Int J Clin Exp Med 2014;7(8):2223-2229
www.ijcem.com /ISSN:1940-5901/IJCEM0001166

Original Article

Value of segmental coronary calcium score on diagnosis and interventional treatment of coronary lesions by 320-slice DVCT

Xiao-Yan Li[1*], Guo-Ming Zhang[1*], Hong-Ming Zhang[1*], Gang Sun[2], Shu-Fang Han[1], Hong Tan[1], Yu-Qi Gao[1], Qun Jin[1], Yan-Min Li[1], Jie Fang[3]

[1]*Department of Cardiology, Jinan Military General Hospital, Jinan 250031, China;* [2]*Department of Radiology, Jinan Military General Hospital, Jinan 250031, China;* [3]*Graduate School of Liaoning Medical University, Jinzhou, Liaoning 121001, China.* [*]*Equal contributors.*

Received June 19, 2014; Accepted July 27, 2014; Epub August 15, 2014; Published August 30, 2014

Abstract: The global coronary calcium score has been widely used in the evaluation of coronary plaque burden and cardiovascular disease events. In this study, we investigated the value of segmental coronary calcium score (SCCS) on the diagnosis and interventional treatment. We studied 87 patients with coronary angiography (CAG) and coronary CT angiography (CTA) by 320-slice dynamic volume CT (DVCT). SCCS was determined for each segmental separately. All lesions which SCCS was greater than 0 were enrolled, and were divided into three groups, mild calcification group (SCCS were less than 80), Moderate calcification group (SCCS were more than 80 and less than 200) and Severe calcification group (SCCS were more than 200). From above three groups, lesions received the intervention treatment were elected as subgroup. The position of lesions, plaque morphology, calcification proportion and interventional treatment data were analyzed. Severe calcification group were more frequent in the proximal lesions, stenosis with lesser extent, nubbly and nodular types of plaque, and the inconsistency with CAG was higher than the other two groups ($P < 0.05$). In the subgroup, more pre-dilatation and post-dilatation balloon were used in severe calcification group, with higher expansion pressure of balloon and stent ($P < 0.05$), but the diameter of stents was no difference between the three groups. Conclusion: SCCS is better than GCCS in the evaluation of coronary calcification, and play an important role in the judgment of stenosis by coronary CT and in the choice of interventional therapeutic devices.

Keywords: Segmental coronary calcium score, plaque morphology, calcification, dynamic volume CT, coronary angiography

Introduction

Ischemic heart diseases (CHD) remain among the leading causes of death worldwide, due to a combination of socio-cultural and genetic factors. Its early diagnosis and the evaluation of high-risk patients are important for prevention and treatment. The basic lesion of CHD is atherosclerosis, and coronary calcification is one indication and early sign of atherosclerosis. The severity of atheromatous plaque can be reflected by the quantitative analysis of coronary calcification [1, 2]. Coronary calcium score (CCS), which was reported first by Agatston [3], has been widely used in the evaluation of coronary plaque burden and cardiovascular disease events [4, 5-8]. Most previous studies focused on the evaluation of plaque development with global coronary calcium score (GCCS). However, the majority of patients may have more than one atheromatous plaques which are in different development phases of atherosclerosis, thus GCCS can not accurately reflect the change of plaque. The calculation of segmental coronary calcium score (SCCS) can avoid the above shortness [7]. In this study, we explored the necessity and feasibility of calcified plaque measurement by SCCS and also further investigated the value of SCCS to coronary interventional treatment.

Materials and methods

The ethics committee of the General Hospital of Jinan Military Command approved all the study

Table 1. Comparison in the position of lesion

	Mi-CP (n = 91)	Mo-CP (n = 35)	Se-CP (n = 41)
LAD lesion	39	20	26
LCX lesion	22	10	4
RCA lesion	30	6	11
Proximal lesion	31•	17	25$^{*,\Delta}$
Middle lesion	46	15	14
Distal lesion	14	3	2
Ostial lesion	9	3	5
Non-ostial lesion	82	32	36

Note: Mi-CP, mild calcification group; Mo-CP, moderate calcification group; Se-CP, severecalcification group; *Compared with the mild calcification group, $P < 0.05$; ΔCompared with themoderate calcification group, $P < 0.05$; •Compared with the severe calcification group, $P < 0.05$.

protocols and the consents were informed all patients or relatives before CTA and CAG.

