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ORIGINAL ARTICLE

Coronary Artery Calcium Score Measured by Computed Tomography and Its Correlation with Carotid Intima-media Thickness and Subcutaneous Abdominal Fat Thickness

Y Greeshma, T Lokeshkumar, K Udhayakumar, A Ramalingam, BR Nagaraj

Department of Radiology, Mahatma Gandhi Medical College and Research Institute, Pondicherry, India

ABSTRACT

Objective: *To determine the correlation between coronary artery calcium score (CACS), carotid intima-media thickness (CIMT), and subcutaneous abdominal fat thickness (SAFT) for atherosclerosis.*

Methods: *Between December 2014 and September 2016, 50 patients were referred to the department of radiology, where CACS was measured by computed tomography, and CIMT and SAFT were measured by ultrasonography. Correlations between the CACS, CIMT, and SAFT were determined.*

Results: *A total of 36 men and 14 women aged 28 to 74 (mean, 50.3) years were assessed. The mean CACS was 137.8. The mean CIMT was 0.05 cm. The mean SAFT was 1.9 cm. The CACS significantly correlated with CIMT ($r = 0.450, p = 0.001$) and SAFT ($r = 0.250, p = 0.004$), and patient age ($r = 0.336, p = 0.009$). Age was not significantly correlated with CIMT ($r = 0.171, p = 0.118$) or SAFT ($r = 0.096, p = 0.253$). CIMT was not significantly correlated with SAFT ($r = 0.151, p = 0.148$).*

Conclusion: *CACS is a dependable marker for atherosclerosis, as are CIMT and SAFT. In patients with a CACS of 0, CIMT can be used for early detection of atherosclerotic changes.*

Key Words: *Carotid intima-media thickness; Coronary stenosis; Subcutaneous fat, abdominal*

中文摘要

電腦斷層掃描測量冠狀動脈鈣化評分及其與頸動脈內膜中層厚度和皮下腹部脂肪厚度的相關性

Y Greeshma、T Lokeshkumar、K Udhayakumar、A Ramalingam、BR Nagaraj

目的：確定冠狀動脈鈣化評分（CACS）、頸動脈內膜中層厚度（CIMT）與皮下腹脂肪厚度（SAFT）之間的相關性。

方法：2014年12月至2016年9月間，共有50例患者被轉介到放射科作冠狀動脈電腦斷層掃描（CT）

Correspondence: Dr Y Greeshma, Department of Radiology, Mahatma Gandhi Medical College and Research Institute, Pondicherry, India.
Email: greeshma.yarlagadda9@gmail.com

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和超聲檢查。CACS由CT評估，而 CIMT和SAFT由超聲評估。並確定CACS、CIMT和SAFT之間的相關性。

結果：共評估了36名男性和14名女性年齡28至74歲（平均50.3歲）。平均CACS為137.8、平均CIMT為0.05 cm、平均SAFT為1.9 cm。CACS與CIMT（r = 0.450，p = 0.001）、SAFT（r = 0.250，p = 0.004）和患者年齡（r = 0.336，p = 0.009）顯著相關。年齡與CIMT（r = 0.171，p = 0.118）或SAFT（r = 0.096，p = 0.253）無顯著相關。CIMT與SAFT無顯著相關（r = 0.151，p = 0.148）。

結論：與CIMT和SAFT一樣，CACS是動脈粥樣硬化的可靠標誌物。在CACS為0的患者中，CIMT可用於早期檢測動脈粥樣硬化改變。

INTRODUCTION

Atherosclerosis affects the coronary arteries and other vascular structures, particularly the carotid arteries.[1] Atherosclerotic plaques contain mostly calcium, and the presence of calcific foci in the coronary artery walls is indicative of coronary artery disease that may result in myocardial infarction or stroke. In addition, fat deposition can be used as a marker for early detection of coronary artery disease. The latent period for manifestation of cardiovascular diseases may take years; the pathophysiological process of atherogenesis starts at various levels of the vascular tree.

The coronary artery calcium score (CACS) was derived using the Agatston method[2] (Table 1) on coronary computed tomography (CT) of 202 angioplasty patients.[3] The CACS has been reported to be associated with conventional angiography and predictive of coronary artery disease; a cut off of 350 yields an optimal sensitivity and specificity of 83% and 70%, respectively.[1] The CACS is considered a screening tool for coronary CT angiography to determine the patency of the coronary artery lumen.

