Editorial

Tissue Doppler echocardiography

The assessment of ventricular function is one of the principal tasks of any echocardiographic laboratory and standards have been established for the determination of overall left ventricular systolic function.[1] Analysis of regional ventricular function is of particular importance because abnormalities may be detected before any change is apparent in measures of global function. Until now, quantitative evaluation of regional function has been performed by digitised ventriculography,[2] cross sectional echocardiography with segmental analysis,[3] regional M mode echocardiography in the long and short axis views,[4] and magnetic resonance imaging tagging.[5] Tissue Doppler echocardiography (TDE) is a new imaging method which has the potential to assess segmental systolic and diastolic function in both the left and right ventricle.

Technical background

TDE is a modification of conventional colour Doppler technology in which signals arising from the tissues (<10 cm/s and of high amplitude), rather than from blood flow (10–100 cm/s and of low amplitude), enter the autocorrelation and velocity calculation units. This is achieved by a reduction in overall gain and bypass of the high pass filter.[6–8] The calculation of low velocities is enhanced and these are displayed with full scale of colour brightness. Aliasing is not observed because these low tissue velocities do not exceed the Nyquist limit, which is determined by the pulse repetition frequency. Further technological advances have achieved higher frame rates (up to 95 Hz) by parallel processing and improvements in velocity resolution (0·2 cm/s).[9] TDE velocity measurements have been validated experimentally against rotating phantoms[7] and show good correlation with clinical M mode endocardial velocity measurements.[8] But the great advantage of TDE over M mode echocardiography is that it will convert multiple samples of velocity data onto a two dimensional image. The velocities recorded are influenced by the incident angle of the Doppler ultrasound beam and by whole heart motion; important issues for TDE which remain to be resolved.

Myocardial thickening

Studies using implanted ultrasound crystals and Doppler ultrasound have demonstrated that the rate of myocardial thickening is not uniform across the ventricular wall, being highest in the subendocardium and lowest in the subepicardium.[10 11] TDE shows this normal pattern as a transmural gradient of velocities (fig 1), and this gradient has been shown to be reduced in patients with ischaemic heart disease and congestive cardiomyopathy.[12] Though measurement of thickening of the entire myocardial wall is not suitable for evaluation of subendocardial function, the combination of TDE with dynamic or pharmacological stress may prove important for the early detection and analysis of regional myocardial dysfunction before wall motion abnormalities develop.[13]

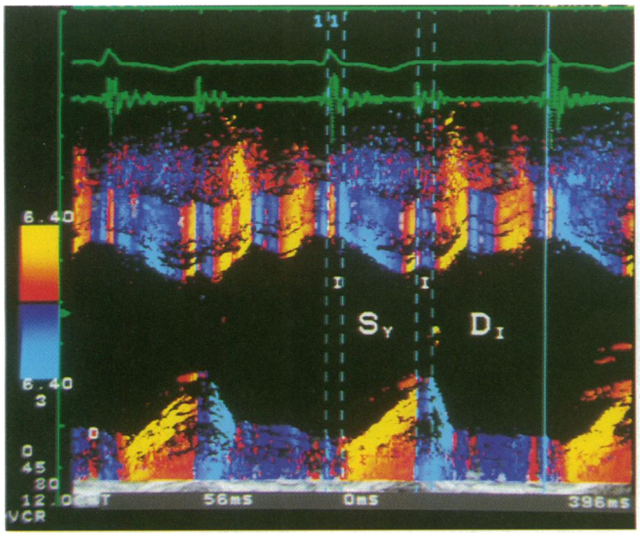

Figure 1 Parasternal M mode tissue Doppler echocardiogram, showing the normal contraction pattern and distribution of velocities. The highest myocardial velocities are indicated by light blue and yellow and lower velocities by dark blue and red. During systole (S_Y) and early diastole (D_I) the subendocardial layers are coded with light blue and yellow, whereas the subepicardial layers are coded dark blue and red. The transmural velocity gradients in the interventricular septum and posterior wall are normal.

