European Heart Journal Supplements (2016) **18** (Supplement E), E27–E30
The Heart of the Matter
doi:10.1093/eurheartj/suw020

Multimodality cardiac imaging at IRCCS Policlinico San Donato: a new interdisciplinary vision

Massimo Lombardi[1]*, Francesco Secchi[1,2], Francesca R. Pluchinotta[1,3], Serenella Castelvecchio[1], Vincenzo Montericcio[1], Antonia Camporeale[1], and Francesco Bandera[1,4]

[1]*Multimodality Cardiac Imaging Section, IRCCS Policlinico San Donato, Piazza Malan 2, 20097 San Donato, Milan, Italy*
[2]*Radiology Unit, IRCCS Policlinico San Donato, Piazza Malan 2, 20097 San Donato, Milan, Italy*
[3]*Department of Pediatric Cardiology and Adult with Congenital Heart Disease, IRCCS Policlinico San Donato Piazza Malan 2, 20097 San Donato, Milan, Italy*
[4]*Heart Failure Unit, IRCCS Policlinico San Donato Piazza Malan 2, 20097 San Donato, Milan, Italy*

KEYWORDS
Multimodality imaging;
Cardiac imaging

Multimodality imaging is the efficient integration of various methods of cardiovascular imaging to improve the ability to diagnose, guide therapy, or predict outcome. This approach implies both the availability of different technologies in a single unit and the presence of dedicated staff with cardiologic and radiologic background and certified competence in more than one imaging technique. Interaction with clinical practice and existence of research programmes and educational activities are pivotal for the success of this model. The aim of this paper is to describe the multimodality cardiac imaging programme recently started at San Donato Hospital.

Introduction

The rapid development of new technologies has deeply changed the capabilities of the different imaging techniques providing the physician a large spectrum of information either on the diagnostic or on the prognostic point of view. In the last decade, the efficient integration of various methods of cardiovascular imaging has improved our ability to diagnose, guide therapy, or predict outcomes. Because imaging tests are frequently performed in sequence, we sometimes deal with patients evaluated by several imaging techniques during a specific workup for known or suspected heart disease, especially when the first approach did not provide all the information sought. This new scenario stresses the importance of a multimodality approach to cardiovascular imaging that implies not only the availability of different technologies in a single unit but also the presence of personnel, dedicated to cardiac imaging, with both a robust cardiologic and radiologic background as well as strong connections with the cardiology units of the hospital who can identify the best imaging modality for a given clinical scenario and help the clinicians in the diagnostic and decision-making process. Recently, the San Donato Hospital started a large programme of multimodality cardiac imaging comprehensive of echocardiography, both transthoracic and transesophageal, cardiac magnetic resonance (CMR), and cardiac multidetector computed tomography (MDCT). The aim of the present article is to discuss the organization and the targets of the new multimodality cardiac imaging (MCI) section that has been founded in September 2014.

Human resources and technological facilities

One of the basic principles of the internal organization of the MCI section is related to the relationship between the operators and the other departments of the hospital. By choice, part of the permanent team of the MCI section is formed by operators fully dedicated to cardiac imaging. Furthermore, the youngest are facilitated into operating within an outside clinical section independently by their

* Corresponding author. Tel: +39 02 5277 4235, Fax +39 02 5277 4272, Email: massimo.lombardi@grupposandonato.it

involvement in the imaging section. The aim of this choice is related to the concept that, to be a reliable imaging expert, it is mandatory a direct involvement in the routine clinical activity. This peculiar organizing approach has also allowed reducing the conceptual distance with respect to the other clinicians not involved into the imaging section (*Figure 1*). This has also increased the level of appropriateness of the examination and it is the prerequisite for a more structured research activity.

