COST ANALYSIS OF ELECTIVE PERCUTANEOUS CORONARY INTERVENTION AND ITS PREDICTORS IN MALAYSIA

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THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PUBLIC HEALTH

FACULTY OF MEDICINE
UNIVERSITY OF MALAYA
KUALA LUMPUR

2017

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ABSTRACT

With the increasing burden of metabolic syndrome, the prevalence of coronary artery disease (CAD) is rising in Malaysia. Percutaneous coronary intervention (PCI) is a common treatment modality for CAD. Cost of PCI and other cardiac procedures are escalating with the advancement in medical technology. Scarcity of local cost evidence impedes the planning for sustainable cardiology service. Cost analysis is vital for healthcare resource allocation. Limitations in the quality and availability of patient and financial data from low- and middle-income countries (LMIC) often constrain the implementation of cost analysis. This research aimed to estimate the cost of PCI in Malaysia via a modified costing method. By evaluating the cost variation between cardiac centres, we outlined the cost-saving strategies for cardiology service in Malaysia. This cost analysis was conducted from the perspective of healthcare providers at 5 cardiac centres from January to June 2014. Clinical data was extracted from a national cardiac registry. Cost data collection was conducted using mixed method of top-down and bottom-up approaches. The primary outcome of interest was the cost of PCI hospitalization. Using a clinical event pathway, cost items under each unit of analysis are identified, valuated and calculated to produce unit cost estimates. Unit costs of interest were costs of hospital general overheads, cardiac ward admission, cardiac catheterization laboratory utilization and PCI consumable; which made up total hospitalization cost. Average cost by centre were derived with top-down approach and compared between centre. Individual-level costs were generated via mixed method to enable patient-level comparison and determination of cost predictors. Analyses included descriptive statistics, logistic regression to determine the predictors of long hospitalization and linear regression to predict increased hospitalization cost. The average total hospitalization cost for an elective PCI patient ranged from RM 11,519 to RM 14,356 at the 5 centres. The dominant cost driver was PCI consumable. Day-care facility resulted in 80.5% cost reduction. With a sample of 2260 patients, individual patient-level mean hospitalization cost showed a wide distribution of RM 16,999 ± 7,337. Regression analysis showed number of stents as a strong cost predictor. Patients with acute coronary syndrome, presence of bifurcated lesion, involvement of left main stem artery and failed revascularization during PCI were also expected to incur higher hospitalization cost. Using the findings from this study, similar cost studies can be conducted for other healthcare services. The modified costing methods will be useful for like-minded researchers in LMIC who intend to conduct health economic evaluation in the setting of limited data availability. In conclusion, the PCI cost burden on Malaysian public cardiac centres was considerably high. PCI consumable especially cardiac stents was the biggest cost contributor. Alternative consumable procurement practice such as collaborative purchasing arrangement may deliver cost reduction. Establishment of day-care facility is another viable cost-saving strategy. The study recommendations will be vital for policy makers during decision-making on resource allocation and budget planning. This will bring us one step closer towards achieving high quality, equitable and affordable cardiology service in our country.

Key words: PCI, cardiology, low- and middle-income countries, economic evaluation, angioplasty

ABSTRAK

Berikutan dengan meluasnya sindrom metabolik, kes penyakit arteri koronari di Malaysia (CAD) semakin meningkat. 'Percutaneous coronary intervention' (PCI) merupakan salah satu rawatan utama untuk CAD. Perkembangan teknologi perubatan menyebabkan penambahan kos PCI dan juga rawatan kardiak yang lain. Perancangan jangka panjang untuk perkhidmatan kardiak di Malaysia memerlukan maklumat kos tempatan yang terperinci. Namun, maklumat sedemikian kurang tersedia di Malaysia. Kos analysis amat penting untuk pengagihan sumber namun kekurangan dari segi kualiti dan akses data perubatan dan kewangan menjadi halangan terhadap pelaksanaan kos analysis di negara-negara berpendapatan sederhana dan rendah (LMIC). Tujuan kajian ini adalah untuk menganggar kos PCI dan membuat perbandingan di antara pusat kardiak bagi mengenal pasti kaedah penjimatan kos rawatan di Malaysia. Kajian kos prosedur PCI telah dijalankan di 5 pusat kardiak umum dari Januari hingga Jun 2014. Data klinikal diperolehi dari registri kardiak kebangsaan. Data kos diperolehi melalui gabungan kaedah "Top-Down" dan "Bottom-up" bagi pengiraan kos keseluruhan untuk prosedur PCI di hospital. Unit kos analisis termasuk kos "overhead" hospital, kos rawatan di wad, kos penggunaan makmal angioplasti dan kos konsumable. Kos item di bawah setiap unit analisis dikenalpasti, dinilai dan ditambah untuk memperoleh kos keseluruhan. Kos purata melalui kaedah "Top-Down" digunakan untuk membuat perbandingan di antara pusat rawatan. Kos individu yang diperolehi melalui gabungan kaedah-kaedah yang dinyatakan membolehkan perbandingan secara terperinci dilakukan selain untuk mengenalpasti kos dominan di peringkat pesakit PCI. Data-data telah dianalisis dengan statistic deskriptif serta model regresi logistik dan linear. Purata kos hospital keseluruhan untuk prosedur elektif PCI berjumlah antara RM 11,519 dan RM 14,356 di 5 pusat kardiak tersebut. Kos dominan di semua pusat kardiak adalah kos konsumable. Penjimatan setinggi 80.5% direkod di pusat kardiak yang mempunyai

pusat harian. Jurang kos hospital yang dicatat antara kesemua 2260 orang pesakit adalah RM 16,999 ± 7,337. Bilangan "stent" yang digunakan merupakan peramal kos yang kuat. Selain itu, kos hospital juga dijangka lebih tinggi di kalangan pesakit yang mempunyai sindrom akut koronari, arteri yang tersumbat adalah di bahagian cabang, penglibatan arteri 'left main stem' dan kegagalan prosedur. Keadah pengiraan kos dalam kajian ini boleh digunapakai untuk evaluasi ekonomik prosedur perubatan yang lain. Kaedah ini juga akan memanfaatkan penyelidik-penyelidik dari LMIC yang menghadapi masalah kekurangan data yang serupa. Kesimpulannya, beban kos PCI di pusat kardiak umum di Malaysia adalah amat berat. Kos konsumable PCI terutamanya stent kardiak merupakan penyumbang kos yang tertinggi. Amalan pembelian alternatif seperti pembelian konsumble secara borong boleh mengurangkan kos pembelian. Penggunaan pusat harian untuk pesakit selepas prosidur juga boleh mengurangkan kos rawatan. Pemerhatian ini boleh diamalkan sebagai langkah pengagihan sumber dan kewangan secara optima di peringkat kebangsaan. Dalam jangka panjang, langkah-langkah sedemikian amat bermanfaat untuk pelaksanaan perkhidmatan kardiak yang berkualiti, saksama dan bersesuaian di Malaysia.

