

MULTI-SLICE CARDIAC TOMOGRAPHY (MSCT)

In general, in Spain, there is a good access to MSCT. When a physician (mainly clinical cardiologist) wants to refer a patient to this technique do not have problems, because in most tertiary centers there is a MSCT equipment.

The type of personnel involved in the evaluation of MSCT images and results varies among different centers. The most usual situation is the combination of radiologists and cardiologists, but the level of expertise of cardiologist is very variable. In some centers, they are very qualified, but in others the quality may not be very high. This may explain that reliability of interpretation may be heterogeneous among different centers.

However, the waiting list of MSCT is longer than for coronary angiography, and also access for this invasive technique is easier.

Physicians sending patients to MSCT, and deciding whether the patient goes to MSCT or coronary angiography are mainly clinical cardiologist, but also some other physicians do it occasionally. Among clinical cardiologist, those who are in charge of outpatient clinics, rather than hospitalized patients, are the most important. There are two explanations for this:

- 1) Most patients that are hospitalized have suffered an acute heart disease, and in these situations an invasive management is usually recommended, with invasive coronary angiography without the need for doing non-invasive tests.

- 2) In patients that are hospitalized, waiting list is usually shorter for coronary angiography than for MSCT.

Some studies have evaluated the potential usefulness of MSCT at the emergency room for easy and early classification of patients with chest pain. However, in most centers this is not been applied. The most frequent approach for these patients is the classical use of electrocardiogram and cardiac enzymes for deciding whether one given patient may be discharged at home or must be hospitalized for further evaluation and treatment. In centers in which MSCT is used at the emergency room in patients with chest pain (mainly in those with suspected ischemic chest pain), the cardiologist are who decide to do this approach. This is because in the vast majority of centers in which there is a 24 hours availability of this technique, there is also a clinical cardiologist available.

The type of personnel involved in the evaluation of MSCT images and results varies among different centers. The most usual situation is the combination of radiologists and cardiologists. Usually, radiologists (and also technicians) perform the technique, and cardiologists interpret the images. The level of expertise of cardiologist is very variable. In some centers, they are very qualified, but in others the quality may not be very high. This may explain that reliability of interpretation may be heterogeneous among different centers. There are some recommendations about training, competence and certification for performing cardiac CT (e.g. *J Cardiovasc Comput Tomogr* 2011;5:279-85), but these recommendations are not mandatory and usually are not considered for selecting personnel for performing/interpreting MSCT.

The optimal patient population for cardiac MSCT is constituted by subjects with low probability of significant coronary artery disease. Within these patients, there are some subgroups such as:

- 1) Patients scheduled for mitral or aortic valve and without angina that need an evaluation of coronary arteries before cardiac surgery;

2) Patients with low probability of coronary artery disease (e.g. atypical chest pain, no coronary risk factors and inconclusive non-invasive test);

3) Patients with previous revascularization procedures (either percutaneous or surgical) and atypical chest pain. There are some recommendations (*J Am Coll Cardiol* 2010;56:1864-94), that detail which are the most appropriate indications for MSCT. These recommendations classify indications in appropriate, uncertain, and inappropriate.

Basically, in our setting, patients undergoing MSCT may be included in 4 subgroups:

1) Patients without previous history of coronary artery disease, no typical chest pain and inconclusive non-invasive tests;

2) Patients without suspected coronary artery disease, but that need a proof that do not have coronary artery disease (e.g. those with left ventricular dysfunction of unknown origin, or those undergoing scheduled mitral or aortic valve replacement);

3) Patients with previous myocardial revascularization (either surgical or percutaneous) and atypical chest pain.

4) Patients with previous invasive coronary angiography that need MSCT for a more detail evaluation (e.g. coronary arteries of anomalous origin; chronic coronary occlusions to evaluate distal vessel or length of occlusion).

In most of the European centers, MSCT is mainly performed in patients with stable ischemic heart disease, rather than in unstable clinical implications, such as in those located at the emergency room. This is because patients with unstable clinical presentations (e.g. unstable angina) are usually considered directly for an invasive approach, with cardiac catheterization and coronary revascularization if suitable. For patients that are admitted at an emergency room because of chest pain with normal cardiac enzymes, and normal

electrocardiogram, MSCT could be an option for diagnosing coronary artery disease, but in most centers the classical approach of a non-invasive test (mainly exercise treadmill test) is the preferred strategy. When MSCT is performed at the emergency room, it is because physicians want also to discharge other diseases such as aortic dissection, or pulmonary embolism.