The CACS is associated with coronary artery luminal narrowing in both patients and autopsy specimens, and there is a positive remodelling effect on the coronary arteries.[4,5] In a study of 288 patients with a CACS of 0, 17.4% had non-calcified plaques.[6]

Carotid intima-medial thickness (CIMT) is the combined thickness of the intimal and medial layers of the carotid artery and is most commonly assessed by B-mode ultrasonography, which is a safe, non-invasive, and cost-effective tool. Increased CIMT is caused by hypertrophy of the intimal or medial layer or both because of a cellular or molecular mechanism. Increased CIMT is associated with subclinical and asymptomatic atherosclerotic vascular diseases, and therefore can be used to detect primordial atherosclerosis. The extent of a lesion in the common carotid artery is associated with the extent of atherosclerotic lesions in other arteries of the body. CIMT is defined as the area of tissue starting at the luminal intimal interface and the media-adventitia interface of the common carotid artery.[3] On B-mode ultrasonography, CIMT is the double-line pattern formed by two parallel echogenic lines representing the junction of the vessel lumen with the intimal and media-adventitia interface. Both CIMT and CACS are recognised by the American Heart Association as surrogate markers for coronary artery disease. The advantage of CIMT (measured by B-mode ultrasonography) over the CACS (measured by coronary CT) is the lack of ionising radiation and the ability to detect disease at a young age when the CACS is often 0. CIMT is predictive of myocardial infarction and stroke. It may be used to discriminate low- and high-risk patients.[7]

Subcutaneous abdominal fat thickness (SAFT) is defined

Table 1. Coronary artery calcium score (CACS) based on the Agatston method on electron-beam computed tomography.

CACS	Calcium plaque	Clinical interpretation
0	None	Very low risk of cardiovascular disease
1-10	Minimal	Significant coronary artery disease very unlikely
11-100	Mild	Likely mild or minimal coronary stenosis
101-400	Moderate	Moderate non-obstructive coronary artery disease highly likely
>400	Extensive	High likelihood of at least one significant coronary stenosis (>50% diameter)

as the distance between the fat skin interface anteriorly and the anterior surface of the linea alba posteriorly. SAFT is associated with visceral fat thickness and CIMT.[1]

This study aimed to determine the correlation between the CACS, CIMT, and SAFT for atherosclerosis.

METHODS

This study was approved by the ethics committee of the Mahatma Gandhi Medical College and Research Institute and was conducted in compliance with the Declaration of Helsinki. Written informed consent was obtained from each patient. Between December 2014 and September 2016, 50 patients were referred to the department of radiology for coronary CT and ultrasonography. Patients with serum creatinine of >1.5 mg/dL or any contraindication for coronary CT were excluded.

For CACS, patients were instructed to take 5 mg of ivabradine twice daily for 2 days to control the heart rate for better electrocardiography gating and undistorted images prior to coronary CT. CT images were taken using the Optima CT 660 128-slice machine (GE Healthcare, Chicago [IL], US) with a tube current of 400 mA, tube voltage of 120 kV, tube rotation time of 400 ms, and section thickness of 0.0625 mm. Post-acquisition reformatting and calcium score summation was performed. CT images were acquired from just below the level of the carina to 2.5 cm below the diaphragm level with electrocardiography gating and heart rate was maintained at 55 to 65 beats per minute. Administration of non-ionic, water-soluble, iodinated, low-osmolarity contrast (1.5 mL/kg body weight) — iobitridol — containing 350 mg/mL iodine was through an 18 G cannula to the right antecubital vein at 5.5 mL/s. CT images were analysed using semi-automated software (Figure 1). The Calcium Smart Score enabled the observer to select the calcium density foci and label the affected artery, after which the total Agatston calcium score was auto-evaluated.

For CIMT, ultrasonography was carried out using the ACUSON S2000 ultrasound system (Siemens Healthcare, Munich, Germany), with a 9 to 12 MHz transducer. Patients were positioned supine, with a pillow below the shoulders for proper neck extension. The CIMT of the left and right carotid arteries were measured at 2 cm proximal to the carotid bulb on the far wall at a plaque-free area (Figure 2). Two measurements were taken on each side and the average was calculated.