Kata Kunci PCI, kardiologi, negara-negara berpendapatan sederhana dan rendah, evaluasi ekonomik, angioplasti

ACKNOWLEDGMENTS

It is a pleasure to thank everyone who helped to make this thesis a reality. Above all, I would like to express my deepest gratitude to my principal supervisor, Prof Dr Maznah Dahlui for her expert guidance and immense patience throughout the time of my DrPH research. I am also grateful for the good advice and support of my co-supervisor, Associate Prof Dr Mas Ayu Said. Their immense kindness and continuous encouragement have been invaluable on both an academic and a personal level, for which I am forever indebted.

My sincere appreciation go to all the cardiologists, site coordinators and data enumerators at the participating cardiac centres-Prof Dr Wan Azman Wan Ahmad, Dr Omar Ismail, Dr Rosli Mohd Ali, Dr Ong Tiong Kiam, Dr Liew Huong Bang, Dr Liau Siow Yen, Dr Lawrence Anchah, Dr Syuhada Hamzah and Miss Low Ee Vien. Without their contribution, the cost data collection process would not have materialized.

Many thanks to the lecturers and staffs of Social and Preventive Medicine Department, Faculty of Medicine, University of Malaya for providing academic and technical assistance. I am also thankful to my DrPH colleagues who have shared this journey of academic exploration with me. I owe a deep sense of gratitude to three very special friends; Karen Liaw, Kong Siew Hwee, and Salwana Ku Md Saad, who helped me immensely emotionally and not letting me give up during this challenging period.

Last but certainly not least, to my mother, Tan Kim Suan, who supports me relentlessly in all my pursuits, and my husband, Dr Wan Kwong Lee for his unwavering confidence and unconditional love, and my son, Marcus Wan, who will always be my treasure and my inspiration, this thesis is dedicated to all of you.

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LIST OF ABBREVIATIONS

ACC	American College of Cardiology
ACS	Acute Coronary Syndrome
AHA	American Heart Association
ALOS	Average Length of Stay
BMS	Bare Metal Stent
BVS	Bio-absorbable Vascular Scaffolds
CABG	Coronary Artery Bypass Grafting
CAD	Coronary Artery Disease
CCS	Canadian Cardiovascular Society
CL	Cardiac Catheterization Laboratory
CVD	Cardiovascular Disease
CW	Cardiac Ward
DALYs	Disability Adjusted Life Years
DEB	Drug-eluting Balloon
DES	Drug-eluting Stent
DRG	Diagnosis-related Group
EAC	Equivalent Annual Cost
FFPS	Full-Fee Paying Scheme
GDP	Gross Domestic Product
HIC	High-income Countries
IHD	Ischaemic Heart Disease
IJN	'Institut Jantung Negara'/National Heart Institute
LMIC	Low- and middle-income Countries
LOS	Length of Stay

MI	Myocardial Infarction
MACCE	Major Adverse Cardiac and Cardiovascular Events
MO	Medical Officer
MOH	Ministry of Health
NCD	Non-communicable Diseases
NCVD	National Cardiovascular Disease Database
NHAM	National Heart Association of Malaysia
NSTEMI	Non-ST Segment Elevation Myocardial Infarction
NYHA	New York Heart Association
PCI	Percutaneous Coronary Intervention
PGH	Penang General Hospital
PJHUS	'Pusat Jantung Hospital Umum Sarawak'/Sarawak Heart Centre
QE2	Queen Elizabeth 2 Hospital
STEMI	ST Segment Elevation Myocardial Infarction
UMMC	Universitiy Malaya Medical Centre
UKMMC	Universiti Kebangsaan Malaysia Medical Centre
WHO	World Health Organization

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CHAPTER 1: INTRODUCTION

1.1 Epidemiology of Cardiovascular Disease

Cardiovascular disease (CVD) is a leading cause of morbidity and mortality in the world. This used to be a major problem only in affluent developed countries. However, in the past few decades, the epidemiological transition has seen drastic urbanization, industrialization and lifestyle changes in lower and middle-income countries (LMIC) resulting in an increasing prevalence of CVD.

In 2012, CVD accounted for 17.5 million deaths worldwide, representing 31% of all global deaths. Mortality from CVD is predicted to reach 23.4 million in 2030 (World Health Organization, 2016a). It is also the main cause of years of life lost (YLLs) from premature death in many countries. Every 3 out of 4 CVD deaths happened in the developing world (Mendis, 2014). In these countries, CVD affects the population at a much younger age than in high-income countries (HIC). As a result, CVD contributes to a disproportionately higher loss of potential years of healthy life and economic productivity in LMIC.

As a rapidly developing middle-income country, Malaysia is not spared of the same epidemic. In 2013, CVD was the leading cause of death and accounted to 25% of total mortality in Malaysia (Ministry of Health Malaysia, 2014). It was one of the top 5 causes of hospitalization in both public and private hospitals in 2013 (Ministry of Health Malaysia, 2014).

1.2 Coronary Artery Disease and Treatment

CVD encompasses a range of medical conditions such as coronary artery disease (CAD), cerebrovascular disease, peripheral artery disease, hypertension, rheumatic heart disease, congenital heart disease and heart failure. Among the various CVD, CAD is the most commonly encountered; every 4 out of 10 CVD deaths can be attributed to CAD.

