MULTIMODALITY IMAGING IN THE ASSESSMENT OF CARDIAC ISCHAEMIC HEART DISEASE

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Abstract: Cardiovascular disease accounts for 30% of the annual causes of death worldwide. Amongst them, ischaemic heart disease is one of the most important and life-threatening. Proper recognition, diagnosis and treatment of this disease can reduce mortality and improve life quality. The development and implementation of imaging techniques is invaluable in assessing and guiding the appropriate therapeutic strategy in patients with ischaemic heart disease. The purpose of this paper is to underline the importance of each of these imaging techniques and their impact the management of cardiac ischemic heart disease patients. Multimodality imaging provides an earlier and more accurate assessment of cardiovascular patients and allows specific and time-adapted treatment.

Key words: multimodality imaging, ischaemic heart disease, echocardiography, cardiac magnetic resonance, computed tomography.

1. Introduction

Cardiovascular diseases include, in a broader context, ischemic heart disease (chronic, acute coronary syndromes, coronary artery disease), cerebrovascular disease, vascular peripheral disease, hypertension, congestive heart failure, valvular heart disease and congenital heart disease.

Cardiovascular disease accounts for about 30% of worldwide deaths each year. 80% of these occur in low or middle income areas, which account for about 85% of the world's population. It is the leading cause of death in the world in each geographical area, with the only exception being the sub-Saharan Africa, where infectious diseases prevail [2], [4], [11], [16].

At the moment, 58% of deaths in Romania are still due to cardiovascular disease, and at European level, Romania ranks 1st in terms of cardiovascular disease mortality.

All these particularly worrying statistics raise alarm signals and require further development and implementation of measures, techniques, prevention guidelines, diagnosis and treatment of these pathologies that still manage to decimate populations by 3 times higher than neoplastic pathology, deaths caused by neoplastic diseases in their variety accounting for 20% of deaths in Romania.

The Romanian healthcare system is nowadays beginning to adapt to European standards and requires a proper understanding of the pathology in itself.

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and of the ability of the new technological means to ensure an accurate and rapid diagnosis of a pathology which decimates and invalidates thousands of people yearly.

In this context there is the need for more studies to assess the way in which classical and tridimensional echocardiography and the study of myocardial deformation, along with cardiac computed tomography (CT) and cardiac magnetic resonance (CMR) can bring a real benefit in everyday practice and can help implement new diagnostic and management strategies for ischemic heart disease.

2. Objectives

The aim of this paper is to evaluate the importance of the issue represented by ischaemic heart disease and the impact of the developing imaging techniques on the diagnosis and management of patients with ischaemic heart disease.

3. Material and Methods

Ischemic heart disease has a prevalence of 2.8 million in Romania in 2006 and an incidence of 256.4 / 100,000 inhabitants in 2004 [1] and therefore deserves particular attention in today’s clinical practice. The development of non-invasive imaging techniques allows a better assessment of patients at risk.

The diagnosis and evaluation of ischaemic heart disease has multiple aspects, with increasing importance of the contribution of the development of numerous new ultrasonographic methods (three-dimensional echocardiography, myocardial deformation study) and non-ultrasonographic ones (cardiac magnetic resonance, computed cardiac tomography).

These are all complementary diagnostic methods that enhance a more comprehensive morphological and functional evaluation of patients with ischemic heart disease [19].

3.1. Classification of Ischaemic Heart Disease

Ischemic heart disease is classified as:

- *Chronic coronary heart disease* - including the concepts of
  - Stable Coronary Artery Disease (SCAD)
  - Other clinical forms of ischemic coronary artery disease (Microvascular Angina, Silent Ischemia, Prinzmetal Angina)

- *Acute Coronary Syndromes*:
  - Unstable Coronary Artery Disease and Myocardial Infarction without ST segment elevation
  - ST segment elevation myocardial infarction

Ischemic heart disease remains a global issue and even more so at national level and requires the use of all current diagnostic and therapy techniques [4].

3.2. Imaging Techniques

3.2.1. Echocardiography

Echocardiography is a non-invasive imaging technique that uses ultrasound to recompose real-time motion pictures of the cardiovascular device and is currently the most used imaging research in cardiology [4].

In the evaluation of myocardial ischemia, echocardiography has a role in:

- Diagnosis of ischemic coronary artery disease
- Assessing the patient with chest pain at the on-site emergency room, having a negative predictive value of 97% [13].
- Risk stratification and complications evaluation (ischemic mitral regurgitation, complications of myocardial infarction)
Doppler echocardiographic evaluation of coronary flow

Echocardiography mainly evaluates indirect myocardial ischemia following endocardial movement and parietal systolic thickening (regional contractile function) [12]. Each stage of the ischemic cascade can be diagnosed by some imaging investigations. Regional parietal dysfunction occurs if critical ischemic mass is > 20% of parietal thickness [14]. Dyskinesia occurs if the necrosis ≥30-40% of the wall thickness.