General data

Patients enrolled in this study were those who were admitted to Cardiology Department of The General Hospital of Jinan Military Command from January 2010 to May 2012. All the enrolled patients met the following criteria: 1. Different degree of coronary stenosis were found through CTA examination (320-row DVCT). 2. CAG examination in the following two weeks confirmed the existence of coronary stenosis. 3. Acute coronary syndrome did not happen one month before and after the CTA and CAG examination. 4. CTA and CAG showed good imaging quality; 5. There was no history of the following conditions: allergy to iodine preparation, implantation of a permanent cardiac pacemaker, artificial cardiac valve replacement, severe cardiac or renal insufficiency, and inability to hold breath.

CTA examination

Toshiba Aquiilion one 320-row DVCT (Siemens, Germany) was used for CTA, with the scanning range from the inferior margin of tracheal carina to 1 cm beneath diaphragmatic muscle. Sure Start software was used for intelligent triggering scan; the triggering point was thoracic aorta at the central slice of the scanning range, and the triggering threshold was 180 Hu. The scan parameters were below: 120 kV, 500 mA, 320 slices × 0.5 mm for acquisition of volume data, rotary speed of CT scanner: 350 ms/r, and scanning time: 0.35-1.4 s. The high-quality data from reconstruction were sent to Vitrea II. fx graphic processing workstation and then subjected to post-processing with the corresponding software system. The following indicators were analyzed by two experienced CT physicians, and reevaluation was required if there were different opinions.

Extent of coronary stenosis: The internationally accepted visual diameter observation method was used, i.e., extent of vascular stenosis = (normal vascular diameter of proximal segment- vascular diameter at stenosis)/normal vascular diameter of proximal segment × 100%.

Morphology of main plaque and calcification: In case of coronary occlusion, the segment distal to occlusion was not analyzed. Long-axis image obtained from curved planar reformation was used to analyze coronary morphology at the long-axis direction. Then the curved planar reformation image was rotated to locate the plaque at the tangential position of the lumen, so as to observe morphology of the plaque (calcification) at the position, and perform classification analysis of coronary plaque (calcification). Morphology of the plaques causing the most severe stenosis was analyzed in long-axis image obtained from curved planar reformation, and the plaques were classified according to the method of Kajinam [9]. Classification criteria were as follows: 1) nubbly type: length of the plaque > 2/3 inner diameter of the reference blood vessel, and width of the plaque > 2/3 inner diameter of the reference blood vessel; 2) nodular type: length of the plaque < 2/3 inner diameter of the reference blood vessel, and width of the plaque > 2/3 inner diameter of the reference blood vessel; 3) strip type: length of the plaque > 2/3 inner diameter of the reference blood vessel, and width of the plaque < 2/3 inner diameter of the reference blood vessel; 4) focal type: length of the plaque < 2/3 inner diameter of the reference blood vessel, and width of the plaque < 2/3 inner diameter of the reference blood vessel. For classification of morphology of calcification in the plaque was compared with width of the plaque.

Calcification proportion in main plaque: For the main plaque causing the most severe stenosis, curved planar reformation image was taken.