CAD refers to a spectrum of diseases characterized by narrowing of the blood vessels supplying the heart muscle. At least half of the CAD patients present with chronic stable angina; which is characterized by chest discomfort that radiates to the jaw, shoulder or back, and relieved with rest or medication. It happens when atheromatous plaque causes the obstruction of at least 1 large epicardial coronary artery. If the plaque continues to proliferate, the subsequent coronary artery blockage may lead to a series of potentially fatal manifestations ranging from unstable angina to non-ST segment elevation myocardial infarction (NSTEMI) and ST segment elevation myocardial infarction (STEMI), collectively known as acute coronary syndrome (ACS).

Over the years, developments in modern technology and pharmaceutical devices have led to tremendous revolution in CAD treatment. The mainstay of treatment includes percutaneous coronary intervention (PCI), pharmacological reperfusion therapy and coronary artery bypass graft (CABG). CABG is only reserved for severe cases due to its invasive nature. Between PCI and pharmacological reperfusion with fibrinolytic agents, PCI was superior in terms of better successful rate of revascularization and lower complication rates of non-fatal myocardial infarction, stroke and mortality (Keeley, Boura, & Grines, 2003; Van de Werf, 2006).

However, the cost of PCI is notably higher. While the advancement of stent and other device-related technology continue to improve the outcome of PCI, the newer generation of drug eluting stents (DES) and bio-absorbable vascular scaffolds (BVS) also incur a much higher cost compared with traditional bare metal stents (BMS). Furthermore, the capital cost and human resource costs need to be factored in the establishment of PCI service as it requires a sophisticated cardiac catheterization laboratory manned by interventional cardiologists and highly skilled supporting staff.

Despite the high cost, many developing countries, including Malaysia, have stepped up the effort to establish PCI service across the nation in view of the proven clinical effectiveness. The availability and access to coronary catheterization facility is often viewed as a key performance indicator of a healthcare system. The PCI service in Malaysia first began in 1983. By 2007, it was estimated that at least 35 private and public hospitals were performing approximately 9000 PCI procedures annually (Liew, Rosli, Wan Azman, Robaayah, & Sim, 2008).

1.3 Current Cardiology Service in Malaysia

PCI is an integral part of the cardiology service. The development of the cardiology service in Malaysia since the era of independence greatly mirrored the transformation in the national healthcare service provision throughout the decades. From the time of 1960s to the early 1980s, cardiac care was provided by state-level public hospital, and complicated cases were usually referred to University Hospital (now known as University Malaya Medical Centre-UMMC). The cardiac unit in University Hospital was set up in 1968.

Privatization drive in the 1980s witnessed the establishment of private hospitals in the urban areas, offering fee-for-service healthcare. Some of the earliest private cardiac centres providing angioplasty and PCI services were located in the central region of Malaysia, an area surrounding the capital city Kuala Lumpur (collectively known as Klang Valley). Subsequently, many doctors ventured into private healthcare in search of better remuneration.

In the 1990s, as part of the effort to stem the brain drain of health professionals to private sector, the government launched the corporatization plan on the healthcare service. The National Heart Institute, or more commonly known as *Institut Jantung Negara* (IJN); became the first corporatized healthcare centre in Malaysia. Under this arrangement, IJN has a public wing and a private wing. The private wing receives "fee-for-service" patients who are charged at full rates whereas the public wing provides care for public sector employees and their dependents and/or parents at a subsidized rate. The discrepancies in the hospital charges of these public patients are subsequently reimbursed by government (Chan, 2014). Based on unpublished account, it was estimated to be in the range of RM 200 million in the year of 2012. Charges from private patients and reimbursement from government contribute to the operational budget of IJN.

On the contrary, public cardiac centres depend on the annual budget allocation from the Ministry of Health (MOH) for daily operations. Labour cost of hospital staffs are paid by the central government agency of Public Service Department. Separate provisions are made for general operational cost of the centre and specific consumable cost of the coronary devices such as cardiac stents and catheters. In 2012, the total annual budget provided by MOH to public cardiology service for the purchase of PCI consumables amounted to approximately RM 120 million. The total amount was shared between the 10 public cardiac centres, with each centre being allocated between RM 4-16 million depending on the caseloads in the previous years. Many of these centres have experienced premature depletion of funds before the end of the year as a result of fluctuation in number of procedures and purchase price of consumables. Therefore, more prudent planning on budget distribution are needed at central and hospital level.

1.4 Current Healthcare System and Financing in Malaysia

To better understand the development and financing of cardiology service in Malaysia, an introduction to the overall healthcare system in Malaysia is warranted. Malaysia has a fundamentally tax-financed public healthcare system complemented by fee-for-service private healthcare sectors. The main provider of public health services is the MOH. It provides highly subsidized services to all citizens. The private sector mainly caters for the urban populations that are medically insured or can afford out of pocket payment. The public sector provides about 82% of inpatient care and 35% of ambulatory care, while the private sector provides 18% of inpatient care and 62% of ambulatory care (Hussein, 2009).

Compared to most countries at the same level of income, this public-private mix of healthcare system in Malaysia has been providing a less costly, but equitable and effective services (Chee & Barraclough, 2007). In 2014, the total health expenditure in Malaysia was 4.2% of national gross domestic product, increasing from 3.0% in 2000 to 4.0% in 2013. Public and private healthcare sector expenditures were almost equal at 52.3% and 47.4% (Malaysia National Health Accounts Unit, 2014; World Health Organization, 2014).

This amount of healthcare expenditure was considered modest by comparison to many other countries, but there was concern among the government officials over the long-term sustainability of healthcare budget with such annual increase, especially for the public sector. Furthermore, the expenditure pattern is not a good reflection of the difference in the utilization rate between the public and private sectors. Utilization rate of public healthcare service in Malaysia continues to be higher because it is provided free or at a highly subsidized rate. Therefore, the economic burden on the public healthcare sector is much larger.

Following the establishment of IJN as a corporatized healthcare centre, the government intended to convert larger public hospitals into a corporatized entity as a strategy to control cost while maintaining quality and access of healthcare services. This corporatization model was designed as part of the plan to facilitate the disbursement of funds for a single-payer health insurance scheme that was been considered in the early 2000s (Ministry of Health Malaysia, 2003).

