Left ventricle diastolic function in the patients after coronary arteries bypass graft combined with left ventricle aneurismectomy according to tissue doppler imaging: one year follow-up

Maryna N Dolzhenko, S A Rudenko, S V Potashev, T V Simagina, N N Nosenko, T G Kravchenko

Postgrad Med J 2007;**83**:320–324. doi: 10.1136/pgmj.2006.053553

See end of article for authors' affiliations

Correspondence to:
Maryna N Dolzhenko,
Shupik's National Medical
Academy of Postgraduation
Education, Chokolovskiy, 4,
apt.9, Kiev, 03186 Ukraine;
marinadolzhenko@mail.ru

Received 14 September 2006
Accepted 29 November 2006

Aim: To evaluate left ventricle (LV) diastolic function dynamics in patients after acute myocardial infarction (AMI) after combined operation of coronary artery bypass graft with LV aneurismectomy (CABG + AE) according to the results of tissue Doppler imaging (TDI).

Methods: Forty patients after AMI underwent Doppler echocardiography (EchoCG) with TDI and M-mode colour-flow imaging before and in 3 and 12 months after CABG + AE. Mitral annulus (MA) TDI with velocity indices was performed in 4 segments of LV.

Results: Conventional transmitral diastolic Doppler indices before and after CABG + AE remained unchanged. TDI showed significant improvement of LV systolic (systolic movement velocity S: 6.1 ± 0.8 , 7.4 ± 1.2 and 6.9 ± 1.3 cm/sec. before and in 3 and 12 months after the operation, respectively, $p < 0.01$) and diastolic function after the operation (MA early diastolic movement velocity (e'): 7.3 ± 2.1 , 8.4 ± 1.5 and 8.9 ± 1.8 cm/s.; ratio of transmitral early-flow velocity (E) to MA early-diastolic movement velocity (E/e'): 18.4 ± 2.2 , 12.3 ± 1.8 and 11.5 ± 2.3 ; ratio of E diastolic flow propagation velocity (Vp) 3.1 ± 0.45 , 2.2 ± 0.38 and 1.8 ± 0.16 before and in 3 and 12 months after the operation, respectively, $p < 0.01$).

Conclusions: Results of the study demonstrate significant improvement of LV diastolic function in the patient after CABG + AE according to TDI, regardless of transmitral flow pattern. TDI is more sensitive and preload independent method of LV myocardial function evaluation.

In patients with coronary artery disease (CAD), left ventricle (LV) diastolic dysfunction usually precedes the systolic. Myocardial ischemia, hypertrophy and aging are associated with sarcoplasmic reticulum calcium uptake inhibition. The latter is an energy-dependent process, therefore, leading to LV relaxation impairment. That is why diastolic dysfunction is a casual finding in CAD patients, promoting heart failure (HF) symptoms and significantly worsening their prognosis.^{1–3} On the other hand, post-infarction LV aneurism promotes the remodeling processes, worsening LV diastolic function. Myocardial diastolic function may improve with adequate blood supply renewal. This is the aim of revascularization procedures, ie, coronary arteries bypass graft (CABG),^{4–6} while operational LV aneurism excision – aneurismectomy – may significantly influence the remodeling process by restoring LV geometry, decreasing internal pressures and thus slowing down HF progression. Most recent papers studying diastolic function before and after operational revascularization include relatively small numbers of patients with short follow-up periods. Moreover, surgeon revascularization itself is the reason for reversible short-term diastolic dysfunction.^{4,7,8} The golden standard for LV filling pressure and diastolic function evaluation is its direct measurement during catheterization. Unfortunately, this invasive method is hardly suitable for widespread use and routine follow-up. Conventional pulsed-wave transmitral flow has been traditionally used for diastolic function evaluation within populations. However, transmitral filling indices are very labile and depend on various factors, e.g. heart rate and preload.^{3–9} In recent years the method of Doppler evaluation using myocardial movement velocities – tissue Doppler imaging (TDI) – has been developing intensively. The character of myocardial wall kinetics clearly resemble LV

relaxation. In addition, TDI results compared to transmitral flow Doppler are more direct and do not depend upon preload.^{10,11} Up to now there have been few attempts to use TDI widely in patients after AMI before and after CABG combined with aneurismectomy (CABG + AE) to study LV diastolic function changes due to treatment, especially compared to conventional transmitral pulsed-wave Doppler. The aim of this study was to evaluate left ventricle diastolic function dynamics in patients after acute myocardial infarction following a combined operation of coronary artery bypass graft with LV aneurismectomy according to the results of TDI.

