Invasive Hemodynamics of Valvular Heart Disease

Michele Pighi, MD, Anita W. Asgar, MD, MSc*

KEYWORDS

• Valvular heart disease • Hemodynamics • Stenosis • Regurgitation

KEY POINTS

- Invasive hemodynamics assessment is an important diagnostic tool in the management of patients with valvular heart disease.
- Proper tools, technique, and understanding pitfalls are important.
- Appropriate diagnosis and treatment are necessary for optimal patient outcomes.

INTRODUCTION

The evaluation of valvular heart disease has made a dramatic shift in the past several decades with the evolution of 2-dimensional echocardiography and Doppler echocardiography. These noninvasive techniques have become the mainstay of the evaluation and follow-up of valvular heart disease. The 2014 American Heart Association/American College of Cardiology Valvular Heart Disease Guidelines recommend transthoracic echocardiography as a class I indication for the diagnosis, to determine prognosis and for the timing of intervention in valvular heart disease.[1] Despite this recommendation, invasive hemodynamic assessment remains an essential tool in equivocal cases. The interventional cardiologist remains the expert in hemodynamic evaluation and a thorough understanding of the tools, interpretation of data and pitfalls is fundamental. This article reviews the indications, technique, and interpretation of hemodynamic assessments in valvular heart disease.

General Principles of Invasive Hemodynamic Assessment of Valvular Heart Disease

A thorough, systematic approach to the hemodynamic assessment of valvular heart disease should begin with a review of the noninvasive imaging to understand the question being asked and the diagnostic dilemma requiring clarification. Once this has been identified, a plan of the necessary measurements and assessments should be made and vascular access and tools required determined. In general, high quality pressure measurements often require either 6-Fr or 7-Fr vascular access and rebalancing and zeroing of the baseline should be done to ensure accurate values. Ideally, all catheters should undergo periodic flushing with heparinized saline during the procedure to prevent the formation of microthrombi. In some cases, operators use doses of systemic unfractionated heparin for longer procedures or complex anatomies.

Valvular stenosis

The evaluation of valve stenosis requires the measurement of the valve gradient and calculation of valve area.[2] In the cardiac catheterization laboratory, valve areas are calculated using the transvalvular pressure gradient and cardiac output by way of the Gorlin or Hakki equation (Table 1).

Valve gradients are best measured with catheters positioned on both sides of the valve being evaluated and simultaneous pressure measurement. Peak valve gradients have traditionally been measured in the catheterization laboratory; however, these "artificial" gradients are now recognized to be nonphysiologic and have

Department of Medicine, Montreal Heart Institute, Universite de Montreal, 5000 Rue Bélanger, Montreal, Quebec H1T 1C8, Canada
* Corresponding author.
E-mail address: anita.asgar@gmail.com

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Table 1
Equations used to calculate valve area in the catheterization laboratory

	Formula
Gorlin	AVA = (CO/HR × SEP)/44.5 × $\sqrt{\Delta P}$ AVA = aortic valve area (cm^2); CO = cardiac output (L/min); HR = heart rate (beats/min); SEP = systolic ejection period (s); 44.5 = constant; ΔP = mean systolic pressure gradient
Hakki	AVA = CO/$\sqrt{\Delta P}$ AVA = aortic valve area (cm^2); CO = cardiac output (L/min); ΔP = peak systolic pressure gradient

been largely replaced by the measurement of mean gradients over the systolic ejection period, which is felt to be a better indicator of valve stenosis severity.[3]

The cardiac output is ideally measured for each patient. The gold standard for estimating cardiac output is the Fick principle, in which cardiac output is O_2 consumption divided by the difference between arterial and venous O_2, although many sites rely on the thermodilution method. Care must be taken when using thermodilution because it may be less accurate in the setting of intracardiac shunts, low cardiac output states, significant tricuspid regurgitation, or arrhythmia.

The Gorlin equation incorporates cardiac output, heart rate, systolic ejection period (or diastolic filing period), an empirical constant, acceleration of gravity factor, and the pressure difference across the stenotic valve to calculate valve area. The simplified Hakki equation uses the cardiac output and pressure gradient to arrive at a valve area with similar accuracy to that of the Gorlin equation.[4]

AORTIC STENOSIS

Indication

Invasive hemodynamic assessment of aortic stenosis is recommended when the results of noninvasive tests are equivocal or when the patient's symptoms are out of proportion to gradients and valve area measured noninvasively. In fact, underestimation of valve gradients may occur by echocardiography if the Doppler beam is not aligned parallel to the aortic jet; the Doppler velocity and, therefore, the true transvalvular gradient may be underestimated. In addition, calculation of the aortic valve area by echo uses the continuity equation, which may be subject to inaccuracies related to the assumption of a circular left ventricular (LV) outflow tract and the measurement of the LV outflow tract diameter.

Technique

A simultaneous assessment of LV and ascending aortic pressures[5] is required for the evaluation of aortic stenosis to measure the mean aortic transvalvular gradient. This is ideally performed using a catheter with side holes such as a pigtail catheter and can be performed using either a retrograde or an anterograde (transseptal) technique.

The retrograde technique requires the use of a dual lumen pigtail catheter measuring pressure above and below the aortic valve, in the ascending aorta and left ventricle, respectively. This technique does require retrograde crossing of the aortic valve to position a catheter in the LV, which may be best accomplished by the use of an Amplatz or Judkins Right catheter and straight-tip wire as shown in Table 2. Once in position in the left ventricle, the catheter should be changed using an exchange wire for a dual lumen pigtail catheter. In the absence of a dual lumen catheter, measurement may be performed using a pigtail in the left ventricle and pressure from the femoral artery, or via a second arterial access point with a second pigtail in the ascending aorta. A realignment of the pressure tracing will be necessary when using the femoral artery owing to delays in arterial wave transmission to the extremities.

Table 2
Evaluation of aortic stenosis

Approach	Vascular Access	Equipment
Retrograde	Arterial 6 Fr	Amplatz AL1 Judkins Right (JR4) Straight-tip wire 150 cm Exchange wire (J-tip) 260 cm Pigtail catheter 6 Fr (dual or single lumen)
Anterograde	Venous 7 Fr	Mullins sheath and dilator 0.032 inch J-tip wire Brockenborough needle (BRK or BRK1) Pigtail 7 Fr
	Arterial 6 Fr	Pigtail 6 Fr