Similar to social health insurance scheme in many other countries, this scheme, previously termed as ‘1Care’ reform package, entailed compulsory contributions by all Malaysian citizens. It also affords patients the flexibility to choose between public and private healthcare providers (Bridel, 2012). This proposed transformation was not received well by the public, mainly due to the concern about the extra contribution they have to make for their healthcare on top of the national taxes. Significant public opposition towards this healthcare transformation in the country forced the government to shelve any further plans for single-payer health insurance. Without stronger commitment from the government, the public healthcare system will struggle to meet the demand of the rising expectations from the public (Savedoff & Smith, 2011).

While the struggle over the need and direction of healthcare reform continues, it is important to identify the essential elements in the design and implementation of a high quality and sustainable universal healthcare system. One of the major reasons why the proposed 1Care received lacklustre support from the public was the lack of transparent and detailed data on current healthcare utilization and expenditure in the country. To determine the most suitable healthcare transformation that aligns with the need of the people, policy makers need more robust research and statistical evidence, especially in terms of cost information at national, hospital and patient level.

1.5 Justification of Study

With the increasing prevalence of metabolic syndrome among the Malaysian population, CAD continue to be on the rise. Expansion of cardiology service across Malaysia is underway. Today, the cardiology care service in Malaysia are provided by a multitude of centres; including public sector state-level hospitals, Ministry of Higher Education's university linked teaching hospitals, private hospitals, and also the corporatized IJN. However, there is limited research evidence on the cost of provision of cardiology service in Malaysia.

Among the various cardiac procedures, PCI is one of the most commonly conducted procedures. In the first report of the NCVD-PCI Registry for the year 2007-2009, approximately 3,400 to 3,600 PCI procedures per year were performed at the 6 participating cardiac centres; with 90% being elective PCI procedures (Wan Ahmad & Sim, 2009). While there is no latest published data available, it is estimated there are more than 60 public and private hospitals providing PCI service in 2014, with approximately 12,000 cases being conducted annually, majority being elective cases.

The escalating cost and increasing demand for PCI have the potential to incur additional expenditures on the healthcare system. The scarcity of health resources means that cardiology service will be competing for the same financial support with other fields and specialties. As a result, the economics of the access and provision of such care need to be thoroughly researched to ensure smooth delivery of efficient cardiology service.

Many of the published evidence on the cost of PCI provision were done in developed countries of different disease profile and health system from Malaysia. Thus, local policy makers and healthcare professionals will be interested to gain more insight into the actual costs of performing important cardiac procedure in local cardiac centres to ensure proper budget allocation. The identification of cost drivers across cardiac centres and cost predictors at individual patient levels will enable the stakeholders to devise cost-reduction strategies for sustainable care in the long term. This will lead to identification of areas of improvement, which are necessary to improve efficiency of service provision.

To date, no comprehensive cost analysis on the cardiology service has been conducted in Malaysia. Elective PCI, as one of the cardiac procedure that is commonly conducted and involving only minor variation between patients, serves as a suitable choice to analyze the pattern in the patient presentation, resource utilization and cost variation among different cardiac centres. Cost analysis of PCI across different centres will provide valid and robust information to guide the decision-making process about resource allocation for the betterment of cardiology service in Malaysia. In addition, the unit cost output derived from such a cost analysis will form the basis for further economic evaluation such as cost effectiveness analysis and cost utility analysis.

1.6 General Objective

The overall aim is to determine the cost incurred in the provision of percutaneous coronary intervention (PCI) and its predictors at various cardiac centres in Malaysia.

1.7 Specific Objectives

- To compare the clinical characteristics and treatment characteristics of patients who underwent elective PCI.
- To identify the cost items in the provision of PCI care based on the resources utilized at different stages of clinical pathway.
- To calculate and compare the average cost of all the centres on;

  i. Cost of general hospital overhead per user

  ii. Cost per bed day cardiac ward admission,

  ii. Cost per cardiac catheterization laboratory utilization,

  iii. Cost of PCI consumable per PCI procedure,

  iv. Cost of PCI hospitalization per elective PCI patient

- To determine the predictors of long hospital stay among the patients who underwent PCI.
- To calculate the individual patient-level PCI hospitalization cost and to determine its predictors.
- To ascertain the relationship between hospital and patient characteristics with PCI hospitalization cost.

1.8 Research Hypotheses

The following hypotheses were tested in this study:

1. The average total hospitalization cost and the proportion of contribution of each unit of analysis will not differ significantly between the cardiac centres.

2. There are differences in the clinical characteristics and treatment characteristics of individual PCI patients between the participating cardiac centres.

3. There are associations between patient characteristics and treatment details with the length of hospitalization. Poorer comorbid status, complex procedures and development of complications would lead to higher possibility of long hospital stay.

4. There are relationship between certain patient characteristics and treatment details with the total hospitalization cost. Poorer comorbid status, complex procedures and development of complications are predictors of hospitalization cost.

1.9 Outline of the Thesis

This thesis is organized into six chapters. Chapter 1 focused on the background and significance of the study, outlining the research gaps and the objectives of the study. Chapter 2 reviews the published literature relevant to the study topic, including the burden of CVD, the cost of PCI and its determinants, local healthcare system and cardiology service, and how it influences the costing approach used in this study. Chapter 3 outlines the research design, costing approach, data collection and data analysis in each phase of the cost analysis. Chapter 4 reports on the average hospitalization cost and the dominant cost drivers at each centre while chapter 5 presents the results of various analyses conducted with individual patient-level cost data. Chapter 6 is a discussion on the main findings of the study, strength and limitations of the study, implications for public health as well as directions for future research. Finally, chapter 7 presents the conclusion of the study.

1.10 Summary

This thesis was developed based on the need for cost information regarding cardiology service in Malaysia in view of the increasing CAD prevalence and the escalating healthcare cost. Major stakeholders were interested in finding out the actual cost of cardiac care provision in different cardiac centres. Elective PCI was the chosen procedure as it was one of the most commonly conducted procedures with minimal heterogeneity among the patients and providers. It is hoped that the results would provide much needed evidence towards the planning for cardiology service expansion in the effort of providing high quality and sustainable healthcare to the people.

CHAPTER 2: LITERATURE REVIEW

The aim of this chapter is to produce a summary of the latest research findings revolving the study topic. The relevant publications in the area of costing, especially with regard to cardiac procedures and percutaneous coronary intervention (PCI) will be highlighted to provide some directions towards fulfilling the study objectives.