Ventricular asynchrony

The homogeneous contraction of the left ventricle is easily appreciated on the typical TDE presented in fig 2. In the apical view, irrespective of angle correction, myocardial

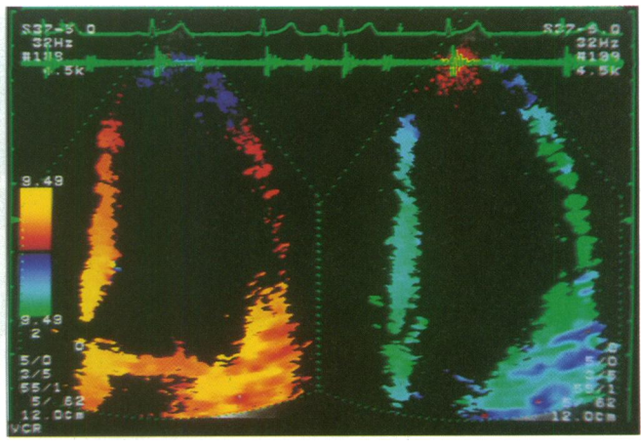

Figure 2 Apical four-chamber tissue Doppler echocardiogram, showing the normal pattern of relaxation and contraction. Myocardial velocities are highest in the base of the heart and decrease toward the apex, with reversal in the apical area. Note the synchrony of the septum and lateral wall as indicated by the same myocardial velocities in the opposite wall layers.

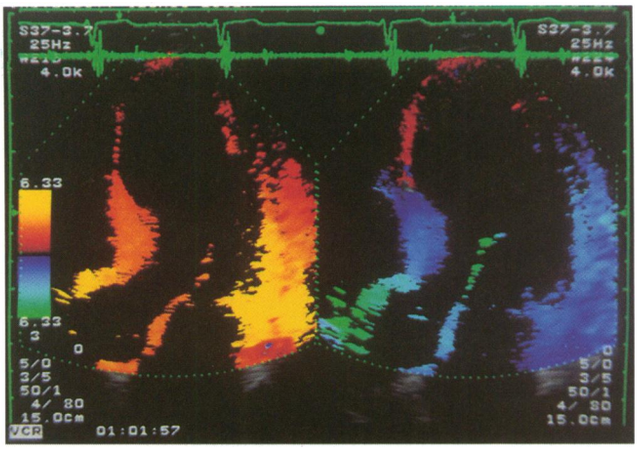

Figure 3 Apical four-chamber tissue Doppler echocardiogram, showing asynchrony of the left ventricle caused by coronary artery disease. During systole (left) the apex is colour coded red (outward motion) and during early diastole (right), the distal septum is colour coded red, indicating motion towards the transducer in a direction opposite to that of the lateral wall or proximal septum (colour coded blue).

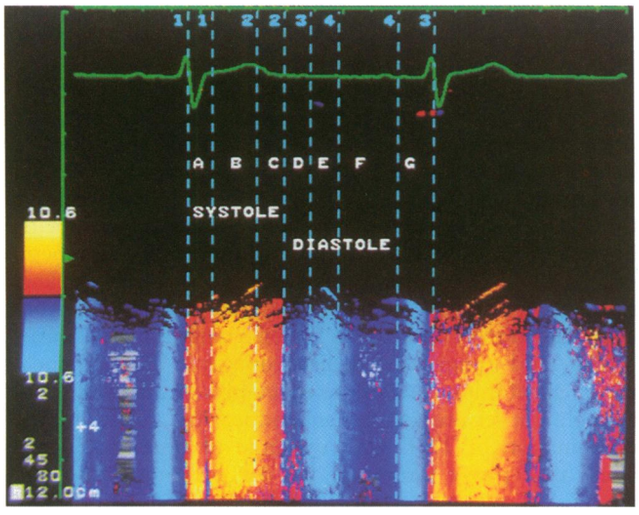

Figure 4 M mode images of the septum obtained from the apex, showing simple identification of the different physiological time intervals. A = isovolumic contraction; B = rapid ejection; C = late ejection; D = isovolumic relaxation; E = rapid ventricular filling; F = diastasis; G = atrial contraction.

velocities are higher at the base of the heart than in the mid ventricular region, and are in a direction opposite to that of the apex. This characteristic pattern of contraction was initially described by Ingels *et al*, after a detailed analysis of the motion of myocardial markers implanted in the left ventricle during cardiac surgery.[14] The centre of gravity was defined by the trajectories of the implanted markers, which crossed a line from the base to the apex of the heart at 69% of the distance, and this technique proved more reproducible than either the half axis or radiant method. The velocity vectors of TDE, resulting from the forward and inward motion, similarly demonstrated that the centre of gravity is located close to the apex.

