CT angiography of the coronary arteries: setting new diagnostic standards in cardiovascular medicine

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Abstract. CT Coronary Angiography of the heart is one of the fastly developing techniques in cardiovascular imaging. It is rapidly emerging and quickly entering the clinical practice and international guidelines. The increasing evidence regarding the strong role in the assessment of coronary artery lumen is progressively expanded by evidences of the important role of coronary wall imaging. The prognostic importance of CT Coronary Angiography is worldwide reported and the main question that is posed at the moment concerns the potential impact in primary prevention. In this review we will discuss the current applications and technology state of the art, X-ray dose issues, the training requirements and implementation in the healthcare context of CT Coronary Angiography. (www.actabiomedica.it)

Key words: CT Coronary Angiography, diagnostic accuracy, prognostic value, primary prevention, healthcare organization

Introduction

Multislice Computed Tomography (MSCT) was introduced in the late ’90 and rapidly changed the approach and the field of application of CT in general (1-12).

The newer 4-slice CT technologies proved to be effective in imaging the heart and small vessels opening the clinical field of CT-angiography (1-12).

The driving force for further developments was at that time the feeling that MSCT could become the modality of choice for the visualization of heart (13-38). The application was called CT coronary angiography (CTCA). Both from the standpoint of business and clinical impact, any modality with this capability would radically change the approach to atherosclerosis, coronary artery disease, pharmacological treatment, and so forth (13-38).

In the following years several new generations appeared on the market (8-slice, 16-slice, 32-slice, 40-slice, 64-slice) in a tough challenge towards the adequate imaging of the “Holy Grail” of clinical medicine: non invasive assessment of coronary arteries (1-12).

Technical and clinical considerations

Since the beginning it was clear that CTCA was a technique able to provide nice images of the coronary arteries at the price of a variable amount of radiation exposure. This was always a pitfall of the technique and still remains one of the major concerns in the widespread application. The amount of radiation to which a patient is exposed while undergoing CTCA is between 7-8 mSv and 15-20 mSv depending on several variables (1-12). Conventional invasive coronary angiography (CAG) for diagnostic purposes ranges with 4-6 mSv (1-12). If we imagine that a plain chest X-ray provides 0.1/0.2 mSv we can surely understand the relatively cautious enthusiasm of several medical specialists in sending patients to this technique.

Multiple validation papers with all generations of MSCT scanners proved an increasing diagnostic accuracy compared to the gold/reference standard (i.e. conventional invasive coronary angiography). The reported values were above 90% both in sensitivity and specificity, but most of all, the negative predictive value ranged close to 100%. This means that a negative CTCA reduces the probability of having any atherosclerosis almost to "0". This reflects also into the prognosis of the patients undergoing CTCA. Recent studies reported a very high capability of prediction for CTCA. Patients undergoing CTCA and reported to have no coronary artery disease at all showed very little or no events (both major adverse cardiovascular events and "hard" events) at 1-2 years follow-up.

Current Technical State of the Art

Currently, the state of art of technology in the field of CTCA is the 64-slice and above. However, the lines of research and development of the companies involved are dividing at this point in time (1-12).

For many years technology in this field developed following the law of "more slices are better". Things are changing. Some manufacturers are developing in this direction (Siemens Medical with 128 slices, Philips Medical with 256 slices and Toshiba Medical with 320 slices). Others are developing into high resolution (i.e. new detector hardware) technology (GE medical). Others are developing into higher temporal resolution (Siemens Medical with Dual Source technology). Others are developing also into concomitant Dual Energy platforms (GE Medical and Siemens Medical). It is not clear at the moment weather one development will prevail on the others. We know for sure that current benchmark (i.e. 64-slice CTCA) is performing already very well in experienced hands.

The advantages of more slices (between 128 and 320 slices) are inherent to the very short scan time (1-2s) and to potential for myocardial perfusion. The "price" might be related to constraints in temporal resolution and an increased radiation dose. The advantages of high resolution technology are inherent to better image quality with the same radiation dose or to the same image quality with a lower radiation dose. The advantages of higher temporal resolution are inherent to a reduced use of drug administration. The advantages of a dual energy platform are inherent to totally unexplored spectral imaging capabilities.