2.1 Disease Burden of Cardiovascular Disease

Cardiovascular disease (CVD) is well recognized as a major cause of mortality and morbidity across the globe. In most affluent countries, prevalence of CVD peaked in the middle of the last century, but had progressively declined since then with the combination of effective primary and secondary preventive strategies for cardiovascular health. Mortality from CVD decreased by more than half since the 1990s in developed high-income countries (HIC) such as the United States, United Kingdom and Canada (World Health Organization, 2016b).

During the same period, the epidemiological and nutritional transition took place in many low- and middle-income countries (LMIC), resulting in drastic increase in non-communicable diseases (NCD). Among all the NCD, CVD is responsible for the largest fraction of mortality, followed by cancer, chronic obstructive pulmonary diseases and diabetes (Hunter & Reddy, 2013). China and India, the world's 2 most populous nations, recorded CVD as the leading cause of mortality in the past 5 years (Basu, Yudkin, Sussman, Millett, & Hayward, 2016).

The CVD burden in LMIC now slowly exceeds that suffered by many HIC. In most LMIC, there is a higher prevalence of CVD among young productive adults thus leading to greater loss of potential years of healthy life and economic productivity. About 75% of global deaths and 82% of the total disability adjusted life years (DALYs) occurred in the low and middle-income countries. In a comparison study, DALYs lost were only 5 and 8 per 1,000 in Australia and the United States as compared to 20 per 1,000 in India (Mackay & Mensah, 2004).

Similar to other LMIC, the Global Burden of Disease Study 2010 revealed that CVD was the top contributor of DALYs in Malaysia. Another study showed that of the 1.5 million years of life lost (YLLs) due to premature death in 2008, 35% was due to CVD (Yusoff et al., 2013). The incidence was highest among middle-aged adults between age 30 and 59 years old. This significant number of years lived with disability (YLDs) and YLLs in this productive age group are alarming for a developing nation like Malaysia.

Furthermore, the prevalence of CVD risk factors such as obesity, hypertension, smoking, and diabetes are escalating at a rapid rate in developing countries. China has witnessed a 4-fold increase in the rate of obesity from 1990-2010 (Asia Pacific Cohort Studies, 2007). The prevalence of diabetes in Indian is projected to double from 32 million in 2000 to 79 million in 2030 (Wild, Roglic, Green, Sicree, & King, 2004). The lower socioeconomic status and health literacy in these LMIC are likely to further complicate the efforts in controlling the CVD epidemic.

In a recently published study, two-thirds of the Malaysian population had at least one CVD risk factor whereas one-third had two or more risk factors. Furthermore, this phenomenon of cardiovascular risk factors clustering is shifting towards younger age group of Malaysian adults (Selvarajah et al., 2013). As a result, the cardiovascular epidemic is expected to worsen in the near future as the high prevalence of risk factors will likely lead to high numbers of CVD and increased need for medical intervention. This directly translates into increased cost in the healthcare sector. Furthermore, reduced productivity among the productive age group will ensue, thus resulting in unfavourable economic impact, especially on a developing nation like Malaysia.

2.2 Economic Burden of Cardiovascular Disease

CVD cast an enormous economic impact on individuals, households and nations. Among the many types of CVD, coronary artery disease (CAD) remains as the leading cause of loss of productivity. In 2001, there were 7.3 million deaths and 58 million DALYs lost due to CAD worldwide (Guilbert, 2003). By year 2020, it is projected that total DALYs lost from all CVD will amount to 150 million globally, with approximately half, or 82 millions of DALYs lost contributed by CAD (World Health Organization, 2016a).

Furthermore, as a chronic condition with potentially lifelong complications requiring frequent follow-ups and hospitalizations, CVD places a direct economic burden on the healthcare system. The cost of CVD in European Union reached as high as 169 billion euros (USD 168 billion) in 2004, with 62% of the total costs attributed to healthcare expenses (Luengo-Fernandez, Leal, Gray, Petersen, & Rayner, 2006). In the United Kingdom, there were 1.6 million admission episodes related to CVD in the National Health System (NHS) hospitals and more than £6.8 billion (USD 11.3 billion) was spent on treating CVD in 2013 (Bhatnagar, Wickramasinghe, Williams, Rayner, & Townsend, 2015). The total direct and indirect cost of CVD in the United States for 2009 was estimated to be USD 312.6 billion, and this figure was more than the cost of all cancers and benign neoplasms (USD 228 billion) (Go et al., 2014). In a recent update, there is an increasing trend in the hospitalizations attributed to CVD in majority of the European hospitals (Nichols, Townsend, Scarborough, & Rayner, 2014). This directly translates into a cost burden on the healthcare system.

Data from World Bank showed that LMIC spent 25 times less per capita on healthcare than developed nations (World Bank, 2013). In other words, it can be projected that resources allocated to the prevention and management of CVD in LMIC is lower than HIC. However, the overall economic burden of CVD is actually more profound in LMIC. As mentioned in the previous section, there is a higher prevalence of CVD in LMIC with majority of the mortality and morbidity occur in the working age population. A study published in 2007 highlighted the significant economic burden of CVD on LMIC. It showed the foregone gross domestic product (GDP) of CVD to be over USD 1 billion in 23 developing nations. The loss is estimated to increase by 150% by 2015 if disease trends remain unchanged (Abegunde, Mathers, Adam, Ortegon, & Strong, 2007). Therefore, any modest reduction in CVD incidence, morbidity and mortality may result in very large economic impacts, especially for LMIC.

To be able to achieve a reduction in CVD burden, timely accurate diagnosis and cost-effective management of CVD are of the utmost importance. Treatment strategies for CVD need to be geared towards "best buys" approach based on sound evidence of cost and effect. Many of such strategies have been proven to be cost effective in HIC, but further tailoring is required to make them affordable, effective and accessible for LMIC settings (R. Joshi, Jan, Wu, & MacMahon, 2008). In order to do that, it is a prerequisite to obtain robust information on the cost and utilization data from LMIC. At present, there is a lack of information on the economic burden of CVD in Malaysia, be it from the perspective of providers or patients. Therefore, further research on economic implications of cardiovascular care in the country will be vital and informative.