Table 2. Comparison in the morphology and characters of lesions

	Mi-CP (n = 91)	Mo-CP (n = 35)	Se-CP (n = 41)
Character of lesion			
Diffuse lesion	15	7	12
Tubular lesion	58	17	23
local lesion	18	11	6
Total occlusion lesion			
Yes	4	2	1
No	87	33	40
Stenotic extent	$80.22 \pm 8.94^{\bullet}$	75.28 ± 6.18	$70.53 \pm 10.27^{*}$
Morphology of main plaque			
Nubbly type	$30^{\Delta,\bullet}$	22^{*}	29^{*}
Nodular type	$10^{\bullet}$	8	10^{*}
Strip type	30	2	2
Focal type	21	3	0
Calcification proportion (%)	$29.80 \pm 8.28^{\Delta,\bullet}$	$54.28 \pm 10.15^{*,\bullet}$	$62.43 \pm 13.46^{*,\Delta}$
Calcification morphology			
Nubbly type	$5^{\Delta,\bullet}$	$9^{*,\bullet}$	$21^{*,\Delta}$
Nodular type	$3^{\bullet}$	12	10^{*}
Strip type	7	6	7
Focal type	76	8	3
Compared with CAG			
Consistent	$82^{\bullet}$	30	29^{*}
Inconsistent	$9^{\bullet}$	5	12^{*}

Note: Mi-CP, mild calcification group; Mo-CP, moderate calcification group; Se-CP, severe calcification group; *Compared with the mild calcification group, $P < 0.05$; $^{\Delta}$Compared with the moderate calcification group, $P < 0.05$; $^{\bullet}$Compared with the severe calcification group, $P < 0.05$.

Image pro plus 5.02 was used to outline calcification spot and plaque areas and calculate the proportion.

Determination of SCCS: According to Agaston's method [3], a calcification lesion was confirmed if the calcification area was > 1 mm^2 and the peak CT number (CTN) was higher + 130 HU. The SCCS for each calcification lesion was calculated by the peak CTN multiplying the corresponding calcification area (unit: 1 mm^2).

CAG examination

All the elected 87 patients underwent CAG within 2 weeks after check of CTA. Artis dTA angiographic system (Siemens, Germany) was used. The stenotic extent of all coronary segments with a lumen diameter ≥ 1.5 mm was evaluated by two experienced cardiologists using internationally accepted visual diameter observation method (proximal vascular diameter- at the lesion)/(proximal vascular diameter × 100%). If there was disagreement, re-evaluation was performed till consensus.

Study protocols

The analysis was performed according to the 15 coronary segmentation method of ACA. All lesions with SCCS > 0 were selected and divided into three groups, mild calcification group (SCCS < 80), moderate calcification group (SCCS = 80-200), and severe calcification group (SCCS > 200). In these three groups, the lesions receiving interventional treatment served as subgroup and were compared.

Statistical analysis

SPSS 17.0 software was employed for statistical analysis. The quantitative data were presented as mean ± standard deviation. Independent-sample *t* test was used for mean comparison between two samples and chi-square test for comparison of qualitative data. For all analysis results, $P < 0.05$ suggested a significant difference.

Results

General data

Totally 87 patients were enrolled, including 55 males and 32 females, and average age was 82.16 ± 10.26 years old. There were 167 lesions in total, including 6 cases of acute coronary syndrome, 64 cases of stable angina pectoris and 17 cases of coronary atherosclerosis.

Position of lesions

Lesions position was according to 15 coronary segmentation method of ACC, as shown in **Table 1**. It was found that the proportion of proximal lesions in the severe calcification

