Age-related transmural peak mean velocities and peak velocity gradients by Doppler myocardial imaging in normal subjects

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Doppler myocardial imaging is a new cardiac ultrasound technique based on the principles of colour Doppler imaging which can determine myocardial velocities by detecting the changes of phase-shift of the ultrasound signal returning directly from the myocardium. To determine the normal range of transmural velocities in healthy hearts a prospective study was carried out involving 42 normal subjects (age from 21 to 78, mean 47 ± 16 years). Using M-mode Doppler myocardial imaging the peak values of the mean velocity and velocity gradient across the left ventricular posterior wall were measured during standardized phases of the cardiac cycle. Peak mean velocities had the following values during the cardiac cycle: isovolumic contraction — 1-3 ± 1-2 cm . s⁻¹, early ventricular ejection 4-2 ± 1-2 cm . s⁻¹, late ventricular ejection 1-8 ± 1-1 cm . s⁻¹, isovolumic relaxation — 2-0 ± 0-8 cm . s⁻¹, rapid ventricular filling — 6-6 ± 2-2 cm . s⁻¹, atrial contraction — 2-8 ± 1-8 cm . s⁻¹, atrial relaxation 1-2 ± 1-1 cm . s⁻¹. Peak velocity gradients were: isovolumic contraction 1-3 ± 1-9 s⁻¹, early ventricular contraction 4-7 ± 1-9 s⁻¹, late ventricular contraction 1-1 ± 1-0 s⁻¹, isovolumic relaxation — 0-6 ± 0-5 s⁻¹, rapid ventricular filling 6-1 ± 3-4 s⁻¹, atrial contraction 2-6 ± 1-7 s⁻¹, atrial relaxation 0-0 ± 0-3 s⁻¹. Linear regression analysis showed that with the increase of age, peak velocity gradient decreases during rapid ventricular filling (r=0·83; P<0·0001) and increases during atrial contraction (r=0·86; P<0·0001) while peak mean velocity increases only during atrial contraction (r=0·80, P<0·0001). Thus, there was no correlation between increasing age and systolic peak mean velocity and peak velocity gradient but both diastolic filling phases rapid ventricular filling and atrial contraction demonstrated age-related changes.

In summary, this study has determined the age-related range of normal transmural myocardial velocities within the left ventricular posterior wall in healthy hearts during the cardiac cycle. We conclude that these measurements of peak mean velocities and peak velocity gradients, should form the baseline for subsequent Doppler myocardial imaging clinical studies on myocardial diseases processes. (Eur Heart J 1996; 17: 940-950)

Key Words: Ultrasound, colour Doppler, myocardium.

Introduction

In 1992 McDicken and Sutherland et al.1 described a new ultrasound technique for interrogation of the myocardium — Doppler myocardial imaging. The technique, based on the principles of colour Doppler imaging, detects the phase shift of the ultrasound signal returning directly from the myocardium and can quantify intramural velocities. An important feature of Doppler myocardial imaging is that it is relatively independent of the amplitude of the returning signal and is not directly affected by the attenuating effect of the chest wall. Thus, the Doppler myocardial imaging technique has the potential to provide better quality images than B-mode echocardiography in poorly-echogenic patients. The potential clinical applications of Doppler myocardial imaging have been evaluated in a series of initial in vitro and in vivo studies3-4. In addition, an off-line computer based analysis system has been developed for the accurate quantitative analysis of myocardial velocities5-6. This parameter could be an important new index for the assessment of regional myocardial function. Thus, the aims of this study were, first, to define the normal range of myocardial transmural velocities and their changes during sequential phases of
systolic and diastolic in healthy hearts and to identify what, if any, changes occur in these indices with ageing. Second, to define the correlation between the Doppler myocardial imaging parameters and standard echocardiographic parameters of systolic and diastolic left ventricular function. This should thus form the baseline for subsequent clinical studies on myocardial pathological processes.

**Methods**

**Subjects**

Table 1 lists the clinical information on the study group of 42 randomly selected healthy subjects. No subjects were excluded on the basis of echocardiographic image quality. Informed consent was obtained from all subjects prior to entry into the study. The study was carried out in the Department of Medical Physics and Medical Engineering in the University of Edinburgh. Before the Doppler myocardial imaging information was obtained, all subjects underwent a detailed standard echocardiographic study. Each examination consisted of M-mode, two-dimensional and transvalvular Doppler blood flow measurements. None of the study volunteers had any clinical, electrocardiographic or echocardiographic evidence of cardiac disease.

