Tissue Velocity Imaging in the Investigation of Myocardial Structure and Function of the Right Ventricle

E. EBNER
Medizinische Klinik des Sophien- und Hufeland-Klinikum gGmbH, Weimar, Germany

Summary

Tissue velocity imaging (TVI) is a novel echocardiographic method based on the pulsed wave Doppler technology. The procedure provides additional information on the myocardial structure and functional capability that was not available with standard echocardiographic techniques. This article will illustrate the potential value of TVI in the clinical evaluation of the right ventricle. The origin and movement of myocardial activity, contraction as a function of velocity and direction and analysis of structures may be investigated in great detail using TVI. This innovative diagnostic technique may open up a new era in the investigation of physiological and pathophysiological mechanisms within the ventricles.

Key words

Echocardiography, tissue velocity imaging, right ventricle

Introduction

Doppler echocardiography is one of the most valuable noninvasive diagnostic tools in clinical cardiology. The echocardiographic techniques have recently been enriched by the introduction of TVI, which enables the physician to perform punctual assessments of the myocardial structure and of the direction and velocity of the myocardial activity [2-4]. With the aim of studying the hemodynamic pacemaker systems using myocardial contractility for rate adaptation, we evaluated the very defined area under the lead tip regarding contractility with the help of TVI.

Technological background

The TVI methodology is a derivation of the pulsed Doppler technique. Compared to the Doppler signal reflecting blood flow, the Doppler signal of the myocardial tissue is stronger, of lower speed, and with a narrower rate range. These differences between the two Doppler signals regarding blood flow and myocardial tissue are sufficient to differentiate them easily. With the help of specific filters blood flow can be absorbed, while tissue movement is visualized in colour. Identification of direction of movement is colour coded and standardized. Red represents tissue movements in the direction of the transducer (Figure 1), whereas blue color indicates movements in the opposite direction (Figure 2). The difference in speed is shown by different color shades and brightness. Following the positioning of the cursor, TVI enables the display of an anatomical Doppler in an analog graph.

A simultaneous comparison of a variety of myocardial regions as well as digital velocity profiles obtained by pulsed and anatomical Doppler yield precise measurements and a diagnostic description of the myocardial function. Analysis of the shapes of the curves in conjunction with the common Doppler methodology allows reproducable comparisons of different tissue segments.

In addition to the analysis of cardiac wall motion, the anatomical Doppler enables monitoring of the generation and spreading of electrical impulses. A high quality computer display and digital memory without loss of data enable TVI to be an independent echocardiographic method of very high value. It encounters new insights in myocardial function and electrophysiological mechanisms.

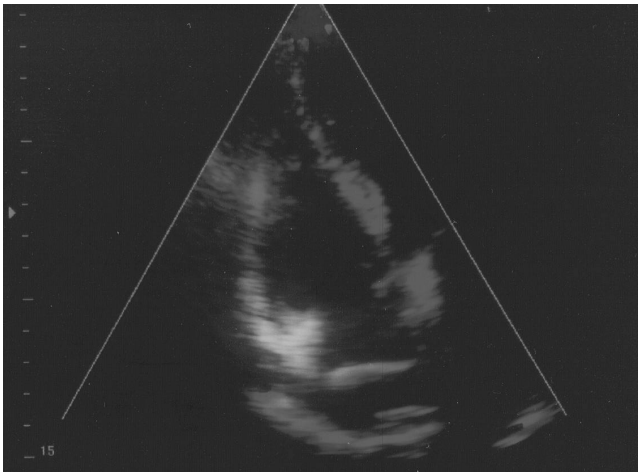

Figure 1. Direction of contraction during excitation of the right ventricle.

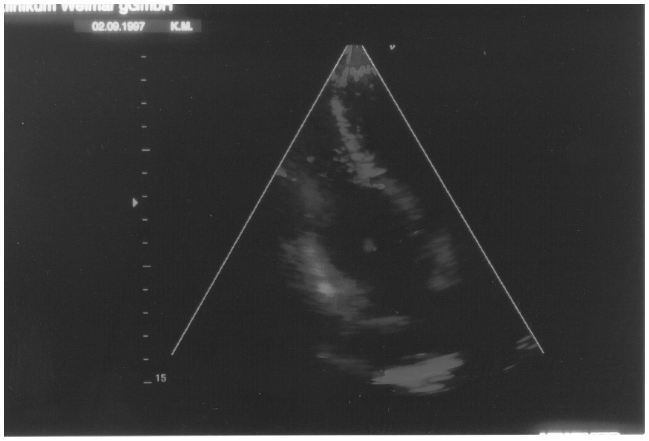

Figure 2. Direction of contraction during repolarization of the right ventricle.

