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Estimation of mitral valve degenerative behavior with mitral regurgitation

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Abstract

Degenerative mitral valve prolapse without proper monitoring can cause severe mitral valve failure and occasionally lead to sudden death if the surgical correction is not performed on time. In most cases, mitral valve prolapse would cause mitral regurgitation which in a severe case would lead to left ventricle failure due to hemodynamic burden. The aim of this study is to develop a model to predict the degeneration behaviour of mitral valve which will aid the medical practitioner to estimate the mitral valve condition based on the available mitral regurgitation data by echocardiogram assessment. Minimal hemodynamic model has been adopted with modification to obtain mitral regurgitation severity information. The stress-strain behaviour of mitral leaflet has also been studied to model the degeneration of the mitral valve leaflet. Both models were validated with the previously published data generated using Windkessel and Burkhoff methods. The coupling of both models gave the degenerative behaviour of mitral valve leaflet in relation with mitral regurgitation severity. The mitral valve degeneration was assessed by mitral valve leaflet elasticity properties while the severity of mitral regurgitation was measured by the volume of mitral regurgitation into the left atrium. It was found that the reduction of mitral valve leaflet elasticity would cause an increase of the mitral regurgitation volume into the left atrium. Mitral regurgitation severity was found to be less than 10% of left ventricle stroke volume when the mitral valve leaflet degenerates more than 90%. At this point, even with a slight increase of less than 10% in the degeneration of mitral valve leaflet, the regurgitation volume might increase suddenly from 5% up to 95% of the left ventricle stroke volume.

Keywords: Mitral degeneration, Estimation model, Mitral regurgitation

Nomenclature

A	area [m²]
C	coefficient
D	damping factor [rad-1]
E	Young's Modulus [kPa , MPa]
E	elastance [mmHg/ml]
l	length [m]
L	inductance [mmHg·s²/ml]
P	pressure [mmHg]
Q	flow rate [ml/s]
R	resistance [mmHg·s/ml]
r	radius [m]
t	time [s]
u	velocity [m/s]
V	volume [ml]
z	distance [m]

Greek Symbols

δ	deflection [m]
λ	parameter for EDPVR
θ	angle [rad]
ρ	density [kg/m³]

Subscripts

ao	aorta	*tc*	tricuspid valve
av	aortic valve	*sys*	systemic system
d	discharge		
ed	end diastolic		
es	end systolic		
lv	left ventricle		
max	maximum		
mt	mitral valve		
o	initial		
pa	pulmonary artery		
pu	pulmonary vein		
pul	pulmonary system		
pv	pulmonary valve		
reg	regurgitation		
rv	right ventricle		
s	static		