Contractility Disorders:
- Present during angina have high specificity for the diagnosis of ischaemia [9].
- Localize ischemia or myocardial infarction [13].
- They may occur in the absence of myocardial ischemia (when a differential diagnosis is required between Left Bundle Brach Block (LBBB)-induced contractility disorders, right ventricle (RV) stimulation and ischemia).

Fig. 1. Coronary Territory and LV segments [18]

The segmental function of the left ventricle (LV) is assessed by qualitative, semiquantitative and quantitative methods.

There are also methods for assessing the overall function of the LV.

These methods do not locate the ischemic region, but determine the impact of ischemia on the left ventricular global (diastolic and systolic) ischemia, indicating a decrease in global systolic function (LV or RV ejection fraction) or the occurrence of various types of diastolic dysfunction.

Due to the large number of techniques used to evaluate the systolic function of the LV, there are classifications based on the appearance of the systolic function assessed as pump performance (ex. systolic flow), ventricular performance versus filling conditions (ex. Ejection Fraction (EF), Shortening Fraction-SF), the contractile function (ex: dp/dt, Tei index, etc.).

Each parameter has a multiple determinism (contractility, preload, post-load, etc.). Therefore, an easy classification is based on the used echocardiographic method (two dimensional -2D, three dimensional -3D, Doppler ultrasound, new imaging techniques for myocardial deformation, etc.) [12].

Fig. 2. Classification of systolic function parameters according to the echocardiographic method [7]

3D echocardiography and the study of myocardial deformation are amongst the latest innovative ultrasound techniques of the recent years. Nowadays 3D echocardiographic evaluation uses individually connected crystal arrays to allow real-time 3D imaging:
- Full-volume: acquisition of a large pyramidal volume (maximum 90°x90°) with optimal temporal resolution (25-40vps) by "joining" several partial-multi-beat sub-volumes (acquired over 4-7
successive heart cycles with Electrocardiography (ECG) gating, while the patient remains immobile and in apnea); Acquisition can be done with or without 3D color Doppler;

- Single-beat: Acquisition of a pyramidal volume (up to 90°x90°) from a single heart cycle - real-time full volume 3D (eliminates limitations related to arrhythmias, dyspnea, etc., but has the disadvantage of a low temporal resolution compared to a multi-beat of the same dimensions) [10], [12].

Viewing can be:

- In the form of multiple 2D-multi-plane or multi-slice sections - displayed simultaneously either in real time or after the 3D volume acquisition. Unlike traditional echocardiography, the orientation of 2D sections can be modified (corrected) by angular or translational maneuvers
- In the form of 3D anatomical images of the left ventricle (LV) (including cavity, walls, mitral valve and subvalvular apparatus, ejection tract etc.)
- 3D rendering with or without Doppler 3D.

The analysis of the images is based on:
- 3D imaging (volume rendering): it is useful only for identifying abnormal structures (thrombi, tumors), but not for quantification of the LV geometry and function parameters.
- Surface rendering obtained by 3D reconstruction of the LV cavity by removing the parietal myocardium: allows the measurement of the volumes, the ejection fraction, the mass, the sphericity index and the systolic deformation (strain, torsion) of the LV. After an initial manual definition of VS anatomical markers, the software automatically identifies the 3D endocardial surface and possibly the epicardial surface (for the measurement of LV mass and 3D parietal-strain deformation)
- Evaluation of the global LV function: A LV surface image is created from which the volumes can be derived without geometric presumptions. On the basis of these images there can be processed data of synchronism, regional deformation, regional parietal stress.
- Evaluation of segmental systolic function: one can calculate for each myocardial segment the contribution to volume LV change, expressed as volume / time curve, i.e. a measure of segmental kinetics.

3D techniques have proven superiority in volume measurement compared to 2D techniques (both as accuracy and reproducibility), but there is a systematic tendency to underestimate them compared to the gold standard which is the Cardiac Magnetic Resonance (CMR). LVEF (Left Ventricular Ejection Fraction) measured by eco 3D is comparable to 2D, but it has the advantage of a much lower intra- and interobserver variability. The reproducibility of the technique depends to a large extent on the quality of the 2D image and thus on the patient's ecogenicity [5].

**Evaluation of systolic function through tissue Doppler imaging**

Doppler myocardial or tissue Doppler imaging (TDI, or Doppler myocardial imaging, DMI) uses the Doppler principle for quantification of myocardial velocities. TDI involves the use of adapted filters as the myocardium moves during the low-velocity (less than 20 cm / s) heart rate cycle, with an increased density of the 2D signal. Thus, TDI uses filters that remove structures that travel at high speeds and have low reflectivity.

Based on the Doppler tissue data, the myocardial deformation analysis is performed. It has 3 main components: longitudinal, radial and circumferential. The strain (S) is the deformation of an
object relative to its original dimension. Expressed as a percentage (elongation +%,
shortening -%). [5] The strain rate (SR) is the speed at which deformation occurs,
expressed in s⁻¹.