2.3 Treatment Modality of Coronary Artery Disease

To tackle the CVD epidemic, a dual approach focusing on the 2 main types of interventions, i.e. population-wide and individual-based, should be used in combination. While it is true that efforts made to strengthen primary interventions such as lifestyle modifications targeted at population level will eventually lead to reduction in CVD incidence over a long-term period, we cannot sideline the current need for individual-level medical intervention. With a younger age shift in the risk factors and prevalence of CVD in LMIC, it is projected that more patients will require active medical intervention at a younger age in Malaysia.

There are various treatment modalities available for CVD, depending on the type of CVD. Among all the different illnesses under CVD, coronary artery disease (CAD) or also known as ischaemic heart diseases (IHD), is the most prevalent. It also accounts for the highest mortality and morbidity among all the CVD. CAD is characterized by narrowing of the blood vessels supplying the heart muscle. It can present from mild angina attack to potentially fatal acute coronary syndrome (ACS), a spectrum ranging from unstable angina to non-ST segment elevation myocardial infarction (NSTEMI) and ST segment elevation myocardial infarction (STEMI).

Over the decades, tremendous efforts in research and development of treatment modalities for CAD have led to marked improvement in the outcome of patients with CAD worldwide. The main treatment involves reperfusion therapy to relieve the obstruction in the coronary artery. It can be achieved via intravenous thrombolysis, also known as fibrinolysis using pharmaceutical agents, and percutaneous coronary intervention (PCI), i.e. catheter-based coronary angioplasty with balloon or stent insertion. For patients with severe obstruction or have contraindications against thrombolysis, coronary artery bypass grafting (CABG) would be offered.

The method of reperfusion choice often depends on patient and lesion characteristics. Patient factors to be considered include the underlying cardiac status, comorbid conditions and suitability of the patient for surgery. Lesion factors such as the angiographic characteristics and complexity also impact on the selection of treatment modality. The decision also depends on the availability and access to invasive facilities such as cardiac catheterization laboratory and operation theatre.

Among the 3 main treatment modalities for CAD, intravenous thrombolysis has the advantage of easy administration; it can be offered to patients in hospitals without invasive facilities before transfer to cardiac centre. However, there is a significant risk of bleeding especially in the elderly, and a relatively high rate of failure in restoring normal coronary blood flow.

As an alternative reperfusion therapy, PCI is superior to thrombolysis as it can achieve complete reperfusion in 95% of patients. It is also associated with significantly lower short-term mortality, non-fatal myocardial infarction and stroke (Keeley et al., 2003; Van de Werf, 2006). Among young patients, the long-term outcome is good. One of the earlier studies on 140 PCI patients recorded a 96% 10-year survival rate and a 58% of 10-year event-free rate from myocardial infarction and future need for elective CABG, or repeat PCI (Buffet et al., 1994).

Many studies have been conducted to compare the feasibility and outcomes between CABG and PCI. A systematic review came to the conclusion that both are reasonable options for patients with advanced CAD (Deb et al., 2013). However, CABG is preferred for patients with complex coronary lesions and anatomy; whereas PCI should be reserved for patients with less complicated coronary diseases or higher surgical risk. Recent statistics have shown the plateauing rates of CABG, but annual increase in PCI. The preference for PCI is mainly due to its low invasiveness and proven cost effectiveness in different population of patients. (Deb et al., 2013; Kappetein, Head, Osnabrugge, & van Mieghem, 2014; Sipahi, Akay, Dagdelen, Blitz, & Alhan, 2014; Zhang et al., 2015). Over the years, stent and device-related techniques continue to evolve, leading to advancement in PCI technology.

Table 2.1 showed a summary on the evidence surrounding different treatment modalities for CAD.

Table 2.1: Evidence table on comparison between different treatment modalities for Coronary Artery Disease

Author/ Year	Study Objectives	Study Design	Intervention and Outcome Measures	Results	Limitations	Implications
(Bakhai, Hill, Dundar, Dickson, & Walley, 2005)	To examine evidence on cardiac-related outcomes after CABG or stenting, with implications for resource use, resource allocation and informing patient choice.	Systematic review and meta-analysis Only RCTs comparing stents used with PTCA with CABG.	Outcomes: composite event rate (major adverse cardiac event, event free survival), death, AMI, repeat revascularization.	Nine studies (3519 patients) comparing CABG to stenting. No statistical difference in mortality or AMI, but lower composite cardiac event and revascularization rates for CABG.	Sample not fully representative, short follow-up, and rapid development of surgical and stenting techniques.	CABG is associated with reduced rates of major adverse cardiac events, mostly driven by reduced repeat revascularisation. Need to research on real-world patient data.
(Boden et al., 2007)	To determine if including PCI in the initial management of CAD improve the outcome compared to optimal medical therapy	RCT: N= 1149 for PCI with optimal medical therapy (PCI group) n=1138 (medical-therapy group).	Primary outcome: Death/ MI. Secondary outcomes: Composite of death, MI and stroke and hospitalization for unstable angina.	2287 patients with significant CAD. 4.6-year cumulative primary-event rates were 19.0% (PCI group) and 18.5% (medical-therapy group) (Hazard ratio 1.05; 95% CI 0.87 to 1.27; p=0.62). No significant differences between 2 groups for secondary outcomes.	Preponderance of male patients and Caucasian patients. BMS used mostly as DES were not widely available yet.	Addition of PCI to optimal medical therapy reduced the prevalence of angina but did not reduce long-term rates of death, nonfatal myocardial infarction, and hospitalization for acute coronary syndromes.

