TISSUE DOPPLER MYOCARDIAL PERFORMANCE INDEX

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Summary

A simple, reproducible, noninvasive myocardial performance index (MPI) for the assessment of overall cardiac function has been described previously. The purpose of this study was to compare the MPI obtained by pulsed Doppler method with the MPI obtained by tissue Doppler echocardiography (TDE) in normal subjects. Twenty-eight healthy subjects were included. In order to calculate MPI by TDE, isovolumetric contraction (IVCT), relaxation time (IVRT) and ejection time (ET) were measured at two different sites of mitral annulus: septum and lateral. MPI was calculated by dividing the sum of IVCT and IVRT by ET at each site of measurement. The mean MPI value was found by dividing the sum of these MPI values into two. The same parameters were measured using the mitral inflow and left ventricular outflow velocity time intervals in pulsed Doppler method. At all sites measured, MPI by TDE correlated well with conventional MPI (at septal site r=0.82, p<0.0001; at lateral site r=0.86, p<0.0001). The highest correlation was observed in mean value of MPI by TDE; r=0.94, p<0.0001.

This study demonstrated that MPI may be measured by TDE and correlated well with conventional MPI in normal subjects. The mean of MPI by TDE values measured at two different mitral annular sites may be a more reliable way of assessing global LV function. ***(Arch Turk Soc Cardiol 2003;31:262-9)***

Key words: *Cardiac functions, myocardial performance index, tissue Doppler echocardiography*

Özet

Doku Doppler Miyokard Performans İndeksi

Miyokard performans indeksi (MPİ) basit, kullanılabilir ve girişimsel olmayan bir yöntem olarak kardiyak fonksiyonları değerlendirmek amacıyla daha önce tanımlanmıştır. Bu çalışmanın amacı sağlıklı bireylerde pulse Doppler metodu ile elde edilen MPİ'ni doku Doppler (DD) metodu ile elde edilen MPİ ile karşılaştırmaktır. Çalışmaya 28 sağlıklı birey alındı. DD ile elde edilen MPİ'ni hesaplamak amacıyla izovolumetrik kontraksiyon (İVKZ), izovolumetrik relaksasyon (İVRZ) ve ejeksiyon zamanı (EZ) mitral anulusun iki farklı bölgesinden (septum ve lateral) alındı. MPİ her bir bölgeden ölçülen İVRZ ve İVKZ toplamının EZ'na bölünmesi ile hesaplandı. Ortalama MPİ değeri hesaplanan MPİ değerlerinin ikiye bölünmesi ile elde edildi. Aynı parametreler

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mitral giriş ve sol ventrikül çıkış yolu hız zaman intervalleri kullanılarak pulsed Doppler metodu ile ölçüldü. Ölçülen tüm bölgelerde, DD ile elde edilen MPİ pulsed Doppler metodu ile hesaplanan MPİ ile iyi derecede korelasyon göstermekte idi (septal bölge r=0.82, p<0.0001; lateral bölge r=0.86, p<0.0001). En yüksek korelasyon ortalama MPİ değeri ile gözlendi; r=0.94, p<0.0001.

Sonuç olarak, bu çalışma normal bireylerde MPİ'nin DD yöntemi ile hesaplanabildiğini ve geleneksel MPİ ile iyi korele olduğunu gösterdi. Mitral anulusun iki farklı bölgesinden hesaplanan ortalama DD MPİ değerleri, global kardiyak fonksiyonların değerlendirilmesinde daha güvenilir bir yol olabilir. ***(Türk Kardiyol Dern Arş 2003;31:262-9)***

Anahtar kelimeler: *Doku Doppler ekokardiyografi, kardiyak fonksiyonlar, miyokard performans indeksi*

A new Doppler derived myocardial performance index (MPI) combining systolic and diastolic time intervals, was proposed by Tei and co-workers[1,2]. This index, which is defined as the sum of isovolumic contraction (IVCT) and relaxation time (IVRT) divided by the ejection time, was reported to be simple, reproducible and independent of heart rate and blood pressure[3]. However, one important limitation is that the IVCT, IVRT and ejection time are measured sequentially and not on the same cycle. Consequently, the accuracy of the results may be compromised by heart rate fluctutations. Tissue Doppler echocardiography (TDE), which is a new ultrasound technique, enables us to simultaneously measure both the diastolic and systolic intervals from the myocardium[4-6]. The purpose of this study was to compare the MPI by TDE with conventional MPI in normal subjects.

