25.1 Echocardiographic Assessment of RV Function

Imaging of the right ventricle by b-mode echocardiography has notoriously been difficult. In order to assess right ventricular (RV) ejection fraction, the end-diastolic and end-systolic volume need to be measured. As the RV shape is very complex, none of the formulas to measure RV volume and calculate RV ejection fraction from cross-sectional (b-mode) images has stood the test of time [1]. With the advent of three-dimensional (3D) echocardiography it has been possible accurately to calculate right ventricular (RV) volumes. We have validated 3D echocardiographic measurements of RV volume in vitro [2] and in vivo [3] and have applied it clinically in patients with tetralogy of Fallot [4]. Recent developments in 3D echocardiography have made the method a lot less time consuming and thus expanded its clinical applicability (Fig. 25.1). Unfortunately RV ejection fraction is a poor index of ventricular contractile function because it is very load dependent. Loading conditions are abnormal or widely variable in many patients with congenital heart defects, so the use of any ejection-phase index to determine RV function in congenitally malformed hearts is questionable.

Simple alternative methods to assess RV function like the myocardial performance (TEI) index may be applied independent of RV shape but have similar limitations as ejection fraction with regard to load dependency [5].

Furthermore, many patients with congenitally malformed hearts have abnormal regional RV function on top of a reduced global dysfunction.

Myocardial Doppler which is based on sampling myocardial velocities anywhere along the ventricular wall has the potential to (1) assess global function independent of RV shape and (2) to assess regional wall motion [6].

Doppler myocardial imaging (DMI)-derived peak systolic and diastolic velocities, strain and strain rate have emerged as useful tools to quantify regional ventricular function [6–8]. Their utility to assess global function is limited, like most single-beat ejection-phase indices by both pre- and afterload dependency [9, 10]. However, they have greatly facilitated the assessment of regional ventricular function [7] and have led to new clinical insights [6]. For the assessment of global function, measurements of myocardial contraction during the isovolumic period are likely to be more robust than ejection phase-based indices. One of the most common measured isovolumic indices remains dP/dtmax which can only be assessed by invasive techniques [11]. Previous myocardial Doppler studies have assessed myocardial velocities during isovolumic contraction or so-called pre-ejection [12]. The peak myocardial velocity during isovolumic contraction, measured in the posterior wall of a short-axis section, changed appropriately with m-mode-derived ejection fraction changes during dobutamine infusion. The lack of further pharmacologic manipulation with negative inotropic drugs, a lack variation of pre- or afterload, and the use of ejection fraction as the index of contractility to which velocities were compared to make interpretation of these data difficult.

Ten years ago, the acceleration of the endocardium was measured using an accelerometer sensor mounted on a pacemaker lead [13]. An almost linear increase of endocardial acceleration during an infusion with dobutamine was detected [13]. More importantly, these studies found that peak endocardial acceleration occurred during isovolumic contraction rather than during the ejection phase [14]. Recently, endocardial acceleration assessment was also used to detect acute myocardial ischemia during percutaneous transluminal coronary angioplasty [15].
Myocardial Doppler allows for noninvasive measurement of acceleration during isovolumic contraction. If the peak myocardial velocity is known, and temporal resolution is adequate, the calculation of the acceleration during isovolumic contraction (IVA) is straightforward (Fig. 25.2). This measurement has been tested by our group in a variety of experimental and clinical settings.

25.2 Validation of IVA as an Index of Contractile Function

We used myocardial Doppler to measure the acceleration of the myocardium during isovolumic contraction (IVA), after we had noticed that the ventricular myocardial velocity during isovolumic contraction increased more markedly than the peak systolic velocity during dobutamine stress evaluation of contractile reserve in adults with congenital heart disease.

Subsequently we validated experimentally IVA as an index of contractile function, comparing it to myocardial acceleration, and velocities measured during the ejection phase [16]. For the purpose of these experiments we chose a 15–17 kg closed-chest pig model, which offered the best compromise between good echocardiographic windows and neck vessel diameters suitable for insertion of six and seven French catheters. As the independent index of contractility for comparison of DMI data, we used pressure–volume analysis, derived by conductance catheter, to measure endsystolic (Ees), and maximal elastance (Emax) in the LV and RV, respectively [17, 18]. Our studies confirmed that small changes in contractile function during beta blockade (esmolol) or beta-receptor stimulation (dobutamine) can be detected by measuring IVA. Importantly, changes in pre- and afterload in a physiological range did not affect IVA, while the DMI-derived ejection phase indices were all influenced significantly by these changes. To some extent therefore ejection indices, such as peak systolic velocities and strain or strain rate, offer little advantage over ejection/shortening fraction in terms of assessing ventricular performance. Conversely, IVA represents a robust measurement of LV or RV contractile function with a sensitivity approaching or exceeding those indices traditionally measured using invasive techniques [19].

25.3 Clinical Validation of IVA to Assess RV Function

We have applied IVA to the evaluation of myocardial disease in right ventricular disease. In the clinical validation study, we addressed the important problem of evaluating contractile function in patients with a morphologic right ventricle supporting the systemic circulation. In patients with complete transposition of the great arteries who have been treated with atrial redirection procedures, such as the Mustard or the Senning operation, the right ventricle remains the systemic ventricle. Some of these patients develop systemic ventricular dysfunction as early as the second or third decade of life. We assessed the contractile reserve of the right ventricle supporting the systemic circulation in 12 clinically well patients with transposition of the great arteries and a Mustard or Senning operation. Under beta-receptor stimulation by dobutamine (10 mcgs/kg/min for 10 min) we analyzed conductance-catheter-derived pressure–volume relations, to assess endsystolic elastance (Ees), and measured IVA.