For SAFT, the same ultrasonography protocol was used to measure three equidistant points in the midline between the xiphoid process and umbilicus (Figure 3). The subcutaneous fat extended from the posterior aspect of the skin–fat interface anteriorly to the linea alba posteriorly. Three measurements were obtained and the average was calculated.

Pearson correlation analysis was used to determine correlations between the CACS, CIMT, and SAFT.

RESULTS

In total, 36 men and 14 women aged 28 to 74 (mean, 50.3) years were assessed. The mean CACS was 137.8 (standard deviation [SD], 304.9; range, 0-1193). The mean CIMT was 0.05 (SD, 0.01; range, 0.04-0.08) cm. The mean SAFT was 1.9 (SD, 0.4, range, 1.4-2.7) cm.

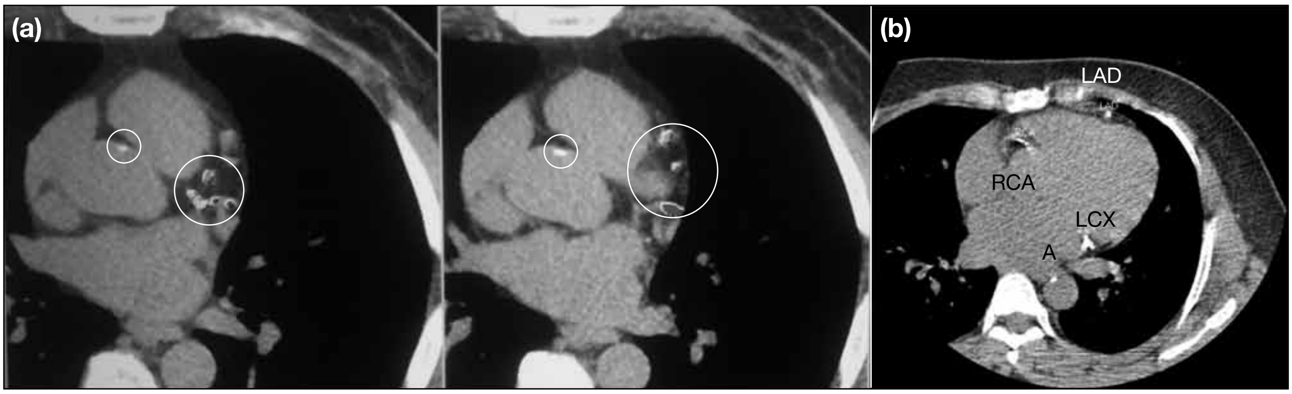

Figure 1. (a) The Calcium Smart Score software showing selection of calcific foci (circled). (b) Axial plain coronary computed tomography showing calcific foci in the aorta (A), left anterior descending artery (LAD), left circumflex artery (LCX), and right coronary artery (RCA).

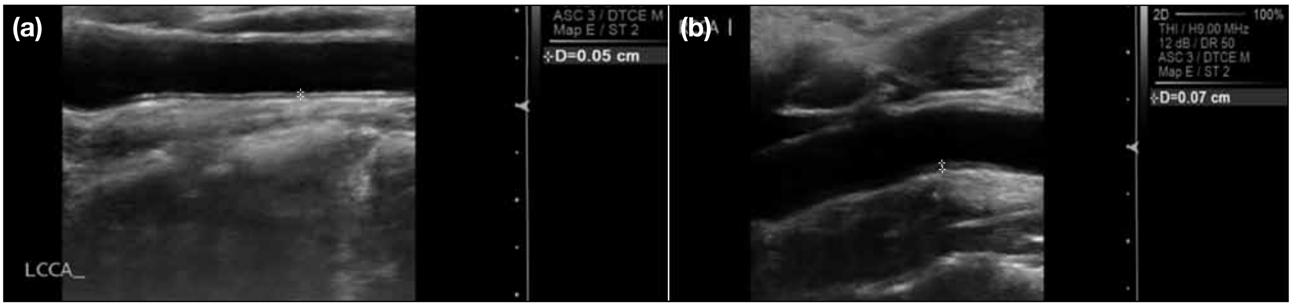

Figure 2. Ultrasonography showing the carotid intima-media thickness of the (a) left and (b) right common carotid arteries (outlined by callipers).