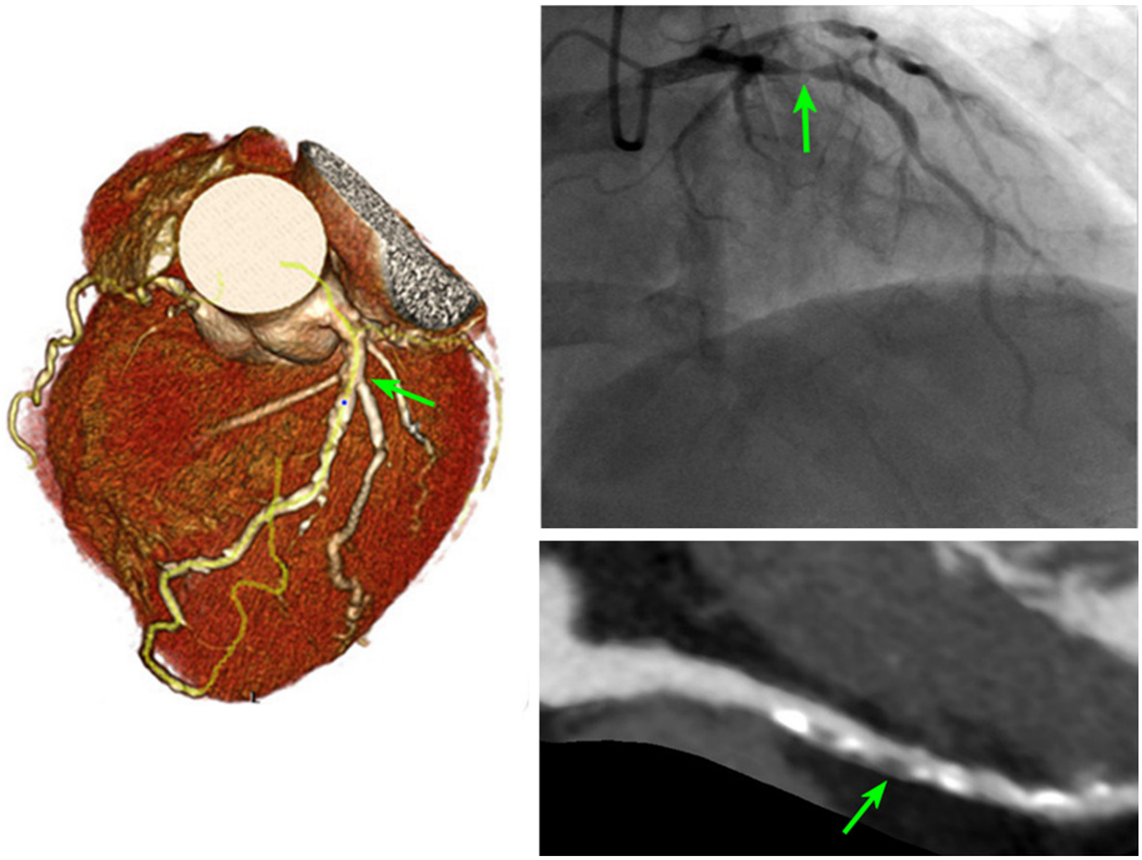

Figure 1. Severe calcification effected judgment of coronary stenosis degree by CTA. CAG showed severe stenosis of 99 percent in the proximal of LAD, CTA showed the stenosis of about 30%.

group was significantly higher than that in the mild calcification group (P < 0.05), but no difference was observed in other parameters among three groups.

Morphology and characters of lesions

The classification of main plaques by morphology and characters was shown in **Table 2** and **Figure 1**. Stenosis extent was lower in the lesions of the mild calcification group than the in the severe calcification group. Nubbly and nodular type of plaques and calcifications were more frequent, and the calcification proportion was higher than lesions in the mild calcification group ($P < 0.05$). At the same time, inconsistency in the judgment of stenosis by CT and CAG was more frequent in the severe calcification group than mild calcification group ($P < 0.05$).

Analysis of interventional therapy subgroup

The lesions receiving coronary interventional treatment were selected from the three groups and subjected to subgroup analysis, as shown in **Table 3**. The proportion of lesions with either pre-dilation balloon or post-dilation balloon was evidently greater in the severe calcification group than in the mild calcification group ($P < 0.05$), and the expansion pressure of pre-dilation, post-dilation and stent was higher ($P < 0.05$). However, there was no significant difference in stent diameter among three groups ($P > 0.05$).