The main advantage of myocardial deformation imaging is its ability to detect
early changes in ventricular function before decreasing LVEF and other

Fig. 3. Strain profiles from three apical views. Speckle-tracking echocardiography
analyses in the apical 4- (A), 2-chamber (B) and apical long-axis (C) view with the
respective speckle-tracking echocardiography measurements. Average segmental values in each segment are used
to generate a “bull’s-eye” display of left ventricular myocardial deformation (D) [9]

Speckle-tracking technique

The methodology is based on the frame-by-frame tracking of the direction and
distances of the movement of some tissue markers, thus deriving data on velocity and
myocardial deformity. This technique, independent of the angle of incidence, allows the measurement of the deformation
in all myocardial segments. There have been developed speckle tracking 2D and
more recent 3D techniques. [5]

In the Automated Function Imaging (AFI) complement technique, after
calculating the longitudinal deformation for each segment, the average for all segments - global longitudinal strain
(GLS) can be calculated and based on the bull's eye image the coronary territory
affected by coronary artery disease.

Fig. 4. Speckle tracking imaging from apical long axis (APLAX) view showing global longitudinal strain (GLA of -19.9%.
Regional peak systolic strain is also shown in the left bottom panel. Strain curves from
different LV regions are also shown in the upper right panel along with the cardiac
event of aortic valve closure (AVC). The bottom right panel portrays longitudinal
strain from six LV segments in a flat panel color format. The basal infero-lateral
segment is represented at the top and the basal anteroseptum at the bottom of the
display. The horizontal axis represents time and the vertical axis represents the six
LV segments [9]

3.2.2. Cardiac Magnetic Resonance

In the last decade Cardiac Magnetic Resonance (CMR) has developed very
much and becomes an increasingly used imaging diagnostic tool. With a particular
spatial and temporal resolution without exposing the patient to ionizing radiation,
CMR provides morphological and
functional characterizations detailed for most cardiac diseases.

Evaluation of ischemic coronary disease CMR imaging is capable of characterizing the various pathophysiological stages described within the spectrum of ischemic coronary disease.

The current CMR protocols for ischaemic heart disease integrate morphological, cinematic, contrast, late contrast, stress tests, allowing visualization of edema, myocardial perfusion in rest and stress, fibrosis / myocardial scar zones, and a comprehensive assessment of anatomy and Myocardial physiology.

Late Gadolinium Enhancement (LGE) is currently the most accurate non-invasive method of quantifying the size and morphology of an infarction [1], [8].

3.2.3. Cardiac Computed Tomography

Progress in the technical development of cardiac computed tomography (CCT) over the last decade now allows the acquisition of rapid and accurate imaging of the cardiovascular system, including coronary arteries, coronary artery wall, heart valves, myocardium, and associated structures.

Clinical indications for cardiovascular CT include a wide range of target anatomical images and clinical scenarios. These can be divided into seven categories:

1. Detection of coronary artery disease in symptomatic patients without known prior cardiac disease
2. Assessing the risk of coronary artery disease in asymptomatic patients
3. Detection of coronary heart disease in other cardiac pathologies
4. Using CT angiography after other tests
5. Use after revascularization
6. Evaluation of cardiac structures and functions
7. Evaluation of intra-cardiac and extracardiac structures [1], [8].

4. Results and Discussions

Diagnosis and management of the patient with coronary artery disease remains a burning problem because this pathology remains the leading cause of death worldwide. There are a lot of unsolved issues and a lot of future perspectives. What is the type of patient most at risk of developing complications of ischemic heart disease? Can we properly diagnose and evaluate a patient at the first onset of angina? What are the steps he / she has to follow? Are we able to assess their cardiac status well enough? Can current assessments predict life expectancy, the risk of developing malignant rhythm disorders or other late complications of myocardial infarction? How does the echocardiographic evaluation in the emergency room influence the prognosis of a patient? How does access to complex echocardiography influence it? What is the degree of accessibility of CT imaging? Who has access to CMR?

For the moment CT scan is reserved to patients with suspicion of ischaemic heart disease, but not eligible for invasive imaging techniques i.e. angiography, whereas the reduced number of performing MRI scanners along with the high demand of examinations for non-cardiac diagnosis, make the access for cardiac patients to this sort of examination more difficult and it is a matter for which we are devoting part of this project’s work.

4. Conclusions

The differences between the European and the Romanian national health systems make the degree of accessibility of the Romanian patients to the latest methods of diagnosis and therapy to be distinct from that of European patients. However, it depends to a large extent on the current efforts and the struggle to overcome these differences in order to be able to sense the importance of global imaging techniques and to turn these developments into real solutions for improving the prognosis of ischaemic heart disease patients.

Diagnostic and treatment centers with adequate facilities and multidisciplinary teams are required, including a cardiologist, radiologist, intervention cardiologist, cardiovascular surgeon, anesthesiologist. There are few centers in Romania which can provide a multimodal evaluation of cardiac ischaemic disease patients.

We believe that it is necessary and justified to launch local level projects where multimodality evaluation strategy can be implemented in the management of as many patients with ischemic heart disease, and to assess the benefits of this approach. This will allow us to have a better view over a pathology which has been studied and known for many years and which continues to pose problems from the moment of onset until the development of the latest complications.

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References

2. Decline in deaths from heart disease and stroke – United States, 1990-1999,