frequent indications for which they had ever referred a patient for CMR were angiography – more specifically, ascending aortography for aneurysm detection and sizing – and myocardial viability. The fact that they would rarely refer their patients for any of the other indications of CMR, even for aortography, which is a much more common indication in the everyday clinical practice of an adult cardiologist, means that they are either unaware of these indications, or they think that other imaging methods reveal enough information for managing their patients. This is relevant to the answers given when we asked which imaging method would be considered equivalent to CMR for any of the indications for CMR that cardiologists know. Most of them would answer either echocardiography (55%) or catheterisation (46.7%). Apparently, there is a lack of knowledge regarding the capabilities of a CMR examination, so cardiologists are limited to echocardiography and cardiac catheterisation as their main imaging tools. This also applies to cardiac CT, which only 23.3% of cardiologists think gives equally accurate information as CMR. Nowadays, with a CMR study we are able to acquire information regarding cardiac anatomy, myocardial and valvular function, myocardial ischaemia and viability, taking advantage of more sophisticated and advanced sequences than simple spin-echo, such as gradient echo, flow-velocity mapping, late gadolinium enhancement, etc.<sup>9</sup> Apart from specific information provided exclusively by CMR, the latter reveals a lot of information complementary

to echocardiography that is often necessary for optimal patient management over a wide spectrum of cardiac diseases.<sup>18-20</sup> Lack of knowledge is obviously associated with poor education regarding the capabilities and applications of CMR. Lack of education and non-availability of the method lead to lack of familiarity and confidence, which explains the fact that most cardiologists feel competent to examine and interpret the images from an echocardiographic (83.3%) or catheterisation (51.7%) study, whereas only a small minority would be able to understand a recording containing CMR (8.3%) or cardiac CT (13.3%) imaging information.

Poor education and training in modern imaging modalities, and underestimation of the importance of non-invasiveness and radiation exposure, explain the answers given regarding the advantages of CMR. Cardiologists would answer that image quality is the most important (55%). However, less than half of them would point out that the method is non-invasive (36.7%), and does not employ ionising radiation (23.3%). Especially as concerns the non-involvement of ionising radiation, it has been shown that non-radiologists generally tend to underestimate the issue of radiation when ordering imaging examinations.<sup>21</sup>

Regarding what they consider the disadvantages of the method, it was very interesting that most of them would refer to the high costs (58.3%) and non-availability of scanners (25%). Obviously, the latter is not a disadvantage of CMR, but is related to a complex relationship between costs and lack of referrals, which leads to this situation and is projected as a disadvantage of the method by cardiologists. Another interesting observation is that most cardiologists think that a non-invasive imaging method would be of value if it could clarify coronary anatomy (81.7%). This is also confirmed by the fact that 16.7% of them think an important disadvantage of CMR is not being able to visualise the coronary arteries. The current role of CMR coronary artery imaging is rather limited and mostly allows for imaging of the origin of the coronary arteries.<sup>22,23</sup> However, CMR has good sensitivity and intermediate specificity in the detection of significant coronary artery disease.<sup>24</sup>

Concerning the contraindications for CMR, we asked specifically about pacemakers/ICDs, metallic implants, metallic valves and stents. It was reassuring to see that most cardiologists (75%) are aware of the fact that currently having a pacemaker or ICD implanted constitutes a contraindication for CMR. However, it was disappointing that more than half of them would

consider metallic valves or non-ferromagnetic implants (orthopaedic, etc.) and 21.7% coronary stents, as contraindications for CMR. Also, many cardiologists admitted to being ignorant as to whether one of the above is a contraindication or not (13.3-30%) (Table 3). Only a small minority answered all the questions correctly (3%). This confusion surely contributes to the lack of referrals for CMR, but mainly underlines the fact that more training and education in CMR are needed.

When we asked our colleagues why they hesitate to refer patients for CMR, out of 4 specified options, non-availability of scanners, high costs, and lack of knowledge and education were almost universal answers<sup>25</sup> (Figure 1). Regarding the first two, they are obviously the main obstacles to the further development of CMR in Greece and probably worldwide.<sup>16</sup> In our region there are 3 scanners, one (0.5 T) in the university hospital and two (1.5 T) in private diagnostic centres. None of them is equipped with cardiovascular sequences, apart from those required for aortography. The scanners are there; however, they are not being used for CMR. This is due to a lack of personnel (physicians and technicians) trained in cardiac MRI.<sup>16</sup> People are not interested in training in CMR for two reasons: difficulties in training and thinking that this might be a wrong career choice in terms of income. Within the field of MRI, cardiac imaging is perhaps the most challenging. Both technicians and physicians need to understand and be familiar with MRI physics, cardiac anatomy and physiology, aspects of heart disease, post-processing software and, last but not least, a constantly evolving complex technology.<sup>2,26</sup> This might not be very attractive for many young cardiologists. Difficulties in gaining access to specialised centres for training are also important. In our country, for example, there does not exist any specialised programme for CMR training. Young doctors are forced to go abroad for training – which is not an easy decision, mainly because of financial issues. Regarding the possibility that physicians and technicians may think that training in CMR would be a wrong career choice, this is certainly related to the attitude of cardiologists: i.e. not referring patients for CMR. Given this situation, a typical cardiologist who is running a successful practice doing echocardiography and other non-invasive tests and/or cardiac catheterisations, does not feel compelled to establish a CMR capability, for both clinical and financial reasons.<sup>16</sup> Obviously, this is a vicious circle, in which the lack of referrals begets a lack of CMR experts and *vice versa*.