Discussion

Coronary artery calcification (CAC) is an indication of coronary atherosclerosis. It is an inevitable product when coronary atherosclerosis develops up to a certain extent, strongly correlated with coronary atherosclerosis [5, 10, 11]. Thus the quantification of CAC can reflect the severity of coronary atherosclerotic. CCS is the quantitative analysis on CAC using CT. Kondons et al. [8] compared CCS and other common risk factors in the correlation with CHD in a 37-month follow-up of nearly 6,000 cases. Their results showed that the value of CCS to

Table 3. Analysis of interventional treatment

	Mi-CP (n = 58)	Mo-CP (n = 20)	Se-CP (n = 25)
Use of pre-dilation balloon	$30^{\bullet}$	15	21^{*}
Pressure of pre-dilation balloon (ATM)	$11.84 \pm 3.41^{\bullet}$	13.13 ± 2.26	$13.81 \pm 2.48^{*}$
Stent diameter (mm)	2.95 ± 0.75	3.05 ± 0.24	3.03 ± 0.32
Pressure of stent expansion (ATM)	$13.19 \pm 3.92^{\bullet}$	14.15 ± 4.17	$15.82 \pm 5.13^{*}$
Use of post-dilation balloon	$15^{\Delta,\bullet}$	8	$18^{*,\Delta}$
Pressure of post-dilation balloon (ATM)	$16.11 \pm 2.12^{\bullet}$	17.40 ± 3.25	$18.83 \pm 3.16^{*}$
Use of tirofiban	16	6	9

Note: Mi-CP, mild calcification group; Mo-CP, moderate calcification group; Se-CP, severe calcification group; "Use of tirofiban" meant tirofiban was used to treat lesion following the judgment by the interventional physician. *Compared with the mild calcification group, P < 0.05; $^{\Delta}$Compared with the moderate calcification group, P < 0.05; $^{\bullet}$Compared with the severe calcification group, P < 0.05.

CHD was markedly higher than those of diabetes and smoking (10.5 vs. 1.98 and 1.4). Higgin et al. [12] classified CCS into four levels: 0 meant no risk of cardiac events actually; 1-100 meant a low risk of cardiac events in the next five years; 100-400 meant a middle risk of cardiac events; > 400 meant a high risk of cardiac events.

Electron beam CT (EBCT) is the gold standard to evaluate the extent of CAC. In the recent years many studies showed that CCS measured by multiple detector CT (MDCT) was correlated well with EBCT [13-15]. With 320-slice DVCT, the latest generation of MDCT, it is available to acquire the complete whole-heart scan data from cardiac base to cardiac apex only by one cycle of scanning, and the effects of heart rate and breathing movement on image quality are reduced obviously. 320-slice DVCT is predominant in time resolution and spatial resolution, and can evaluate plaque morphology more accurately, analyze and identify the nature of plaque [10, 16-18]. The calculation of CCS involves two factors, CT value at the lesion and lesion area. With the above advantages, 320-slice DVCT greatly increases the accuracy of CCS. In the previous studies, GCCS was generally used to evaluate the development of CAC; however, one patient may have lesions in different sites under different development phases. Therefore, it is difficult for GCCS to accurately reflect the actual change of CAC. In this study we used coronary segments as study object, which lowers the error probability and may be superior to GCCS. Several years ago, the calcification measurement by plaque was proposed by some foreign scholars [19], but there are only individual reports about its application [11, 20]. They found that the shape of calcification and CCS of single coronary artery had greater significance to evaluate CHD.

This study showed that severe calcification was more frequent in the proximal lesions. Several years ago, this result was similar to the previous study finding. Such a finding may be attributed to that the proximal segment has a greater shearing force due to the hemodynamic effect, so more atherosclerosis develops in this segment. Calcification is often observed in the coronary segments with localized high stenosis; however, it was found in the previous studies that the calcification extent was not positively correlated with the stenotic extent of plaque. In this study, we found the stenotic extent of lesions in the severe calcification group was much lesser than that in the mild and moderate calcification groups. At present, there are few studies of CAC morphology at home and aboard [21, 22]. Thilo et al. found [7] shell-like and diffuse calcifications were significantly more frequently associated with > 50% stenosis and non-calcified plaque than calcified nodules. It was found in this study that nubbly and nodular lesions were more frequent in the severe calcification group, and these lesions also had nubbly and nodular calcification in morphology. From the consistency of stenosis judgment by CAG and CTA, the match degree decreased with the increase of calcification extent, which might be due to the shielding effect of calcification.