The combination of non-ionizing radiation technologies, such as echocardiography and CMR, and technologies that use X-ray, such as MDCT, requires the competency of cardiologists and radiologists. The cardiologists and radiologists working within our MCI section are enrolled and trained according to the international guideline/consensus documents.[1] Both professional figures are working with the same rights and slightly different duties. In fact while the radiologist is requested to drive the examinations at the MDCT control room, during a stress CMR, a specialist in cardiology with certified experience in Basic Life Support-Advanced Cardiac Life Support must always be present. Furthermore, the subgroup of patients with complex congenital heart disease, which represents a significant part of our activity, are scheduled and evaluated under the direct responsibility of a paediatric cardiologist who underwent a specific training in CMR. The MCI section's staff is currently formed by one supervisor (a well-experienced cardiologist with a specific sub-specialization in cardiac radiology), one radiologist, two cardiologists, one paediatric cardiologist, and two residents (one radiologist and one cardiologist). Two more cardiologists are involved exclusively in echocardiography but extensively exposed to CMR and cardiac MDCT for research activities. Independently from the background, each single operator is admitted to perform an examination and to report the results only after an adequate training, which can be summarized in at least 300 CMR examination under the supervision of an expert in the field (Level 3 of Euro CMR consensus document[1]). The number of exams is similarly for qualification in MDCT (at least 300 cardiac patients) and echocardiography (at least basal Echo, Transesophageal, and Stress Echo).

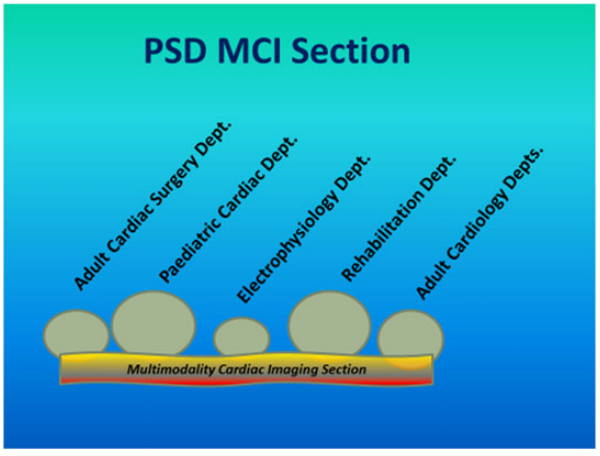

Figure 1 The current organization of the Multimodality Cardiac Imaging section at Policlinico San Donato. Within the Multimodality Cardiac Imaging section, operators exclusively involved into the imaging activity coexist with personnel who maintain their dependency to other specialized groups in the hospital but who have also some relevant responsibilities within the imaging section.

The MCI section is equipped with a 1.5 T MR scanner with 55 mT gradients and 70 cm diameter bore, dedicated to cardiac examination. About 1800 cardiac examinations per year are performed. Of these ~100 are performed during deep sedation or general anaesthesia mainly in small children with congenital heart disease and in a minority of adult patients suffering of claustrophobia. About 150 stress magnetic resonance imaging are performed per year to detect inducible cardiac ischaemia using dipyridamole, adenosine, or high dosage dobutamine. Patients undergoing viability evaluation by late gadolinium enhancement might be also evaluated by low-dosage dobutamine stimulation during the same scanning procedure if appropriate.

A 64 MDCT scanner is dedicated to cardiac examinations 2 days per week. About 1000 patients per year are evaluated for clinical purposes. Due to the increasing request of exams and with the aim of developing innovative research programmes, the selection of a new MDCT scanner is ongoing and the installation of a new scanner is expected early on 2016. Considering the high number of underage patients affected by congenital heart disease who need a MDCT evaluation, a systematic effort has been carried out to reduce the radiation dosage and currently a routine examination for coronary morphology is performed with 2–4 mSv. Moreover, a further effort has been performed to reduce the dosage in young paediatric patients with congenital heart disease where a whole morphologic study is performed routinely with a dosage <0.5 mSv. The reduction of mean radiation dose in the last 5 years in paediatric patients due to the increasing of expertise is shown in *Figure 2*.

Figure 3 is an example of low-dosage CT image in a patient with congenital heart disease.

Three echo scanners are available for the clinical activity of the MCI section. One of them is equipped with a transoesophageal probe and recording facilities to perform stress echocardiography.

All the imaging modalities are connected with the cardiac-PACS storage and images can been reviewed in remote workstations equipped for viewing, analysing, and reporting images.

