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Tissue Myocardial Doppler Echocardiography in Assessing the Functional Capacity of the Left Ventricular Myocardium

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Annotation: Currently, two-dimensional (2D) echocardiography (EchoCG) is one of the most widely used methods for diagnosing acute myocardial infarction (AMI). This method is informative and safe, can be easily applied at the hospital bed and is of great importance for the dynamic monitoring of the patient. EchoCG has been shown to have diagnostic advantages in making the diagnosis, establishing the location and size of myocardial infarction (MI), and in identifying mechanical complications after MI.

Keywords: echocardiography, acute myocardial infarction, complications of myocardial infarction.

INTRODUCTION

EchoCG is also extremely useful in assessing prognosis and risk stratification. When using routine, as well as more complex (tissue doppler echocardiography (TDG) and "speckle tracking") echocardiographic techniques, a large number of important prognostic parameters can be obtained. The review also discusses the possibility of using contrast echocardiography and other modern echocardiographic techniques for prognosis.

Traditional echocardiography parameters for prognosis in acute myocardial infarction:

Left ventricular volumes and ejection fraction

Left ventricular (LV) function has traditionally been considered an important predictor of AMI outcome. Several large studies [1–6] have shown the prognostic value of post-MI LV ejection fraction (LVEF) calculated from contrast ventriculography. In addition, the importance of determining LVEF for assessing the prognosis after MI according to echocardiography was confirmed. Moller JE, et al. studied 767 patients with AMI and showed that LVEF, determined by echocardiography on day 1 of hospitalization for AMI, was a strong predictor of all-cause mortality over a mean follow-up of 19 months. Although LVEF is widely used to characterize LV function, its prognostic value after MI is still being studied. On the one hand, low LVEF may be a consequence of reduced contractile function due to extensive myocardial damage or residual ischemia; on the other hand, a consequence of LV dilatation caused by the spread of the infarction zone and stretching of the scarred area of the myocardium. In addition, the assessment of LVEF in the early stages of MI may be incorrect due to the presence of stunned myocardium. There is an opinion that end-systolic (ESV) and end-diastolic volumes (EDV) of the LV may be more important predictors of prognosis than LVEF. White HD et al. in 605 patients with AMI, ESR was determined to be the primary predictor of survival after MI. Also, the prognostic value of ESR was shown compared with EF in patients with reduced LVEF (<50%) or small ESV (<100 ml).

Left ventricular wall motion index (WMSI)

According to some researchers, optimal assessment of LV function in patients after myocardial infarction is possible using segmental LV function analysis rather than global LV function analysis. This approach consists of dividing the LV into a number of segments and assessing the movement of the walls of each of them. This can be done using the regional contractility index, or LV wall motion index (WMSI), which provides powerful prognostic information. After MI, pronounced disturbances in local contractility may be detected, however, in the presence of compensatory hyperkinesis of intact segments, LVEF may remain almost normal;

The prognostic value of LV WMSI after AMI has been demonstrated in several relatively small studies. Galasko GI, et al. studied LV WMSI in 120 patients with AMI who underwent thrombolysis. The authors showed that LV WMSI independently predicted cardiovascular events over a mean follow-up period of 13 months. When compared with LVEF, echocardiographically determined LV WMSI was more accessible and, as a result, a more preferable technique in cases of mild LV dysfunction after AMI. In a study by Carissus E. et al. 144 patients with primary AMI and thrombolysis were followed for an average of 18 months. Patients with cardiovascular events during the observation period before discharge had higher LV WMSI than patients without these events. In a multivariate analysis, LV WMSI >1.50 was the most powerful predictor of subsequent cardiovascular events ($X = 17.8$, $p < 0.0001$). In addition, Mo11er JE, et al. demonstrated in a larger population of patients with AMI that LV WMSI was an independent predictor of death (relative risk 1.15 for every 0.2-point increase in LV WMSI). LV WMSI was also shown to be an independent predictor of hospitalization due to progression of chronic heart failure (CHF) (relative risk 1.21 per 0.2-point increase). The same study noted that low LVEF was a powerful predictor of overall mortality after AMI, but did not exceed LV WMSI in prognostic significance. In addition, low LVEF did not predict hospitalization due to decompensated CHF.

