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Original article

Extension and Spatial Distribution of Atherosclerotic Burden Using Virtual Monochromatic Imaging Derived From Dual-energy Computed Tomography

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ABSTRACT

Introduction and objectives: We explored the differences between atherosclerotic burden with invasive coronary angiography and virtual monochromatic imaging derived from dual-energy computed tomography coronary angiography.
Methods: Eighty consecutive patients referred for invasive coronary angiography underwent dual-energy computed tomography coronary angiography and were categorized according to the atherosclerotic burden extent using the modified Duke prognostic coronary artery disease index, coronary artery disease extension score, segment involvement score, and the segment stenosis score.
Results: The mean segment involvement score (8.2 ± 3.9 vs 6.0 ± 3.7; $P < .0001$), modified Duke index (4.33 ± 1.6 vs 4.0 ± 1.7; $P = .003$), coronary artery disease extension score (4.84 ± 1.8 vs 4.43 ± 2.1; $P = .005$), and the median segment stenosis score (13.5 [9.0-18.0] vs 9.5 [5.0-15.0]; $P < .0001$) were significantly higher on dual-energy computed tomography compared with invasive angiography. Dual-energy computed tomography showed a significantly higher number of patients with any left main coronary artery lesion (46 [58%] vs 18 [23%]; $P < .0001$) and with severe proximal lesions (0.28 ± 0.03 vs 0.26 ± 0.03; $P < .0001$) than invasive angiography. Levels of coronary artery calcification below and above the median showed a sensitivity, specificity, positive predictive value, and negative predictive value of 100% and 97%; 86% and 50%; 93% and 95%; 100% and 67% for the identification of ≥ 50% stenosis.
Conclusions: Dual-energy computed tomography coronary angiography identified a significantly larger atherosclerotic burden compared with invasive coronary angiography, particularly involving the proximal segments.

Extensión y distribución espacial de la carga ateroesclerótica mediante imágenes monocromáticas virtuales derivadas de tomografía computarizada de doble energía

Palabras clave:
Ateroesclerosis
Placa
Tronco coronario izquierdo

RESUMEN

Introducción y objetivos: Se analizaron las diferencias de carga ateroesclerótica observadas entre la coronariografía invasiva y las imágenes monocromáticas virtuales obtenidas con la tomografía computarizada de doble energía.
Métodos: Se examinó con tomografía computarizada de doble energía y se clasificó a 80 pacientes consecutivos remitidos a una coronariografía invasiva según el grado de carga ateroesclerótica utilizando el índice pronóstico de enfermedad coronaria de Duke modificado, la puntuación de extensión de la enfermedad coronaria, la puntuación de afección de segmentos y la puntuación de estenosis de segmentos.
Resultados: La media de la puntuación de afección de segmento (8,2 ± 3,9 frente a 6,0 ± 3,7; $p < 0,0001$), el índice de Duke modificado (4,33 ± 1,6 frente a 4,0 ± 1,7; $p = 0,003$), la puntuación de extensión de la enfermedad coronaria (4,84 ± 1,8 frente a 4,43 ± 2,1; $p = 0,005$) y la mediana de la puntuación de estenosis de segmento (13,5 [9,0-18,0] frente a 9,5 [5,0-15,0]; $p < 0,0001$) fueron significativamente superiores con la tomografía computarizada de doble energía que con la coronariografía invasiva. La tomografía computarizada de doble energía mostró un número de pacientes con alguna lesión del tronco coronario izquierdo significativamente mayor (46 [58%] frente a 18 [23%]; $p < 0,0001$) y con lesiones proximales graves

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(0,28 ± 0,03 frente a 0,26 ± 0,03; p < 0,0001) en comparación con lo observado en la coronariografía invasiva. Los grados de calcificación arterial coronaria por debajo y por encima de la mediana mostraron sensibilidad, especificidad, valor predictivo positivo y valor predictivo negativo del 100 y el 97%; el 86 y el 50%; el 93 y el 95% y el 100 y el 67% para la identificación de estenosis ≥ 50%.

Conclusiones: La angiografía coronaria con tomografía computarizada de energía dual identificó una carga ateroesclerótica significativamente mayor que la observada con la coronariografía invasiva, en especial por lo que respecta a la afección de los segmentos proximales.