Assessment of global and regional left ventricular function, which uses exclusively end diastolic and end systolic frames, neglects the important role of asynchrony in common cardiac pathologies, such as coronary artery disease and cardiomyopathies. The comprehensive work of Gibson and Brown, who undertook meticulous frame-by-frame analysis of left ventricular cineangiograms, showed marked asynchrony in plots of regional wall movement against time that particularly affected the isovolumic relaxation period.[15] In contrast to this off-line method which is time consuming and not easily incorporated into routine investigation, TDE facilitates rapid, on-line analysis of cardiac asynchrony,[13 16] as shown in fig 3. This may find an application in the assessment of viable myocardium in subjects with abnormal wall motion at rest and in subjects with hypertrophic cardiomyopathy where regional diastolic asynchrony has already been demonstrated by TDE.[17] Thus TDE offers a new perspective on the assessment of global and regional right and left ventricular function.

Physiological time intervals

Compared with the relatively low sampling frequency of two dimensional TDE, the high temporal resolution of M mode TDE may be used to measure systolic and diastolic time intervals on a regional basis. The different colour interfaces of the velocity patterns correspond with the known physiological phases of the cardiac cycle: pre-ejection, ejection, isovolumic relaxation, rapid filling, diastasis, and atrial contraction (fig 4).[18] By this means, regional abnormalities of diastolic time intervals have been demonstrated in coronary artery disease and hypertrophic cardiomyopathy.[17] This may be a new approach not only for clinical cardiology but also for clinical pharmacology.

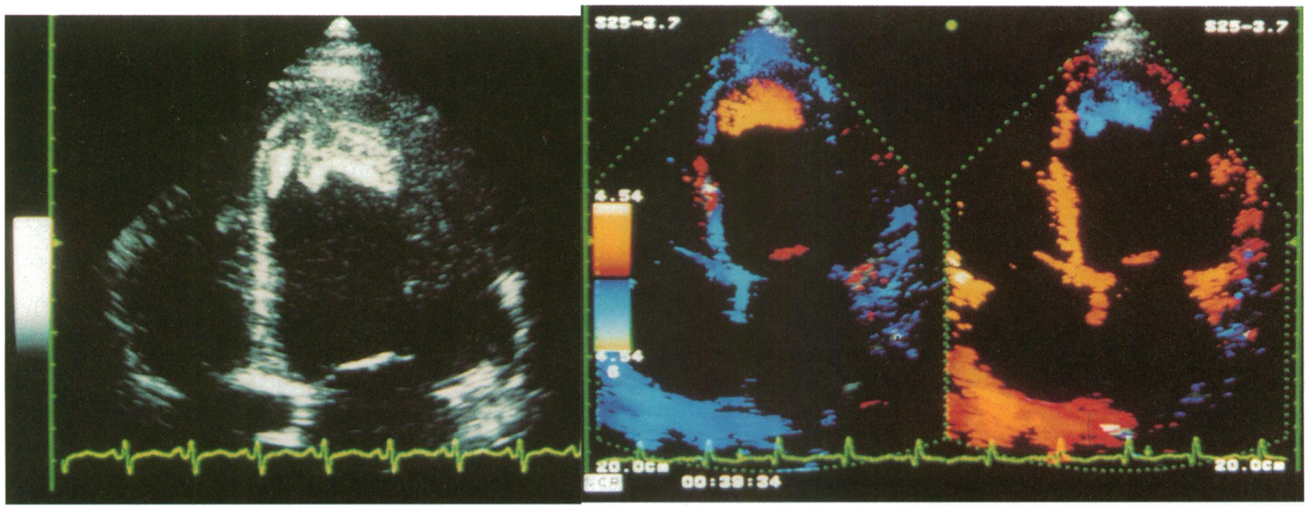

Figure 5 Apical images of a left ventricular apical thrombus (conventional grey scale, left; TDE, right) showing the improved identification of structures by TDE. The direction of motion of the thrombus (colour coded yellow) is opposite to that of the adjacent myocardium (colour coded blue).