Gendlin G.E. et al., when studying LV WMSI in 89 patients with AMI, 37 of whom underwent thrombolysis, concluded that this indicator independently predicts cardiovascular events over three years of observation.

Mitral regurgitation

The presence of mitral regurgitation after AMI is often asymptomatic, and therefore echocardiography should be systematically performed in patients after MI. Standard color Doppler imaging is a highly sensitive method for detecting even small degrees of mitral regurgitation. In addition, echocardiography allows an accurate assessment of the severity of mitral regurgitation by measuring the effective area of the regurgitant orifice, as well as the volume of regurgitation obtained using Doppler echocardiography [15, 25].

In patients with AMI, acute mitral regurgitation develops quite often and is an independent predictor of late cardiovascular and overall mortality [16]. Lehmann KG, et al. examined 206 patients 7 hours after primary MI using contrast ventriculography and showed that mitral regurgitation was present in 13% of patients. In the SAVE (Survival and Ventricular Enlargement) study, Lamas GA, et al. conducted a substudy of 727 patients who had previously undergone ventriculography before 16 days after MI. Mitral regurgitation was present in 141 patients (19%). The presence of mitral regurgitation was associated with the risk of cardiovascular events during the subsequent 3.5 years of follow-up. Patients with mitral regurgitation had a higher rate of cardiovascular mortality (29% vs. 12%, $p=0.002$) and a higher incidence of severe heart failure (24% vs. 16%, $p<0.05$) than in patients without it. It was shown that the presence of mitral regurgitation was an independent factor in cardiovascular mortality with a relative risk of 2.00. Feinberg MS et al. in a study of 417 patients with AMI, using color Doppler imaging performed within 48 hours of hospitalization, found the presence of mild mitral regurgitation in 29%, and moderate or severe mitral regurgitation in 6%. Both minor and major mitral regurgitation were independently associated with increased 1-year mortality, with relative risks of 2.31 and 2.85, respectively. The prognostic value of mitral regurgitation determined by echocardiography was further confirmed by Perez de Isla L, et al., who examined 300 patients hospitalized due to non-ST-segment elevation myocardial infarction (NSTEMI). When conducting echocardiography during the first week after MI, mitral regurgitation was detected in 42%. It was the only independent predictor of poor long-term prognosis during a follow-up period of an average of 14 months.

Diastolic function in acute myocardial infarction

In patients with AMI, Doppler echocardiography can provide reliable information about diastolic function, in particular, about the type of LV filling (Fig. 3) [21, 22]. It has been shown that the restrictive type of LV filling in patients with AMI is a powerful independent predictor of late LV dilatation and cardiovascular mortality [23, 25]. In a study by Nijland F, et al. Shortening of the early filling deceleration time (peak E) has been described as the best predictor of cardiovascular mortality in patients hospitalized for AMI. The 1-year survival rate in patients without restrictive filling type (the ratio of peak early diastolic filling velocity (E) to peak late filling velocity (A) was <1 or between 1 and 2, and deceleration time >140 ms) was 100%, and in the group with restrictive filling (E/A ratio >2 or between 1 and 2, and deceleration time <140 ms) only 50%. Additionally, the 3-year survival rates were 100% and 22%, respectively. In addition to a higher mortality rate, patients after AMI with a restrictive filling type have a higher risk of developing CHF. Roikep SH, et al. during 1 year of dynamic observation after AMI, CHF was detected in 71% of hospitalized patients with a restrictive type of filling, and in 21% of patients, progression of CHF was the reason for readmission.

Cerisano G, et al. conducted a Doppler assessment of LV diastolic function in 104 patients three days after the development of AMI. The survival rate at a mean follow-up of 32 months in patients with a restrictive type of LV filling was 79% (deceleration time <130 ms) versus 97% in patients without a restrictive type (deceleration time >130 ms; p = 0.003). Multivariate analysis showed that, in addition to age, restrictive LV filling pattern was an independent predictor of poor cardiovascular event-free survival.

In a meta-analysis of 12 prospective studies with data from 3396 post-MI patients, the presence of restrictive LV filling was an important independent predictor of mortality not related to LVEF [27, 28].