Abbreviations

CAC: coronary artery calcium
CTCA: computed tomography coronary angiography
DE: dual-energy
ICA: invasive coronary angiography
SIS: segment involvement score
SSS: segment stenosis score

INTRODUCTION

The poor correlation between lesion severity and clinical outcome has been described in a recent study involving a large cohort of patients who underwent invasive coronary angiography (ICA), showing that nonobstructive coronary atherosclerosis is related to a significant increment in the risk of myocardial infarction and all-cause mortality.[1] Mounting evidence mostly involving intravascular ultrasound confirmed that the extent and severity of coronary atherosclerosis is usually underestimated by ICA.[2,3]

Computed tomography coronary angiography (CTCA) has emerged as an accurate method to evaluate coronary atherosclerosis, not only in the lumen but also of the vessel wall. Indeed, CTCA is more closely related to intravascular ultrasound than to ICA and has been shown to provide a significant prognostic value, with an excellent long-term event-free safety window in patients with normal coronary arteries.[4,5] Since the emergence of CTCA, coronary calcification has persisted as a dilemma since it often leads to overestimation of stenosis due to several technical issues such as blooming and beam hardening effects. Virtual monochromatic imaging derived from dual-energy (DE) CTCA has emerged as a novel approach that aims to more accurately assess coronary plaques since it attenuates some of these limitations.[6] We therefore sought to explore the differences between atherosclerotic burden with ICA and DE-CTCA in symptomatic patients referred for ICA.

METHODS

Study Population

The present was a single-center, investigator driven, prospective study that involved patients with suspected coronary artery disease (CAD) referred for ICA. Between May and October 2014, consecutive symptomatic patients referred for ICA who accepted to undergo DE-CTCA within 1 month before the invasive procedure were included in the study. DE-CTCA in patients referred for ICA was encouraged within this period to gain experience in recently acquired DE imaging, although our department has more than 12 years of experience in CTCA. All patients were more than 18 years old, in sinus rhythm, and able to maintain a breath-hold for 15 seconds; none had a history of contrast related allergy, renal failure, or hemodynamic instability. Additional exclusion criteria comprised a history of previous myocardial infarction within the previous 30 days, percutaneous coronary intervention with stent implantation, coronary bypass graft surgery, or chronic heart failure.

Image Acquisition

Patients were scanned using a 64-slice high definition scanner (Discovery HD 750, GE Healthcare, Milwaukee, United States), after intravenous administration of iodinated contrast (iobitridol, Xenetix 350, Guerbet, France). A total of 60 to 80 mL of iodinated contrast was injected using a 3-phase injection protocol. Image acquisition was performed after sublingual administration of 2.5 to 5 mg of isosorbide dinitrate. Patients with a heart rate of more than 65 bpm received 5 mg intravenous propranolol, if needed, to achieve a target heart rate of less than 60 bpm.

All studies were acquired using prospective electrocardiogram-gating by applying a 100 msec padding centered at 75% of the cardiac cycle for patients with a heart rate lower than 60 bpm, a 200 msec padding centered at 60% of the cardiac cycle for patients with a heart rate between 60 and 74 bpm, and a 100 msec padding centered at 40% of the cardiac cycle for patients with a heart rate higher than 74 bpm. DE-CTCA was performed by rapid switching (0.3-0.5 msec) between low and high tube potentials (80-140 kV) from a single source, thereby allowing the reconstruction of low- and high-energy projections and generation of monochromatic image reconstructions ranging from 40 to 140 keV (kiloelectron volt). Iterative reconstruction was performed in all cases at 40% adaptive statistical iterative reconstruction. Other scanner-related parameters were a collimation width of 0.625 mm and a slice interval of 0.625 mm.

Image Analyses

All CTCA image analyses were performed off-line on a dedicated workstation, using a commercially available dedicated software tool (AW 4.6, GE Healthcare) by consensus of 2 experienced level 3–certified coronary CTCA observers (P. Carrascosa and A. Deviggiano), blinded to the clinical data.

Axial planes, curved multiplanar reconstructions, and maximum intensity projections were used at 1-5 mm slice thickness, according to the 16-segment modified American Heart Association classification.[7,8] We did not use the 18-segment Society of Cardiovascular Computed Tomography classification since we aimed to use the same classification applied in the study of Min et al.[9] Whenever plaques were identified, thin multiplanar reconstructions and orthogonal views were obtained at independent monochromatic energy levels ranging from 60 keV to 100 keV to attenuate the beam hardening and blooming artifacts commonly present in calcified plaques, with incremental levels of 10 keV. However, all energy levels were available to the observers. Segments with a reference diameter lower than 1 mm were not