ARTERIAL HEMODYNAMICS IN PATENT DUCTUS ARTERIOSUS STENTING

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ABSTRACT

Cyanotic congenital heart disease (CHD) is the condition when insufficient blood transported throughout the whole body due to anomalies of blood vessels or heart. Hence, the procedure of maintaing the patency of ductus arteriosus were introduced where the stent is implanted at ductus arteriosus that should be closed naturally within 48 hours after the birth. The main purpose of this study is to investigate the hemodyamic effect of patent ductus arteriosus (PDA) after different types of stent design were implanted. Three different types of commercial stent design were used in this study: Closed Cell V stent, Palmaz-Schatz stent and Type One stent. The hemodynamic effect were investigated numerically via computational fluid dynamics by using ANSYS 14.0 software. Three hemodynamics variables were analysed in this study which are wall shear stress (WSS), oscillatory shear index (OSI) and relative residence time (RRT). Each stent affect the hemodynamic within PDA differently. The higher percentage of TAWSS exposed in range of 0.5 Pa to 2 Pa is better shown by Closed Cell V stent with 25.4%. Type One stent shown a good result in OSI which has high percentages exposed below 0.2 with the value of 34%. Palmaz-Schatz stent present a preferable results in both WSS low, 1.2% (low the better) and RRT within range of 10 Pa^-1 at 97.7%. Thus, this study can be useful in stent selection for PDA stenting.

ABSTRAK

Penyakit jantung kongenital sianotik adalah apabila keadaan salur darah atau jantung yang tidak normal menyebabkan darah tidak mencukupi untuk menyalur ke seluruh badan. Oleh itu, stent diletakkan pada ductus arteriosus untuk memastikan ia sentiasa terbuka walaupun ia sepatutnye tertutup dengan semulajadi dalam tempoh 48 jam selepas kelahiran. Tujuan utama kajian ini dijalankan adalah untuk menyiasat kesan hemodinamik pada ductus arteriosus terbuka *(patent ductus arteriosus)* selepas stent diletakkan. Tiga jenis bentuk stent komersial yang berbeza digunakan dalam kajian ini iaitu stent *Closed Cell V*, stent *Palmaz-Schatz* dan stent *Type One*. Kesan hemodinamik disiasat secara berangka melalui *computational fluid dynamics* dengan menggunakan perisian ANSYS 14.0. Tiga pemboleh ubah hemodinamik digunakan dalam kajian ini iaitu tegasan ricih dinding, indeks ayunan ricih dan masa tinggal relatif.Hemodinamik dalam *ductus arteriosus* terbuka berbeza dipengaruhi oleh stent yang berbeza. Stent *Closed Cell V* menunjukkan peratusan yang tinggi dalam TAWSS (0.5 Pa hingga 2 Pa) iaitu 25.4%. Nilai OSI di bawah 0.2 adalah terbaik yang ditunjukkan oleh stent *Type One*. Stent *Palmaz-Schatz* pula menunjukkan keputusan yang lebih baik untuk WSS low dan RRT dengan peratusan 1.2% dan 97.7%. Maka, kajian ini boleh digunakan untuk pemilihan stent bagi prosedur peletakan stent pada *ductus arteriosus* terbuka.

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LIST OF ABBREVIATION

ASD	-	Atrial septal defect
AVSD	-	Atrioventricular septal defect
CFD	-	Computational Fluid Dynamic
CHD	-	Congenital heart disease
CT	-	Computed tomography
c-TGA	-	Corrected Transposition of The Great Arteries
DS	-	Descending
GIT	-	Grid independent test
HLHS	-	Hypoplastic Left Heart Syndrome
IJN	-	Institut Jantung Negara
LPA	-	Left pulmonary artery
NIH	-	Neointimal hyperplasia
OSI	-	Oscillatory shear index
PAIVS	-	Pulmonary Atresia with Intact Ventricular Septal
PDA	-	Patent ductus atriosus
RRT	-	Relative resident time
TA	-	Tricuspid atresia
TAWSS	-	Time-averaged wall shear stress
TAWSSAG	-	Time-averaged wall shear stress angle gradient
TAWSSG	-	Time-averaged wall shear stress gradient
TGA	-	Transposition of The Great Arteries
TOF	-	Tetralogy of Fallot
VSD	-	Vetricular septal defect
WSS	-	Wall shear stress

LIST OF SYMBOLS

$\vec{\tau}$	-	Magnitude of WSS vector
μ	-	Blood viscosity
dt	-	Time step
r	-	Radial direction perpendicular to the arterial wall
T	-	Period of third cycle
u	-	Velocity
τ	-	Wall shear stress (WSS)

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CHAPTER 1

INTRODUCTION

Patent ductus arteriosus is an abnormal condition where ductus arteriosus did not closed naturally after the birth. However, in several conditions of congenital heart diseases, ductus arteriosus had to be subjected to intervention by opening it using wire mesh called stent as an alternative way to supply adequate amount of oxygenated blood to entire body. PDA stenting is a crucial procedure which acts as a first palliative treatment for neonates with cyanotic congenital heart diseases (CHD). This procedure is a temporary procedure between 6 to 12 months before neonates undergo conduit cavopulmonary angioplasty where right pulmonary artery are connected with superior vena cava to lessen the severity of cyanotic CHD.

The complications after the coronary stent surgical such as stent embolization, migration of the stent, protrusion, and acute stent thrombosis have led to the new development of the stent technology to overcome this problem.

Computational fluid dynamic (CFD) can be used to simulate the effect of stent design pattern on the arterial hemodynamic performance. There are several hemodynamic parameters such as wall shear stress (WSS), Low WSS, oscillatory shear indices (OSI) and relative residence time (RRT) being used to predict the development of re-stenosis [1].

Comparative study on stent design pattern effect on the arterial hemodynamic will provide comprehensive knowledge to develop a better design of stent. Thus, several types of stent design pattern will be used to predict the development of re-stenosis in PDA morphology.

1.1 Problem statement

Implantation of stent at PDA region contributes many complications especially re-stenosis [2], [3]. The development of restenosis can be affected by the arterial hemodynamic in clinical findings.

1.2 Hypothesis

Each type of stent design pattern has different effect on arterial hemodynamic performance. Thus, the prediction of re-stenosis can be predicted through the effect of stent design pattern using several hemodynamic variables using CFD.

1.3 Significant of study

The performance of hemodynamic has different effect depend on the stent design pattern. Thus, it is necessary to investigate the performance of the stent hemodynamic in order to predict the development of re-stenosis. The finding from this study may help with stent selection.

1.4 Objectives

1. To investigate the PDA hemodynamic effect for different types of stent design pattern

1.5 Scope of research

1. Only one PDA morphology was studied
2. Three different stent design pattern were used in the simulation
3. Steady and transient flow were considered

1.6 Thesis structure

This thesis consist of five chapter where chapter one is introduction and background of study then followed by chapter two with relevant literature review of study. An overall methodology was employed in this study is elaborated in chapter three. In chapter four, results obtained from analysis were discussed. Then, conclusion and recommendation from this study were presented chapter five.

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