Table 2.1, continued

Author/ Year	Study Objectives	Study Design	Intervention and Outcome Measures	Results	Limitations	Implications
(Pursnani et al., 2012)	To evaluate if PCI, when added to medical therapy improved outcomes for patients with chronic CAD.	Systematic review and meta-analysis of RCT comparing PCI to optimal medical therapy	Primary outcome: All-cause mortality Secondary Outcomes: Cardiovascular death, nonfatal MI, subsequent revascularizati-on, angina-free	12 RCT, 7182 patients. No significant improvement in all outcome measures for PCI group but analysis with only more recent studies showed benefit in terms of mortality. However, PCI patients had angina-free incidence; at short, intermediate and long term intervals.	Symptom reporting is subjective. Sensitivity analysis not done based on dosage of medications administered.	Overall no added benefit of PCI except for better symptom relief. But in more recent studies, higher proportion and newer version of stent usage yielded lower all-cause mortality.
(Dolor et al., 2012)	To compare treatment strategies for women w CAD	Systematic review of 3 comparisons: - PCI v fibrinolysis in STEMI - Early invasive v conservative in NSTEMI/ UA - PCI v CABG v med in stable or UA	Endpoints: Clinical outcomes, effectiveness, safety outcomes	5 studies showed reduction in short-term (30 days) outcomes for PCI over fibrinolysis. Early invasive management beneficial for the composite outcome or death/ MI at 6 months and 1 year. 3 studies showed reduction in composite outcome of death/MI/ repeat revascularization at 5 years with PCI or CABG versus fibrinolysis. 2 studies suggested benefit of PCI in mortality for angina and UA.	Limited number of studies available that report results for women separately.	Greater benefit with revascularization for women compared to medical therapy. Results contrasted with previous meta-analysis that combined results for both gender and reported similar outcomes for either treatment.

Table 2.1, continued

Author/ Year	Study Objectives	Study Design	Intervention and Outcome Measures	Results	Limitations	Implications
(Deb et al., 2013)	To summarize evidence comparing the effectiveness of CABG and PCI in unprotected left main disease, multi-vessel CAD, diabetes, or left ventricular dysfunction.	Systematic review of all RCTs, meta-analysis of trials and/or observational studies comparing CABG with PCI	Choice of revascularizati-on modality among different patient subgroups	13 RCT and 5 MA included. CABG preferred in left main disease, multi-vessel CAD, or patients with LVD. Improved long-term survival and lower cardiac events for CABG in DM patients (5-year MACCE, 18.7% v 26.6% for PCI; p=0.005) Repeat revascularization higher after PCI, whereas stroke is higher after CABG surgery.	Studies included used earlier generations of DES. Meta-analyses used observational studies rather that trials.	Both are reasonable options in advanced CAD but DM patients have better outcomes with CABG. PCI reserved for less complicated coronary disease or patient with high surgical risk.
(Sipahi et al., 2014)	To compare CABG and PCI on long-term mortality and morbidity	Meta-analysis of RCTs on CABG v PCI in patients with multi-vessel disease.	Outcome: Long term mortality. MI, repeat revascularizati on, stroke.	6 RCTs. N= 6055.Average follow-up 4.1 years. Total mortality, MI and repeat revascularization significantly reduced in CABG. No heterogeneity in mortality between trials that were limited to patient w DM/no DM, or whether DES or other stents.	No subgroup analyses as lack of individual patient-level data.	For multi-vessel CAD, CABG reduced long-term mortality, repeat revascularization and MI, regardless of patient's diabetic status.

Table 2.1, continued

Author/ Year	Study Objectives	Study Design	Intervention and Outcome Measures	Results	Limitations	Implications
(Caruba et al., 2014)	To compare efficacy and cost for stable angina patients treated with CABG, medical therapy, PCI with DES, with BMS and without stent.	Meta-analysis on RCT that compared at least 2 of the 5 treatments.	Outcome: mortality, MI, mean cost per patient at 1 and 3 years of follow-up	15 RCT included. Similar rates of mortality and MI at 1 and 3-year follow-up. Weighted cost per patient cheapest with medical therapy, CABG the most costly, and PCI in between.	RCT from over 2 decades (1987-2007) included, during which the development and cost of PCI technology fluctuated. Nature of cost data differed as some included ambulatory costs on top of hospital cost.	Medical therapy appears to be more cost effective but only in patients without acute coronary syndrome.

2.4 Evolution of PCI Technology

In this section, the evolution of PCI technology for CAD treatment was outlined (Table 2.2). PCI first started as simple balloon angioplasty, whereby a balloon is inserted to dilate the obstruction in the coronary artery. However, restenosis would occur in due time, causing recurrence of symptom. In view of the restenosis complication, bare metal stents (BMS), together with adjuvant anti-platelet therapy, were introduced to overcome the problem. However, as high as 40% of patients who received BMS eventually developed in-stent restenosis and stent thrombosis. These complications led to recurrence of symptoms and necessitate repeat revascularization (Lowe, Oesterle, & Khachigian, 2002; Virmani & Farb, 1999).

As a result, drug-eluting stents (DES), a class of stent that is coated with anti-proliferative drugs were designed. DES is associated with a lower incidence of restenosis and major adverse cardiac events (Babapulle, Joseph, Belisle, Brophy, & Eisenberg, 2004; Brunner-La Rocca et al., 2007; Kaiser et al., 2005). Consequently, there was a substantial increase in their use following their introduction. In Malaysia, we saw a similar increasing trend in DES use from 2007 to 2009, which accounted for 64% of all stents as reported in the NCVD-PCI Registry (Ahmad et al., 2013).

However, many initial trials that reported superior outcomes of DES were of small patient samples, and focused only on simple coronary lesions and short-term outcomes. With time, studies with a longer follow-up period revealed that stent thrombosis occurred commonly as a late complication of DES insertion (Camenzind, Steg, & Wijns, 2007). This stimulated further research into development of better DES. These newer generations of DES were manufactured with better polymers and anti-proliferative medications such as paclitaxel or sirolimus, resulting in low risk of stent thrombosis, especially when combined with anti-platelet therapy (Bangalore et al., 2012; Navarese et al., 2013; Palmerini et al., 2015; Windecker et al., 2008).

In recent years, innovation of stents continued with more sophisticated technology such as bio-absorbable vascular scaffolds (BVS), platinum-coated stainless steel stents, diamond carbon-coated stents, and gene therapy/antibody-coated stents (Iqbal, Gunn, & Serruys, 2013). BVS was developed to address issues such as stent fracture and new formation of atherosclerosis that can result in late stent failure. The cost of a BVS could be in the range of 2-3 folds of a conventional DES. Nevertheless, a large-scale, randomized trial showed that BVS was non-inferior to the conventional DES in terms of target lesion failure at 1 year (Stephen G. Ellis et al., 2015).