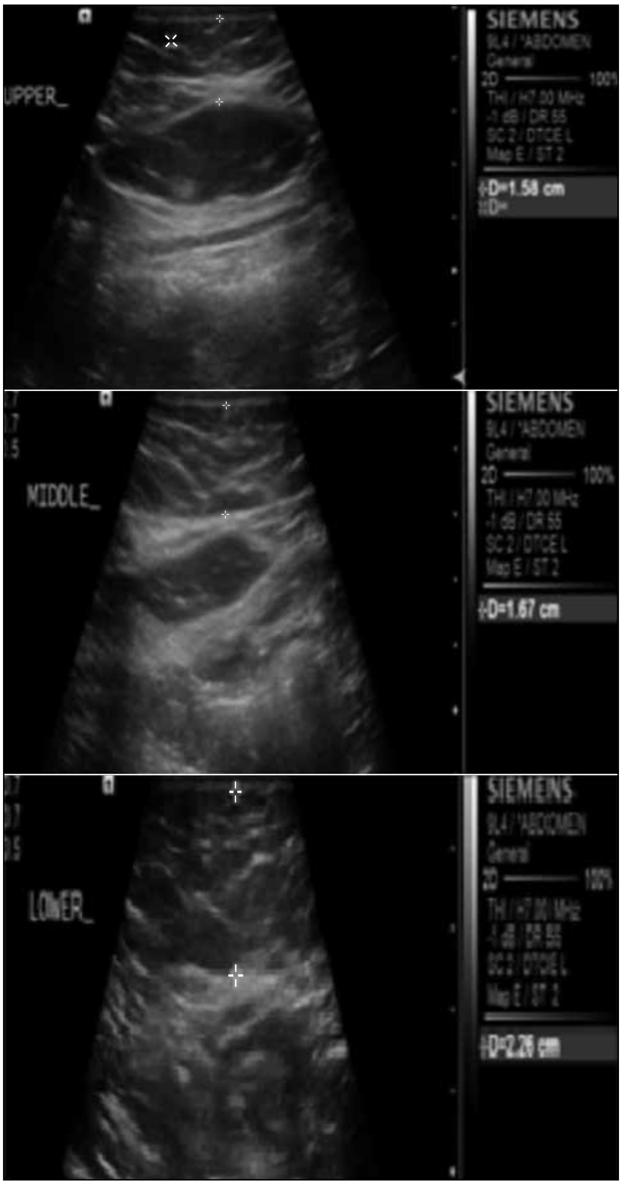

Figure 3. Ultrasonography showing the subcutaneous abdominal fat thickness at three equidistant points between the xiphoid process and just above the umbilicus (outlined by callipers).

The CACS significantly correlated with CIMT (r = 0.450, p = 0.001) and SAFT (r = 0.250, p = 0.004), and patient age (r = 0.336, p = 0.009) [Figure 4 and Table 2]. Age was not significantly correlated with CIMT (r = 0.171, p = 0.118) or SAFT (r = 0.096, p = 0.253). CIMT

