COMPARATIVE CHARACTERISTICS OF RADIODIAGNOSTICS IN CARDIOLOGY AND CARDIOSURGERY

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Radiation methods for studies of various organs and systems continue to be one of the decisive factors in setting the final clinical diagnosis at the earliest stages possible. The latter acquires particular importance when the pathology deals with such a multifunctional organ like the heart.

The task of a clinician is to select the desired set of diagnostic approaches that best reflect the state of the test body both in the anatomical and functional meaning.

The entire arsenal of modern methods used in cardiology is divided into ionizing (x-ray computed tomography with all varieties, coronary angiography, radionuclide methods of research) and non-ionizing (echocardiography and magnetic resonance imaging).

The selective coronary angiography (CAG) is still considered the only reliable method for studying the anatomy of the coronary bed to quantify the degree of stenosis, and myocardial revascularization [1, 25, 18, 10].

Nevertheless, the method has several limitations: invasiveness, radiation exposure, the risk of complications and high costs. However, the negative side of the CAG is purely anatomical and methodological feature: the method is limited only by the assessment of the intraluminal loop of the coronary vessels, not allowing to study the condition of the walls and the functional significance of the stenosis. This fact contributes to inadequate assessment and diagnosis of early manifestations of atherosclerosis.

The following clinical situation occurs: atherosclerosis plaque that does not cause narrowing of the vessel lumen, leads to underestimation or overestimation of the extent and / or severity of atherosclerotic lesions. In these cases, the results of intravascular ultrasound are much more demanded, especially in patients with multiple, but intermediate stenoses [42].

The most reasonable way is to combine the capabilities of modern radiation diagnosis — from the visualization of the coronary arteries to detection of hidden perfusion abnormalities or acute myocardial infarction with *silent* clinic. In recent clinical situations in tandem CAG and echocardiography (ECHO CG) the third method, radionuclide imaging (SPECT or PET), is added.

However, there are certain inherent difficulties of conducting any diagnostic procedure, especially for ECHO CG. They include: anatomy peculiarities of the coronary arteries (CA), small diameter, hyperkinesis, respiratory excursions of the lungs and chest. [7].

But the method of ECHO CG has undeniable advantages: non-invasive, low cost, availability, the possibility of dynamic studies. In turn, the variety of technologies and techniques allow us to study various functions of the heart (hemodynamics, contractility) and the state of the coronary arteries. From a clinical point of view, the following methods: are mostly demanded direct visualization of atherosclerotic plaque, determination of the rate and nature of coronary blood flow evaluation of coronary reserve in the main vessels, state of hemodynamics in the central circulation, the state inotropic function of the heart muscle, the presence of zones of akinesia and hypokinesia.

However, even with these multifunctional capabilities of the method, there are some difficulties in evaluating each of these advantages.

For example, direct imaging of atherosclerotic plaque in CA is possible with considerable calcium component [1], more frequent at the mouths of the left and right coronary arteries. Naturally, the diagnosis of stricture formation or stenosis is primarily based on the use dopplerographic color mapping methods [3, 31].

Without going into details of technical and methodological conditions of ECHO CG, it should be noted that there are 2 access pathways: the transthoracic and transdermal.

If we consider percutaneous ECH CG, this technique allows to qualitatively visualize the proximal and middle portions of the main coronary arteries [4], but with the damage of the middle and distal parts of the coronary bed, it becomes impossible, because they do not fall into the plane of the ultrasound slice.

Sensitivity and specificity of transesophageal ECHO CG in the diagnosis of proximal coronary stenoses and occlusions, according to different authors, ranges between 32 and 91% at stenosis, and from 76 to 100% — at occlusions [4, 3, 31, 30].

In recent years, for non-invasive study of coronary blood flow and coronary reserve, the method of transthoracic ECHO CG is used [32 ,33].

In contrast to transesophageal ECHO CG, the transthoracic approach allows visualization of the middle and distal portions [32–36]. For clinicians, of the greatest interest is the opportunity to study coronary flow reserve in the distal parts, as the latter occurs not only in the area of constriction, but also along the distal vessel. A limitation of the method is the duration of the investigation, qualification of a radiologist, variability of location window in individual patients.

Another extensive branch of radiation diagnostics used in cardiosurgical practice is presented by methods of computed tomography (CT), especially the multislice spiral computed tomography (MSCT).

The dynamics of development and CT research findings, which had the following trends and directions, are extremely interesting. In particular, if at the early stages of studying the role of CT in the diagnosis of coronary artery atherosclerosis the presence and degree of calcification were considered, the results of further investigations showed the opposite. The presence, localization and degree of calcification do not always correspond to the location and degree of stricture formation or stenosis revealed during invasive coronary angiography.

The most interesting one was the clinical observation that acute coronary complications more frequently occur due to spontaneous rupture of non-calcified plaque that are not visible on the native images.

Identifying non-calcified (*tender*) plaques is possible using CT angiography. At intravenous bolus of nonionic iodine-containing contrast there is an opportunity to study coronary bed anatomy, malformations, aneurysms of the coronary arteries, to diagnose and evaluate the degree of stenosis, as well as to assess the patency of aortocoronary mammocoronary shunts.

The sensitivity and specificity of the method for diagnosis of stenosis and occlusion of shunts reaches 83-100 and 88-98%, respectively [9, 29, 38].

The disadvantage of the method is radiation load dose to the patient and the possibility of allergic reactions [8, 37].