The accuracy of MSCT in the diagnosis of coronary artery disease has been evaluated considering invasive angiography as gold standard. Sensitivity of MSCT is more than 95% (either considering the diagnosis per lesion, per segment, or per patient). Also, specificity is more than 95% in most cases. These data, however, are obtained when patients without adequate visualization of the coronary tree are not included in the analysis.

An additional important aspect of the diagnostic accuracy of MSCT is related with the higher sensitivity and specificity of MSCT in comparison with classical non-invasive test (e.g. exercise treadmill test, stress echocardiography, myocardial scintigraphy). This may allow to correctly diagnose patients with significant coronary artery disease in which other non-invasive tests could have missed the diagnosis.

MSCT can reduce the need for invasive coronary angiography, mainly in patients with low probability of coronary artery disease.

Probably, the most valuable diagnostic tool of MSCT is its high negative predictive value, since a normal MSCT almost can exclude significant coronary artery disease. This makes MSCT a very useful technique for patients with low probability of CAD but with symptoms or inconclusive non-invasive tests that need a more accurate diagnosis but do not have clear indication of invasive coronary angiography. Conversely, patients with high probability of coronary artery disease, for example those with clear symptoms of angina, are not good candidates for MSCT, because probably most of them are going to need also invasive coronary angiography.

The added value in quality of life is mainly associated with the patients in which MSCT allows a precise diagnosis (mainly to rule out significant coronary artery disease) without the necessity of performing invasive coronary angiography.

The added value in patient health outcomes may occur mainly in patients in which MSCT allows to detect significant coronary artery disease and therefore a correct treatment. This is related with the significantly higher diagnostic value of MSCT in comparison with conventional non-invasive tests.

The level of acceptance is theoretically high, but there are no specific protocols that include MSCT in the follow-up of the patients. There are some limitations for using MSCT in follow-up:

- 1) The radiation exposure may limit the applicability of MSCT (difficult to justify to repeat periodically MSCT in a given patient...);

- 2) In patients that have been treated percutaneously, the presence of a methallic stent may limit the visualization of the treated segment, thus making difficult to diagnose or exclude an in-stent restenosis;

- 3) From a clinical point of view, it is difficult to justify to perform a MSCT in an asymptomatic patient that have previously received a coronary stent, because the rate of restenosis is very low with the use of drug-eluting stents, and even in case of having an in-stent restenosis, its treatment is not justified in absence of symptoms and/or ischemia at non-invasive tests;

- 4) Patients with previous coronary stenting with recurrence of angina probably need an invasive coronary angiography because the probability of restenosis is high, and in these cases, a new revascularization procedure is probably justified.

The safety risks of MSCT are mainly related with the radiation exposure. We have to consider, for example, that recommendations about non-invasive tests in the diagnosis of coronary artery disease favor more and more stress echocardiography in comparison with myocardial scintigraphy because myocardial scintigraphy produces radiation, despite having a higher sensitivity than stress echocardiography.

Other safety risks, such as contrast induced nephropathy and contrast allergy, are much less important.

Safety risks of invasive diagnostic coronary are those applicable for MSCT (i.e. radiation exposure, contrast-induced nephropathy), but also those associated with the invasive character of cardiac catheterization: mainly vascular and bleeding complications, but also complications at the coronary arteries such as coronary dissection.

The changes in noninvasive imaging technologies in the diagnosis of coronary artery disease that are occurring during the last years and that will continue in the next years include:

- Exercise treadmill test is the simplest and cheapest non-invasive test, but its limitations (e.g. abnormal baseline ECG) and the low sensitivity and specificity are leading to a increase in the use of other non-invasive tests (stress echocardiography and myocardial scintigraphy).
- Sensitivity is slightly higher for myocardial scintigraphy, and specificity is slightly higher for stress echocardiography. Diagnostic accuracy is higher for both tests than for exercise treadmill test. Stress echocardiography is more operators dependent, but it does not produce radiation exposure. Myocardial scintigraphy has lower inter-observer variability, but produces radiation exposure.

- MSCT has higher sensitivity and specificity than exercise treadmill test, stress echocardiography, and myocardial scintigraphy. Because of that, the use of MSCT is being increased during the last years, and will increase even more in the future. Because of that, physicians are increasing the indications of MSCT in order to correctly diagnose patients with coronary artery disease. Also, patients are receiving information about the possibility of the visualization of their coronary arteries non-invasively, and this may also increase the indications of MSCT.