By the analysis of interventional treatment subgroup, it was found that the proportion of lesions using pre-dilation and post-dilation balloons and the expansion pressure of balloon in the severe calcification group were both higher than those in the mild calcification group. The subgroup analysis showed no significant difference in stent diameter among three groups, though proximal lesions were common in the severe calcification group. This might be because the operators selected stents with a small diameter to prevent incomplete stent expansion when there was severe calcification lesion. Despite of a similar stent diameter, the stent expansion pressure in the severe calcification group was significantly greater than the mild calcification group, and the proportion of lesions using post-dilation balloons and the expansion pressure of post-dilation balloon were also higher. It demonstrated the effect of severe calcification on interventional treatment again. Compared with the mild calcification group, a higher proportion of lesions in the severe calcification group used tirofiban after operation, but there was no statistical difference. This suggested that the interventional treatment of severe calcification lesion still might increase the risk of thrombosis.

Selective plaque rotational atherectomy is recommended for severe calcification lesions, especially when vascular intima has circular, superficial, severe calcification, or the guide wire passes through the lesion but the balloon catheter fails, or proper dilation is not feasible to stenotic lesions before stent implantation. Since only few of the selected patients underwent rotational atherectomy in the patients, the corresponding analysis was not performed, which is the shortness of this study. We will study and compare the outcomes of patients between the SCCS group and GCCS group in further study.

In conclusion, it is found in this study that SCCS is better than GCCS in evaluating CAC lesions and can provide reference for the selection of interventional treatment device. Therefore, SCCS is a good reference indicator during clinical diagnosis and treatment.

Acknowledgements

The authors are grateful for the technical contributions of Guoying Li, Min Li and Lingbo Qing.

Disclosure of conflict of interest

None.

Address correspondence to: Xiaoyan Li, Department of Cardiology, Jinan Military General Hospital, Jinan 250031, China. Tel: +86-18660809287; Fax: +86-536-51666547; E-mail: lixiaoyan1@126.com

References

[1] Mautner SL, Mautner GC, Froehlich J, Feuerstein IM, Proschan MA, Roberts WC, Doppman JL. Coronary artery disease: prediction with in vitro electron beam CT. Radiology 1994; 192: 625-30.

[2] Keelan PC, Bielak LF, Ashai K, Jamjoum LS, Denktas AE, Rumberger JA, Sheedy II PF, Peyser PA, Schwartz RS. Long-term prognostic value of coronary calcification detected by electron-beam computed tomography in patients undergoing coronary angiography. Circulation 2001; 104: 412-7.

[3] Agatston AS, Janowitz WR, Hildner FJ, Zusmer NR, Viamonte M Jr, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. J Am Coll Cardiol 1990; 15: 827-32.

[4] Carrascosa P, Capunay C, Deviggiano A, Goldsmit A, Tajer C, Bettinotti M, Carrascosa J, Ivanc TB, Fallahi A, García MJ. Accuracy of low-dose prospectively gated axial coronary CT angiography for the assessment of coronary artery stenosis in patients with stable heart rate. J Cardiovasc Comput Tomogr 2010; 4: 197-205.

[5] Leening MJ, Elias-Smale SE, Kavousi M, Felix JF, Deckers JW, Vliegenthart R, Oudkerk M, Hofman A, Steyerberg EW, Stricker BH, Witteman JC. Coronary calcification and the risk of heart failure in the elderly: the Rotterdam Study. JACC Cardiovasc Imaging 2012; 5: 874-80.

[6] Nucifora G, Bax JJ, van Werkhoven JM, Boogers MJ, Schuijf JD. Coronary artery calcium scoring in cardiovascular risk assessment. Cardiovasc Ther 2011; 29: e43-53.

[7] Thilo C, Gebregziabher M, Mayer FB, Zwerner PL, Costello P, Schoepf UJ. Correlation of regional distribution and morphological pattern of calcification at CT coronary artery calcium scoring with non-calcified plaque formation and stenosis. Eur Radiol 2010; 20: 855-61.