To our mind, another more significant disadvantage is the fact that it is impossible to study at multislice spiral CT (MSCT) the flow velocity characteristics of the coronary flow and, therefore, only anatomical but not functional assessment of stenoses and occlusions significance is conducted. The presence of causal artifacts (pronounced calcification, heart rate greater than 65 beats/min, arrhythmias) also decreases both the use and quality of the obtained images [28, 17, 23, 24].

Another modern imaging technique for coronary vessels visualization is a magnetic resonance imaging (MRI).

A technical advantage of the method is the lack of exposure to the patient, not using iodinated contrast agents [2].

The method allows to estimate the structure of the atherosclerotic plaque with the determination of lipid and fibrous components, to conduct angiography. However, the ability of MRI for detection of coronary calcification is limited [37].

Visualization of the coronary arteries, taking into account the new generations of MRI, is of higher quality, but limited by the size of visible vessels. Upon the study for the detection of stenoses and occlusions contrast material - gadolinium chelates is injected intravenously.

The sensitivity and specificity of this method in detecting coronary artery stenosis ranges between 65–82%(sensitivity) and 82–89% (specificity) [14].

Disadvantages of MRI include: due to the complexity of the implementation, diagnosis and assessment of stenotic coronary artery remains unsatisfactory for practical medicine. Unlike MSCT these circumstances are linked to the complexity of cardiac and respiratory movements suppression, inadequate suppression of the signal from epicardial fat and myocardium, limited spatial resolution and overlapping of layers in the research area of the heart [43].

There are also relative and absolute contraindications to MRI: as absolute ones pacemakers, hemostatic clips on the vessels are considered, metal brackets on the sternum, stents and artificial heart valves are ranked to be relative contraindications. The investigation is also limited by the risk of the implant displacement, its dysfunction and heating at the investigation [1].

Another large group of radioionizing research methods are radionuclide methods of research: myocardial tomography imaging to determine myocardial perfusion and metabolism. Currently, two methods - SPECT and PET imaging — are widely used.

SPECT, or single photon emission computed tomography has expressed functional tendency as non-alternative method for the study of myocardial perfusion and the possibility of reversibility of these changes; most commonly such radiopharmaceuticals as radioactive 99mTc with a set of MIBI (technetium sestamibi) or radioactive thallium-citrate as analog of sodium are used.

Effective and timely reperfusion contributes to the restoration of myocardial contractility, reversibly-injured cardiomyocytes, but this process is only possible after the normalization of energy production and reduction of the intracellular calcium concentration. This recovery occurs more slowly in later periods after the direct reduction of the coronary bed.

Such a situation is possible at hibernating (*stunning*) myocardium (Sokolova R. et al., 2002; Bolli R., 1990; Braunwald E, Kloner RA, 1982). The phenomenon of "stunned" myocardium, especially in the last 10-15 years, is the subject of intense studies [5, 22, 15, 16, 21, 26, 27].

Myocardial scarring is not the only outcome of coronary stenosis and subsequent myocardial ischemia (cardiomyocytes).

In some cases disorder of the inotropic function is accompanied with the preserved viability of cardiomyocytes. Clinical manifestation of such states is ventricular dysfunction (systolic and diastolic).

By the early 1980s, Rahimtoola described a syndrome characterized by reversible damage of the local myocardial contractility at rest with signs of severe prolonged silent ischemia and suggested that the term *hibernation* or *hibernating myocardium* [39, 40] for the characterization of foci of reduced contractility, located in the basin of the stenotic artery [41] .

In our opinion, these studies have had revolutionary significance in cardiology and cardiac surgery, as well as other disciplines, especially in terms of radiation diagnostics.

The author and his followers showed that a decrease of contractile function even though it is a major factor in predictions of deteriorating condition of the patient, may be temporary transient. Hibernating myocardium state may be asymptomatic both clinically and paraclinically.

Diagnosis of *stunned* myocardium is possible only upon using radionuclide techniques — SPECT and PET tomography.

PET investigations allow studying metabolic processes in myocardium, especially the metabolism of fatty acids (FAs) and glucose.

Although the first studies were carried out in 1954. [11], especially for the FAs metabolism, they are invaluable till now. It was shown that FAs are a major source of energy in cardiomyocytes.

Another important source of energy for the heart is glucose, which is metabolized through glycolysis [19]. Under normal physiological conditions, the FAs and glucose utilization is balanced and depend on their delivery. It is believed that the contribution of glycolysis to the total amount of energy production in the myocardium under aerobic conditions is no more than 10%. Ischemia of the heart muscle increases the efficiency of the process.

Compared with glucose FAs are less *profitable*: upon their oxidation for the production of the same amount of ATP by 10% more oxygen is necessary (required) [11]. About 60–70% of oxygen consumed by a man is used for FAs oxidation.

But this proportion might change dramatically during different pathological processes [20]. The authors noted that during hypoxia there occurs inhibition of both glucose and lactate oxidation, as well as the FAs with the simultaneous formation and alteration of energetic process and its deficiency. This is precisely what happens in myocardial ischemia.

To assess glucose and FAs metabolism 11C acetate radiopharmaceutical is used; to study metabolism of glucose — 11R-fluorodeoxyglucose.

The opportunity to study energetic processes in the myocardium by tracing the FAs and glucose is provided by PET imaging method. We have presented the fundamentals and the *basics* of this radiation diagnostics method in detail, as it has no alternative.

In conclusion, we should like to note that the comparative analysis of radiological methods of examinations in cardiology and cardiac surgery indicates that each method has its place in the whole complex of surveys, however, international protocols clearly indicate to the triad of methods: coronary angiography, echocardiography, SPECT/PET tomography.

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