Noninvasive Intracardiac Pressure Measurement Using Doppler Ultrasound*

RICHARD L. POPP, MD, FACC,
PAUL G. YOCK, MD
Stanford, California

Currie et al. (1) report a very useful study in this issue of the Journal. Maximal flow velocity within a tricuspid regurgitation jet, measured with noninvasive Doppler ultrasound, was used to calculate the right ventricular-right atrial pressure difference generating the flow velocity by means of the Bernoulli equation, as simplified by Hade and colleagues (2). This pressure difference was compared with catheter-manometer measurement obtained simultaneously in a group of 63 patients with Doppler-detectable tricuspid regurgitation. This method was then applied to a second group of 64 consecutive patients, identified only by their need for right heart catheterization. Right ventricular systolic pressure was estimated in the second group by 1) adding 10 mm Hg to the Doppler-determined right ventricular-right atrial pressure difference, assuming an arbitrary right atrial pressure, 2) adding an independent observer’s estimate of the mean jugular venous pressure to the ventricular-atrial pressure difference, and 3) one of two regression equations, derived from the first group of 63 patients, depending on whether the estimated jugular venous pressure was greater or less than 20 cm H₂O. This study adds to the growing acceptance of the simplified Bernoulli equation for calculating pressure differences between two cardiac chambers that communicate by way of a jet of blood passing between them. This calculation requires knowledge of only the maximal velocity of the jet, which is now commonly measured by Doppler echocardiography. These data confirm the accuracy of this method in humans (3–6) and show that the principle works in high and low pressure systems and over a wide range of cardiac indexes.

The critic may note that this catheter-manometer system is not optimal for fine measurements of dynamic pressure differences; however, similar systems generate most clinical data. The Doppler velocity signal may be truncated because one cannot be certain that the sound beam is aligned parallel to the flow (despite the rigorous technique reported in this study) although parallel alignment is required for optimal quantitative studies. Misalignment of sound beam to flow direction of up to 30° will result in an underestimation of the velocity of approximately 13%. This study used a clinical estimate of the height of the jugular venous column with chest elevation of 45° from the horizontal position and, presumably, later measurement of right atrial pressure by catheter with the patient supine. For practical purposes, the accessible jugular venous pressure range is 5 to 20 mm Hg (median 15), and the standard error of the estimate of venous pressure is 5 mm Hg; thus, the low correlation coefficient found between nonsimultaneous clinical and catheter measurements of right atrial pressure does not seem important. The key point is that the pressure difference obtained from the Doppler velocity signal is the bulk of the final “value” for most elevated right ventricular pressures, and any of the tested methods work well. These data confirm the use of this method to accurately measure right heart pressure in a high proportion of patients.

Tricuspid regurgitation and right ventricular pressure. Only 54 of the 64 consecutive patients of Currie et al. (1) had any detectable tricuspid regurgitation. Analyzable tracings were obtained in 48 (75%), of the 64 total patients, 40 (80%) of the 50 patients with a right ventricular pressure of more than 35 mm Hg and 8 (57%) of the 14 patients with a right ventricular pressure at or below that level. Other investigators (7) have found a Doppler-detectable tricuspid regurgitation signal in up to 90% of patients with congestive cardiomyopathy and a high proportion of normal adult subjects. A tricuspid regurgitation signal is expected in the majority of patients presenting at our laboratory and the requisite time is spent looking for this signal and optimizing it for quantitation when measurement of right heart pressure is clinically important. Right ventricular pressure derived from a good study is accepted with confidence and used in decision-making at our institution. Obviously, investigators hope to find ways of improving the yield of useful studies so that the method can be applied to many conditions.

The Doppler tricuspid regurgitation gradient method. The desire for a noninvasive technique to assess right heart pressure previously led to approaches using M-mode echocardiography (8), two-dimensional echocardiography (8,9) and Doppler ultrasound (10). The “Doppler tricuspid regurgitation gradient method” discussed here seems the most accurate and generally applicable concept. It requires proper equipment for measurement of high flow velocities, using continuous wave or modifications of the usual pulsed wave Doppler ultrasound systems (6). It also takes
real dedication to master the technique. Currie et al. (1) proved that the method can work well for an isolated determination of right heart pressure in patients of all ages, and in virtually all types of cardiac disease. The variance of the method must be assessed before trying to use it to follow the natural history and the effects of therapeutic interventions on pulmonary artery and right ventricular pressures in humans. The potential for monitoring these pressures in patients with valvular heart disease, primary pulmonary hypertension, congestive cardiomyopathy, congenital heart disease, prosthetic cardiac valves and cor pulmonale is very exciting.

Clinical applications. Knowledge of the pulmonary artery pressure at rest and during exercise is one of the few elements previously lacking in the noninvasive assessment of patients with mitral stenosis, and traditionally provided by catheterization. Similarly, the level of pulmonary hypertension is crucial in the proper timing of cardiac surgery for some forms of mitral regurgitation and serves as an important indicator of prosthetic mitral or aortic valve malfunction. This noninvasive method is well suited to searching among the several proposed therapies for primary pulmonary hypertension or approaches to treatment of dilated congestive cardiomyopathy. The apparent individual variability in drug response and the common development of long-term loss of responsiveness to any one drug could be evaluated repeatedly and easily using Doppler echocardiography. Limited local experience is encouraging but it is at an early stage. Right ventricular pressure is of primary concern in patients with atrial septal defect, right ventricular outflow tract obstruction and many forms of congenital heart disease. Again, serial noninvasive assessment of right heart pressure in these patients is highly desirable. The development of two-dimensional Doppler "color flow mapping" may aid this effort by simplifying the detection of flow velocities of interest and helping to optimize the angle between the sound beam and the direction of flow (11).

The same principles just discussed might provide noninvasive measurement of pulmonary artery diastolic, left ventricular end-diastolic and left atrial pressures (12-14). If the absolute pressure in one of two cardiac chambers is known, and the maximal velocity of blood flowing between the chambers can be measured by Doppler ultrasound, then this velocity can be used to calculate the pressure difference between the chambers, and the pressure in the second chamber can be deduced. This general idea is being investigated with innovative application in many laboratories. The full potential of Doppler ultrasound will not be known until these ideas are tested using improved equipment and appropriate scientific methods as has been done in the recent study from the Mayo Clinic (1).

References