Results and Discussion

The TVI method (Sontron, System Five) represents one part of the routine investigation. The key point is to observe the direction of myocardial motion in relation to the visualized level. An estimation of myocardial motion is only possible to a certain extent and depends on the heart rate. In principal, however, myocardial contraction motion and speed can be recorded in M-mode or as a speed profile. Both methods ensure different and new aspects.

Observing the structure of normal myocardium during contraction a clear uniformity in contraction direction and differentiation in motion change can be seen (Figure 3). Ischemic myocardium and tissue scars show irregular contraction motion, as was expected (Figure 4). Irregularities can be seen, which are similar between consecutive heart beats, but are not clearly defined. These results are true morphological disorders and represent the pathological condition. It becomes apparent, that TVI enables very defined views of the contractile capability of the myocardium, allowing a kind of mapping in the visualized plane [4].

In the region of the apex we also saw different contraction directions within the same cycle. In comparison to ischemic myocardium the movements, however, are well defined and seem to be systematic (Figure 5). When performing the TVI from the base of heart towards the apex the movements of the fibers and its' changes can almost be documented. During one cycle and especially during the systolic phase in the ventricles we found a wide range in contraction velocity. Velocity seems to be higher at the base of the heart

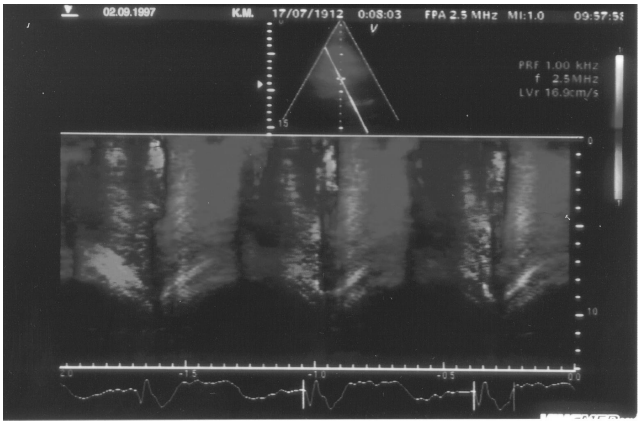

Figure 3. M-mode illustration of TVI after pacemaker stimulation. The movement of contraction is separated sharply and differentiated by several brightness.

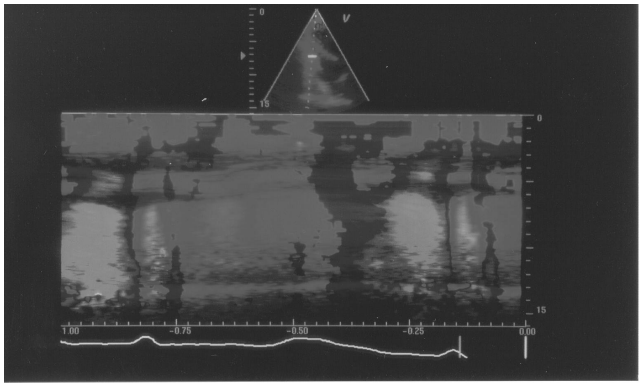

Figure 4. M-mode illustration of TVI with ischemic myocardium. Corresponding to the excitation an irregular contraction is shown.

