Non-Invasive Coronary Angiography With Multislice CT: at Last an Alternative to Conventional Coronary Angiography?

Jordi Estornell Erill

Unidad de TC y RM, ERESA, Hospital General Universitario de Valencia, Valencia, Spain.

Conventional coronary angiography involving the selective injection of an intracoronary contrast medium is currently the standard procedure for visualizing the epicardial coronary arteries and for identifying the lesions causing reductions in their caliber. Conventional coronary angiography can be combined with other techniques, such as intracoronary echocardiography, Doppler echocardiography or the use of pressure guidewires, to obtain complementary information on the anatomy, composition and functional impact of lesions. However, these procedures are invasive, costly and not without risk, and this has encouraged the search for new diagnostic methods that allow the coronary arteries to be visualized non-invasively with sufficient diagnostic accuracy to be systematically used in clinical practice. Two imaging techniques are the major candidates: magnetic resonance (MR) and computed tomography (CT). The article by Leta et al[1] in this issue of the REVISTA ESPAÑOLA DE CARDIOLOGÍA, which analyses the diagnostic accuracy of multi-slice or multi-detector CT compared to conventional coronary angiography, is a step in the right direction. It is the first work to be published that explores the use of this technique in our field of medicine, and the results suggest there are reasons for optimism. To introduce cardiologists to these diagnostic methods—which here overstep somewhat the boundaries of their normal use—the following lines briefly summarize their basic concepts, their current status, their limitations and prospects.

The problems faced by both MR and CT are related to coronary anatomy (tortuous vessels with a small diameter and covered in fat and other structures) and the difficulties caused by arterial pulsations and respiratory and cardiac movements. The solutions to these problems have been provided by the development of sequences that allow more rapid acquisitions with better spatial resolution, a better signal/noise (S/N) ratio, and cardiac synchronism, all achieved during tolerable conditions of apnea. In MR, apnea can be avoided using diaphragmatic navigators.

Since MR involves neither ionizing radiation nor iodized contrast media, it should be the technique of choice unless there are contraindications (claustrophobia, patients with pacemakers, defibrillators or intracranial metallic clips etc). However, coronary angiography performed by MR still suffers important limitations. In MR, spatial and temporal resolutions are inversely proportional, and achieving a balance between them is necessary. In practice these resolutions are usually worse than those achieved with CT, and the S/N ratio is poorer. Thus, coronary angiographic studies performed by MR tend to be limited to the proximo-medial portion of the main coronary arteries, and even then a considerable number of coronary segments cannot be assessed. In addition, exploration times are usually very prolonged and unpleasant for the patient. MR also has other limitations in common with CT, such as artifacts produced by metallic structures (coronary endoprostheses, metallic surgical clips and valve prostheses) and arrhythmias.

It is difficult to draw conclusions on the diagnostic accuracy of coronary angiography with MR despite the considerable number of studies that have been undertaken. The results reported differ substantially between laboratories and the different sequences used. In the only multi-center study published to date[2] (in which centers with different levels of experience took part), 109 patients were subjected to the same image capture protocol which involved respiratory synchronism (diaphragmatic navigator). Analysis was limited to the proximo-medial portion of the three main coronary arteries; mean exploration time was 70 min. Eighty four percent of segments were considered assessable. A sensitivity of 93% and a specificity of 43% was obtained in the detection of significant stenosis (≥50%) in the assessed segments; negative predictive power was 81%. Although the current limitations of MR prevent it being a useful tool in clinical practice, it would be very desirable if its

SEE ARTICLE ON PAGES 217-24

Correspondence: Dr. J. Estornell Erill.
Unidad de TC y RM. Hospital General Universitario de Valencia.
Avda. Tres Cruces, s/n. 46014 Valencia. España.
E-mail: jestornell@eresa.com

technological development, as well as the development of new sequences and contrast agents, allowed coronary angiographic analysis to be added to its already proven efficacy in anatomical and functional studies of the heart and in the assessment of myocardial perfusion and viability.