METHODS

Study population

Twenty-eight healthy subjects (14 M, 14 F; mean age was 47±12 years) without a history of cardiac disease or systemic hypertension and having normal findings on physical examination, chest roentgenography, electrocardiography, 2-D and Doppler echocardiography were studied. Each subject received an explanation of the study and gave informed consent.

Echocardiography

The patients were examined in the left lateral decubitis position with a Hewlett-Packard Sonos 5500 (Andover, Massachusetts) phased-array system equipped with tissue Doppler technology. Measurements were made according to the recomendations of the American Society of Echocardiography[7]. The ejection fraction was calculated from apical 4- and 2-chamber views with Simpson's method. The mitral inflow velocity pattern was recorded with the pulsed-wave Doppler sample volume positioned between the tips of the mitral leaflets. The LV outflow pattern was recorded from the apical 5-chamber view with the pulsed wave Doppler sample volume positioned just below the aortic valve. Three consecutive beats were measured and averaged for each parameter. Two-dimensional and Doppler tracings were recorded over five cardiac cycles at a sweep speed of 100 mm/s.

Doppler measurements

Mitral inflow and left ventricular outflow velocity-time intervals were used to measure Doppler time intervals: isovolumetric contraction (IVCT), relaxation time (IVRT) and ejection time (ET) as demonstrated in Fig. 1. The interval 'a' from the cessation to the onset of mitral inflow was equal to the sum of IVCT, ET, and IVRT (a=IVCT + ET + IVRT). Left ventricular ET 'b' was the duration of left ventricular velocity profile. Thus, the sum of IVCT and IVRT was obtained by subtracting 'b' from 'a'. The MPI was calculated as (a-b)/b [MPI=(a-b)/b]. IVRT was calculated by subtracting the interval 'd', between the R wave and the cessation of left ventricular outflow, from the interval 'c', between the R wave and the onset of mitral inflow[8] (IVRT=c-d). IVCT was calculated by subtracting IVRT from 'a'-'b' [IVCT=(a-b)-IVRT].

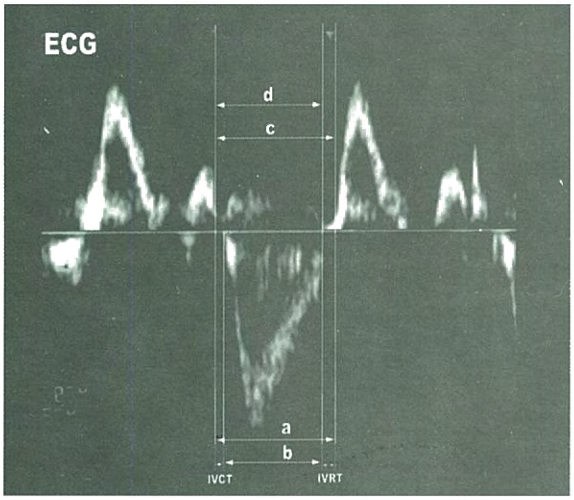

Figure 1: *Doppler time intervals were measured from mitral inflow and left ventricular outflow velocity-time intervals*

Tissue Doppler echocardiography

The pulsed-wave TDE was performed by activating the tissue Doppler function in the same echocardiographic machine. Images were acquired by using a variable frequency phased-array transducer (2.0 to 4.0 MHz). The filter settings were kept low, and gains were adjusted at the minimal optimal level to minimize noise and eliminate the signals produced by the transmitral flow. A 1.7 mm sample volume was used.

Sample volumes were placed at two different sites of mitral annulus corresponding to the septum and lateral sites in order to record major velocity time intervals: IVCT, IVRT and ET. The pulsed – wave TDE tracings were recorded over five cardiac cycles at a sweep speed of 100 mm/s and three of them were used for calculation.

TDE velocity time intervals were measured from the sites at mitral annulus as demonstrated in Fig. 2. The interval (a_1), from the R wave to the onset of diastolic velocity, was equal to the sum of IVCT, ET, and IVRT (a'=IVCT+ET+IVRT). Left ventricular ET (b_1) was the duration of systolic velocity profile. Thus, the sum of IVCT and IVRT was obtained by subtracting (b_1) from (a_1). The MPI was calculated as (a_1-b_1)/b_1 [MPI'=(a'-b')/b']. IVRT was calculated by subtracting the interval (d_1), between the R wave and the cessation of systolic velocity, from the interval (c_1), between the R wave and the onset of diastolic velocity (IVRT=c'-d'). IVCT was calculated by subtracting IVRT from (a_1 – b_1) [IVCT=(a'-b')-IVRT].