METHODS

The study was approved by the local ethical committee.

In the study we prospectively included 40 patients with post-infarction LV aneurism, each eligible for CABG + AE due to multi-vessel CAD with significant stenotic lesions and angina pectoris. Exclusion criteria were a history of recent myocardial infarction (4 weeks before pre-operative angiography), atrial fibrillation, significant valvular heart disease or previous CABG. All patients underwent CABG combined with aneurismectomy. During and after the CABG, standard laboratory markers for myocardial infarction were obtained and none of the patients was diagnosed with perioperative myocardial infarction. Medication treatment in all the post-infarction patients included aspirin, a beta-blocker and an ACE inhibitor. All patients underwent Doppler echocardiography (EchoCG) with TDI prior to the operation and again 3 and 12 months after surgery. Only those patients who survived in the operating period were included in the study. No patients developed acute myocardial infarction during the follow-up period. Twenty age-matched healthy subjects without a history of cardiac and

pulmonary disease or systemic hypertension, and with normal findings at rest ECG and echocardiography, served as controls.

Echocardiography

A standard clinical echocardiographer, equipped with pulsed-wave TDI option (Medison "SonoAce" 9900) was used. Recordings and calculations of different parameters, including LV chamber volumes and ejection fraction (EF), were performed according to the recommendations of the American Society of Echocardiography.¹² Transmitral flow was recorded by pulsed-wave Doppler with the sample volume placed between the mitral leaflet tips in an apical 4-chamber view. Myocardial velocities of the LV were recorded at the mitral annulus using pulsed-wave TDI. A best-quality recording was made using a variable frequency phased array transducer (2.0–4.0 MHz), a low wall filter setting (50 Hz), a small sample volume and an optimal gain. The annular velocities were determined at 4 sites in the LV from the apical 4- and 2-chamber views as described previously (septal, lateral, anterior and inferior walls; and a mean value was obtained from 4 different sites, which was used for the assessment of LV function).¹³ Three major velocities were recorded at the mitral annulus (MA) sites: the peak major positive systolic velocity (peak S) when the annulus moved towards the apex, and 2 major negative velocities when the annulus moved back towards the base (one during the early phase of diastole – peak e', and another during the late phase of diastole – peak a'). A mean of 3 consecutive cycles was used for the calculations of all echo-Doppler parameters (fig 1).

In addition, the integral index of LV diastolic function – the ratio of transmitral peak E velocity to myocardial peak e' velocity – was calculated (normal value <8.0). Colour flow M-mode was used for estimation of diastolic flow propagation velocity (Vp) and calculation of the ratio of transmitral peak E to Vp, considered a sensitive and independent predictor of LV diastolic dysfunction (normal value <1.5).

Coronary angiography

Coronary angiography with ventriculography was conducted and interpreted by trained physicians 1 month preceding CABG

+ AE. A 50% or more reduction of the luminal diameter in 2 orthogonal projections of a major coronary artery or one of its major branches or a bypass graft was considered to be significant for CAD.

Statistics

The results are expressed as the mean and 1 standard deviation. The parameters of patients and healthy subjects were compared using an unpaired t-test. A paired t-test was used to compare results within the same group. A P-value of <0.05 was considered significant.

RESULTS

The main clinical features of the study group patients are presented in Table 1. Transmitral diastolic indices remained unchanged after surgeon operation (Table 2). Compared to the control group, patients with CAD and LV aneurism showed a significant decrease in both systolic (S) and early (e') and late diastolic (a') velocities of MA according to TDI (control group vs. patients: $S = 8.9 \pm 1.2$ vs. 6.1 ± 0.8 cm/s, $p < 0.001$; $e' = 10.8 \pm 2.1$ vs. 6.9 ± 1.8 cm/s, $p < 0.001$ and $a' = 9.4 \pm 2.3$ vs. 8.1 ± 2.1 cm/s, $p < 0.05$). Control EchoCG with TDI 3 and 12 months after CABG + AE showed an improvement in both systolic and diastolic MA movement velocities (table 3 and fig 2), which corresponded to LV ejection fraction growth in the studied group. E/e' and E/Vp ratios were also calculated before and after CABG + AE in appropriate follow-up periods (table 3).

