Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/crvasa

Review article – *Special issue: Imaging in Coronary Artery Disease*

Multimodality imaging in coronary artery disease – "The more the better?"

Simon Greulich *, *Udo Sechtem* *

Division of Cardiology, Robert Bosch Medical Center, Stuttgart, Germany

ARTICLE INFO

Article history:
Received 17 August 2015
Accepted 19 August 2015
Available online 11 September 2015

Keywords:
Multimodality imaging
Coronary artery disease
Computed tomography
Single photon emission computed tomography
Positron emission tomography
Magnetic resonance imaging

ABSTRACT

Multimodality imaging in coronary artery disease (CAD) comprises a combination of information from more than one imaging technique. These combinations, performed in a side-by-side or fusion mode, include computed tomography (CT) and single photon emission computed tomography (SPECT), positron emission tomography (PET) and CT, and PET with magnetic resonance imaging (MRI). Data thus obtained lead to either a summative or synergistic gain of information. For instance, morphology (coronary plaques/stenosis) can be depicted by coronary CT angiography, whereas functional aspects of CAD such as myocardial perfusion abnormalities or myocardial metabolism can be evaluated by the complementary technique in order to separate a hemodynamic significant coronary stenosis from a hemodynamic non-significant stenosis. Distinguishing these two entities has an important impact on patient management. Beyond the diagnostic yield, some of these combinations in multimodality imaging also have prognostic implications. In this article, we will describe different multimodality imaging approaches (CT/SPECT, PET/CT and PET/MRI) for evaluation of CAD in patients with suspected or known CAD and put them into the context of current knowledge.

Contents

* *Corresponding authors at*: Robert Bosch Medical Center, Auerbachstrasse 110, 70376 Stuttgart, Germany. Tel.: +49 711 8101 6048; fax: +49 711 8101 6146.
E-mail addresses: Simon.Greulich@rbk.de (S. Greulich), Udo.Sechtem@rbk.de (U. Sechtem).
http://dx.doi.org/10.1016/j.crvasa.2015.08.007

Introduction

Strictly defined multimodality (hybrid) cardiovascular imaging comprises a combination of a least two out of the four following cardiovascular imaging techniques: CT, SPECT, PET, and MRI. More general, multimodality cardiovascular imaging is frequently used for any combination of imaging techniques employed to study the diagnosis or functional implications of cardiovascular disease. In this article, we will focus on multimodality cardiovascular imaging using the stricter definition.

Non-invasive methods of cardiac imaging have developed rapidly during the last 10 years [1]. This is most obvious in the field of suspected or known coronary artery disease, where non-invasive imaging techniques are employed for the evaluation of diagnosis, prognosis and risk stratification. Besides morphology of the coronary vessels, functional alterations on myocardial perfusion and metabolism due to coronary stenosis are of high clinical interest, since only patients with both anatomically and functionally relevant stenosis benefit from revascularization [2]. The primary aim of a multimodality imaging approach should be providing synergistic rather than summative diagnostic and prognostic information, guiding the clinician in his further treatment options. By the use of multimodality imaging, the clinician should be capable of dividing patients with suspected or known CAD in a conservative, optimal medical therapy group vs. a group who might benefit with reasonable probability from interventional therapies. Despite all improvements and refinements in non-invasive imaging, a patient-tailored approach, which is additionally based on clinical judgment, remains mandatory to find the best practice for the individual patient. This article summarizes commonly used imaging techniques (except echocardiography) and their combinations for the non-invasive evaluation of patients with suspected or known CAD.

Commonly used combinations of cardiac imaging modalities

CT/SPECT

Coronary artery calcium score (CACS) detected by CT has wide implications not only for detection of CAD, but also for patient prognosis. A recent report including 351 patients with symptoms suggestive of CAD could demonstrate that sensitivity for CAD detection by CACS alone was very high (99.2%), whereas specificity was very low (30.3%), with an excellent negative predictive value of 98.5%. Adding SPECT to CACS in patients with CACS >0 yielded to increased specificity (80.9%) with only a slight decrease of sensitivity (87.9%). The authors stated that SPECT perfusion imaging in addition to CACS alone in patients with a CACS >0 increases the diagnostic accuracy for detection of relevant CAD and lowers the number of patients referred for coronary angiography [3]. On the other hand, in asymptomatic patients without previous CAD who have a normal SPECT CACS adds incremental prognostic information, with a 3.6-fold relative increase for any cardiac event (2.8-fold for death/myocardial infarction) when CACS is high (>400) vs. minimal (≤10) [4].

Coronary CT angiography (CTA) is the most promising non-invasive technique to depict both non-calcified and calcified plaques and to estimate luminal narrowing of the coronary arteries. Its negative predictive value is excellent in cohorts of patients with low pre-test probability, sparing the patient further examinations. However, if the pre-test probability is higher, the negative predictive value of coronary CT angiography is not that impressive [5]. A positive coronary CT angiogram has both good diagnostic performance for detecting and ruling out coronary stenoses >50% compared to invasive coronary angiography at least in patients with suspected CAD who have a low to intermediate pre-test probability of stenosis as defined by current data by Genders et al. [6]. The main limitation of coronary CTA is in patients who have densely calcified plaques, which can cause ''blooming artifacts'', resulting in non-interpretable images and lower diagnostic accuracy. Moreover, patients presenting with arrhythmia/tachycardia cannot be studied using low radiation protocols, since diagnostic quality might be severely impaired due to gating problems. Hence, a combination with other imaging techniques providing information about functional parameters, e.g. single photon emission tomography (SPECT), is mandatory in patients who show stenoses by coronary CTA, especially if these stenoses are severely calcified, to increase diagnostic accuracy [7], also see Fig. 1.

SPECT imaging studies also provide good diagnostic accuracy for detecting significant CAD compared to X-ray coronary angiography [8]. Patients with a normal SPECT perfusion have a favorable prognosis, with an annualized event rate of 0.6% which is similar to the event risk in the general population [9]. Conversely, patients with ischemic regions more than ≥10% of the left ventricle (LV) may benefit from revascularization procedures [10].

As SPECT provides 3D-datasets, these can be combined with CT images using dedicated software, permitting correction of misalignment between datasets. Combining these two modalities in patients at higher pre-test probabilities may increase the low specificity of coronary CTA from 63% to 95% and the positive predictive value (PPV) from 31% to 77% [11]. Furthermore, Sato and colleagues demonstrated that of 390 arteries in 130 symptomatic patients with suspected CAD, 54 (14%) were non-evaluable by coronary CTA due to severe calcifications, motion artifacts, and/or poor opacification. All non-evaluable arteries by coronary CTA were considered stenosis-positive leading to a reduced specificity and PPV. The combination with SPECT improved specificity and PPV