**Standard echocardiographic study**

Echocardiographic examinations were performed by an experienced sonographer and then evaluated off-line independently by two cardiologists. Each examination consisted of M-mode, two-dimensional and pulsed-wave Doppler blood flow measurements. M-mode two-dimensional directed measurements were taken at the level of the tips of mitral valve leaflets in the parasternal long-axis view. Standard parameters measured were: left ventricular fractional shortening, and left ventricular fractional thickness change.

Standard methodology was used to measure the left ventricular ejection fraction using the modified biplane Simpson’s method. Doppler transmitral velocity waveforms with the interrogating sample volume placed at the tips of mitral valve leaflets were measured. Recordings were made using a paper speed of 100 mm. s\(^{-1}\). The following Doppler indices were measured: peak E wave velocity, peak A wave velocity, E deceleration time, and isovolumetric relaxation time. Using similar standard techniques, velocity wave forms were recorded from the left ventricular outflow tract using the apical view. Using a paper speed of 100 mm. s\(^{-1}\), the following variables were measured: maximal velocity and mean acceleration of the left ventricular outflow tract velocity. All M-mode, two-dimensional and pulsed-wave Doppler blood flow measurements were obtained from three cardiac cycles.

Table 2 shows the data obtained from standard echocardiographic examinations from all study groups of healthy volunteers.

**Doppler myocardial imaging**

Using the M-mode Doppler myocardial imaging technique, we measured the peak mean velocity and the peak velocity gradient across the left ventricular posterior wall during standardized phases of the cardiac cycle. Fig. 1 illustrates schematically the origin of mean velocity and velocity gradient measured from an M-mode image taken from the left ventricular posterior wall. Mean velocity was defined as the average value of the myocardial velocity estimates measured along each M-mode scan line throughout the thickness of the myocardium. Peak mean velocity was defined as the maximum value of the mean velocity over the duration of a particular cardiac phase. Velocity gradient was defined as the slope of a linear regression of the myocardial velocity estimates along each M-mode scan line throughout the thickness of the myocardium. Peak velocity gradient was defined as the maximum value of velocity gradient over the duration of a particular cardiac phase. Simultaneous M-mode grey-scale and Doppler myocardial imaging were taken from the left ventricular posterior wall at the level of the tips of the mitral valve leaflets from the
The origin of myocardial mean velocity and velocity gradient during cardiac cycle obtained from the analysed M-mode Doppler myocardial image. Mean velocity was defined as the average value of myocardial velocity estimates taken along each M-mode scan line throughout the thickness of the myocardium. Velocity gradient was defined as the slope of the linear regression performed on the velocity estimates taken along each M-mode scan line between endocardium and epicardium. Thus, velocity gradient is non-zero if the endocardium and epicardium have different velocities, and is related to wall thickening and thinning. LVPW = left ventricular posterior wall.