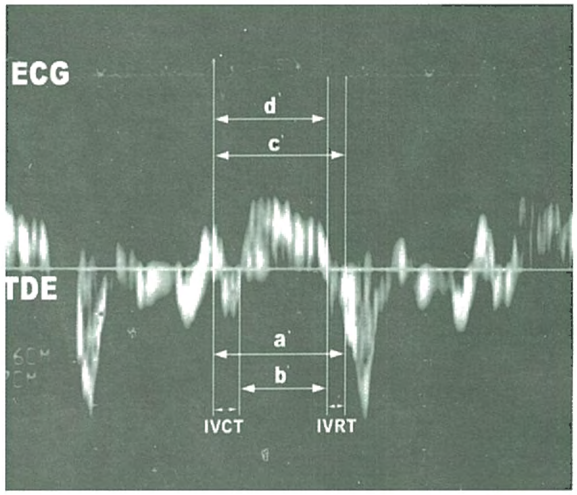

Figure 2: *Tissue Doppler echocardiography time intervals were measured from the mitral annular tissue Doppler velocity time intervals*

Reproducibility

Intra-observer variability was assessed in 10 patients by repeating the measurements on two occasions (1-12 days apart) under the same basal conditions. To test the inter-observer variability, the measurements were performed off-line from video recordings by a second observer who was unaware of the results of the first examination. Variability was calculated as the mean percentage error, derived as the difference between the two sets of measurements, divided by the mean observations.

Statistics

Data were expressed as mean value SD. Linear regression analysis was used to assess the statistical relationships between the time intervals or MPI by TDE and conventional method. In addition, the differences between the measurements obtained by the two different methods were analyzed according to the Bland and Altman method9. A difference was considered significant at $p<0.05$.

RESULTS

The mean intervals (ms) in the different phases of the cardiac cycle and MPI, as determined according to Doppler parameters, are shown and compared to those obtained with TDE at septal (Table I) and lateral side (Table II) of mitral annulus. The time intervals IVRT, IVCT and ET values obtained by TDE all correlated well with the values obtained by conventional method (at septal site r=0.84, p<0.0001; r= 0.81, p<0.0001; r=0.95, p<0.0001; respectively, at lateral site r=0.82, p<0.0001; r= 0.84, p<0.0001; r=0.95, p< 0.0001; respectively). At either site of mitral annulus, there was a highly significant correlation between MPI values obtained by TDE and conventional method (at septal site r=0.82, p<0.0001; at lateral site r=0.86, p<0.0001) (Fig. 3 and 4). The highest correlation was observed in mean values of MPI by TDE (r= 0.94, p<0.0001) (Figure 5). At septal and lateral site of mitral annulus, the mean difference between conventional MPI and MPI by TDE was 0.006±0.02, 0.003±0.015; respectively. The mean difference between mean MPI by TDE and conventional MPI was 0.002±0.013.

Reproducibility: Intra and interobserver variability for Doppler derived parameters (IVRT, IVCT, ET) ranged from 2.2% to 6.2%. Intraobserver variability for conventional MPI was 3.1±2.3%,

Table 1: *Comparison of the different time intervals (ms) and myocardial performance index (%) obtained by pulse-Doppler and tissue Doppler echocardiography for the different phases of cardiac cycle at septal side of mitral annulus*

Cardiac phase	Pulse-Doppler Echocardiography			Tissue Doppler Echocardiography			R	P
	TI (ms)	Range		TI (ms)	Range			
IVCT	38±5	25	50	37±5	23	44	0.81	<0.0001
ET	310±13	280	340	311±13	280	340	0.95	<0.0001
IVRT	76±8	60	90	75±10	55	90	0.84	<0.0001
MPI	0.37±0.04	0.28	0.42	0.366±0.04	0.26	0.42	0.82	<0.0001

TI: Time interval, IVCT: Isovolumic contraction time, ET: Ejection time, IVRT: Isovolumic relaxation time, MPI: Myocardial performance index, MS: Milisecond

Table 2: *Comparison of the different time intervals (ms) and myocardial performance index (%) obtained by pulse-Doppler and tissue Doppler echocardiography for the different phases of cardiac cycle at septal side of mitral annulus*

Cardiac phase	Pulse-Doppler Echocardiography			Tissue Doppler Echocardiography			R	P
	TI (ms)	Range		TI (ms)	Range			
IVCT	38±5	25	50	39±6	24	48	0.82	<0.0001
ET	310±13	280	340	311±14	280	340	0.95	<0.0001
IVRT	76±8	60	90	76±8	63	94	0.84	<0.0001
MPI	0.37±0.04	0.28	0.42	0.37±0.04	0.28	0.44	0.86	<0.0001