Between 3000 and 4000 patients are evaluated each year with a significant percentage of patients undergoing

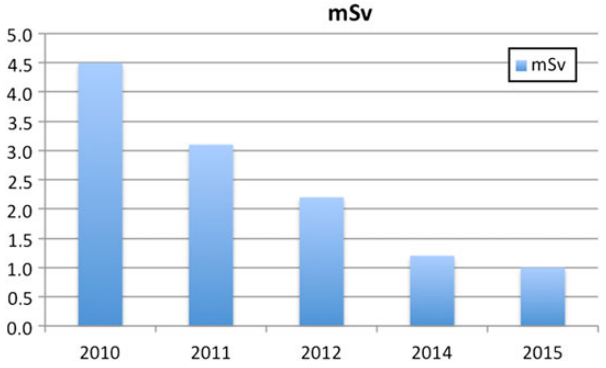

Figure 2 Reduction of mean computed tomography radiation dose in the last 5 years in paediatric patients: millisievert.

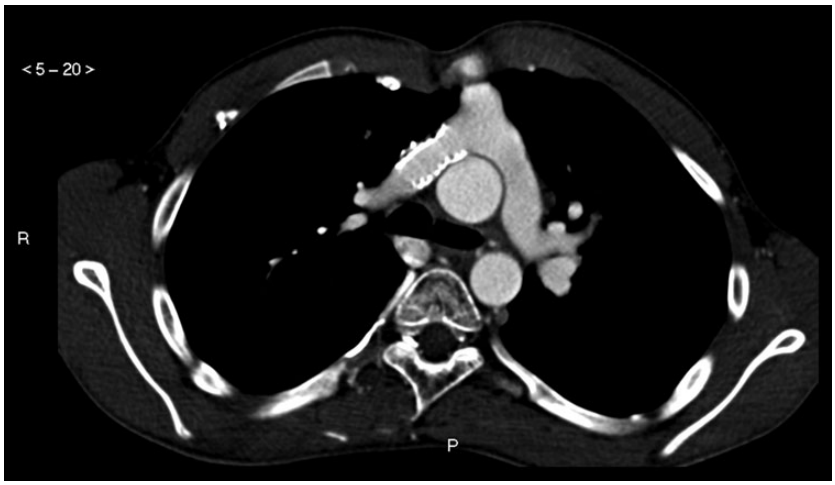

Figure 3 A low-radiation dosage image by a multidetector computed tomography obtained in a paediatric patient affected by a transposition of great arteries treated by arterial switch and Lecompte manoeuvre, stenting on pulmonary vessel. Total radiation dosage 1.2 mSv.