parasternal long-axis view (Fig. 2). All scanner settings remained constant throughout the study except for image magnification, Doppler velocity range, M-mode sweep rate, grey-scale gain and Doppler receive gain. Image magnification was set to display the region occupied by the moving cardiac wall under study. The Doppler velocity range was set at the minimum value at which no aliasing occurred. Fig. 3 presents two Doppler myocardial imaging M-mode images with the velocity range set first at 13 cm \( \cdot \) s\(^{-1} \) and then at 16 cm \( \cdot \) s\(^{-1} \). At the lower velocity range aliasing occurs where the myocardial velocity exceeds 13 cm \( \cdot \) s\(^{-1} \). At the higher velocity range, 16 cm \( \cdot \) s\(^{-1} \), the aliasing effect does not occur. M-mode sweep rate was set to the maximum rate possible for the given Doppler velocity range. Grey-scale gain was adjusted to optimize the clarity of the endocardial and epicardial boundaries. Doppler receive gain was set to achieve the maximum colour Doppler information in the myocardium while limiting the colour appearing in the blood pool. All images were recorded using an Acuson (Mountain View, California) XP/10 ultrasound scanner. The scanner was modified for Doppler myocardial imaging acquisition in the following ways. First, velocity ranges were chosen which were suitable for the display of myocardial motion, i.e. 0.3–24.0 cm \( \cdot \) s\(^{-1} \). Second, the display of the Doppler information was chosen over the regions of the myocardium instead of the blood, the distinction being made on signal strength. Third, image persistence was turned off to eliminate blurring of the moving myocardium. Images were acquired using a 2.5 MHz phased array probe. All images were obtained in freeze-frame mode and downloaded to a Freeland Prism 2000 cardiac image capture system (Freeland Systems, Colorado). Images were downloaded with the Doppler display turned first on and then off so that, both M-mode Doppler myocardial imaging information and grey-scale information from the same image were obtained. To eliminate the influence of respiration on myocardial velocities, three cardiac cycles were stored at end-expiration\(^{19} \). Each cardiac cycle was divided into standardized phases using the combined information derived from the M-mode grey-scale images of the left ventricle at the level of the mitral valve leaflets, and the simultaneously recorded electrocardiogram and phonocardiogram\(^{19} \). These standardized time periods were: isovolumic contraction, early ventricular ejection, late ventricular ejection, isovolumic relaxation, rapid ventricular filling, atrial contraction and atrial relaxation. The format of the captured images was 512
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(a) Healthy volunteer, age 32, female. Doppler myocardial imaging M-mode, long-axis view, interventricular septum and left ventricular posterior wall at the level of the mitral valve leaflets. The heart wall is displayed alternately in red and blue as it moves towards and away from the transducer. The colour bar on the left side of the image shows the range of velocity in cm s⁻¹. (b) Grey-scale M-mode image taken simultaneously with (a).

horizontal pixels by 288 vertical pixels. After collection, the data was transferred to an IBM compatible Personal Computer for processing. Using specially designed software, the endocardial and epicardial boundaries were traced manually on each grey-scale image and these traces were superimposed onto the corresponding Doppler myocardial imaging. This method was used because, in some cases the myocardial interface between the myocardium and the epicardium was better delineated in the grey-scale image.

The scanner Doppler myocardial imaging software was capable of providing the velocity information at single points but did not allow easy calculation of mean velocity and velocity gradient over time. Therefore, a computer program was used to convert colour-coded velocities of the myocardium into velocity estimates using the colour bar displayed at the side of the Doppler myocardial imaging. In each digitized M-mode Doppler myocardial imaging, mean velocity and velocity gradient were calculated along each scan line throughout the thickness of the myocardium. A plot was then drawn of the mean velocity and velocity gradient against time. M-mode Doppler myocardial images are constructed from 64 different colours each of which represents a different velocity. Thirty-two colours represent positive velocities and the remaining 32
Figure 3    Healthy volunteer, age 34, male. Doppler myocardial imaging M-mode, long-axis view, interventricular septum and left ventricular posterior wall at the level of the mitral valve leaflets. (a) The velocity range is set at 16 cm.s⁻¹ where aliasing is absent. (b) The lower velocity range is set at 13 cm.s⁻¹ with the presence of aliasing.

represent negative velocities. The colour bar consists of the same 64 colours. Therefore, a computer program operating on the digitized form of the images was programmed to use the colour bar data as a look-up table for identifying colours in the main part of the image and converting them into estimates of velocity.

Fig. 4 shows a typical example of mean velocity and velocity gradient measurements and the changes of their peak values during one cardiac cycle. The mean velocity of the left ventricular posterior wall was expressed as positive when moving towards the centre of the left ventricle and negative when moving away from the centre of the left ventricle. The velocity gradient was expressed as positive when the subendocardium was moving faster than the subepicardium and negative when the subepicardium was moving faster than the subendocardium.

**Statistical analysis**

The data are expressed as a mean value and a standard deviation (mean ± SD). Linear regression analysis was carried out to test the correlation between Doppler myocardial measurements (peak mean velocity and peak velocity gradient) and age or standard echocardi-
Figure 4 The typical example of the plot of mean velocity (---) and velocity gradient (----) during one cardiac cycle measured from the left ventricular posterior wall by Doppler myocardial imaging technique. The arrows show the peak values of the mean velocity and velocity gradient in sequential phases of the cardiac cycle. AC=atrial contraction; AR=atrial relaxation; ECG=electrocardiogram; EVE=early ventricular ejection; IC=isovolumic contraction; IR=isovolumic relaxation; LVE=late ventricular ejection; MV=mean velocity; RVF=rapid ventricular filling; VG=velocity gradient.