The reasons exposed in the previous question may increase the number of patients that undergo MSCT instead of other non-invasive test, or instead of cardiac catheterization. This may occur mainly in patients with suspected chronic coronary artery disease, but much less frequently in those with acute coronary syndromes, because the latter usually go directly to cardiac catheterization.

However, due to the radiation exposure of MSCT, it is more difficult to justify the use of MSCT in the follow-up of the patients. This could only be justified in some patients in which there is recurrence of symptoms.

See also answer to previous question. Of course some patients are not going to undergo cardiac catheterization because of having been evaluated with MSCT. Patients in which MSCT show absence of coronary artery disease do not undergo to the cath lab. However, there are also some patients in which coronary artery disease has been diagnosed because of having been undergone to MSCT, and these patients need also to be referred also to invasive coronary angiography. It may be that some of these patients would have not been referred to the cath lab if they had not been previously referred to MSCT. Taking into consideration all these aspects, it may be that the absolute number of invasive coronary angiographies with normal coronary arteries will be reduced with the use of MSCT, but

probably the use of MSCT may increase the number of patients with coronary artery disease that are correctly diagnosed, and therefore may also increase the absolute number of patients that undergo percutaneous coronary intervention and even coronary artery bypass grafting.

There is already enough evidence regarding the diagnostic accuracy of MSCT in detecting coronary artery disease in different settings, such as the usefulness of MSCT in the early screening of patients attending the emergency departments because of chest pain of uncertain origin. There are also demonstrating the usefulness of MSCT in the evaluation of coronary grafts, congenital abnormalities of coronary arteries, and chronic coronary occlusions scheduled for percutaneous coronary intervention.

In patients with previous coronary stent implantation, data show that diagnostic accuracy is sub-optimal, mainly due to the limitations related with the metallic platform that may interfere with the visualization of the target segment. In this subgroup of patients there is lack of evidence. Moreover, it is known that asymptomatic in-stent restenosis that is not associated with silent ischemia has a good clinical outcome, and therefore the diagnosis of an asymptomatic restenosis by means of MSCT probably is not justified if other non-invasive tests are negative. In patients with previous coronary interventions that have recurrence of symptoms probably the most adequate approach is to undergo invasive coronary angiography because these patients will need a subsequent revascularization procedure (either related with in-stent restenosis or with progression of the disease). The subgroup of patients with previous coronary interventions that might potentially be benefited from MSCT is constituted by patients that present symptoms that are not suggestive of angina but in which it is important to rule out in-stent restenosis. Evidence of this benefit is, however, not available.

There is also lack of evidence on the benefit of MSCT in the early diagnosis of coronary artery disease in patients that are still asymptomatic. Controversy still remains about the benefit of myocardial revascularization in stable coronary artery disease, and this evidence is

even scarcer in patients that are still asymptomatic. Taking all this into consideration, it is not justified to perform a MSCT in patients that are asymptomatic and also in those with suspected coronary artery disease but in which other non-invasive tests are negative. MSCT could be indicated, however, to obtain a certain diagnosis in those patients in which symptoms and non-invasive tests do not provide a clear diagnosis.

It is easy to imagine that clinical outcome may be better when coronary artery disease is diagnosed earlier using MSCT, or when patients undergoing surgical valve replacement are evaluated by MSCT instead of invasive coronary angiography. It is difficult to demonstrate that a given imaging technique leads to a better clinical outcome (i.e. reduction in cardiovascular events).

I agree that including MSCT as imaging technique in the follow-up of the US RCT may be useful and may be demonstrative that patients that have been treated with BVS may be non-invasively evaluated with this technique. However, probably I would include only one MSCT on the follow-up, and the time from the index procedure could be variable among different patients in order to obtain evidence in different periods of time (1 year, 2 year, etc).

The findings from the MSCT evaluation in this trial, however, may be difficult to extrapolate to the routine clinical practice, and will depend on the results.

The cost of MSCT is higher than that of invasive coronary angiography, because invasive angiography has more personnel involved, and it requires hospitalization. However, in some settings, performing MSCT may be more complicated than referring a patient to the cath lab, depending on the availability of each technique.

- Using MSCT may reduce the consumption of other resources, but probably the most important one is to reduce the number of hospital admissions related with the procedure of invasive angiography.

- It may be also useful to compare the cost of MSCT not only with the cost of invasive angiography (that is not routinely indicated after percutaneous coronary interventions), but also with the cost of other non-invasive procedures, such as stress echocardiography and myocardial scintigraphy.