Of course, what is really important is the aim. The aim is to perform good coronary artery imaging in order to exclude coronary artery disease. For this purpose each solution described as its pros and cons.

X-ray dose issues

In the early experiences of CTCA, the dose appeared together with heart rate and calcifications as one of the major issues for this diagnostic modality. During the years, heart rate was challenged with proper use of beta-blockers and faster CT scanners. Coronary calcifications are still a problem, even though less than in the past, because of the introduction of new filters and newer detector technology.

X-ray dose, instead, remained a big problem for several years. With the latest technologies (i.e. 64-slice CT and Dual-Source CT associated with prospective ECG-triggered acquisition and 100 kV), it has been reported that, combining different strategies for dose reduction, it is possible to obtain a diagnostic CTCA with 1-2 mSv (as compared to the 14-21 mSv, of the latest 64-slice CT). This tremendous reduction in X-ray dose puts this modality as a very safe investigational tool and opens new possibilities. In fact, in the field of low cardiovascular risk and asymptomatic individuals, such a low X-ray dose, may pose the question on whether it is useful to know the presence and amount of the atherosclerotic burden regardless lumen stenosis. With this possibility CTCA is going to become the primary tool for stenosis detection and cardiovascular risk stratification in the near future.

Training, workflow and implementation

The implementation of CTCA remains challenging (13-16). The reason for this is that it is not just the natural evolution of CT. It represents a completely new field of application in which both technology and clinical information are arising every week. The expertise required runs across Radiology and Cardiology and there are still very few people able to provide a reliable knowledge in both fields. For this reason in most of the Hospital this "business" needs to start with the cooperation between the Radiology and the Cardiology Department. Even in this case the time required to have the machine running properly can still be relatively long (>1 year; without previous specific on-site expertise). The constant development of technology and the widening field of application requires a team of professionals both Physicians (Radiologists and Cardiologists) and Technicians. Everyone has to play his/her role in order to have good results. Inadequate training will result in redundant diagnostic tests for the patients, which is the opposite of what we are searching and expecting from this new imaging modality. In fact, due to the very high negative predictive value we expect to reduce the number of invasive coronary angiography investigations hesitating in a "non-significant coronary artery disease" type of report. This type of report ranges between 30% and 50% depending on the country.

The implementation is also very slow because the Cardiologists need to change their approach to coronary artery disease. Instead of thinking "function and then – eventually - anatomy", they will need to think "anatomy and then – eventually - function". This is because, until now, no diagnostic test was able to image the coronary arteries. After a while, however, clinicians will start to appreciate the advantages of CTCA both in terms of diagnostic performance and in terms of added information that this imaging modality can provide. In fact CTCA allows the assessment of coronary arteries and in the meantime, several other conditions can be evaluated. For instance: pulmonary embolism, aortic dissection, pleural effusion, pericardial effusion, and so forth. Basically, the thorax can be explored in all the different types of diseases causing typical pain, atypical pain or just chest discomfort.

The implementation in the settings of out-patients is relatively easy. The main issue concerns the use of oral and/or intra-venous administration of drugs for the reduction of heart rate (e.g. beta-blockers, calcium-antagonists), for the dilation of coronary vessels (e.g. sub-lingual nitrates), for calming down the patient (e.g. oral or IV benzodiazepines).

In the settings of emergency room, instead, the implementation is much more difficult due the requirements of 24/7. It takes some more time to train enough personnel to guarantee CTCA every day and night.

Diagnostic Algorithms and Guidelines

The ideal patients who should undergo CTCA is a patient at intermediate cardiovascular risk with symptoms (i.e. typical or atypical chest pain), with or without a stress test (e.g. stress ECG, stress SPECT, stress Echocardiography) that do not allow a sharp inclusion/exclusion coronary arteries as the main source of the clinical condition (Figure 1) (18-20).

There are no real guidelines since no multicenter multivendor trials have been performed yet. However, the literature is very wide and consistent in suggesting this application as the most important one.

Other fields of applications that are widely recognized in the expert community are: patients with typical chest pain and negative stress test, the follow-up of patients with coronary artery bypass surgery for the assessment of graft patency, patients with acute chest pain with negative/non diagnostic ECG and blood troponine levels, the differential diagnosis of a newly discovered dilated cardiomyopathy, screening for coronary artery disease in patients undergoing non-coronary heart surgery and major non cardiac surgery, patients refusing invasive coronary angiography.

