Cardiovascular CT: Hype or paradigm – Multi slice CT value in cardiac workup algorhytm

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Coronary artery disease (CAD) is the leading cause of hospitalization and mortality in the United States and Europe. The Guidelines of the American College of Cardiology and American Heart Association recommend the use of exercise testing as a first step in evaluating patients with suspected CAD with a sensitivity and specificity of 68% and 77%, respectively. However, due to its limited specificity and sensitivity, stress imaging tests are often necessary as gatekeeper to invasive coronary angiography (ICA). Despite this approach, approximately 25% of patients underwent ICA have no significant CAD. Multidetector computed tomography (MDCT) is a viable alternative in the evaluation of suspected CAD or follow-up of patients treated by revascularization. The purpose of this presentation is to explain the principles of technology, clinical applications and issues of radiation exposure of this new and promising diagnostic method

Technical background

Scanning modality

The evaluation of coronary anatomy requires a method with high spatial and temporal resolution. ICA has represented for almost half century, the only diagnostic procedure for evaluation of coronary anatomy. In the early 90's the first electron beam tomography (EBCT) was introduced. Despite an excellent temporal resolution, the EBCT had a limited spatial resolution. Conversely, the older generation scanner showed a better spatial resolution than EBCT but inadequate temporal resolution. Only in the late '90s the first MDCT with retrospective ECG-triggering became available initially consisting of 4 layers up to the current 320 layers available on the market today with gantry rotation time of 330 msec. However, despite the technological implementation, a low heart rate (HR) was mandatory until the advent of dual source computed tomography (DSCT) at the end of 2005. Regarding to ECG gating, two different modalities are available: retrospective ECG-gating in which continuous helical scan is performed throughout the cardiac cycle while the table moves that is generally associated with high effective radiation dose (ED) or a prospective ECG-gating in which one axial scan is performed in the diastolic phase and therefore a low HR is mandatory.

Patient's preparation

Recent studies have shown that HR plays a key role in the diagnostic performance of MDCT. Indeed, despite the implementation of the temporal resolution of last generation scanners, a HR $\leq$ 65 bpm is always desirable in order to reduce motion artefacts. In particular it was shown that, in groups with low HR, the overall feasibility, image quality and especially the diagnostic accuracy is higher than in patients studied with high HR. To this aim drug protocols to reduce HR are mandatory such as beta-blockers or ivabradine. Finally, some authors showed an improvement in image quality by the use of sublingual nitrates administered immediately before scanning in order to reach maximum coronary vasodilation and better intracoronary contrast attenuation.

Scanning parameters

The standard protocol uses tube voltage and tube current based on the patient's BMI, retrospective or prospective ECG-gating according to the HR, bolus administration of contrast medium followed by a bolus of saline in order to reduce artefacts in the superior vena cava and right heart cavities maintaining a high level of contrast attenuation in coronary arteries.

Post-processing analysis

The axial images obtained by scanning are rarely utilized for diagnostic purposes. Indeed, the dataset is transferred to dedicated workstations and analysed by reconstruction software including three-dimensional and multiplanar reconstructions. There are 3 different methods to estimate the degree of stenosis: qualitative in which significant stenosis (≥ 50% diameter reduction) is detected without performing measurements, semi-quantitative where a score 0 (absence of intraluminal narrowing), 1 (lumen reduction between 0 and 25%), 2 (lumen reduction between 25 and 50%), 3 (lumen reduction between 50 and 75%) and 4 (lumen reduction between 75 and 100%) is provided and quantitative where the percentage of stenosis is calculated as stenosis diameter to reference diameter ratio. Regarding the composition of plaque there is a direct correlation between the contrast attenuation of the plaque and its composition (lipidic plaque <20 HU; fibrotic plaque between 20 and 80 HU, mixed plaque between 80 and 150 HU and calcified plaque >150 HU).