TI: Time interval, IVCT: Isovolumic contraction time, ET: Ejection time, IVRT: Isovohemic relaxation time, MPI: Myocardial performance index, MS: Milisecond

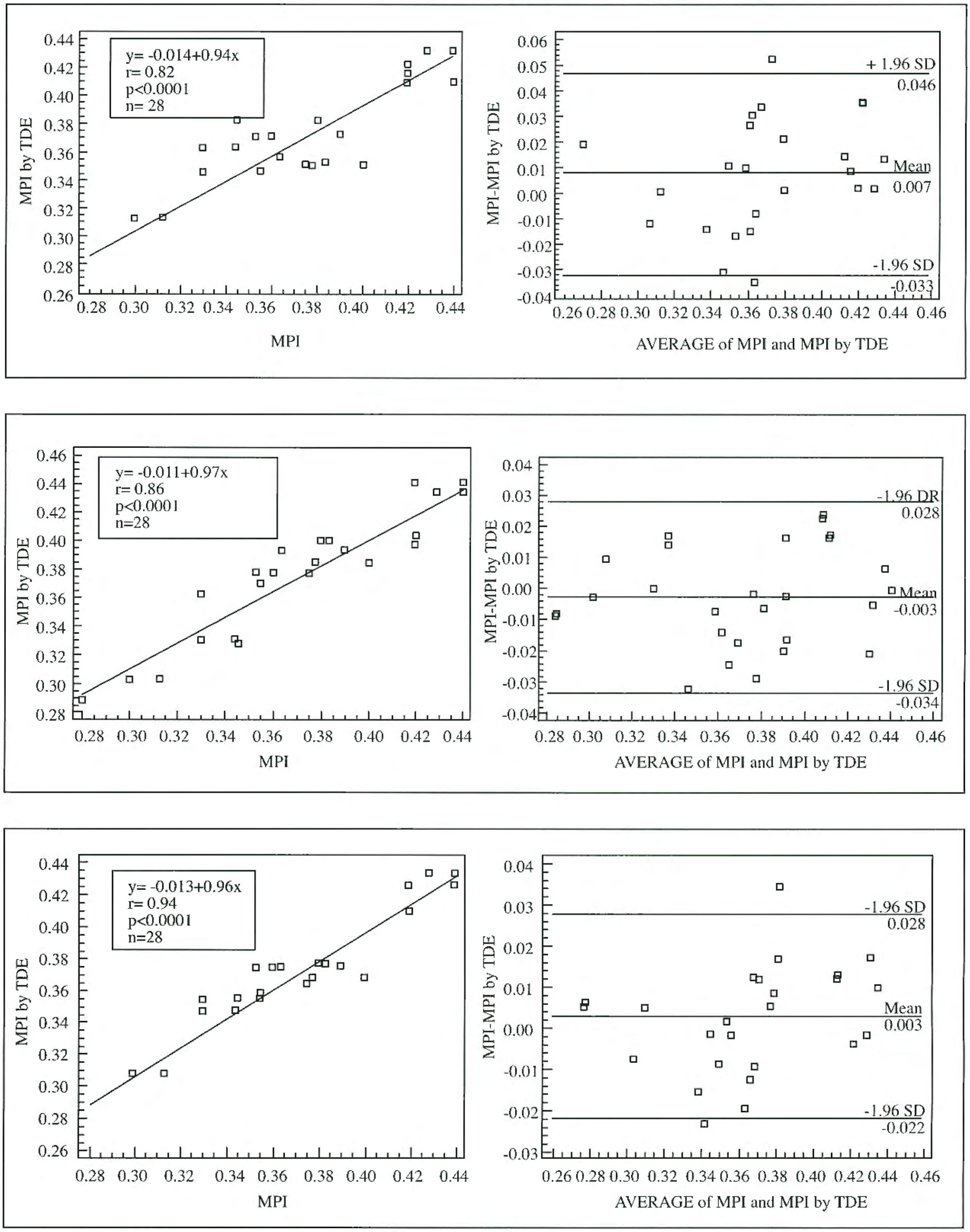

Figure 3-5: *Left panel, correlations between MPI by TDE and conventional MPI in healthy subjects at septal side of mitral annulus. Right panel, Bland and Altman plot of the difference between MPI by TDE and conventional MPI*

MPI: Myocardial performance index, TDE: Tissue Doppler echocardiography interobserver variability was 3.1±2.3%. For TDE measurements (IVRT, IVCT, ET), intra and interobserver variability ranged from 2.6% to 5.8%. Intraobserver variability for MPI by TDE was 3.4±2.8%; interobserver variability was 4.2±1.8%.

