Can we quantify ischaemia during Dobutamine stress echocardiography in clinical practice?

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This editorial refers to “Comparison of deformation imaging and velocity imaging for detecting regional inducible ischaemia during Dobutamine stress echocardiography” by J.U. Voigt et al. on page 1517.

Dobutamine stress echocardiography (DSE) is an accurate non-invasive technique for detecting coronary artery disease and is a test which has significant prognostic value in clinical practice, both in detecting viability and in risk stratification. However, the current clinical implementation of the technique is based solely on the visual detection of ischaemia-induced radial wall motion abnormalities. As such, this approach relies strongly on operator experience and does not attempt to define the distal ischaemic substrate. Reported sensitivities and specificities of DSE for the detection of CAD range between 80% and 85% when performed by experts.

One of the main limitations of DSE is the subjective nature of visual interpretation. This is due to a combination of lack of uniform diagnostic criteria and the inability of the eye to resolve the complex short-lived abnormal mechanical events induced by ischaemia. These two factors are mainly responsible for the poor inter-institutional agreement which exists. Indeed the correct visual interpretation of stress echo images requires long training and continuing experience. This is reflected in the current ASE guidelines which recommend the interpretation of at least 15 DSE per month to maintain interpretational skills. Such intensive individual exposure is not frequent. To overcome these limitations several new ultrasound techniques, based on high frame rate imaging, have been developed which could potentially quantify DSE. These include Doppler myocardial velocity imaging (DMI) and its derivatives, regional strain/strain rate imaging (S/SR). To define an ischaemic substrate any quantitative imaging technique must resolve and measure the amount of systolic versus ischaemia-induced post-systolic deformation at rest and during DSE. Theoretically, this should better be done by strain/strain rate rather than velocity imaging.

DMI velocity imaging has the temporal resolution to resolve and quantify regional longitudinal myocardial velocities. As myocardial ischaemia is earliest expressed as an abnormality in subendocardial function (and this layer is mostly constituted of longitudinally orientated fibres) it is entirely appropriate to use an imaging approach which resolves regional longitudinal function rather than radial. In patients, the regional response in longitudinal peak systolic velocities was shown by Fathi and Cain to offer an improvement in sensitivity and accuracy of DSE with only minimal compromise in specificity. These authors suggested that the use of individual velocities cut-off for each myocardial segment could be used by non-experts to quantify the velocity response accurately and thus overcome the need to be an expert. In a similar multi-centre European study the MYDISE investigators again demonstrated high sensitivities and specificities for such a velocity-based approach but, in contrast to Cain, used a complex regression model for their analysis. Recently, Celeuktiene et al. extended the range of regional velocity parameters which were measured to include regional post-systolic shortening and suggested that the presence and magnitude of post-systolic longitudinal motion measured by PW spectral DMI during DSE was the most sensitive and specific marker of induced ischaemia.

However, regional myocardial velocity evaluation has important limitations. An increase in myocardial peak systolic velocity does not necessarily reflect increased contractile function. Moreover, regional velocity profiles...
and their change during a Dobutamine challenge might not provide sufficient information to define the ischaemic substrate. Furthermore, ischaemic post-systolic motion may not be the optimal parameter to measure as it can occur in transmurally infarcted segments for many days after the acute event and should not be used as an isolated parameter to represent segment viability.

Regional strain rate (the rate of myocardial deformation), and regional strain (percentage deformation), can now be derived by post-processing a high frame rate myocardial velocity data set. One-dimensional regional strain/strain rate (S/SR) imaging has been shown to be a more sensitive technique for quantifying myocardial deformation compared to other standard cardiac imaging modalities.

With the implementation of the regional strain and strain rate imaging, it has been shown in the experimental setting that it is potentially possible to identify all distal ischaemic substrates and the adequacy of their flow reserve.2–9

Clinical studies have shown that S/SR data acquisition is feasible during a standard DSE. In normal subjects during DSE there is a linear increase in peak systolic strain rate and a biphasic peak systolic strain response. Both experimentally and clinically it has been demonstrated that S/SR imaging can detect both resting and DSE induced abnormalities in deformation which occur in the varying ischaemic substrates. Such differentiation is on the basis of the comparison of regional deformation information acquired both at rest and during DSE. During acute induced ischaemia there is a progressive reduction in systolic S/SR with a concomitant development or increase in post-systolic strain (PSS). These ischaemic changes have been shown to be detectable by S/SR imaging earlier then changes in either tissue velocities or in visual detection of regional wall motion abnormalities.

Stunned (post-ischaemic) myocardium has an abnormal deformation pattern at rest that is similar to that of ischaemic myocardium. However, during a low-dose DSE challenge there is a normalization of peak systolic S/SR with an associated progressive decrease in PSS. In contrast, an ischaemic response is characterized by a dose-dependent increase in PSS associated with either a reduction or no changes in systolic SR/S. By combining a baseline study with a Dobutamine challenge, it is also possible to differentiate a transmural myocardial infarction from a non-transmural.

Flow-reserve can also be evaluated during DSE by assessing changes in peak systolic strain. During DSE, a decrease in peak systolic strain compared to baseline indicates the absence of flow reserve; in contrast, an increase in peak systolic strain is an indicator of the adequacy of flow reserve.

In the paper published in this issue, Voigt et al.,10 for the first time, have addressed the issue whether velocity data alone is sufficient to identify and characterise induced ischaemia. They compared the sensitivity and specificity of standard 2D grey-scale imaging, DMI velocity imaging and S/ SR imaging with nuclear perfusion data in a population of 44 patients undergoing DSE. Using conventional echocardiography 97% of segments could be assessed, giving a sensitivity and specificity of 81% and 82%, respectively for the detection of a perfusion defect. Quantitative analysis of tissue velocity imaging was possible in only 92% of segments. Peak systolic velocity was the best of the velocity parameters with which to detect ischaemia. This had a sensitivity of 74% and specificity of 63%. These values are lower than those obtained in other velocity-based quantitative studies, but in contrast to prior studies, Voigt et al., included patients abnormal wall motion at rest in order to study the whole spectrum of ischaemic substrates encountered in clinical practice. In contrast, interpretable regional S/ SR imaging curves were obtained from only 85% of segments. A post-systolic/maximal systolic strain ratio >35% showed the highest sensitivity and specificity in detecting ischaemia (82% and 85%, respectively). Using this combined parameter, Voigt et al. confirmed S/ SR imaging to be a very accurate method for identifying the distal ischaemic substrate even in patients with prior myocardial infarction.

In conclusion, quantifying ischaemia-induced changes in myocardial deformation is necessary to define both the ischaemic substrate and its flow reserve, thus decreasing the subjectivity of the test and at the same time reduce training requirements, allowing the test to be performed and quantified by non-experts.

In light of the above findings, the following approach might be the most appropriate to apply for the quantitation of DSE in clinical practice. Firstly, there should be a visual inspection of the images as the eye is extremely good at detecting synchronicity of motion and a perception of synchronous motion in all left ventricular segments is highly predictive of normality. Quantification is not necessary in such cases. When visual inspection suggests there is a regional radial wall-motion abnormality, the regional long-axis velocity responses during DSE should be used as a first line approach. If this is abnormal, long-axis strain and strain rate imaging should be used to define the ischaemic substrate and assess the regional flow reserve. In hearts with conduction or rhythm disturbances or complex wall-motion abnormalities at rest, deformation imaging should now be used as the first line approach to assessing regional function.

References