Interobserver and intraobserver variability

To test the reproducibility of Doppler myocardial imaging calculations, peak mean velocity and peak velocity gradient were measured by two independent cardiologists in 15 randomly selected normal subjects. Those differences in interobserver (between results obtained from two independent observers) and intraobserver variability (between results obtained from different cardiac cycles) were presented as mean ± SD using the technique described by Bland and Altman. The interobserver variability was low: in peak mean velocity 0.09 ± 0.12 cm.s⁻¹ with r=0.96 (P<0.0001) and in peak velocity gradient 0.1 ± 0.15 s⁻¹ with r=0.94 (P<0.0001). The intraobserver variability was also low: in peak mean velocity 0.1 ± 0.16 cm.s⁻¹ with r=0.94 (P<0.0001) and in peak velocity gradient 0.12 ± 0.18 s⁻¹ with r=0.92 (P<0.0001).

Table 3 Results obtained in normal subjects from the left ventricular posterior wall by Doppler myocardial imaging in sequential phases of the cardiac cycle

<table>
<thead>
<tr>
<th></th>
<th>IC</th>
<th>EVE</th>
<th>LVE</th>
<th>IR</th>
<th>RVF</th>
<th>AC</th>
<th>AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak MV (cm.s⁻¹)</td>
<td>-1.3 ± 1.2</td>
<td>4.2 ± 1.2</td>
<td>1.8 ± 1.1</td>
<td>-2.0 ± 0.8</td>
<td>-6.6 ± 2.2</td>
<td>-2.8 ± 1.8</td>
<td>1.2 ± 1.1</td>
</tr>
<tr>
<td>Peak VG (s⁻¹)</td>
<td>1.3 ± 1.9</td>
<td>4.7 ± 1.9</td>
<td>1.1 ± 1.0</td>
<td>-0.6 ± 0.5</td>
<td>6.1 ± 3.4</td>
<td>2.6 ± 1.7</td>
<td>0.0 ± 0.3</td>
</tr>
</tbody>
</table>

AC=atrial contraction; AR=atrial relaxation; EVE=early ventricular ejection; IC=isovolumic contraction; IR=isovolumic relaxation; LVE=late ventricular ejection; MV=mean velocity; VG=velocity gradient.

The results are expressed as mean ± SD. +peak mean velocity indicates that myocardium is moving toward centre of the left ventricle; - peak mean velocity indicates that myocardium is moving away from the centre of left ventricle; +peak velocity gradient indicates that subepicardium is moving faster than subepicardium; - peak velocity gradient indicates that subendocardium is moving faster than subendocardium.

Results

Table 3 shows mean velocities and velocity gradients measured from the left ventricular posterior wall by Doppler myocardial imaging in normal subjects. Peak mean velocities were positive during early ventricular ejection, late ventricular ejection and atrial relaxation, indicating that in these phases the myocardium was moving toward the centre of the left ventricle. During other phases of the cardiac cycle — isovolumic contraction, isovolumic relaxation, rapid ventricular filling and atrial contraction — peak mean velocities were negative, indicating that the myocardium was moving away from the centre of the left ventricle. The subendocardium was moving faster than the subepicardium, during isovolumic contraction, early ventricular ejection, late ventricular ejection, rapid ventricular filling, atrial contraction. During atrial relaxation, the peak velocity gradient was zero, indicating that during this time period all parts of the myocardium were moving with similar speed. Peak velocity gradients were slightly negative only during isovolumic relaxation, suggesting that during this time period the subepicardium is moving faster than the subendocardium.

Fig. 5 presents the correlation between results obtained from Doppler myocardial measurements at different ages. With increasing age, the peak velocity gradient significantly (r=-0.83, P<0.0001) decreases during rapid ventricular filling and significantly (r=0.86, P<0.0001) increases during atrial contraction. The peak mean velocity increases only during atrial contraction (r=0.80, P<0.0001). We did not find any age correlation in other cardiac phases. Fig. 6 shows typical examples of the pattern of mean velocity and velocity gradient and their peak values during cardiac cycles in different ages.
Figure 5 The correlation between peak mean velocity and age during rapid ventricular filling (a), during atrial contraction (b). The correlation between peak velocity gradient and age during rapid ventricular filling (c), during atrial contraction (d). For abbreviations see Fig. 4.

