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Coronary artery calcium scoring in myocardial infarction

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Background. *The aim of this study was to evaluate coronary artery calcium scoring and the assessment of the risk factors in patients with myocardial infarction (MI).*

Methods. *During the period of three years, 27 patients with MI were analyzed. The average age of patients was 66.1 years (46 to 81). Coronary arteries calcium was evaluated by multi row detector computed tomography (MTDC) «Somatom Volume Zoom Siemens«, and, retrospectively by ECG gating data acquisition. Semi automated calcium quantification to calculate Agatston calcium score (CS) was performed with 4 x 2.5 mm collimation, using 130 ml of contrast medium, injected with an automatic injector, with the flow rate of 4 ml/sec. The delay time was determined empirically. At the same time several risk factors were evaluated.*

Results. *Out of 27 patients with MI, 3 (11.1%) patients had low CS (10- 100), 5 (18.5%) moderate CS (101-499), and 19 (70.4%) patients high CS (>500). Of risk factors, smoking was confirmed in 17 (63.0%), high blood pressure (HTA) in 10 (57.0%), diabetes mellitus in 7 (25.9%), positive family history in 5 (18.5%), pathological lipids in 5 (18.5%), alcohol abuse in 4 (1.8%) patients. Six (22.2%) patients had symptoms of angina pectoris.*

Conclusions. *The research showed high correlation of MI and high CS (>500). Smoking, HTA, diabetes mellitus, positive family history and hypercholesterolemia are significant risk factors. Symptoms are relatively poor in large number of patients.*

Key words: myocardial infarction; coronary vessels; calcinosis; tomography; X-ray computed

Introduction

Atherosclerosis is a systemic generalized disease which usually occurs in different parts of arterial system, and affection of coronary arteries is of special interest.[1,2]

Coronary calcifications are almost always a sign of coronary atherosclerosis.[3] That is the reason why the level of coronary calcification can be considered as a risk factor.[4] Consequently, coronary artery calcium is taken as a predisposing marker of coronary atherosclerosis.[5,6] Therefore, the risk of future cardiac disease can be higher in patients with coronary calcifications than in those without them.

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Coronary calcifications are presented on CT scans as more than two consecutive pixels over 130 HU.[6] Coronary calcification has prognostic value in identification of asymptomatic patients who are at higher risk of coronary disease.[7]

Accurate and reproductive quantification of calcium is essential in the assessment of the progression of coronary calcification, as atherosclerosis markers, in a certain patient.[6]

Screening of coronary calcification started in 1990, primarily for the identification of patients with the coronary artery disease.[1] Agatston *et al*. have introduced this method for quantification of coronary artery calcium, by multiplication of calcified plaques zones based on plaque attenuation values.[6]

However, detection and quantification of coronary calcification is more adjusted for the risk evaluation of a sudden cardiac attack in asymptomatic patients than for the identification of symptomatic patients with the ischemic heart disease.[1]

The fact is that patients with higher Agatston score may have an increased risk for the future cardiac attack. That gives the fundamental motivation for the measurement of coronary calcium scoring, a better definition of patients who are at risk of myocardial infarction and of a sudden coronary death.[4]

The current stand-point of the American Society of Heart is that coronary heart disease (CHD) and atherosclerosis are less likely if a CT shows no coronary calcification. The risk of unexpected cardiac attack, like myocardial infarction and sudden death, can be very low in the period of consecutive two to five years. Besides, patients without coronary calcification will most probably have a normal finding at coronary angiography.[3]

The coronary calcification test is considered to be a strong indicator of cardiac mortality in elderly people, and it is independent of other cardiac risk factors.[8]

However, CHD cannot be confirmed, or ruled out only on the basis of coronary calcification.[3] Initial examinations found noncalcified plaques more often in patients with unstable angina, while calcified lesions were found mostly in patients with stable angina.