Investors are also reluctant to set up a CMR service. At least for a private medical centre, a reasonable volume of referrals is needed to make the method cost effective. Apart from the lack of referrals, establishment of a CMR service on behalf of investors is also unattractive because of other financial issues. A complete CMR study would need at least 40 minutes to be completed, in contrast to more popular magnetic resonance examinations (brain, abdomen, bones); this might be considered a disadvantage for a busy private centre, or even for a public hospital.<sup>16</sup>

The second issue related to the lack of referrals is cost. The cost of a CMR study is quite high – approximately €700 for anatomy, function and viability – which is difficult if not impossible for most patients to afford. On the other hand, with the current social security system in Greece, there is a lot of bureaucracy to be overcome before a patient gets approval for a CMR study from his/her public insurance. It has to be stressed that private insurance is not popular in Greece at the moment. Unfortunately, cost-effectiveness studies in cardiac MRI are scarce in the literature and there is no information regarding our country. Given the lack of CMR in this region, a patient has to travel 200 km to Athens for a CMR study, which would increase expenses further.

Therefore, despite the fact that most cardiologists would agree that cardiac MRI is a technique that can best answer the clinical question under consideration, they would hesitate to refer their patients because of costs and non-availability.

Another issue that has to be overcome concerns the most appropriate person for conducting and interpreting a CMR study: a cardiologist or a radiologist. It is reassuring that most cardiologists would reply both (51.7%) or that this is not important (6.7%); however, 31.7% think that only a cardiologist would be appropriate for this task and only 10% that a radiologist should do the job. We think that this should not be an issue if we want the method to expand.<sup>2</sup> It should not be important who is conducting and interpreting the examination, as long as the physician in question is appropriately trained, reliable and dedicated. An interdisciplinary approach would best benefit both doctors and, especially, our patients.<sup>2</sup>

The complex interplay between the lack of information regarding CMR on the part of ‘end users’ (cardiologists), the lack of trained physicians and technicians, the high costs and non-availability of CMR scanners in this region, is a self-sustaining situation. It is obvious that education and training of cardiologists, cost

reduction if possible, and better access to CMR services would contribute to a wider distribution of this imaging modality.<sup>16</sup> This is in accord with the answers of most cardiologists to this specific question. A specialised cardiac or imaging centre with a dedicated CMR scanner might be the answer, at least to the non-availability and partially to the referral issue.<sup>27</sup> The university hospital could provide such a service; however, this needs cooperation between cardiologists and radiologists, a generous investment on behalf of the ministry of health for a new-generation scanner and, last but not least, investment in the proper training of personnel.<sup>12,28,29</sup> Development of a specialised university CMR centre in our country could change things, and a dedicated fellowship in this centre for young cardiologists and radiologists would attract interest on behalf of the medical community.<sup>27,30,31</sup> Cost-effectiveness studies should be conducted regarding the most common indications for CMR in comparison with other imaging modalities, and people involved in cardiac MRI should present the results to the appropriate funding bodies and industry.<sup>1</sup> A wider survey across the country might also be necessary. If we want cardiac MRI to survive and flourish in our country, we need to conduct a plan for training, cost reduction, and implementation of more scanners – at least in major urban regions outside Athens. All this needs great effort and dedication on the part of people involved in cardiac MRI, mainly the Greek CMR working group. Also, support is needed from scientific bodies such as the Hellenic Cardiological Society. The latter has contributed greatly to the expansion of the method, by organising training sessions, including many subjects on CMR in meeting agendas throughout the year, and by funding the training of young cardiologists in CMR abroad. Obviously this is not enough. Efforts also must be made by the university to persuade the state about the necessity for more MRI scanners in university hospitals. It is also important to include training in newer imaging modalities like CMR and cardiac CT in the educational programme of cardiology fellows and to include the subject in cardiology board examinations in Greece.<sup>12,28</sup>

For all the above reasons, it did not surprise us that 46.7% of cardiologists think that the method would be difficult to expand further, at least in this region of Greece. However, we would like to fall in with the optimistic minority of our colleagues (41.7%) who think that the method is going to expand and flourish in the future. We would concur with Dr. Vivian Lee, one of the most renowned specialists in the field of

body and vascular MRI, that CMR is here to be used and either we do it now or lose it, stressing the need for cooperation, great effort and determination among scientists.

### Conclusions

In an area of Greece 200 km away from the capital Athens, cardiologists who serve a population of about 1 million seem to be relatively unaware of the indications, contraindications and advantages of CMR over other imaging modalities. A complex interplay between lack of education and training in CMR, high cost and non-availability of CMR scanners, seems to have led to a vicious circle that curbs the development and wider implementation of this method. Great efforts must be made by people involved in CMR in order to overcome these issues.

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