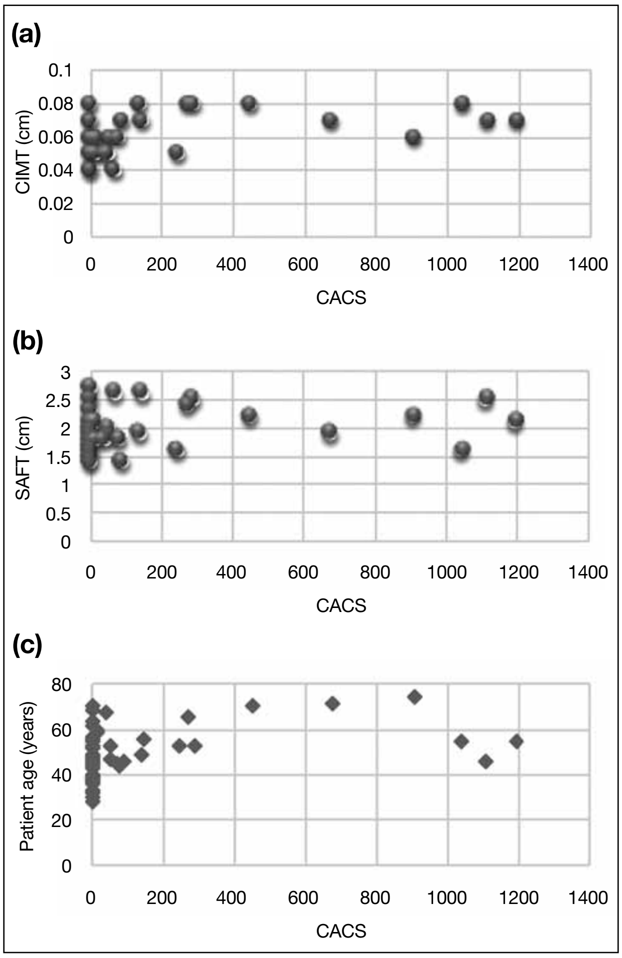

Figure 4. Scatter plots showing significant correlations between coronary artery calcium score (CACS) and (a) carotid intima-media thickness (CIMT), (b) subcutaneous abdominal fat thickness (SAFT), or (c) patient age.

Table 2. Correlations between coronary artery calcium score (CACS), carotid intima-media thickness (CIMT), subcutaneous abdominal fat thickness (SAFT), and patient age.

Variable	CACS		CIMT		SAFT		Patient age	
	r	p Value	*r*	p Value	*r*	p Value	*r*	p Value
CACS	1.000	1.000	0.450	0.001	0.250	0.040	0.336	0.009
CIMT	0.450	0.001	1.000	1.000	0.151	0.148	0.171	0.118
SAFT	0.250	0.040	0.151	0.148	1.000	1.000	0.096	0.253
Patient age	0.336	0.009	0.171	0.118	0.096	0.253	1.000	1.000

Table 3. Correlations between coronary artery calcium score (CACS) and carotid intima-media thickness (CIMT).

Calcium plaque (CACS)	No. of patients	
	Normal CIMT (≤0.06 cm)	Increased CIMT (>0.06 cm)
None (0)	18	11
Minimal (1-10)	2	0
Mild (11-100)	4	4
Moderate (101-400)	1	4
Extensive (>400)	0	6

was not significantly correlated with SAFT (r = 0.151, p = 0.148).

Using a cutoff of ≤0.06 cm, the CIMT was normal in 25 patients and increased in 25 patients. Of the 25 patients with increased CIMT, 11 had no, four had mild, four had moderate, and six had extensive calcium plaque based on the CACS (χ^2 = 14.7, degree of freedom = 4, p = 0.005, Table 3).

DISCUSSION

The CACS has been reported to be an indicator of coronary artery disease and CIMT an indicator of cerebrovascular disease.[8] Nonetheless, the CACS was considered to be the only independent predictor of severe coronary artery disease,[9] as CIMT becomes more predictive at a more advanced age.[10] In our study, the CACS correlated more with CIMT than SAFT, and CIMT and SAFT were not significantly correlated. Vascular calcification is a late process of atherosclerosis, and thus CIMT is more sensitive than CACS in detection of subclinical atherosclerosis.[11]

In a meta-analysis, the age- and sex-adjusted relative risk was 1.26 (95% confidence interval [CI] = 1.21-1.30) for myocardial infarction and 1.32 (95% CI = 1.27-1.38) for stroke for each SD difference of CIMT.[12] CIMT can predict future cardiovascular disease events, but is slightly better in predicting cerebrovascular events.[12]

In a study of a younger population (aged 36-59 years), 75% had a CACS of 0, of whom 47% had evidence of carotid atherosclerosis.[11] This shows the role of CIMT in a low-risk, younger population with a CACS of 0.[11] In our patients (age 28-74 years), 11 (37.9%) of 29 patients with a CACS of 0 had increased CIMT. Thus, CIMT can detect early atherosclerotic changes before the CACS can.

SAFT has been reported to be associated with subclinical atherosclerosis in the general population, obese people, or patients with type 2 diabetes mellitus.[12-14] Regional adiposity of the body is more closely associated with atherosclerosis than the magnitude of generalised obesity.[12,14] Subcutaneous adipose tissue is considered ‘protective fat’, which is mainly in non-abdominal regions such as the gluteal, thigh, or lower leg regions.[15-17] In our study, SAFT was significantly correlated with the CACS but not the CIMT.

Our study had some limitations. The sample size was small, and analysis was not adjusted for sex and age. Comorbidities (such as diabetes mellitus, hyperlipidaemia, and hypercholesterolaemia) and medications were not considered.

CONCLUSION

The CACS is a dependable marker for atherosclerosis, as are CIMT and SAFT. In patients with a CACS of 0, CIMT can be used for early detection of atherosclerotic changes.

