The difficulties of assessing right ventricular function

It is 20 years since Sade and Castaneda concluded from experiments investigating the effect of cautery of the canine right ventricular free wall and from the success of right ventricular bypass procedures for tricuspid atresia that the right ventricle is “dispensable”. Since then the importance of right ventricular dysfunction in many cardiac conditions has become clearer, and the long-term results of the Fontan operation have suggested that the term “dispensable” may have been an oversimplification, because atrial arrhythmias and rising pulmonary impedance are often so poorly tolerated. In addition, it is increasingly apparent that right ventricular function is a significant factor in ischaemic heart disease.

Cohn et al’s description of the syndrome of right ventricular infarction, with raised venous pressure, low output, and clear lungs, suggested that the right ventricle may be of importance in coronary disease, and this was dramatically demonstrated in studies of acute inferior infarction reported by Zehender et al in which right ventricular infarction was associated with a 31% in hospital mortality and 64% major complication rate and in which thrombolysis was only of benefit in those patients with demonstrable right ventricular involvement. It has been proposed that right ventricular function may be a better guide than left ventricular function to functional state and even prognosis in patients with chronic heart failure caused by coronary disease. Furthermore, the assumption that right ventricular dysfunction is simply a marker for raised pulmonary resistance resulting from left ventricular dysfunction is challenged by the observation that right and left ventricular ejection fractions show no correlation in acute infarction and chronic heart failure. In Zehender et al’s patients the left ventricular ejection fractions in groups with and without right ventricular infarction were the same. New techniques for studying ventricular function are therefore being applied to the right ventricle, but usually with disappointing results because it is difficult to assess right ventricular volume.

MRI scanning

Magnetic resonance imaging (MRI) scanning has several advantages over other imaging techniques in the right ventricle. In 1986 Markiewicz et al showed that clear endocardial and epicardial signals from the right ventricle could be identified, and that there was a potential for volume estimation from tomographic cuts. More recently Suzuki et al used cine-MRI to study the right ventricle (estimating volume from 10 mm spaced simultaneous transverse slices analysed by Simpson’s rule) and, by calculating an average of 18 volumes per cardiac cycle, constructed volume-time curves in patients with dilated and hypertrophic cardiomyopathy. On page 186 Naito et al describe the application of a presaturation tagging technique to the study of the right ventricle, and the study shows the advantages and weaknesses of MRI in this context. They confirm the expectation from echocardiographic and anatomical studies that the predominant contraction of the right ventricle is longitudinal and quantify that contraction regionally. However, neither this technique, describing regional shortening fraction, nor Suzuki et al’s volume-time analysis allow the assessment of contractility or compliance that are the fundamentals of ventricular function. The most useful models for this kind of analysis in the left ventricle involve the description of pressure-volume relations within the cardiac cycle, at steady state and when loading varies. The time required to acquire one MRI study is a major obstacle to its application to the study of dynamic right ventricular pressure-volume relations.

Twenty years ago Suga et al described the active and passive properties of an isolated left ventricle as the constants that relate pressure to volume during systole and diastole. One success of this approach has been its ability to distinguish changes in contractility (Emax, preload recruitable stroke work) and compliance (stiffness) from changes in loading conditions and mechanical constraint, in an experimental and clinical setting. The other advantage of this model is that the viscoelastic properties of the
ventricle and vascular bed into which it ejects can be described in common terms as an elastance \( (E_{\text{max}}) \) and effective arterial elastance \( (E_a) \), allowing a simple description of the coupling between the ventricle and its afterload. Maughan \textit{et al}. showed that the assumptions that underlie Suga \textit{et al}.'s "time varying elastance" model are generally valid in the canine right ventricle,\(^1\) and the coupling between the right ventricle and the pulmonary circulation has been extensively investigated in animal models. In the pig, right ventricular stroke volume increased in response to increasing afterload until arterial elastance exceeded \( E_{\text{max}} \), when falling stroke volume signalled right ventricular pump failure.\(^2\)

The ability to distinguish between the effects of loading and intrinsic changes in ventricular function makes pressure-volume analysis ideal for the study of right ventricular function in coronary disease and other causes of congestive heart failure. Conventional and new imaging techniques have as yet been unable adequately to provide a reliable, continuous right ventricular volume signal at a high enough acquisition frequency for the construction of continuous pressure-volume cycles, and it is likely that non-image dependent conductance catheter technology will provide the method for distinguishing between ventricular overload and ventricular failure in the future.

In conclusion, MRI provides a non-invasive method of assessing right ventricular volume at an acquisition frequency sufficient for the study of change during the cardiac cycle, and tagging adds the facility for a degree of regional wall motion analysis. Without the capacity for simultaneous pressure recording and real time acquisition and display, however, it does not allow right ventricular function to be characterised in much more depth than the estimates of ejection fraction that are currently available from radionuclide techniques. It is well recognised that deteriorating right ventricular pump function may reflect the sensitivity of the right ventricle to changes in ventricular loading that may occur during left ventricular disease—directly through abnormal septal function and indirectly through increasing impedance in the pulmonary circulation. However, the high incidence of circulatory collapse independent of arrhythmia and more importantly of left ventricular function in patients with right ventricular involvement in acute inferior infarction suggests that right ventricular dysfunction is more than simply an index of left ventricular filling pressure. In Zehender \textit{et al}.'s patients, those with infarction limited to the left ventricle had a mean left ventricular ejection fraction of 43% compared with 44% in the group with right ventricular involvement. Despite this, 27% of the patients in which the right ventricle was affected developed cardiogenic shock compared with 5% of those with simple left ventricular infarction. The right ventricle can therefore no longer safely be assumed to be following its dominant partner. It requires independent assessment and perhaps treatment in many patients.

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