Early diagnosis is important for the plaque characterization, and the selection of treatable patients before the appearance of an ischemic attack. This helps a physician to distinguish lesions which are reversible with the medical treatment, from these that will need a surgical or endovascular treatment. It is believed, that the most promising techniques will be those which will be able to detect inflammatory processes in the plaque.[1]

CHD have been the most common cause of hospitalization and mortality in industrialized countries for many years.[9] It is usually caused by the rupture of an atherosclerotic plaque, which results with the total occlusion of the coronary artery. In developed world, 1/2 of a male and 1/3 of a female population will suffer from it after the age of 40 years.[7]

Currently, main available options for treatment are surgical revascularization with the coronary artery bypass graft (CABG), and interventional transluminal, catheter based procedures. Selection of treatment procedure depends on reliable diagnostic assessment of coronary arteries.[9] However, imaging of the coronary arteries is challenging. Their small dimension and position, together with breathing and heart pulsation artefacts, make visualization and detection of stenosis particularly difficult.[10]

Cardiac catheterization is a method of choice for determining the morphological status of coronary arteries, and it was often combined with interventional treatment procedures, like balloon angioplasty and stent implantation.[9] A selective catheterization of the heart primarily shows morphological changes combined with stenotic CHD, but also gives the parameters of myocardial function, and possibility for the measurement of haemodynamic parameters.

The main limitations of the coronary an-

giography are general contraindications, projection, and stenosis of the left branch, myocardial bypasses, endoluminal summation effects, and impossibility of the coronary artery wall visualization.[7] Cardiac catheterization is an invasive method which is connected with a certain risk and certain complications.

In recent years, many intensive researches have been undertaken with diagnostic procedures of low risk in order to replace and supplement, at least partially, current diagnostic cardiac procedures. Alternative imaging methods are: electron beam computed tomography (EBCT), multirow detector CT (MDCT) and magnetic resonance imaging (MRI).[9]

EBCT was the first CT modality which made possible the imaging of coronary arteries without movement artefacts. Agatston and co-operators proved EBCTs superiority in the detection of coronary calcification over fluoroscopy. Besides, they set up the quantification algorithm for the identification of patients with and without ischemic coronary artery disease.[3]

EBCT has the best overall accuracy, and is considered to be even better than MRI on the adequate visualization of proximal and middle segments of coronary artery, as well as on the detection of stenosis in these segments. Both modalities can be used, and they are complementary to each other. Being time-consuming, they cannot be alternative to the conventional coronary angiography for the time being.[10]

CT and MRI have a wide range of indications in non-invasive diagnostics, and they are partially overlapping in their clinical application.[9]

Besides the visualization of the coronary artery lumen, the vessel wall can also be seen on CT transversal scans.[3]

Non-invasive CT coronary angiography (CTA) may have even higher potential in the presumption of cardiac risk than calcium scoring. So, not only the lumen of the coronary artery can be visualized, but also non-calcified and non-stenotic atherosclerotic plaques can be detected on axial CT scans.[4] With contrast enhancement, both calcified and non-calcified lesions can be completely evaluated.[3]

A high negative predictive value of the coronary CTA can justify the examination of symptomatic patients with low or moderate pre-test probability of coronary artery disease. This technique could be used for the exclusion of coronary microangiopathy, and to avoid unnecessary cardiac catheterizations. Past researches proved that the wall of the coronary artery and its lumen can be seen by MDCT.[11] This method gives the possibility to follow-up the progression of coronary atherosclerosis in a non-invasive way.[5] MDCT coronary artery calcium scoring has been improved with retrospective ECG – gated data acquisition.[12]

CT and MRI have proved to be useful in the assessment of the changes in the vessel wall, and in the identification of highly risk patients who may benefit from treatment.[1]

MR angiography of the coronary arteries and MDCT angiography are the leading ways to supplement the diagnostic cardiac catheterization, whose role is mainly limited to the diagnosis of coronary atherosclerosis and measurement of the degree of stenosis.[13]

The aim of this study was to confirm coronary artery calcium scoring (CS), and risk factors in patients with the history of the previous myocardial infarction (MI). In this way, we wanted to indirectly confirm the relation of MI and the level of CS, as a risk factor.