Two forms of CT are used in the study of the coronary tree: multi-slice or multi-detector CT, and electron beam computed tomography [EBCT]). Both have high spatial and temporal resolutions as well as an excellent S/N ratio, which allows the entire length of the coronary arteries to be studied. They have the drawback, however, that they employ ionizing radiation and iodized contrast media, and this limits their use in sequential examinations. They are also contraindicated in patients allergic to iodine and in those with kidney failure.

Electron beam computed tomography uses a fixed source of x-rays and fixed detectors that allow parallel tomographic slices to be obtained by moving the table before each firing. Capture is performed with electrocardiographic synchronization (one slice per cardiac cycle) over a predefined percentage of the RR interval (normally diastole) and in apnea (to reduce the production of artifacts due to cardiac and respiratory movements). Since the capture time is mainly influenced by heart rate, atropine is sometimes administered to increase the latter and therefore reduce the duration of apnea.

Electron beam computed tomography has greater temporal resolution (but lower spatial resolution) and a lower S/N ratio than multi-slice CT. In addition, it exposes patients to less radiation since, unlike multi-slice CT, image capture is performed only during diastole rather than over the entire cardiac cycle. Although more experience has been gained with this method, both in the quantification of coronary calcium and in non-invasive coronary studies, and despite many studies that show agreement between the results of different groups, this technology is only available at a few hospitals.

Multi-slice or multi-detector CT uses a mobile source of x-rays as well as detectors that move in constant rotation with the table. Multiple, parallel tomographic slices are therefore obtained in each rotation (up to 16 slices in 0.5 s for the latest models), with cardiac synchronism, and for the whole cardiac cycle. Image reconstruction is performed retrospectively for the most adequate phase of the cardiac cycle (usually diastole—in order to avoid artifacts caused by heart movements). As well as the rotation speed and the number of scanners, the size of the heart also influences acquisition time. Beta-blockers are usually given to patients with high heart rates in order to prolong diastole and therefore minimize the number of movement artifacts. Recently, image reconstruction algorithms have been introduced that integrate the data obtained from several cardiac cycles with the aim of increasing the temporal resolution in patients with high heart rates.[3] However, these are very sensitive to variations in RR from one cycle to another, so the administration of beta-blockers is usually unavoidable. Since images are obtained over the whole cardiac cycle, the exposure to radiation is much greater than with EBCT, and even greater than that associated with conventional angiography.[4] Since image construction generally involves the diastole phases, capture protocols have been proposed that reduce the radiation used during systole, and thus the total dose of radiation received.[5] Despite its lower temporal resolution, multi-slice CT has a higher spatial resolution and better S/N ratio than EBCT. In addition, this technology is available at more centers and, while experience in its use is still limited, the studies that have been published show it to have a diagnostic accuracy similar to that of EBCT.

Apart from the limitations of CT mentioned above (apnea durations difficult for patients to withstand, etc, and artifacts caused by arrhythmias and metallic elements) which are common to all three diagnostic techniques, extensive calcification of the coronary arteries is usually a serious problem in the interpretation of the images obtained. Furthermore, though it is possible to visualize the entirety of the coronary tree, it is sometimes difficult to assess the circumflex artery owing to its trajectory (which follows the atrioventricular sulcus next to the great cardiac vein, also made opaque by the contrast medium) as well as the small diameter coronary branches.