Clinical applications

Coronary artery evaluation

Several studies showed high feasibility and accuracy of MDCT in the diagnosis of CAD with a significant reduction of artefacts in patients with HR <55 bpm. Regarding the diagnostic accuracy, several multicentre studies showed a very high negative predictive value close to 100%. However, it is strictly influenced by the characteristics of study population. Indeed, in high risk patient MDCT showed a limited positive predictive value ranging between 60% and 75% while in a population with a low to intermediate pretest likelihood of CAD a negative predictive value up to 99% has been reached. Based on these evidences, one of the main indications of MDCT is the presence of atypical angina and positive stress test. However, the clinical role of MDCT in the clinical setting of typical angina and negative stress test remains an issue of debate. A second clinical application of MDCT is dilated cardiomyopathy (DCM). Several studies with both 16 and 64-slice scanners showed a feasibility and diagnostic accuracy close to 100%. Indeed, the systolic dysfunction associated with DCM allows a reduction of motion artefacts. The last but not least clinical indication of MDCT is to rule out CAD in patients with low to intermediate likelihood of CAD and with surgical indication for non-coronary cardiac surgery with a sensitivity, specificity, positive and negative predictive value of 100%, 92%, 82% and 100%, respectively.

Moreover a potential prognostic role of MDCT has been described. These evidences are reinforced by recent data showing that although the prognosis of patients with positive myocardial nuclear stress test is worse than in patients with negative nuclear stress test, similarly the prognosis of patients with positive nuclear stress test and negative MDCT is the same of the patients with negative nuclear stress test and positive MDCT.

Intrastent restenosis evaluation

Coronary stenting is a major therapeutic aid currently used for myocardial revascularization. A recent meta-analysis has documented on a total of 2003 a feasibility, sensitivity, specificity, positive and negative predictive value and diagnostic accuracy of 90%, 90%, 92%, 72%, 97% and 91%. However this performance is very scattered in individual studies ranging from 63% to 100%. The main factors that influence the diagnostic performance of MDCT in the diagnosis of intrastent restenosis are: stent size, thickness and the presence of overlapping stents. Nowadays, the recommendations of scientific societies define the MDCT as still inadequate for the follow-up of stent, reserving its use in patients unable to perform functional tests.

Coronary artery bypass grafting

The evaluation of coronary artery bypass grafting (CABG) by ICA is currently the diagnostic gold standard. However, the risk of side effects, is estimated about 1.8% (arrhythmias, stroke, coronary dissection, bleeding) with a rate mortality of 0.1%. In addition it is sometimes difficult to describe the graft anatomy by ICA. For this reason, the MDCT has become a non-invasive alternative to ICA. The main limitations in the evaluation of CABG using MDCT are blooming artefacts due to metal clips, the distal anastomosis evaluation and assessment of native coronary vessel lumen after anastomosis. Currently, the scientific societies have classified the follow-up of CABG by MDCT with a level of evidence IIB.

Issues of radiation exposure

Depending on the technology used and the scanning mode, effective radiation dose (ED) up to 29 mSv has been reported in the literature. It was estimated that an ED of 10 mSv is associated with a cancer risk of 1/2000. Several strategies to reduce ED can be used such as the optimization of scanning parameters, the use of fast scanners as dual-source MDCT or 256/320 layers or more recently the use of prospective ECG-gating. The latter option is the more robust. The reduction of the effective dose is achieved through two main mechanisms: the absence of overlapping and the reduction of the scattered radiation reaching a reduction in the ED up to less 2 mSv.

Conclusions

The MDCT is now a non-invasive alternative to ICA for the evaluation of suspected CAD, for the evaluation of intrastent restenosis and follow-up of CABG. Its diagnostic accuracy is bound to a careful selection of candidates including patients with regular cardiac rhythm, low HR, low to intermediate pretest likelihood of CAD. In this clinical setting, MDCT will play an increasing strategic role in the diagnosis, prognosis and follow-up of coronary artery disease.