Methods

During the three-year period, a large number of patients with various referral diagnoses were examined at our Institute of Radiology. Among them, 27 patients had the history of

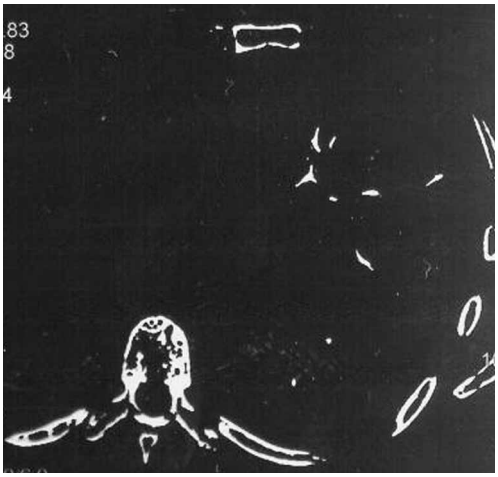

Figure 1. »Calcium Window« for identification of calcified plaques.

previous myocardial infarction. The average age of the patients was 66.1 years, the youngest was 46 and the oldest patient was 81 years old. Out of these patients, 23 (85.2%) were male and 4 (14.8%) female. In all patients, CS was determined according to the Agatston. The patients were divided into three categories based on the CS results: patients with the lowest CS (10-100), the intermediate CS (101-499), and the highest CS (>500) (Figure 1).

All patients were examined on MDCT machine with the four-row detectors, Siemens »Somatom Volume Zoom«. Calcium quantification Agatston calcium score program was used for examinations, native and contrast series were done, with non-ionic contrast medium applied by the automatic injector in the cubital vein. We used the collimation 4 x 2.5 mm, rotation time 500 msec, pitch 1.5 and FOV 200. 130 ml of contrast medium was injected, followed by 20 ml of saline, and a flow rate of 4ml/sec applied. The delay time was empirically determined, and it was in the range from 25 to 30 sec. The retrospective ECG gating was used during the examinations as well.

The following risk factors were taken from the patient's histories as relevant: smoking, arterial hypertension, diabetes mellitus, family history, increased lipids, alcohol abuse, and symptoms of angina pectoris.

Results

In the period from 2001 to 2003, we examined 27 patients with the history of myocardial infarction. The ratio of men to women was 5.7 to 1. In average, women were older than men for 3.9 years (Table 1).

In 27 patients with the history of myocardial infarction by whom we measured Agatston calcium score, 3 (11.1%) patients had low CS (10-100), 5 (18.5%) moderate CS (101-499), and 19 (70.4%) patients high CS (>500). Of risk factors, smoking was confirmed in 17 (63.0%) patients, high blood pressure (HTA) in 10 (37.0%), diabetes mellitus in 7 (25.9%), positive family history of cardiac disease in 5 (18.5%), pathological lipids in 5 (18.5%), and alcohol abuse in 4 (14.8%) patients. Six (22.2%) patients had symptoms of angina pectoris.

Discussion

As it has been shown by this study, coronary artery disease is predominantly a male disease because 85.2% of our patients were male, while only 14.8% were female. Therefore, male were 5.7 times more often victims of myocardial infarction. Besides, female who had myocardial infarction were in average older than male (69.7 to 65.8 years). This proves that age and male sex are significant risk factors, which is in accordance with the results from the literature.

