ANALYTICAL SOLUTION OF FRACTIONAL FLOW RESERVE IN EVALUATION OF CORONARY ARTERY STATE

Sasa Njezic[1], Nenad Filipovic[2], Fatima Zivic[2], Dragoljub Lj Mirjanic[1]
[1]Faculty of Medicine, University of Banja Luka
[2]Faculty of Engineering, University of Kragujevac

Introduction

Fractional flow reserve (FFR) is the quotient of intracoronary pressure measured distally from stenosis and aortic pressure in conditions of maximum hyperemia and the obtained value from 0 to 1. Stenosis is an abnormal narrowing of the blood vessel wall. Functional insignificant coronary artery stenosis are greater than 0.75. Values less than 0.75 are functionally significant coronary artery stenosis. By measuring the fractional flow reserve, a physiological view of the myocardium was obtained, which after many years of examination became a significant diagnostic tool in the estimated ischemic potential of the lesion. Ischemia is a decrease in blood flow through the observed blood vessel or organ, and myocardial ischemia occurs when blood flow to the heart is reduced by partial or complete blockage of the coronary arteries. A lesion is damage, a change in the shape and structure of a cell, tissue or organ. The fractional reserve of myocardial flow is clinically used as an index specific for stenosis. There is a relationship between fractional flow reserve and degree of stenosis as well as aortic and venous pressure and capillary flow. The degree of stenosis is defined by reducing the cross section of the blood vessel.

Poiseuille`s equation

$$\frac{\partial \rho}{\partial t} + div(\rho \vec{v}) = 0$$

$$\rho\left[\frac{\partial \bar{v}}{\partial t} + (\bar{v} \cdot \nabla \vec{v})\right] = \rho \vec{f} - gradp + \eta \nabla \vec{v} + \left(\zeta + \frac{1}{3}\eta\right) graddiv\vec{v}$$

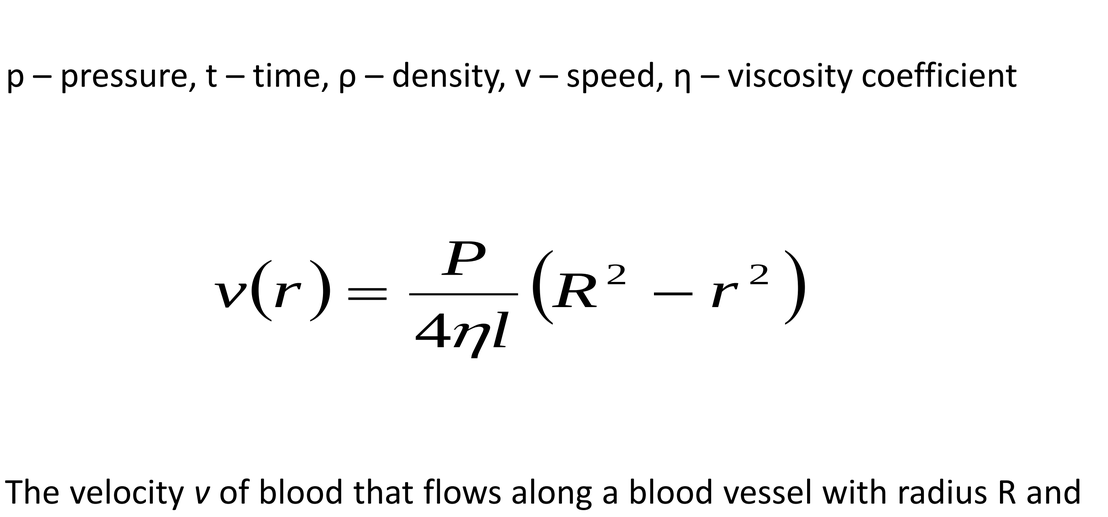
$$p = F(\rho)$$

p – pressure, t – time, ρ – density, v – speed, η – viscosity coefficient

$$v(r) = \frac{P}{4\eta l}\left(R^2 - r^2\right)$$

The velocity *v* of blood that flows along a blood vessel with radius R and length l at a distance r from the central axis, where P is the pressure difference between the ends of the vessel and η is the viscosity of the blood.

Fractional Flow reserve (FFR)