DISCUSSION

The diastolic phase of the cardiac cycle consists of three components: (1) Isovolumic (active) relaxation and rapid early filling, which is energy dependent; (2) diastasis, a period of passive filling, which is dependent upon ventricular compliance; (3) active filling during atrial contraction, which is highly dependent upon the left ventricular diastolic pressure at the onset of atrial contraction.

The rate of relaxation and the filling characteristics are also dependent upon preload, afterload, heart rate and contractility.

Figure 1 Recording of septal segment mitral annular velocities (MAV) in patients after AMI. E, Early diastolic MAV; A, Late diastolic MAV; S, systolic MAV (own observation).

Figure 2 LV diastolic function indices dynamics according to TDI and M-mode colour flow. * All indices changes are significant ($p < 0.05$).

During diastole, the left ventricle should be able to accept a wide range of blood volumes without an elevation in filling pressure. The healthy ventricle also completes most of its filling during the initial phases of diastole; this property is particularly helpful at rapid heart rates when diastole is abbreviated.

Almost any process that affects the systolic function of the myocardium or increases its mass or connective tissue content affects diastolic function as well. Impaired left ventricular relaxation and/or poor left ventricular compliance may lead to elevated filling pressures, pulmonary congestion, and clinical symptoms of heart failure. This problem is termed diastolic dysfunction; it can accompany systolic dysfunction or occur alone.

Therefore, LV diastolic dysfunction is a constant finding in patients after AMI, reflecting LV overload and increased filling pressure. Traditionally, diastolic function was evaluated by transmitral pulsed-wave Doppler which has a drawback of being preload-dependent.³⁻⁹ In our study this is reflected by the finding of mean transmitral E/A ratio being >1.0 , pointing at increased preload in the patients studied, while DT and IVRT had values corresponding to LV impaired relaxation profile. This fact corresponds to decreased LV EF in post-infarction patients and evidence of elevated LV filling pressure.

Recent studies widely use TDI for LV myocardial function estimation. MA motion resembles LV longitudinal function. Today, various TDI methods are used to evaluate myocardial function, including pulsed-wave Doppler, colour myocardial imaging and strain rate calculation.¹⁰⁻¹¹ As TDI indices are preload-independent, they reflect earlier and subtle changes not only in diastolic (e' and a' velocities) but also longitudinal

Table 1 Clinical features of the patients studied

Age	58 ± 6
Men/Women (n)	36/4
LV EF (%)	40.3 ± 7.1
LV EDD (mm)	54 ± 5
Diabetes mellitus (n)	10
Hypertension (n)	32
Lesions localisation	
3-vessels disease and/or left main (n)	31
2-vessels disease (n)	7
1-vessel disease (n)	2
Aneurism localisation	
Predominantly anterior LV aneurism (n)	12
Anterior + posterior + apical aneurism (n)	12
Anterior + septal + apical aneurism (n)	16
Type of aneurism surgery	
Linear resection (n)	14
Endoventricular plastics (n)	16
Endoventricular plastics with patch (n)	10
CABGrafts per patient	
One (n)	10
Two (n)	6
Three (n)	16
Four (n)	4
Five (n)	4

*Data are presented as total (n) or $M \pm SD$ ($n = 40$).

systolic function (s'). Therefore, their values are more sensitive than conventional transmitral flow indices, which can vary within one patient during a day, depending on exercise and treatment options.