Minor fields of applications (because the imaging modality has a lower diagnostic performance or because the number of patients is lower) are: the follow-up of coronary artery stents (but only stents when are >3.0/3.5 mm) and coronary artery anomalies (usually an incidental finding during invasive coronary angiography or during CTCA itself).

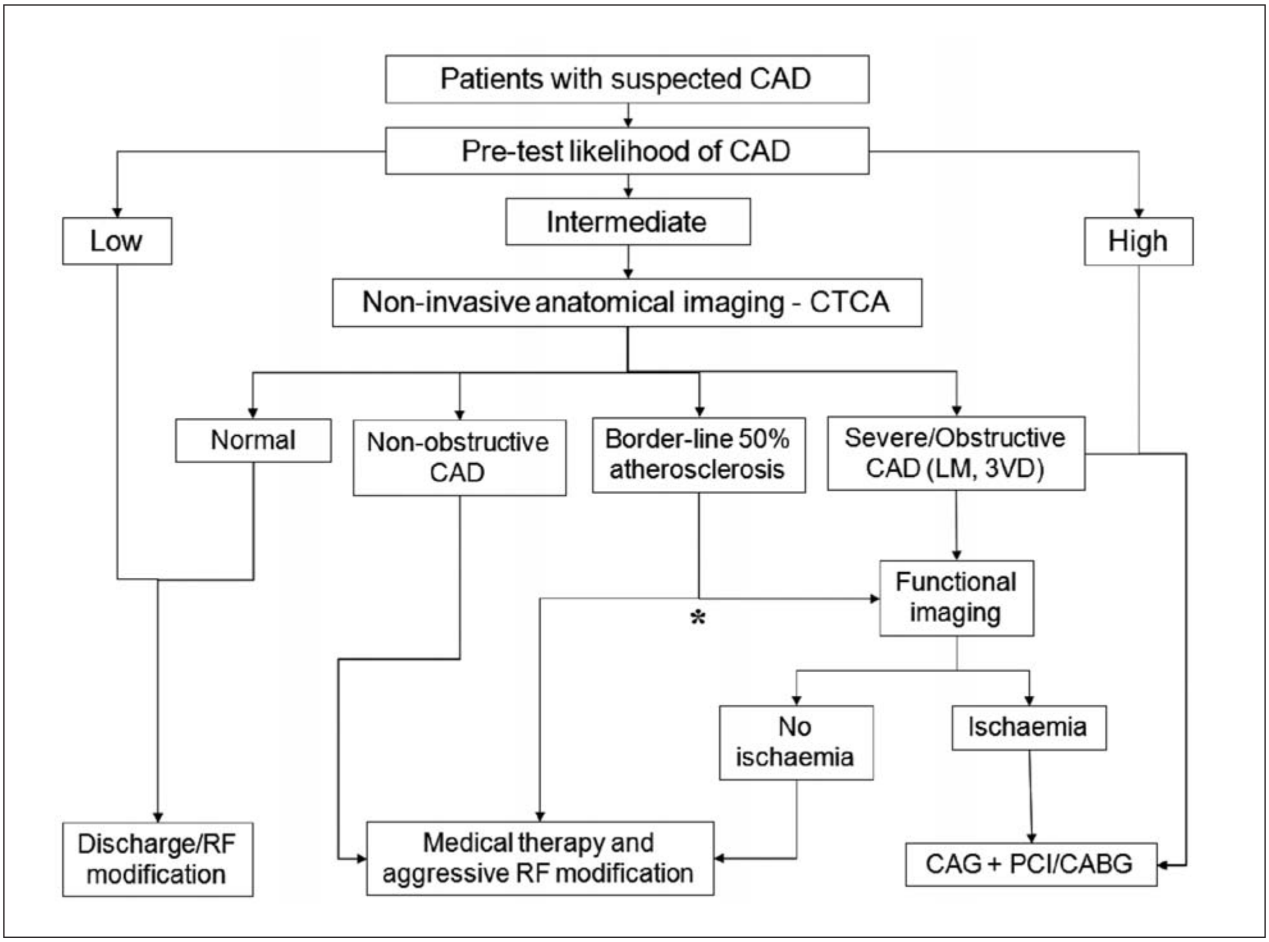

Figure 1. The figure shows a potential algorithm for the implementation of CTCA in clinical practice. After risk stratification, the patient with suspected coronary artery disease (CAD) undergoes non-invasive anatomical imaging with CTCA (i.e. Computed Tomography Coronary Angiography) if he/she falls into the group at intermediate risk. If CTCA reveals no CAD the patient is safely discharged. If CTCA demonstrates the presence of atherosclerosis without significant stenosis (<50% lumen reduction) the patient can be approached with medical therapy and aggressive risk factors (RF) modification. When CTCA reveals the presence of borderline/intermediate obstructive CAD (around 50% lumen reduction) the patient, depending on clinical settings (*), can be treated medically or sent for functional assessment. When CTCA depicts clear-cut obstructive CAD it is possible to perform functional testing (to determine the extent of coronary flow reserve reduction) or send directly to invasive coronary angiography (CAG), depending on the extent, location and degre of obstruction. Patients undergoing CAG will be sent to percutaneous coronary intervention (PCI) with stent positioning or to coronary artery bypass graft surgery (CABG). When, after risk stratification the patient is at low risk there is a conservative approach with RF modification on demand. On the contrary, when the patient is at high risk the further diagnostic algorithm should follow an aggressive approach with CAG and eventually revascularization (with PCI or CABG).
Modified from Cademartiri F, Maffei E, Mollet NR. Is dual-source CT coronary angiography ready for the real world? Eur Heart J 2008 Mar; 29 (6): 701-3 and Schuijf JD, Bax JJ. CT angiography: an alternative to nuclear perfusion imaging? Heart 2008 Mar; 94 (3): 255-7

Overall, the algorithm should always take into account that a patient with a very high probability of having obstructive coronary artery disease should not undergo CTCA. On the contrary, patients with intermediate-to-low risk of coronary artery disease and any clinical suspicion are good candidates for CTCA.

In all cases, asymptomatic individuals should not undergo CTCA for screening purposes, unless they have instrumental evidence of abnormalities suggesting a possible underlying coronary artery disease.

Screening and risk stratification