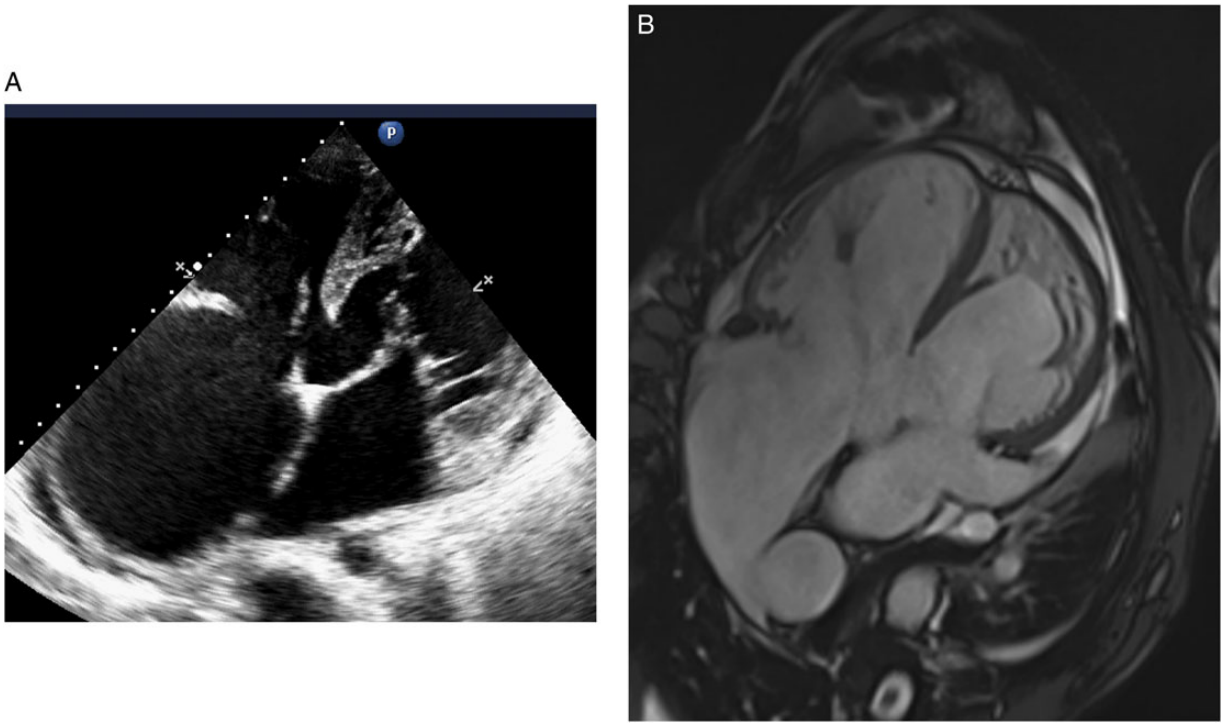

Figure 4 Transthoracic echocardiogram (*A*) and cardiac magnetic resonance imaging (*B*) of a patient with diagnosis of congenitally corrected transposition of the great arteries and large ventricular septal defect in destrocardia.

the transoesophageal procedure or pharmacological stress.

A fourth echo scanner is fully dedicated to research and mostly applied within a research programme, which has a multidisciplinary structure. This project is focused on surgical left ventricular remodelling in patients with a previous myocardial infarction. In fact, at Policlinico San Donato, the largest worldwide experience and database has been collected regarding the clinical, bioumoral, and imaging parameters for the extensive characterization of patients undergoing the surgical treatment of ischaemic heart failure. All patients entering into the project are prospectively evaluated by a comprehensive pre-operative clinical and multimodality imaging assessment of their cardiovascular status. A similar approach is also applied in serial follow-up evaluations. Imaging techniques, such as echocardiography (M-mode and two-dimensional in transthoracic approach—TTE), cardiac MR, and cardiac MDCT, are extensively used with an integrated approach to provide informations on LV dimensions (internal diameters and volumes) and systolic function, regional wall motion abnormalities, and diastolic function when combined with Doppler and Tissue Doppler Imaging[2] (*Figure 4*). Imaging technologies are also used to assess the mitral valve apparatus in terms of geometry and mitral regurgitation severity. An echo-pack workstation is also equipped with the

software that allows the Speckle tracking analysis, a new technology that provides important additional information related to systolic and diastolic function of the ventricles.[3]

Accreditation and certification

One of the main targets of the MCI section is to provide each of the operators with the proper competency in at least two of the three techniques available. The certification of competency is recommended albeit without legal value, as it is the demonstrations that the operators have acquired knowledge from appropriate sources and developed skills in the practice in the modalities they are involved in. Similarly, an accreditation process is already running for each modality at operative unit level. When available, the certification/accreditation process scheme offered by ESC will be applied.[1] Otherwise, the indications deriving from the main imaging societies will be followed (see SCMR, ESCR, and EACVI websites).

Educational activities

A residency programme has been activated, and fellows from Italy and from foreign countries are regularly accepted in a limited numbers to assure the optimal ratio between the tutors and the attendees. In general, no more than three fellows are accepted for each modality. Fellows are deeply involved into the imaging clinical activity under the supervision of certified and expert personnel. Several students of Medical School of Medicine of Milan are involved in projects with the both aim of graduation and publication of a paper in a peer review journal.

Research projects

Research plays a critical role in our practice. We have a large group of clinical researchers to offer new and improved diagnostic–therapeutic paths to our patients. Research areas of interest are fluidodynamics evaluation both in the great arteries and the ventricles, cardiomyopathies, and computational models for risk stratification in patients with congenital heart disease. There is an ongoing collaboration with biomechanical groups to look for potential advantages of 4D flows to predict diseases' evolution and short-term prognosis both in congenital and adult heart disease.