Fig. 7 presents two examples of Doppler myocardial images and corresponding grey-scale M-mode images taken from two healthy subjects, a 34- and a 72-year-old man. Table 4 presents the timing periods between the onset of the R-wave in electrocardiogram and peak mean velocity and peak velocity gradient for each phase of the cardiac cycle.

Finally, Table 5 shows the results of a linear correlation between the standard echocardiographic measurements of regional and global systolic and diastolic function and Doppler myocardial imaging information measured in relevant phases of the cardiac cycle. In systole, a good correlation existed only between the left ventricular posterior wall fractional thickening and Doppler myocardial imaging measurements. In diastole, good correlation was present between Doppler myocardial imaging measurements and the following standard echocardiographic parameters: peak E wave, peak A wave velocities, E deceleration time.

Discussion

Doppler myocardial imaging is a new ultrasonic technique which interrogates the myocardium and allows the quantification of regional transmural myocardial velocities\(^\text{(13,35)}\). Using this technique, it is also possible to assess the spatial distribution of the myocardial velocities between the endocardium and epicardium\(^\text{(4,5)}\). The information thus obtained is not dependent on the amplitude of the returning ultrasonic signal, is not affected by the attenuating effect of overlying tissues and is obtained directly from the myocardium\(^\text{(1)}\). Thus, Doppler myocardial imaging information may play an important role in the future studies by allowing the evaluation of intramural myocardial function. Previous ultrasonic studies on myocardial contractility have been based on pulsed echo M-mode or two-dimensional images and have assessed the differences either between end-systolic and end-diastolic myocardial wall thickness and left ventricular dimension, or have involved digitization of the endocardial and epicardial echoes\(^\text{(11-13)}\).

In our previous work we have shown that specific phases of the cardiac cycle could be distinguished by identifying distinctly different peak mean velocities and their directions\(^\text{(5)}\). However, the Doppler myocardial imaging information was obtained only from a small group of young volunteers. In this study using the same technique, we measured not only peak mean velocities but also peak velocity gradients of the left ventricular.
Doppler myocardial imaging

Figure 6 (a) A graph showing the pattern of mean velocity and their peak values during sequential phases of the cardiac cycle in different age groups. --- 34 years old; ••••, 52 years old; ---, 74 years old. (b) Graph showing a typical example of the pattern of velocity gradients and their peak values during sequential phases of the cardiac cycle in different ages. ---, 34 years old; ••••, 52 years old; ---, 74 years old. *=shows peak mean velocity and peak velocity gradient in sequential phases of the cardiac cycle. PCG=phonocardiogram. For other abbreviations see Fig. 4.

posterior wall in a group of normal subjects of different ages. We have shown that during systolic cardiac phases — isovolumic contraction, early ventricular ejection, late ventricular ejection and diastolic cardiac phases (rapid ventricular filling and atrial contraction) — the subendocardium was moving faster than the subepicardium. These results are in agreement with our earlier reports and reports of others. In our previous work each cardiac cycle was divided into nine predetermined time-periods. In this study, the division was restricted to only seven phases which were more clinically relevant. However, in the current study we found that during isovolumic relaxation the subepicardium was moving faster than the subendocardium. These results are in agreement with our earlier reports and reports of others. In our previous work each cardiac cycle was divided into nine predetermined time-periods. In this study, the division was restricted to only seven phases which were more clinically relevant. However, in the current study we found that during isovolumic relaxation the subepicardium was moving faster than the subendocardium. These results are in agreement with our earlier reports and reports of others.

Correlations between peak mean velocity and peak velocity gradient with increasing age show that during rapid ventricular filling the peak velocity gradient decreased but during atrial contraction both peak mean velocity and peak velocity gradient increased with age. During other phases of the cardiac cycle there was no correlation between the analysed Doppler myocardial imaging parameters and age. These findings are in agreement with previously reported changes in pulsed Doppler transmitral flow velocity profiles which occur as a result of the normal ageing process changing the diastolic filling characteristics of the left ventricle.

The comparison of Doppler myocardial imaging measurements and standard echocardiographic parameters of left ventricular function showed that in systole, a good correlation existed between left ventricular posterior wall fractional thickening and both Doppler myocardial imaging measurements (mean velocity and velocity gradient). Interestingly, there was no correlation between other standard echocardiographic measurements of left ventricular systolic function. In diastole, a good correlation existed between both Doppler myocardial imaging measurements and peak E wave, A wave velocity and E deceleration time measured from a transmural blood flow.