REFERENCES

1. Hong C, Becker CR, Schoepf UJ, Ohnesorge B, Bruening R, Reiser MF. Coronary artery calcium: absolute quantification in nonenhanced and contrast-enhanced multi-detector row CT studies. Radiology. 2002;223:474-80. Crossref

2. 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. Crossref
3. Arjmand Shabestari A. Coronary artery calcium score: a review. Iran Red Crescent Med J. 2013;15:e16616. Crossref
4. Rumberger JA, Brundage BH, Rader DJ, Kondos G. Electron beam computed tomographic coronary calcium scanning: a review and guidelines for use in asymptomatic persons. Mayo Clin Proc. 1999;74:243-52. Crossref
5. Guerci AD, Spadaro LA, Popma JJ, Goodman KJ, Brundage BH, Budoff M, et al. Relation of coronary calcium score by electron beam computed tomography to arteriographic findings in asymptomatic and symptomatic adults. Am J Cardiol. 1997;79:128-33. Crossref
6. Buyukterzi M, Türkvatan A, Büyükterzi Z. Frequency and extent of coronary atherosclerotic plaques in patients with a coronary artery calcium score of zero: assessment with CT angiography. Diagn Interv Radiol. 2013;19:111-8.
7. Liviakis L, Pogue B, Paramsothy P, Bourne A, Gill EA. Carotid intima-media thickness for the practicing lipidologist. J Clin Lipidol. 2010;4:24-35. Crossref
8. Folsom AR, Kronmal RA, Detrano RC, O'Leary DH, Bild DE, Bluemke DA, et al. Coronary artery calcification compared with carotid intima-media thickness in the prediction of cardiovascular disease incidence: the Multi-Ethnic Study of Atherosclerosis (MESA). Arch Intern Med. 2008;168;1782. Crossref
9. Tresoldi S, Bigi R, Gregori D, Ravelli A, Pricolo P, Flor N, et al. Comparison between carotid artery Doppler ultrasound and coronary calcium score as predictors of significant coronary artery disease in patients undergoing computed tomography coronary angiography. Cardiol Pharmacol. 2014;3:116.
10. Newman AB, Naydeck BL, Ives DG, Boudreau RM, Sutton-Tyrrell K, O'Leary DH, et al. Coronary artery calcium, carotid artery wall thickness, and cardiovascular disease outcomes in adults 70 to 99 years old. Am J Cardiol. 2008;101;186-92. Crossref
11. Lester SJ, Eleid MF, Khandheria BK, Hurst RT. Carotid intima-media thickness and coronary artery calcium score as indications of subclinical atherosclerosis. Mayo Clin Proc. 2009;84:229-33. Crossref
12. Kim SK, Kim HJ, Hur KY, Choi SH, Ahn CW, Lim SK, et al. Visceral fat thickness measured by ultrasonography can estimate not only visceral obesity but also risks of cardiovascular and metabolic diseases. Am J Clin Nutr. 2004;79:593-9. Crossref
13. Kim SK, Park SW, Kim SH, Cha BS, Lee HC, Cho YW. Visceral fat amount is associated with carotid atherosclerosis even in type 2 diabetic men with a normal waist circumference. Int J Obes (Lond). 2009;33:131-5. Crossref
14. Kawamoto R, Ohtsuka N, Ninomiya D, Nakamura S. Association of obesity and visceral fat distribution with intima-media thickness of carotid arteries in middle-aged and older persons. Intern Med. 2008;47:143-9. Crossref
15. Snijder MB, Visser M, Dekker JM, Goodpaster BH, Harris TB, Kritchevsky SB, et al. Low subcutaneous thigh fat is a risk factor for unfavourable glucose and lipid levels, independently of high abdominal fat. The Health ABC Study. Diabetologia. 2005;48:301-8. Crossref
16. Bays HE, Fox KM, Grandy S; SHIELD Study Group. Anthropometric measurements and diabetes mellitus: clues to the "pathogenic" and "protective" potential of adipose tissue. Metab Syndr Relat Disord. 2010;8:307-15. Crossref
17. Park JS, Cho MH, Ahn CW, Kim KR, Huh KB. The association of insulin resistance and carotid atherosclerosis with thigh and calf circumference in patients with type 2 diabetes. Cardiovasc Diabetol. 2012;11:62. Crossref