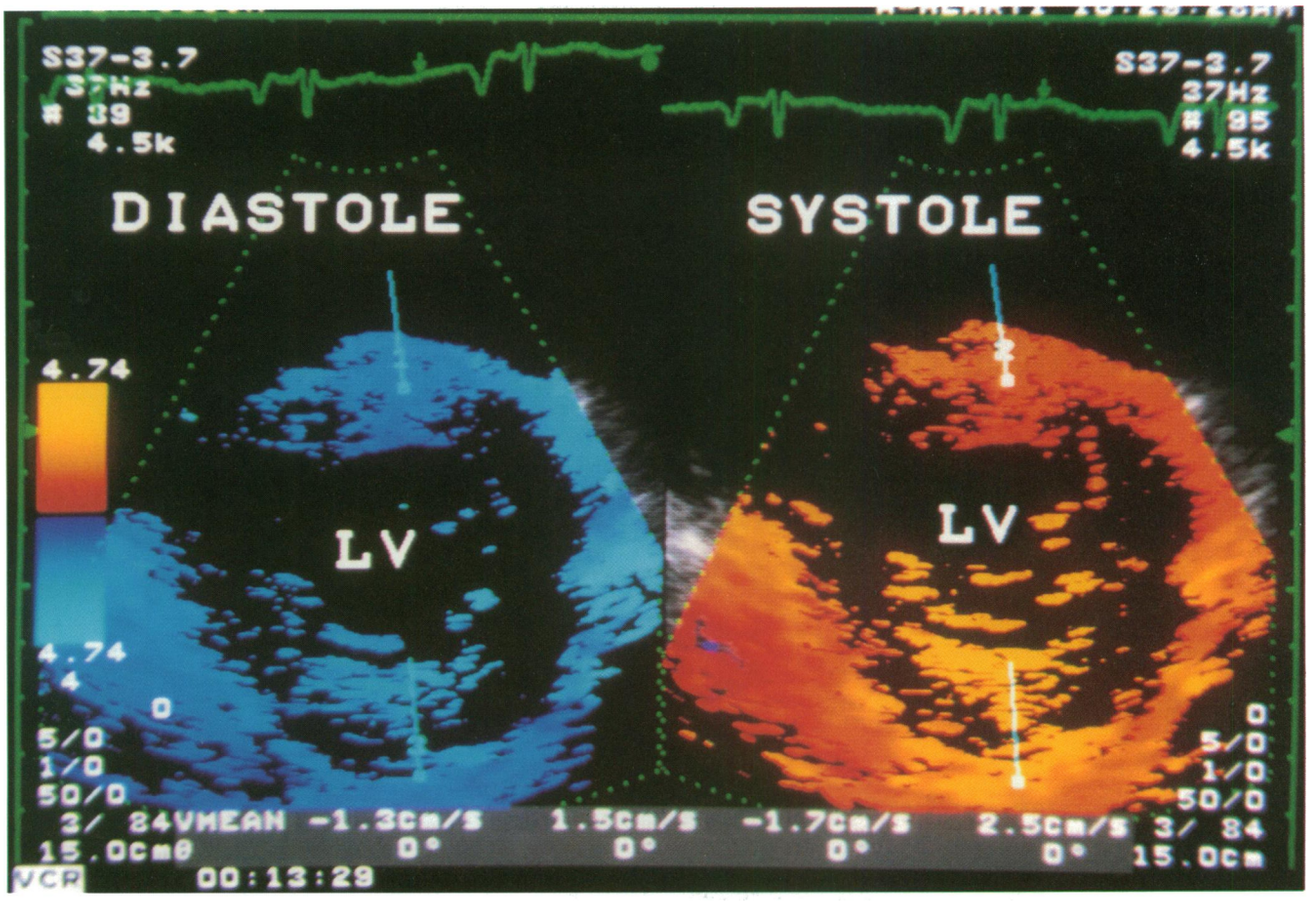

Figure 6 Parasternal short axis tissue Doppler echocardiogram from a subject with cardiac amyloidosis, showing the characteristic sandwich pattern. In both diastole (left) and systole (right) the epicardial and endocardial layers are colour coded, but the velocity of the myocardium is very low and therefore is colour coded black.