The first application of CT to coronary imaging was Calcium Score (25-33). This is a quantitative method to assess the calcium burden of the coronary arteries. It correlates very well with cardiac events. A higher calcium score implies a progressively higher risk of cardiovascular events. It has been suggested that the proper use of this technique could better stratify patients at intermediate risk for whom the medial strategy falls in between discharge and further testing. Even though this method is available since the early '90s, it has never become a clinical tool. A very large literature has been published on this topic but since the main application would be in asymptomatic individuals it never entered major guidelines. Most individuals self refer to this imaging modality.

Healthcare context

In the set up of national healthcare, a CT equipment should not be based on CTCA investigation alone. Since the reimbursement of CTCA is still under discussion in Europe (not in many States of the US in which proper reimbursements are already established), the CT equipment should perform a high number of investigations/patients in order to break-even in a reasonable timeframe. In addition, the developing technology pushes towards fast "aging" equipments. An Institution should therefore take into account that to offer the latest technology should change/update the hardware of the equipment every 3-4 years at the most. Large Institutions with several CT equipment can more easily keep the pace by rotating the update of technology. Smaller Institutions with only one CT equipment will have more difficulties in doing so.

The workload that a 64-slice CT can take is only limited nowadays by the preparation of patients. In good settings with trained personnel, a 64-slice CT equipment can investigate at least 4 patients/hour. As usual, the out-patient settings favors higher workloads.

Another thing to take into account concerns the widening indications for CT angiography studies others than cardiac. The robust and relatively easy implementation of CT for the investigation of carotid arteries, cerebral arteries, peripheral vessels in general represents a positive spin off of edge CT technology in any Institution.

Conclusions

CTCA is the "rookie" in cardiac imaging, however, it is rapidly gaining the hot spot: "the modality of choice for the population at intermediate risk". This population is the widest in western countries (about 40% of the population). Patients with symptoms or instrumental evidence of suspected coronary artery disease should undergo CTCA as first imaging modality in the diagnostic algorithm because of the very high negative predictive value. However, in the near future, because of significant X-ray dose reduction, CTCA will become the modality of choice for primary cardiovascular risk stratification.

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