[8] Kondos GT, Hoff JA, Sevrukov A, Daviglus ML, Garside DB, Devries SS, Chomka EV, Liu K. Electron-beam tomography coronary artery calcium and cardiac events: a 37-month follow-up of 5635 initially asymptomatic low- to intermediate-risk adults. Circulation 2003; 107: 2571-6.

[9] Kajinami K, Seki H, Takekoshi N, Mabuchi H. Coronary calcification and coronary atherosclerosis: site by site comparative morphologic

study of electron beam computed tomography and coronary angiography. J Am Coll Cardiol 1997; 29: 1549-56.
[10] Gang S, Min L, Li L, Guo-Ying L, Lin X, Qun J, Hua Z. Evaluation of CT coronary artery angiography with 320-row detector CT in a high-risk population. Br J Radiol 2012; 85: 562-70.
[11] Gao D, Ning N, Guo Y, Ning W, Niu X, Yang J. Computed tomography for detecting coronary artery plaques: a meta-analysis. Atherosclerosis 2011; 219: 603-9.
[12] Higgins CL, Marvel SA, Morrisett JD. Quantification of calcification in atherosclerotic lesions. Arterioscler Thromb Vasc Biol 2005; 25: 1567-76.
[13] Zidan M, Nicoll R, Schmermund A, Henein M. Cardiac multi-detector CT: its unique contribution to cardiology practice. Int J Cardiol 2009; 132: 25-9.
[14] Leber AW, Knez A, Becker C, Becker A, White C, Thilo C, Reiser M, Haberl R, Steinbeck G. Non-invasive intravenous coronary angiography using electron beam tomography and multislice computed tomography. Heart 2003; 89: 633-9.
[15] Carr JJ, Crouse JR 3rd, Goff DC Jr, D'Agostino RB Jr, Peterson NP, Burke GL. Evaluation of subsecond gated helical CT for quantification of coronary artery calcium and comparison with electron beam CT. AJR Am J Roentgenol 2000; 174: 915-21.
[16] Tabibian B, Roach CJ, Hanson EH, Wynn BL, Orrison WW Jr. Clinical indications and utilization of 320-detector row CT in 2500 outpatients. Comput Med Imaging Graph 2011; 35: 266-74.
[17] Qin J, Liu LY, Fang Y, Zhu JM, Wu Z, Zhu KS, Zhang JS, Shan H. 320-detector CT coronary angiography with prospective and retrospective electrocardiogram gating in a single heartbeat: comparison of image quality and radiation dose. Br J Radiol 2012; 85: 945-51.
[18] Sun G, Li M, Li L, Li GY, Zhang H, Peng ZH. Optimal systolic and diastolic reconstruction windows for coronary CT angiography using 320-detector rows dynamic volume CT. Clin Radiol 2011; 66: 614-20.
[19] Janowitz WR, Agatston AS, Viamonte M Jr. Comparison of serial quantitative evaluation of calcified coronary artery plaque by ultrafast computed tomography in persons with and without obstructive coronary artery disease. Am J Cardiol 1991; 68: 1-6.
[20] Moselewski F, O'Donnell CJ, Achenbach S, Ferencik M, Massaro J, Nguyen A, Cury RC, Abbara S, Jang IK, Brady TJ, Hoffmann U. Calcium concentration of individual coronary calcified plaques as measured by multidetector row computed tomography. Circulation 2005; 111: 3236-41.
[21] Enrico B, Suranyi P, Thilo C, Bonomo L, Costello P, Schoepf UJ. Coronary artery plaque formation at coronary CT angiography: morphological analysis and relationship to hemodynamics. Eur Radiol 2009; 19: 837-44.
[22] Rasouli ML, Shavelle DM, French WJ, McKay CR, Budoff MJ. Assessment of coronary plaque morphology by contrast-enhanced computed tomographic angiography: comparison with intravascular ultrasound. Coron Artery Dis 2006; 17: 359-64.