Miscellaneous applications

Because only moving structures are colour-encoded, TDE can be used for structure identification, facilitating measurement of right ventricular wall thickness[19] and delineation of tumours, thrombi (fig 5), and vegetations.[16] In Wolff-Parkinson-White syndrome, Nakayama *et al* demonstrated that two dimensional TDE could reliably identify the insertion of an accessory pathway into the left ventricle and normalisation of the contraction pattern after successful ablation.[20] It seems likely, therefore, that TDE will complement existing imaging techniques applied to cardiac electrophysiology. Cardiac amyloidosis has a characteristic conventional M mode appearance with a complete loss of thickening and thinning of the posterior wall caused primarily by a reduction in the amplitude of endocardial motion. The TDE findings are similarly striking, with a marked reduction in endocardial and myocardial velocities and diminution of the transmural velocity gradient. A "sandwich" pattern is seen, owing to the fact that mid wall velocities are below the lower limit of detection and that only the endocardium and epicardium are colour coded (fig 6).[16]

Conclusions

TDE provides a new method for the already rich armamentarium of echocardiography. Transmural velocity gradients can be measured, asynchronous ventricular contraction and relaxation visualised on-line, and global and regional systolic and diastolic time intervals documented. TDE is a relatively young technology and clinical applications continue to emerge for it.

R ERBEL
D R WALLBRIDGE
J ZAMORANO
J DROZDZ
H J NESSER

Department of Cardiology, Division of Internal Medicine, University Clinic, Hufelandstrasse 55, 45122 Essen, Germany

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STAMPS IN CARDIOLOGY

René Théophile-Hyacinthe Laennec (1781–1826)

This is the only stamp to feature Laennec. It was issued by France on 7 November 1952 as a single stamp and not part of a set featuring other personalities or celebrities. As is frequently the case the rare appearance of notable medical personalities on postage stamps is usually seen from their country of origin or their country of major medical practice.

René Théophile-Hyacinthe Laennec, the inventor of the stethoscope, was born in West Brittany the son of a lawyer and was a pupil of Jean-Nicolas Corvisart at La Charité Hospital, Paris. He introduced the technique of indirect (mediate) auscultation—rather than applying the ear directly to the chest—first by using a cylinder of rolled paper to auscultate the heart of a girl as "her age and sex forbade an examination [by direct auscultation]". Although his first stethoscope was a cyclinder formed of three quires of paper he explored the use of other materials to obtain the best sound transmission. He finally settled on a wooden stethoscope 13 to 18 inches long and 1·5 inches in diameter perforated longitudinally by a bore one quarter inch wide and hollowed out into a funnel shape at one end. He published his text on mediate auscultation *De L'Auscultation Médiate ou Traite du Diagnostic des Maladies des Poumons et du Coeur* with diagrams of his stethoscope in 1819.

He identified for the first time that the cardiac cycle consisted of two sounds and described the auscultatory findings in cardiac and pulmonary disease. He also introduced his method of mediate (or indirect) percussion, striking the chest with his fingers while listening with his stethoscope.

In his classification of pericardial diseases, under the category of "accidental productions", he described the pathological findings in tuberculous pericarditis often in association with widespread pulmonary involvement. In 1826 he introduced the term dissecting aneurysm (in the second edition of *Traite de L'Auscultation Medicale*) although he subscribed to the belief that dissection preceded the formation of all aneurysms.

Throughout much of his life he suffered from pulmonary tuberculosis and died from this disease at the age of 45.

M K DAVIES
A HOLLMAN