Out of other risk factors related to the increased CS and development of myocardial infarction, smoking is at the first place, then hypertension, diabetes mellitus and hypercholesterolemia. It is also proved that only $^1/_4$ of the patients with the history of the my-

Table 1. Frequency of the risk factors in relation to age, sex and CS in patients with myocardial infarction

N	Age	Sex	Smoking	HTA	F. History	Diabetes	HHL	MI	Alcoholism	AP	CS
1	70	M	+	+	-	+	+	+	+	-	75
2	68	M	+	-	-	-	-	+	-	+	>500
3	44	M	+	+	-	+	+	+	-	-	>500
4	71	F	+	+	-	-	-	+	-	+	>500
5	72	F	+	+	+	+	-	+	-	-	>500
6	62	M	+	-	-	-	-	+	-	-	>500
7	62	M	+	+	-	+	-	+	+	-	>500
8	66	M	+	-	-	-	-	+	-	+	>500
9	70	M	+	-	+	-	+	+	-	+	>500
10	80	M	+	-	+	-	+	+	-	-	187
11	71	M	+	-	-	-	-	+	-	-	>500
12	61	M	-	-	-	-	-	+	-	-	**222**
13	46	M	-	-	-	-	-	+	-	-	**257**
14	68	M	+	+	+	-	-	+	-	+	**232**
15	81	M	+	-	-	-	-	+	+-	-	>500
16	63	M	+	-	-	-	-	+	-	-	>500
17	61	M	-	-	-	-	-	+	-	-	>500
18	78	F	-	-	-	-	-	+	-	-	**323**
19	77	M	-	-	-	+	-	+	-	-	>500
20	78	M	-	-	-	+	-	+	-	+	>500
21	72	M	+	+	-	-	-	+	-	-	>500
22	66	M	-	-	-	-	-	+	-	-	**97**
23	58	F	+	+	-	-	-	+	-	-	>500
24	64	M	-	-	-	-	-	+	-	-	>500
25	61	M	-	-	-	-	-	+	-	-	>500
26	75	M	+	+	-	-	-	+	-	-	>500
27	48	M	-	+	+	+	+	+	+	-	**10**
Total			**17**	**10**	**5**	**7**	**5**	**27**	**4**	**6**	
%			**63.0**	**37.0**	**18.5**	**25.9**	**18.5**	**100**	**14.8**	**22.2**	

N = number; HTA = high blood pressure; F. History = positive family history; HHL = Hypercholesterolemia; MI = myocardial infarction; AP = angina pectoris; CS = calcium score; M = male: F = female

ocardial infarction had symptoms of angina pectoris. That points out the importance of CS and the necessity of precaution in patients with high CS and those who are without any symptoms.

Data from the literature show the correlation between the high coronary artery calcium scores and the increased risk of the coronary artery disease and death.[8]

The same data show that the persons with the score over 500 had 2.7 times higher risk of death caused by heart attack than those with the score 101 or lower. Therefore we can conclude that 23.7 more deaths per 1000 people/per year are among patients with the highest score sets. Persons with scores from 101 to 500 have shown two-times higher risk of cardiac death in comparison to persons with scores lower than 101.[8]

In this study, CS score was measured in patients with the history of previous myocardial infarction, and, as it is showed in the Table 1, 19 (70.4%) patients had calcium score >500, while only 3 (11.1%) patients had a low

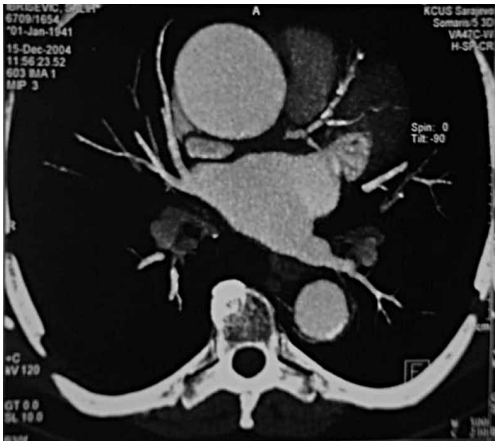

Figure 2a. Calcification of left coronary artery.