Left atrium volume

Doppler measurements of LV diastolic function are influenced by several factors (particularly afterload) that can change rapidly after MI. In contrast, left atrial (LA) volume is less dependent on acute hemodynamic changes and reflects subacute or chronic diastolic dysfunction. The prognostic value of LA size and volume after MI has been studied in several studies. Mo11er JE, et. a1. evaluated LA volume indexed to body surface area (indexed LA volume) during hospitalization of 314 patients due to AMI. During an average follow-up of 15 months, 46 patients (15%) died. Indexed LA volume was a powerful and independent predictor of mortality (relative risk 1.05 per 1 ml/m increase in index LA volume). The significance of LA volume in relation to clinical outcome after MI was confirmed by Vetal R, et al. The authors demonstrated in 395 patients with AMI that the index LA volume, determined within 48 hours after hospitalization, was an independent factor in 5-year mortality, having a prognostic significance exceeding the significance of clinical and other echocardiographic data. Patients with LA volume index >32 ml/m had significantly higher mortality compared with patients with LA volume index <32 ml/m (34.5% vs. 14.2%, respectively).

Right ventricular function in myocardial infarction

It is clear that LV dysfunction is associated with a poor prognosis in patients after AMI. However, the significance of right ventricular (RV) dysfunction after MI is not well understood. In the SAVE echocardiography substudy, conducted an average of 11 days after MI in 416 patients with LV systolic dysfunction (LVEF <40%), Zornoff LA, et al. analyzed the relationship between pancreatic function and clinical outcome. When conducting a multivariate analysis, the change in the area of the pancreas from the end of diastole to the end of systole (fraction of change in the area of the pancreas) in the apical four-chamber position was an independent predictor of overall and cardiovascular mortality, as well as the development of chronic heart failure.

In contrast to these data, Gadsboll N, et al. found no relationship between RV function and 1-year mortality in 423 patients after AMI, but many of these patients had normal LV function. Additionally, in the TIMIII (Thrombolysis in Myocardial Infarction) study, in which all patients underwent reperfusion (n=1110), RV abnormalities were observed in only 5% of patients after MI and were not associated with increased mortality during the 1-year follow-up after MI. discharge from the hospital. However, this population included only patients with inferior MI. Obviously, larger and longer studies are needed to clarify the prognostic value of RV dysfunction after MI.

New prognostic parameters for myocardial infarction

Recently, the prognostic value of LV strain (strain), which reflects changes in the length of the LV segment under study, as well as the strain rate (strain rate), which reflects the time during which deformation of this segment occurs, has been widely studied in patients who have suffered an MI. Longitudinal, transverse and circumferential strain and LV strain rate can be assessed using TDH or the recently proposed speckle tracking technique. The latter technique uses natural acoustic markers, or spots, that are visualized within the myocardium on standard ultrasound images of the heart. This modern technique makes it possible to distinguish between active and passive myocardial contraction and, unlike TDH, is independent of the scanning angle, because is not based on Doppler technology [39, 49]. The speckle tracking technique has been validated using microcrystals and cardiac magnetic resonance imaging (MRI) [38, 48].

The depth of cardiac muscle necrosis during MI determines the functional recovery ability of the myocardium and has prognostic significance. Traditionally, complex techniques such as MRI are used to assess the depth of myocardial necrosis. However, Vartdal T, et al. showed that myocardial deformation can also serve as an important predictor of the final size of myocardial infarction, and therefore may be an important clinical tool for stratifying the risk of complications in the acute stage of myocardial infarction. The authors examined 30 patients with acute anterior myocardial infarction, measuring longitudinal strain using TDH 1.5 hours after revascularization. After a 9-month follow-up period, MRI was performed to assess the exact extent of scar tissue in 16 myocardial segments. To obtain the global longitudinal strain of the LV, strain data from 16 segments were averaged. At the same time, a close correlation was revealed between global longitudinal deformation and infarct size (r = 0.77;). Multivariate analysis showed that LV global peak strain was independently associated with MI size measured by MRI. In addition, a clear inverse relationship was revealed between segmental deformation and the degree of transmurally of scar tissue in individual segments (r = 0.67).

In another study, Zhang Y, et al. studied data from 47 patients with primary AMI and 60 healthy subjects included in the control group. Within a few days after the MI, all patients underwent TDG with strain rate calculation and contrast MRI to determine its depth. The peak systolic strain rate of segments with transmural infarction was significantly lower than in segments with normal myocardium or non-transmural infarction. The threshold value of peak systolic strain rate, which allows detecting transmural scar tissue with high sensitivity (90.9%) and specificity (96.4%), was -0.59/sec, and peak systolic strain rate -0.98/sec to -1.26/sec allowed to distinguish subendocardial scar tissue from normal myocardium with a sensitivity of 81.3% and a specificity of 83.3%. In summary, the authors showed that peak strain rate can help differentiate transmural from non-transmural MI and allows non-invasive determination of the volume of post-MI scar tissue (which reflects the size of nonviable myocardium).