The advantages of pulsed-wave TDI of MA movement are its simplicity and availability in any patient.¹³⁻¹⁵ Unlike myocardium itself, MA is easy to visualize, while the velocities are simple to register because of an absence of myocardial drop-outs, trabeculae, etc. It has been known for many years that LV diastolic function, as assessed by transmitral flow velocity profiles, is altered in patients with coronary artery disease. Using TDI, LV diastolic dysfunction has also been reported in patients with coronary artery disease.¹⁵⁻¹⁶ Peak early diastolic annular velocity is usually used as a sensitive marker of diastolic dysfunction. Our data agree with previous studies,¹⁷ where, in patients with CAD, decreased mitral annular velocity was registered. In addition, we also used the propagation flow indices according to colour flow M-mode, which also is known to be a sensitive marker of diastolic dysfunction in the patients with CAD.

As usual, surgeon revascularization leads to symptoms relief in post-infarction patients with angina. In addition, aneurismectomy allows avoiding an important factor of LV remodeling and volume overload, both improving contractility and minimizing LV volume. Various previous studies using conventional echo-Doppler parameters have shown quite different results for both systolic and diastolic function after the operation.⁴⁻⁵ These studies were conducted on small numbers

Table 2 Transmitral pulsed-wave Doppler flow patterns before and 3 and 12 months after CABG + AE

	Before CABG + AE	3 months after CABG + AE	12 months after CABG + AE
HR, beats per min.	62 ± 13	67 ± 14	65 ± 12
BP, mm Hg	144/82	141/81	143/83
LV EF, %	40.3 ± 7.1	44.2 ± 6.8, $p = 0.014$	47.1 ± 8.2, $p < 0.001$
E, cm/s	0.67 ± 0.17	0.68 ± 0.19, n/s	0.70 ± 0.18, n/s 0.67 ± 0.18, n/s
A, cm/s	0.67 ± 0.17	0.59 ± 0.18, n/s	1.1 ± 0.5, n/s
E/A ratio	1.1 ± 0.5	1.2 ± 0.7, n/s	224 ± 49, n/s
DT, ms	235 ± 55	217 ± 65, n/s	110 ± 12, n/s
IVRT, ms	112 ± 8	114 ± 10, n/s	

Results are presented as $M \pm SD$, $n = 40$

Table 3 TDI MA velocities and M-mode colour flow before and 3 and 12 months after CABG + AE

Doppler indices	Before CABG + AE	3 months after CABG + AE	12 months after CABG + AE
S, cm/s	6.1 ± 0.8	7.4 ± 1.2***	6.9 ± 1.3*
e', cm/s	7.3 ± 2.1	8.4 ± 1.5*	8.9 ± 1.8***
a', cm/s	8.1 ± 2.1	8.0 ± 2.5, n/s	8.8 ± 2.2, n/s
e'/a' ratio	0.9 ± 0.3	1.1 ± 0.4*	1.1 ± 0.3**
E/e' ratio	9.2 ± 2.2	8.1 ± 1.8*	7.9 ± 2.3*
E/Vp ratio	3.1 ± 0.45	2.2 ± 0.38***	1.8 ± 0.16***

Results are presented as M ± SD, n=40. *p<0.05, **p<0.01 and ***p<0.001 compared to data before CABG + AE.

of patients, with a short follow-up period. Our results showed that TDI can be successfully used for diastolic function evaluation after CABG + AE as a more sensitive method compared to conventional pulsed-wave Doppler, which showed no significant changes over a year of follow-up. Improvement in annular movement velocities in patients after CABG + AE reflects a relief of ischemia, which is one of the most common causes of diastolic dysfunction in such patients.

Previous studies showed E/e' ratio to be a sensitive predictor of LV diastolic dysfunction.^{18,19} Our study confirms these data, having shown significant improvement in this index in patients after surgeon revascularization.

In general, the results of our study show that diastolic function evaluated by TDI takes place rather early, within 3 months after CABG + AE, and improving even more one year after surgery. It is possible that diastolic function, like systolic function, reflects processes of stunning or hibernation with a variable time course in recovery after revascularization.

Study limitations

In our study, diastolic function was evaluated only according to mitral annular velocity, which is a longitudinal change of LV kinetics. No changes in the short axis were noted. However, the method for assessing mitral annular velocity is easy and previous studies have demonstrated its usefulness in determining systolic and diastolic LV function.¹⁵⁻²⁵ Registering annular velocities in 4 segments should anyway provide information of diastolic function or ischemic changes in other segments, since changes in any distal segment would have an impact on mitral annulus.²⁰⁻²⁶

Other diastolic indices, such as pulmonary veins flow, were not performed in the study owing to the inadequate quality of registration in many of the patients.

