NUMERICAL STUDY OF PULSATILE FLOW THROUGH MODELS OF AORTIC VALVE STENOSES AND ASSESSMENT OF GORLIN EQUATION

Ramesh Agarwal*, Robert Rifkin, E. Okpara, J. Daiber

*Washington University in St. Louis
1 Brookings Drive, St. Louis, MO 63130, USA
e-mail: rka@wustl.edu

ABSTRACT

For determining the blockage (stenosed valve area) in the aortic valve, Gorlin equation has been used in clinical practice for past fifty years [1]. It has been derived using the Bernoulli equation across the stenosed valve and making the approximation that the velocity of the fluid behind the stenosis is much greater than the velocity upstream of the stenosis (it is a good assumption for a valve with severe stenosis). The Gorlin equation is generally expressed in the form:

$$A_V = \frac{Q}{50.4\sqrt{\Delta P_d}} \qquad (1)$$

where Q = flow rate through the valve (ml/sec), Av = area of aortic valve (cm^2) and ΔP_d = pressure difference across the valve (dynes/cm^2). Based on many clinical studies, it is well documented that the Gorlin equation (1) has large error in predicting the stenosed valve area under mild stenosis and at low flow rates [2]. In last fifty years, a large number of theoretical/numerical studies have been reported in the literature to improve upon the predictions of the Gorlin equation; however none of them has found acceptance in clinical practice. The goal of this paper is to study the pulsatile flow in models of aortic valve with actual waveform of the heart using the commercial CFD software FLUENT. Computations for steady and pulsatile Newtonian flow are performed for four axisymmetric models with valve areas of 0.5 cm^2, 1.0 cm^2, 1.5 cm^2 and 2.0 cm^2 at flow rates of 5.0 *l*/min, 7.5 *l*/min, 10.0 *l*/min, 12.5 *l*/min, 15.0 *l*/min, 17.5 *l*/min, and 20 *l*/min. Thus a total of 28 cases are computed to assess the range of validity of the Gorlin equation. The flow was turbulent in all cases downstream of the stenosis; thus a modified k-epsilon turbulence model was employed in the computations. Using the calculated pressure drop across the stenosis, Gorlin equation was used to determine the stenosed area of the valve. For all the 28 cases, the error in valve area computed from Gorlin equation varied from 10 to 80%. The Gorlin equation was modified so that it retains its basic nal data. The modified Gorlin equation is as follows:

$$\mathbf{A_v} = \left(0.8^2 + \frac{\mathbf{Q}}{0.35\sqrt{\Delta \mathbf{P_d}}}\right)^{0.5} - 0.8 \qquad (2)$$

The stenosed valve area computed with equation (2) gives results within 3 to 5% error when compared to the exact valve areas used in FLUENT computations. Clinical data using 35 patients covering the whole range of flow rates and severity of stenosis of the aortic valve was obtained by Dr. Rfikin of the Washington University School of Medicine. The valve area from clinical data was compared with that obtained from equations (1) and (2) for various flow rates and pressure drops. For high flow rates, the original Gorlin equation (1) predicts the valve area which is significantly different from clinical valve area; however the modified Gorlin equation is in very good agreement with the clinical results for all physiologically relevant flow rates and stenoses from mild to severe. Therefore we recommend the use of equation (2) by the physicians. The details of the calculation will be presented in the complete paper.

References

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