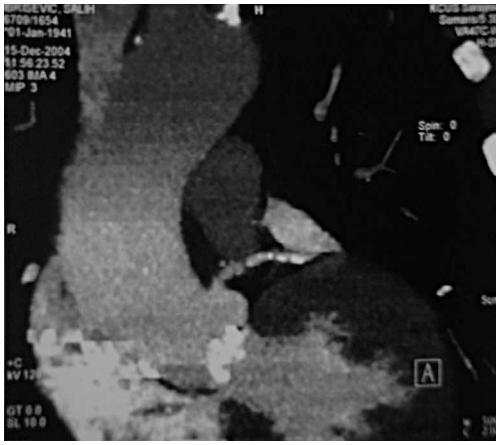

Figure 2b. Calcification of left coronary artery (arrow)

CS, and 5 (18.5%) patients had an intermediate CS. Therefore, among the patients with myocardial infarction, there were 6.3 times more those with the high CS than those with the low CS, and 3.8 times more than those with the intermediate CS.

During the study, it was noticed that the most of coronary calcification was in the proximal 2/3 segments of the coronary arteries, while the distal parts were less affected. Distal segments are also more difficult to analyze on the four-row detector MDCT machine. These findings are in accordance with the data from the literature (Figures 2a and 2b).

In autopsy studies, which included over 14.000 corpses with CHD, only 16% of stenosis was found in distal parts of coronary artery, while 66% of all haemodynamically relevant stenosis was located in a proximal third and 40% in a medial third of one or more coronary arteries.[9]

It can be visualized 68% of all segments of coronary artery by a four-row detector CT angiography (CTA). In these segments available for the analysis, sensitivity and specificity in detection of significant luminal stenosis, in comparation with conventional angiography, is 91% and 84%, respectively. This is in accordance with the previous reports.[14]

As shown in the literature, and proved by this study as well, the measurement of CS is important in patients suspect of CHD, it is predictive for coronary accident and correlates with the severity of it. The next step is going to be the analysis of the soft plaque, and the technical development of MDCT (64 row detectors); with its transversal plains it should make it possible. According to the literature, soft plaque can be even more dangerous than the calcified atherosclerotic plaque, although the latest contains soft parts too.

Previous data show that, besides the measurement of CS in CHD, CTA has a significant role as well. In comparison to cardiac catheterization, coronary CTA has positive and negative predictive value in coronary arterial stenosis 59-85% and 96-98%, respectively. In other words, coronary CTA can exclude CHD with highly negative predictive value. Patients with low to moderate pre-test values are particularly good candidates for the coronary CT examination.[3]

Some previous studies show that MDCT's negative predictive value of 96-98% for coronary artery stenosis, is sufficient for the identification of patients who do not need cardiac catheterization. Its positive predictive value, with the range from 60 to 85%, suggests that some improvements have to be made before it replaces catheterization.[13] Other studies on MDCT angiography (MDCTA) show mean sensitivity, specificity, accuracy, and positive

and negative predictive values for detecting significant coronary artery stenosis as 86%, 90%, 76% and 97%, respectively. This indicates that high negative predictive value of MDCTA can really exclude coronary artery disease.[11]

When talking about CS in patients with the history of previous myocardial infarction, a question arises - what was the condition before the infarction, and in what extent the coronary calcification, or high CS, is the result of reparatory mechanisms after the infarction?

Therefore, this problem needs further researches, to give the insight into the other factors significant for development of CHD, as well as for the position of CS and soft plaque in this context. Some of these solutions are already coming in sight with the further development of MDCT and MRI.

Conclusions

This study shows the high correlation between the level of coronary artery calcium scoring, calculated by Agatston method, and myocardial infarction, or that 70.4% patients with the previous myocardial infarction had CS > 500. The low CS was rarely found in patients who had a myocardial infarction, which presumes that the same is less commonly connected with the coronary artery disease. It leads to the conclusion that coronary CS is the significant screening method in predicting a potential coronary attack in asymptomatic patients, and in those with the symptoms of angina. Thanks to this method, it is often possible to avoid coronary angiography in certain number of patients. The main risk factors include: age, sex, smoking, hypertension, diabetes, heredity and hypercholesterolemia.

MDCT has shown to be an efficient method for the examination of coronary calcifications in proximal 2/3 segments of coronary arteries.

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