DISCUSSION

In the present study, both methods of measuring MPI, TDE and conventional, correlated well with each other in healthy subjects regardless the site of measurement at the mitral annulus. These results are similar to the findings of a recent study of Harada et al.(10) in which, lateral site of the tricuspid annulus was used in the evaluation of the right ventricular function and a close correlation between conventional MPI and MPI by TDE was found in children without heart disease. Although the correlation between conventional MPI and MPI by TDE at two sites of mitral annulus was high in both groups, we found this correlation was higher at the lateral site than that obtained at the septal site. Possible explanation of this finding is that the function of septal site of mitral annulus may be affected by the function of adjacent structures such as right ventricular function. Furthermore, the mean of MPI by TDE values obtained at two sites of mitral annulus correlated better with the conventional MPI than did the MPI by TDE at either site of mitral annulus. This finding may indicate that mean MPI by TDE at two sites of mitral annulus is a more reliable way of assessing global LV myocardial function than measuring MPI by TDE at only one single site of mitral annulus.

In another study of Harada et al(11) in which, lateral site of the mitral annulus was used in the evaluation of global left ventricular function and a close correlation between conventional MPI and MPI by TDE was found in healthy children and patients with heart disease. The use of lateral site of mitral annulus in measuring MPI by TDE and the study population are two major differences in the methodology of Harada et al(11). In our study only healthy subjects were studied and lateral and septal site of mitral annulus were used in measuring MPI by TDE. In the study of Harada et al(11) MPI measured by TDE may be influenced by regional cardiac dysfunction, such as asynergy on the lateral wall. While the conventional MPI is intending to assess the global left ventricular function, this MPI by TDE is actually assessing the regional left ventricular function. In the study of Harada et al(11), patients with heart disease may make the difference between conventional MPI and MPI by TDE.

Mitral annulus was used in measuring tissue Doppler time intervals. Left ventricular contraction involves both a reduction of the short axis diameter and a shortening along the longitudinal axis of the chamber(12,13). The longitudinal systolic shortening of the left ventricle is reflected by the motion of the mitral annulus toward the cardiac apex in systole, whereas its recoil away from the apex is the result of diastole. As there is no appreciable motion of the apex in relation to the imaging transducer, the magnitude of mitral annular motion reflects the extent of myocardial shortening along its longitudinal axis(12). Recording the mitral annular motion has the advantage that it is devoid of trabeculea, myocardial dropouts, etc, and therefore is independent of echo quality. The major advantage of pulsed – wave mitral annular velocity measurements is that the ultrasound beam is parallel to the LV contraction. Moreover, it probably measures the transmural myocardial velocity, not only the epicardial and endocardial velocities. Introduction of pulsed – wave TDE of different mitral annular sites of the left ventricle opens up a new possibility. Thus, the pulsed –wave TDE parameters may be used as an additional method that could increase the accuracy of echocardiographic LV studies. Conventional MPI has been reported to be independent of heart rate and blood pressure(1).

However, the inability to measure the interval between the end and onset of mitral inflow and the ejection time simultaneously is a major limitation of conventional MPI. Due to this limitation, results are probably less reliable in the presence of physiologic heart rate changes during examination. The TDE used in this study can simultaneously record systolic and diastolic mitral annular velocities. Thus, the MPI by TDE may reduce inaccuracy due to heart rate fluctuation and has practical advantages over the conventional MPI.

The other possible disadvantage of conventional MPI is the effect of loading conditions on conventional MPI. Tei et al.[14] found a high correlation between conventional MPI and peak dp/dt, suggesting a relationship between MPI and preload. Thus, even when contractility is constant, significant changes in preload may cause significant alterations in conventional MPI. Measurement of MPI by TDE may not be altered by preload changes. Further studies are needed to confirm this hypothesis.

Limitations

This study analyses the clinical applicability of MPI determined by pulsed - wave TDE by using the myocardial velocity along the long axis. One limitation is that contraction of the left ventricle along its short axis caused by circumferential fiber was not taken into consideration. Another limitation is that coronary and LV angiography were not performed to assess the LV global function.

Conclusion

This study clearly demonstrated that MPI could be measured by TDE and it correlated well with conventional MPI in normal subjects. Moreover, MPI by TDE has the advantage of recording systolic and diastolic velocity patterns simultaneously. The mean of MPI by TDE values measured at two different mitral annular sites may be a more reliable way of assessing global LV function.

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