If the direct connection of traditional prognostic parameters with survival is already an indisputable fact, then LV strain and strain rate mainly serve only as indirect indicators of clinical outcomes.

Park YH, et al. studied 50 patients with acute anterior myocardial infarction and primary reperfusion (percutaneous coronary intervention (PCI) in 44 patients and thrombolysis in six patients) and assessed LV longitudinal strain using both TDH and speckle tracking in seven LV segments belonging to the zone blood supply to the left anterior descending coronary artery. LV remodeling was observed in 22 patients (LV dilatation with an increase in EDV >15% during follow-up); these patients initially had significantly lower LV longitudinal strain, calculated using two echocardiography methods. Strain assessed by both TDH and speckle tracking was an independent predictor of LV remodeling (hazard ratio 1.430 and 1.307, respectively) during 18-month follow-up. It is important to note that in this relatively small study, LV strain parameters obtained with both techniques were independent predictors of death or congestive heart failure during follow-up (hazard ratio 1.436 and 1.455, respectively). In addition, Hung CL, et al. demonstrated in more than 600 patients participating in the VALIANT (valsartan in acute myocardial infarction) trial that both LV strain and strain rate (assessed using speckle tracking) were independent predictors of death, with strain rate in particular predicting the significance which after MI exceeded the prognostic significance of LVEF. There is also information about the prognostic significance of the systolic velocity of the mitral annulus (S'). Thus, Biering-S0rensen T, et al. studied the prognostic value of TDH after ST-segment elevation AMI in 391 patients after primary percutaneous transluminal coronary angioplasty (PTCA). The authors showed that patients with low s' peak velocity had a more than twofold increase in the composite endpoint (all-cause mortality, recurrent MI, or hospitalization for CHF) compared with patients with high s' (hazard ratio 2.60). Liu S, et al. also showed that S' was a powerful predictor of the further course of coronary artery disease in acute coronary syndrome.

Left ventricular dyssynchrony

The clinical significance of post-infarction LV remodeling, i.e. increased LV volumes with decreased EF was previously highlighted by White HD, et al. Patients who died during follow-up after MI had significantly larger LV volumes and lower EF compared to those who survived. In addition, the authors found that LV ESV is the primary predictor of survival after MI. Thus, early identification of patients at risk of developing LV remodeling is important for determining prognosis and optimizing medical treatment.

Mollema SA, et al. examined 124 patients with AMI who underwent primary PTCA. 48 hours after the intervention, two-dimensional echocardiography was performed with calculation of LV dyssynchrony using color TDG. The authors found that the presence of baseline LV dyssynchrony (>65 ms) had a strong relationship (r=0.73) with the degree of LV dilatation at 6 months of follow-up. Another study by the same authors showed that LV dyssynchrony, assessed using radial strain analysis using speckle tracking data, is an early predictor of LV remodeling (increase in LV ESV >15%) after 6 months of follow-up after AMI [48]. It included 178 patients hospitalized with AMI who underwent primary PTCA. 48 hours after the intervention, two-dimensional echocardiography was performed to calculate LV dyssynchrony. Patients who developed LV remodeling at 6 months of follow-up (20%) had comparable characteristics to the group without LV remodeling (80%), with the exception of higher maximum values of troponin T, creatine phosphokinase, wall motion index, E/e' ratio (velocity ratio early mitral blood flow to the speed of early diastolic movement of the mitral annulus), as well as a greater degree of LV dyssynchrony. Multivariate analysis showed that LV dyssynchrony was an independent predictor of LV remodeling. ROC analysis noted that a threshold value of LV dyssynchrony of 130 ms had 82% sensitivity and 95% specificity in predicting LV remodeling after 6 months of follow-up. Despite the lack of survival analysis, the importance of detecting LV dyssynchrony >130 ms at 48 h after admission in relation to the clinical outcome of AMI (the development of LV remodeling) has been emphasized [48].

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