In general, a better correlation was found between peak velocity gradient rather than peak mean velocity measurements and standard echocardiographic parameters. This may be explained by the fact, that peak velocity gradient measurement is very much 'region specific' and is affected only by the contraction of myocardial fibres at the point in the wall where the ultrasound beam intersects it, whereas peak mean velocity measurement is less region specific as overall heart wall motion can cause the changes in mean velocities measurements. Thus, we can conclude that the peak velocity gradient might be a better index of regional left ventricular systolic and diastolic function rather than a peak mean velocity measurement.

Limitations

Our Doppler myocardial imaging measurements have been restricted to M-mode images. Due to the angle dependence of Doppler measurements, we only analysed left ventricular posterior wall velocities derived from the parasternal long-axis view in which the interrogating beam was perpendicular to the myocardium. Future developments to create angle-independent two-dimensional Doppler myocardial imaging should allow for the interrogation of all parts of the left ventricle. A series of in vitro phantom studies have confirmed the accuracy of Doppler myocardial imaging velocity encoding over the range of velocity at which normal myocardium would be expected to move. Velocity estimation...
Figure 7  (a) Healthy volunteer, age 34, male. Doppler myocardial image M-mode (top) and simultaneously recorded standard grey scale imaging (bottom), long-axis view at the level of the mitral valve leaflets. (b) Healthy volunteer, age 72, female. Doppler myocardial imaging M-mode (top) and simultaneously recorded standard grey scale imaging (bottom), long-axis view at the level of the mitral valve leaflets. Arrows show the differences in velocities between a young and an old heart during rapid ventricular filling and atrial contraction.

Table 4  Time measured between the onset of the R-wave in electrocardiogram and the time of peak of mean velocity and velocity gradient occurrence in each phase of the cardiac cycle in normal subjects

<table>
<thead>
<tr>
<th>Time (ms)</th>
<th>IC</th>
<th>EVE</th>
<th>LVE</th>
<th>IR</th>
<th>RVF</th>
<th>AC</th>
<th>AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak MV</td>
<td>9±12</td>
<td>98±18</td>
<td>313±26</td>
<td>349±36</td>
<td>407±45</td>
<td>778±25</td>
<td>890±27</td>
</tr>
<tr>
<td>Peak VG</td>
<td>8±14</td>
<td>96±17</td>
<td>312±27</td>
<td>340±38</td>
<td>400±47</td>
<td>774±27</td>
<td>895±32</td>
</tr>
</tbody>
</table>

The data are expressed as mean ± SD. For abbreviations see Table 3.

has been shown to be affected by target velocity, target material, system receive gain and the pulse train size, but the inherent error is at worst ±10% of the measured mean velocity. The spatial resolution of the two-dimensional velocity is at worst 3 x 3 mm, with a slightly inferior axial resolution compared to standard grey-scale imaging but similar lateral resolution. This means that Doppler myocardial imaging technique is as good a spatial discriminator as both Positron-emission tomography and current nuclear perfusion techniques and thus, potentially, could be used in myocardial perfusion and viability studies if Doppler myocardial imaging could determine both myocardial perfusion (in conjunction with a venous left heart contrast agent) and reversible myocardial ischaemia (in conjunction with low-dose dobutamine stress test).

Clinical future potentials

This study allows a better understanding of trans-mycocardial velocity patterns during systole and diastole in healthy hearts. It also shows how peak mean velocities and peak velocity gradients change with increasing age. Measurement of velocity gradient during ventricular ejection can be used as a new index of regional
myocardial systolic function especially in patients with ischaemic heart disease. Our initial work showed that the measurement of Doppler myocardial imaging parameters can determine both global and regional myocardial diastolic function. Such quantitative information could be helpful in the assessment of regional myocardial viability if a predictable and specific return in contractile velocities could be induced during a low dose dobutamine infusion test. Moreover, the measurement of peak velocity gradients might have the potential to diagnose patients with different kind of myocardial hypertrophy or might be helpful for monitor therapy in patients with dilated cardiomyopathy.

We can conclude that both parameters derived from Doppler myocardial imaging, peak mean velocities and peak velocity gradients can be used as baseline values for future studies of myocardial disease process.

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