The results obtained by Leta et al[1] (sensitivity 75%, specificity 91% for stenosis ≥50% in conventional coronary angiography) are similar to those reported in 2 previous studies using the same technology[6,7] (specificity 92% and 95%, respectively, specificity 86% and 93%, respectively). The good results obtained by the above authors, plus the small percentage of segments that could not be assessed (11.6%—only 2.3% of which were due to movement artifacts) are noteworthy, especially when it is remembered that beta-blockers were not provided (these drugs were provided in other studies when the heart rate was >60-65 beats per min). Instead, Leta et al used the image reconstruction algorithms mentioned above to increase temporal resolution, and achieved an optimum result. The use of a sub-millimetric slice size (0.5 mm) and the better spatial resolution thus obtained would certainly have helped, reducing the number of non-interpretable segments due to intense coronary calcification (3.8%) and allowing better visualization of the narrow distal vessels and secondary branches. A drawback of the protocol used in this study is the estimated effective dose of radiation received by patients—24.2 mSv—which is very much greater than the doses received in other studies[6,7] (generally below 9 mSv). As the authors point out, an important limitation is the difficulty in assessing coronary endoprostheses due to the metallic artifacts produced (the segments containing endoprostheses were in fact considered non-assessable). In these cases, though it is impossible to assess the degree of intralumen stenosis, it is possible to evaluate its permeability and to identify the stenosis affecting the edges of the stent. Another persistent limitation pointed out by the authors is the impossibility of identifying occlusive lesions and of distinguishing them from critical stenoses when the distal vessel is filled with blood from collateral vessels: dynamic images of the passage of the contrast medium through the coronary arteries cannot be obtained. Finally, although it is risky to draw conclusions from the reduced number of coronary bypasses examined, the potential of CT in their non-invasive assessment can be seen. This agrees with the results of the few studies published in this area.[8,9]

CONCLUSIONS

If one had to choose today between MR or CT as the better coronary angiography technique, the balance would fall in favor of the latter since it allows visualization of the entire length of the main coronary arteries in a short time, and the plaques responsible for stenoses can be characterized during the same examination.[10] Of the CT methods available, the choice for the moment would have to be multi-slice CT, the applications of which in other areas of medicine have made it available at many centers. The use of EBCT is usually limited to research groups. Although none of these non-invasive coronary angiography techniques has been fully developed, the moment when MR can match the results of CT and allow a global study of ischemic heart disease still seems far away.

It would be adventurous to respond positively to the question posed in the title of this editorial without multi-center studies involving a large number of patients. However, thanks to recent advances in CT, cardiologists are quickly becoming very optimistic about the future of these techniques, despite their current limitations.

REFERENCES

1. Leta R, Carreras F, Alomar X, Monell J, García-Picart J, Augé JM, et al. Coronariografía no invasiva mediante tomografía computarizada con 16 detectores: estudio comparativo con la angiografía coronaria invasiva. Rev Esp Cardiol 2004;57:217-24.
2. Kim WY, Danias PG, Stuber M, Flamm SD, Plein S, Nagel E, et al. Coronary magnetic resonance angiography for detection of coronary stenoses. N Engl J Med 2001;345:1863-9.
3. Flohr Th, Ohnesorge B. Heart rate adaptative optimization of spatial and temporal resolution for electrocardiogram-gated multislice spiral CT of the heart. J Comput Assist Tomogr 2001;25:907-23.
4. Morin RL, Gerber ThC, McCollough CH. Radiation dose in computed tomography of the heart. Circulation 2003;107:917-22.
5. Jakobs TF, Becker CR, Ohnesorge B, Flohr Th, Suess C, Schoepf UJ, et al. Multislice helical CT of the heart with retrospective ECG gating: reduction of radiation exposure by ECG-controlled tube current modulation. Eur Radiol 2002;12:1081-6.
6. Ropers D, Baum U, Pohle K, Anders K, Ulzheimer S, Ohnesorge B, et al. Detection of coronary artery stenoses with thin-slice multi-detector row spiral computed tomography and multiplanar reconstruction. Circulation 2003;107:644-66.
7. Nieman K, Cademartiri F, Lemos PA, Raaijmakers R, Pattynama PM, de Feyter PJ. Reliable noninvasive coronary angiography with fast submillimeter multislice spiral computed tomography. Circulation 2002;107:2051-4.
8. Gurevitch J, Gaspar T, Orlov B, Amar R, Dvir D, Peled N, et al. Noninvasive evaluation of arterial grafts with newly released multidetector computed tomography. Ann Thorac Surg 2003;76:1523-7.
9. Nieman K, Pattynama PM, Rensing BJ, van Geuns R-J, DeFeyter PJ. Evaluation of patients after coronary artery bypass surgery: CT angiographic assessment of grafts and coronary arteries. Radiology 2003;229:749-56.
10. Fayad ZA, Fuster V, Nikolau K, Becker C. Computed tomography and magnetic resonance imaging for non-invasive coronary angiography and plaque imaging. Circulation 2002;106:2026-34.