CONCLUSION

The study of mitral annular velocities by TDI showed significant improvement of LV systolic and diastolic function after CABG combined with aneurismectomy in post-infarction patients, regardless of the unchanged conventional pulsed-wave Doppler indices obtained from mitral valve flow. Results of the study show a high sensitivity of pulsed-wave TDI and usefulness of the method in follow-up of post-infarction patients after combined revascularization with aneurismectomy. The independence of TDI indices from preload makes TDI a preferable method of myocardial function evaluation compared to traditional transmitral flow evaluation by conventional pulsed-wave Doppler.

Authors' affiliations

Maryna N Dolzhenko, S V Potashev, T V Simagina, N N Nosenko, T G Kravchenko, Shupik's National Medical Academy of Postgraduation Education, Chokolovskiy, 4, apt.9, Kiev, 03186 Ukraine
S A Rudenko, Institute Of Cardiovascular Surgery of Academy of Medical Sciences Of Ukraine

REFERENCES

- 1 Senni M, Tribouilloy CM, Rodeheffer RJ, et al. Congestive heart failure in the community: a study of all incident cases in Olmsted County, Minnesota, in 1991. *Circulation*, 1998 Nov 24, **98**(21):2282-9.
- 2 Rydberg E, Willenheimer R, Erhardt L. The prevalence of impaired left ventricular diastolic filling is related to the extent of coronary atherosclerosis in patients with stable coronary artery disease. *Coron Artery Dis*, 2002 Feb, **13**(1):1-7.
- 3 Nishimura RA, Tajik AJ. Evaluation of diastolic filling of left ventricle in health and disease: Doppler echocardiography is the clinician's Rosetta Stone. *J Am Coll Cardiol*, 1997 Jul, **30**(1):8-18.
- 4 Gorcsan J III, Diana P, Lee J, et al. Reversible diastolic dysfunction after successful coronary artery bypass surgery. Assessment by transesophageal Doppler echocardiography. *Chest*, 1994 Nov, **106**(5):1364-9.
- 5 Carroll JD, Hess OM, Hirzel HO, et al. Left ventricular systolic and diastolic function in coronary artery disease: effects of revascularization on exercise-induced ischemia. *Circulation*, 1985 Jul, **72**(1):119-29.
- 6 Inoue T, Marooka S, Hayashi T, et al. Left ventricular diastolic dysfunction in coronary artery disease: effects of coronary revascularization. *Clin Cardiol*, 1992 Aug, **15**(8):577-81.
- 7 Casthely PA, Shah C, Mekhjian H, et al. Left ventricular diastolic function after coronary artery bypass grafting: a correlative study with three different myocardial protection techniques. *Thorac Cardiovasc Surg*, 1997 Aug, **114**(2):254-60.
- 8 McKenney PA, Apstein CS, Mendes LA, et al. Increased left ventricular diastolic chamber stiffness immediately after coronary artery bypass surgery. *Am Coll Cardiol*, 1994 Nov 1, **24**(5):1189-94.
- 9 Cohen GI, Pietrolungo JF, Thomas JD, et al. A practical guide to assessment of ventricular diastolic function using Doppler echocardiography. *J Am Coll Cardiol*, 1996 Jun, **27**(7):1753-60.
- 10 Waggoner AD, Bierig SM. Tissue Doppler imaging: a useful echocardiographic method for the cardiac sonographer to assess systolic and diastolic ventricular function. *J Am Soc Echocardiogr*, 2001 Dec, **14**(12):1143-52.
- 11 Garcia MJ, Thomas JD. Tissue Doppler to assess diastolic left ventricular function. *Echocardiography*, 1999 Jul, **16**(5):501-8.
- 12 Schiller NB, Shah PM, Crawford M, et al. Recommendations for quantization of the left ventricle by two-dimensional echocardiography. *J Am Soc Echocardiogr* 1989;**2**:358-67.
- 13 Alam M, Wardell J, Andersson E, et al. Characteristics of mitral and tricuspid annular velocities determined by pulsed wave Doppler tissue imaging in healthy subjects. *J Am Soc Echocardiogr*, 1999 Aug, **12**(8):618-28.
- 14 Zuber E, Rosfors S. Effect of reversible hypoperfusion on left ventricular volumes measured with gated SPECT at rest and after adenosine infusion. *J Nucl Cardiol* 2000;**7**:655-60.
- 15 Alam M, Wardell J, Andersson E, et al. Effects of first myocardial infarction on left ventricular systolic and diastolic function with the use of mitral annular velocity determined by pulsed wave doppler tissue imaging. *J Am Soc Echocardiogr*, 2000 May, **13**(5):343-52.
- 16 Bach DS, Armstrong WF, Donovan CL, et al. Quantitative Doppler tissue imaging for assessment of regional myocardial velocities during transient ischemia and reperfusion. *Am Heart J*, 1996 Oct, **132**(4):721-5.
- 17 Ohte N, Narita H, Hashimoto T, et al. Differentiation of abnormal relaxation pattern with aging from abnormal relaxation pattern with coronary artery disease in transmitral flow with the use of tissue Doppler imaging of the mitral annulus. *J Am Soc Echocardiogr*, 1999 Aug, **12**(8):629-35.
- 18 Ommen SR, Nishimura RA, Appleton CP, et al. Clinical utility of Doppler echocardiography and tissue Doppler imaging in the estimation of left ventricular filling pressures: a comparative simultaneous Doppler-catheterization study. *Circulation*, 2000 Oct 10, **102**(15):1788-94.
- 19 Nagueh SF, Middleton KJ, Kopelen HA, et al. Doppler tissue imaging: a noninvasive technique for evaluation of left ventricular relaxation and estimation of filling pressures. *J Am Coll Cardiol*, 1997 Nov 15, **30**(6):1527-33.
- 20 Madler CF, Payne N, Witkenschoff U, et al. Myocardial Doppler in Stress Echocardiography (MYDISE) Study Investigators. Noninvasive diagnosis of coronary artery disease by quantitative stress echocardiography: optimal diagnostic models using off-line tissue Doppler in the MYDISE study. *Eur Heart J*, 2003 Sep, **24**(17):1584-94.
- 21 Leitman M, Sidenko S, Wolf R, et al. Improved detection of inferobasal ischemia during dobutamine echocardiography with Doppler tissue imaging. *J Am Soc Echocardiogr*, 2003 May, **16**(5):403-8.
- 22 Wada Y, Murata K, Kimura K, et al. Diastolic response during dobutamine stress echocardiography evaluated by a tissue velocity imaging technique is a sensitive indicator for diagnosing coronary artery disease. *J Am Soc Echocardiogr*, 2003 Apr, **16**(4):309-17.