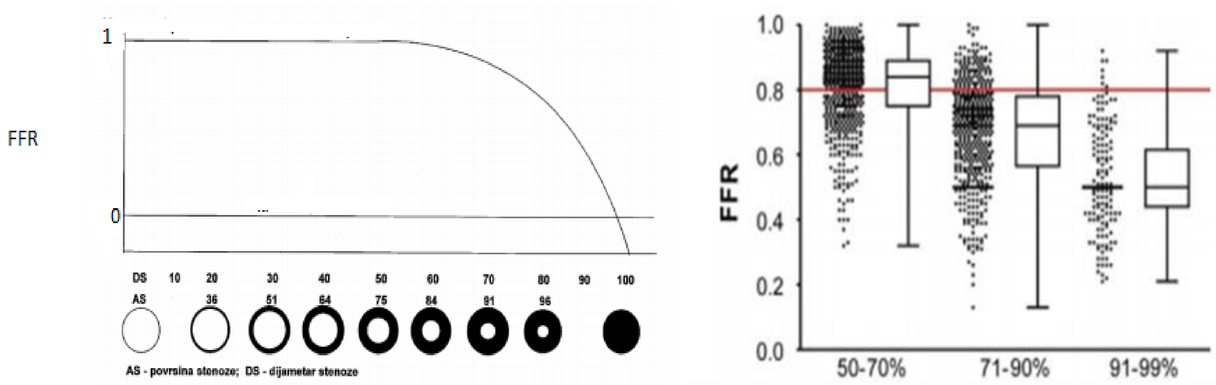


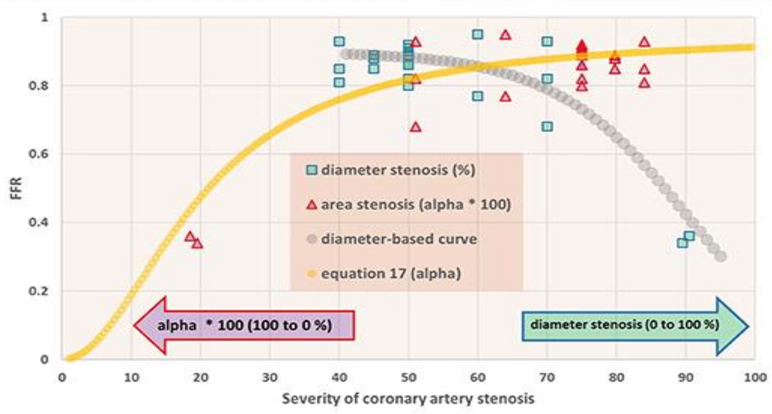
$$vFFR = \frac{P_{distal}}{P_{aorta}}$$

$$FFR = \frac{p_D}{p_A} = \frac{R_C \alpha^2}{R_0 + R_C \alpha^2} + \frac{R_0}{R_0 + R_C \alpha^2}\frac{p_V}{p_A}$$

α – degree of stenosis, Rc – capillary resistance, R0 –hemodinamic resistance of the coronary artery without stenosis

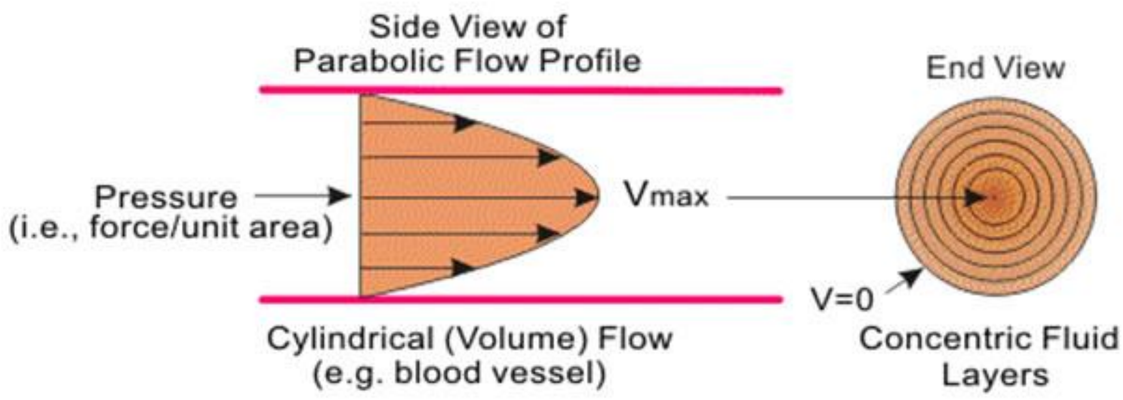
Functional dependence of fractional flow reserve and stenosis





Results

An analytical procedure for obtaining the fractional flow reserve using the Poiseuille`s equation has been developed. And the relationship between the fractional flow reserve and the degree of stenosis in the observed blood vessel was obtained, including the influence of aortic and venous pressure as well as capillary resistance. Fractional flow reserve values correlated with the occurrence of myocardial ischemia and values without myocardial ischemia were obtained. The results correlate with noninvasive tests to provoke myocardial ischemia. A fractional flow reserve value of 0.75 was taken as the reference value. Aortic pressure is obtained using a coronary catheter and distal pressure via a pressure measuring sensor placed on a standard coronary wire.



Conclusions

The advantage of fractional flow reserve over other diagnostic methods is in good spatial resolution when determining the origin of ischemia. With this method, each segment of the coronary artery can be analyzed separately and the overlap of one zone of ischemia with another more serious ischemic zone is avoided. For an adequate study of the fractional flow reserve, it is necessary to provide technical preconditions, avoid artifacts during measurement, make adequate selection of lesions for examination and cause suitable hyperemia. This fractional flow reserve study is based on the original use of the coronary circulation model. Therefore, it is limited due to the use of Poiseullian resistance in a model that neglects the influence of non-Poiseullian pressure and flow ratio in the coronary arteries, neglects neuronal and hormonal factors, neglects microvascular autoregulation and neglects coronary tree anatomy.

Acknowledgement

This work has been supported by the research grant EC HORIZON2020 689068 SMARTool project