Having access to high-resolution cardiac imaging, recently, we focused our interest on three-dimensional (3D) printing technology to create heart prototypes of complex congenital cardiac defects. The use of 3D cardiac models allows for previously unavailable visualization, understanding, handling, and analysis of anatomy of complex heart disease. In most cases, the 3D model affords key information for planning interventional or surgical procedures: it allowed both imagers and surgeons to see, touch, and manipulate the heart helping the team to gain a better understanding of the problem that needs to be addressed and improving treatment planning.

Reduction of dosage of ionizing radiations has been and it is one of the main methodological target for the use of cardiac MDCT in adults and namely on congenital heart disease in children. The latter undergoing the exam during deep sedation. One of the research and development strategies the MCI section is pursuing is still related to a further optimization of the procedure to minimize the risk related to the use of this technology.

Conclusions

Multimodality imaging is the efficient integration of various methods of cardiovascular imaging to improve the ability to diagnose, guide therapy, or predict outcomes. To be successful, specifically trained staff must be confident with strengths and weaknesses of each imaging modality to know which is ideal for any given clinical situation and to help the clinicians in the diagnostic and decision-making process. While the certification/accreditation process assure a standardized model of organization in terms of acquisition of images and reporting, the continuous exposition of the operators to clinical and methodological research projects leads to a permanent exchange of knowledge either within the internal environment or at national and international level. All these efforts are producing an increasing consensus within the surroundings medical Units and among patients and their relatives.

For more information on the Multimodality Imaging Section at IRCCS Policlinico San Donato, please visit www.policlinicosandonato.it.

Conflict of interest: none declared.

References

1. Plein S, Schulz-Menger J, Almeida A, Mahrholdt H, Rademakers F, Pennell D, Nagel E, Schwitter J, Lombardi M; Working Group on Cardiovascular Magnetic Resonance, European Society of Cardiology. Training and accreditation in cardiovascular magnetic resonance in Europe: a position statement of the working group on cardiovascular magnetic resonance of the European Society of Cardiology. *Eur Heart J* 2011;**32**:793–798.
2. McMurray JJ, Adamopoulos S, Anker SD, Auricchio A, Böhm M, Dickstein K, Falk V, Filippatos G, Fonseca C, Gomez-Sanchez MA, Jaarsma T, Køber L, Lip GY, Maggioni AP, Parkhomenko A, Pieske BM, Popescu BA, Rønnevik PK, Rutten FH, Schwitter J, Seferovic P, Stepinska J, Trindade PT, Voors AA, Zannad F, Zeiher A; Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012 of the European Society of Cardiology, Bax JJ, Baumgartner H, Ceconi C, Dean V, Deaton C, Fagard R, Funck-Brentano C, Hasdai D, Hoes A, Kirchhof P, Knuuti J, Kolh P, McDonagh T, Moulin C, Popescu BA, Reiner Z, Sechtem U, Sirnes PA, Tendera M, Torbicki A, Vahanian A, Windecker S, McDonagh T, Sechtem U, Bonet LA, Avraamides P, Ben Lamin HA, Brignole M, Coca A, Cowburn P, Dargie H, Elliott P, Flachskampf FA, Guida GF, Hardman S, Iung B, Merkely B, Mueller C, Nanas JN, Nielsen OW, Orn S, Parissis JT, Ponikowski P; ESC Committee for Practice Guidelines. ESC guidelines for the diagnosis and treatment of acute and chronic heart failure 2012: The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association (HFA) of the ESC. *Eur J Heart Fail* 2012;14:803–869. doi: 10.1093/eurjhf/hfs105. No abstract available. Erratum in: *Eur J Heart Fail* 2013;15:361–362.
3. Bertini M, Ng AC, Antoni ML, Nucifora G, Ewe SH, Auger D, Marsan NA, Schalij MJ, Bax JJ, Delgado V. Global longitudinal strain predicts long-term survival in patients with chronic ischemic cardiomyopathy. *Circ Cardiovasc Imaging* 2012;**5**:383–391.