- 23 **Sohn DW**, Kim YJ, Kim HC, *et al*. Evaluation of left ventricular diastolic function when mitral E and A waves are completely fused: role of assessing mitral annulus velocity. *J Am Soc Echocardiogr*, 1999 Mar, **12**(3):203–8.
- 24 **Altinmakas S**, Dagdeviren B, Turkmen M, *et al*. Usefulness of pulse-wave Doppler tissue sampling and dobutamine stress echocardiography for identification of false positive inferior wall defects in SPECT. *Jpn Heart J*, 2000 Mar, **41**(2):141–52.
- 25 **Pellerin D**, Sharma R, Elliott P, *et al*. Tissue Doppler, strain, and strain rate echocardiography for the assessment of left and right systolic ventricular function. *Heart*, 2003 Nov, **89**(Suppl. 3):iii9–17.
- 26 **Jensen J**, Brodin LA, Lind B, *et al*. Deterioration in peak systolic velocity is closely related to ischemia during angioplasty: a vectorcardiographic and tissue Doppler imaging study. *Clin Set (Land)*, 2001 Feb, **100**(2):137–43.

Let us assist you in teaching the next generation

Figures from all articles on our website can be downloaded as a PowerPoint slide. This feature is ideal for teaching and saves you valuable time. Just click on the image you need and choose the “PowerPoint Slide for Teaching” option. Save the slide to your hard drive and it is ready to go. This innovative function is an important aid to any clinician, and is completely free to subscribers. (Usual copyright conditions apply.)