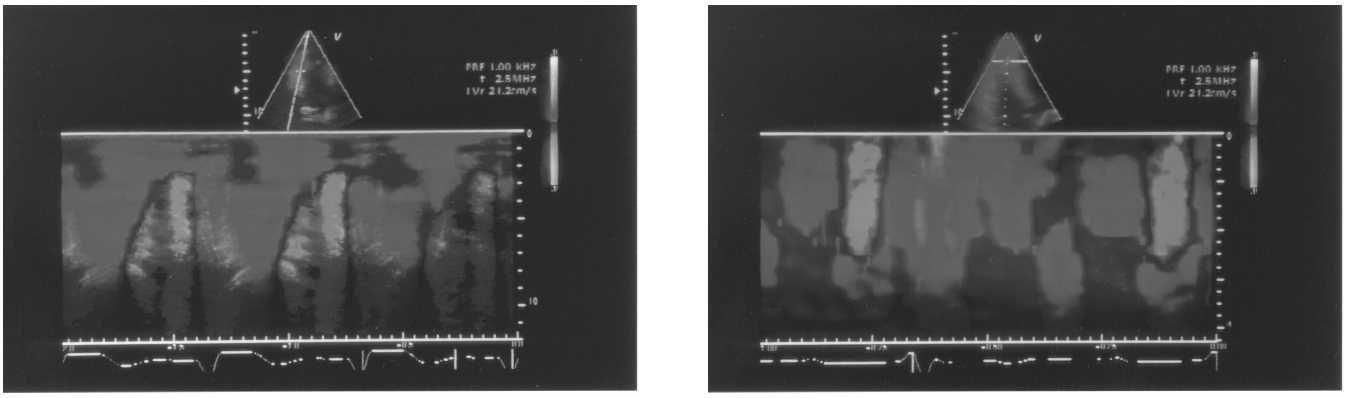

Figure 5. M-mode illustration of TVI near the apex (left) and in the apex (right). The direction of contraction and the intensity are different but can be distinguished. The different directions of contraction result from the myocardium of the left and right ventricle.

(Figure 6) compared to the apex and overall it is highest during the isovolumetric phase of the systole (Figure 7).

Velocity curves can be identical in different but congruent parts of the heart, e.g. in the lateral free wall and the septum of the right ventricle (Figure 8). In contrast to the lateral free wall the interventricular septum shows obviously a more balanced contraction which could be explained with participation of the thick left ventricle.

According to the present knowledge, obtained by observations, in the area of measurement the signal is composed of the totally movement of the ventricle and the contraction of the single myocardial fibrils. In order to differentiate the two influences more clearly, additional investigations are necessary in the future, however it is clear that the contraction of the myocardium dominates.

In addition TVI represents an important and reliable method to investigate and describe the cooperation of the left and right ventricle under physiological and pathophysiological conditions.

In the context with rate responsive pacemaker systems based on the contractility, different statements can be derived from the investigation with TVI. In contrast to systems obtaining their signal out of the region around the tip of the electrode, the local restricted contractility does not have the same importance to systems based on acceleration transducers located in the electrode. In this case the described morphologic peculiarities,

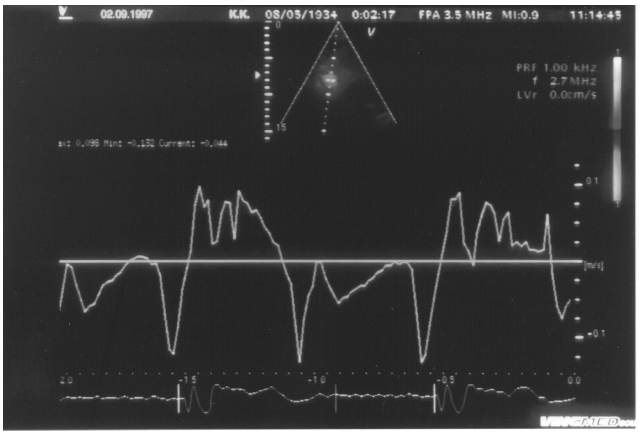

Figure 6. Contraction velocity curve during an heart cycle in the middle area of the free lateral wall of the right ventricle. The movement before the excitation caused by a stimulation can be seen.

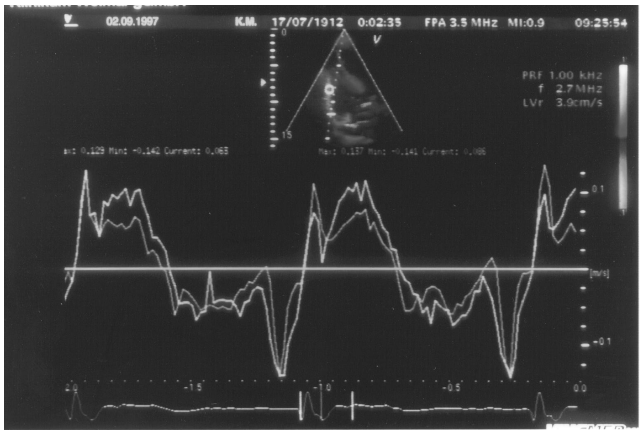

Figure 7. Contraction velocity curve of the middle area of the free lateral wall of the right ventricle in comparison to the basis (bright line).

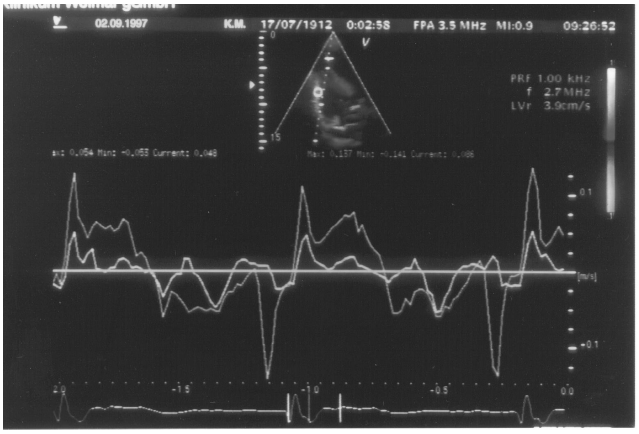

Figure 8. Contraction velocity curve of the middle area of the free lateral wall of the right ventricle in comparison to the apex (bright line).

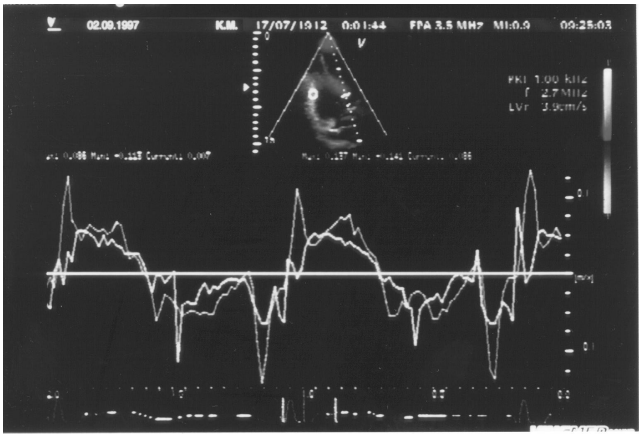

Figure 9. Contraction velocity curve of the middle area of the free lateral wall of the right ventricle in comparison to the septum (bright line).

which can be observed in each single case, could be important for the stability and therefor the reliability of the pacemaker system. Here the TVI could be used as a diagnostic tool.

Furthermore the use of TVI within the echocardiography enables the additional investigation of a number of important aspects to get more and new information about the contractility of the heart. The analysis of local disturbances in the contractility as well as the contraction velocity during the single heart cycles make it possible to identify the origin of the electrical impulse and its distribution. Therefor the origin of the excitation becomes visible which can be useful, not only in the case of an intrinsic regular excitation or a stimulation by a pacemaker but also in the case of preexcitation syndrome and ectopic centers [1]. As indicated above the direction of contraction and therefor the contraction velocity curves are influenced by the kinetic of the complete heart resulting from the interplay of atrium and ventricle. The contraction of the atrium is obviously the reason for the observation of an high velocity in the early systole, even though the isovolumetric contraction phase represents the most contractile. However, the valence of the TVI method is not restricted.

The power of myocardial contractility is determined by three quantities: the contractility, Frank-Starling mechanism and the inotropy. It should be mentioned, that the contraction velocity is influenced by changes in the preload resulting from AV-delay modifications how they are provoked by dual chamber pacemakers. The shortening of the AV-delay, which leads to a diminished stroke volume and cardiac output, influences velocity profile measured by TVI. In contrast the prolongation of the AV-delay leads on the one hand side to a clear separation of the atrial action from the ventricular contraction and on the other hand to a moderate diminished amplitude during the isovolumetric contraction phase. Herewith the changes in diastolic function of the ventricle can be described by the TVI method.

Conclusion

TVI allows a description of the ventricular excitation, the contraction and also the elasticity of ventricles. TVI opens a new field of investigation to clear some aspects in future.

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