With the rapid development in stent technology, the choices of stent available for cardiologist and patients are widened invariably, but these new stents come with a high cost. Considering the exorbitant cost of these new stents, these results have left many cardiologists to adopt a watchful waiting strategy over the decision of switching over to BVS. Apart from the stent acquisition cost, there are other factors that affect the cost of PCI. Both the cost and its determinants are important for provision planning and performance evaluation of the PCI service.

Table 2.2: Evidence table on the evolution of Percutaneous Coronary Intervention

Author/ Year	Study Objectives	Study Design	Intervention and Outcome Measures	Results	Limitations	Implications
(Nordmann, Bucher, Hengstler, Harr, & Young, 2005)	Does primary stenting reduce clinical outcomes in AMI patients compared to primary balloon angioplasty?	Systematic review selection: RCT only, at least 1 month follow-up	Outcomes: Mortality, re-infarction, CABG, target vessel revascularization, need for vascular repair or blood transfusion.	9 trials (4433 participants). At 1 month, OR for mortality compared to balloon angioplasty was 1.16 (95% CI 0.78 to 1.73); for re-infarction was 0.52 (95% CI 0.31 to 0.87, and for target vessel revascularization was 0.45 (95%CI 0.34 to 0.60).	Potential confounding due to unbalanced post-interventional antithrombotic/ anticoagulant therapies	No evidence to suggest that primary stenting reduces mortality when compared to balloon angioplasty. But stenting is associated with a reduced risk of re-infarction and target vessel revascularization.
(Hill et al., 2004)	To assess the effectiveness and cost-effectiveness of the use of coronary artery stents in patients with CAD.	Systematic review and economic evaluation of RCT comparing: 1. PTCA with and without stent, 2. Stent versus CABG and 3. DES versus non-DES	Outcome measures: Combined event rate or event-free survival, death, acute myocardial infarction, target infarction, target vessel revascularisation and repeat treatment.	50, 6 and 12 RCT respectively for comparison 1, 2 and 3. Event rate lower in DES than BMS. For patients with MVD, no difference in mortality between stent and CABG. CABG more cost effective in long term, regardless of stent types.	DES in studies was first generation stents. No long-term follow-up data.	DES will be cost effective if right subgroups of patients were targeted. Need long-term study to focus on mortality rate.

Table 2.2, continued

Author/ Year	Study Objectives	Study Design	Intervention and Outcome Measures	Results	Limitations	Implications
(Tu et al., 2007)	To compare the effectiveness and safety of DES and BMS	Propensity score matched cohort groups from a population-based clinical registry.	Primary outcomes: Target vessel revascularization (TVR), MI and death	TVR at 2 years lower in DES group especially in high-risk patients with diabetes, small vessels and long lesions. MI rate was similar but mortality rate was lower in DES group.	Observational study thus unable to account for possible confounders	DES reduces the need for TVR among high-risk patients. Need further RCTs with larger population and longer follow-up.
(Palmerini et al., 2013)	To compare DES and BMS in STEMI patients	Network meta-analysis.	Stent thrombosis, MI, cardiac death.	22 trials, 12,453 patients. DES led to lower stent thrombosis, cardiac death, MI and TVR at 1 year.	Follow-up only 1 year.	Steady improvement made from BMS to first generation DES and second generation DES over the years.
(Stefanini et al., 2013)	To determine safety and efficacy of DES in women during long-term follow-up	Patient-level pooled analysis of 26 RCT.	Primary endpoint: Death or MI, secondary endpoint: stent thrombosis, target lesion revascularization. Analysis by intention to treat.	N= 43904, 11557 females. Primary endpoint was 12.8% in BMS, 10.9% in DES, 9.2% in new DES. Secondary endpoint of stent thrombosis was 1.3%, 2.1%, and 1.1%; for target lesion revascularization was 18.6%, 7.8%, 6.3% for BMS, DES and new DES.	Heterogeneity between patients from the pooled trials. Generalizability limited by individual trial patient selection criteria.	DES is more effective and safer than BMS in females. New generation DES should be the standard of care of PCI in women

Table 2.2, continued

Author/ Year	Study Objectives	Study Design	Intervention and Outcome Measures	Results	Limitations	Implications
(Palmerini et al., 2015)	To investigate the long-term safety and efficacy of first and second generation DES and BMS.	Network meta-analysis.	Major adverse cardiac event, target vessel failure, death, and thrombosis	51 RCTs with 52,158 patients. Median follow-up of 3.8 years. Target-vessel revascularization were reduced with all DES compared with BMS, better among second generation DES.		All DES demonstrated superior efficacy than BMS. Second generation DES performed better than first.
(Kang et al., 2016)	To compare the safety and efficacy of BMS, DES and BVS.	Systematic review and meta-analysis	Primary end point: stent thrombosis at 1 year, myocardial infarction, and mortality.	147 RCTs with 126,526 patients. DES less stent thrombosis. No significant difference in all cause or cardiac mortality. But BVS has lower risk of repeat revascularization.	Short follow-up period	DES has less stent thrombosis than BMS. Extended follow-up period required to assess long-term safety.

2.5 Cost of PCI and Its Determinants

As mentioned, the cost of PCI has been steadily increasing in view of the new advancements in stent and other device-related technology. The newer generation of DES are the preferred choice nowadays because of the proven clinical superiority and cost effectiveness. However, DES can cost two to three times more than BMS; other newer generations of stents such as BVS may even cost up to five times that of BMS. As a result, stent cost is often a major determinant in the total cost of PCI provision.

In 2011, a report from the United States showed that PCI accounted for over $5 billion in estimated costs, making it one of the top ten contributors to the national healthcare costs (HCUP Databases, 2011). Among PCI patients who were Medicare beneficiaries, those who received DES had higher initial hospitalization cost compared to BMS. (Groeneveld, Matta, Greenhut, & Yang, 2008). Another study on the cost trends of patients treated with PCI showed that the cost increased by 21% from USD 15,889 in 2001 to USD 19,349 in 2009. Further analysis in the same study pointed towards DES as the main driver of the increased cost due to the similar timeline in the introduction and uptake of DES (Afana, Brinjikji, Cloft, & Salka, 2015).

Apart from the consumable items such as stents and other devices inserted during the procedure, another major requirement for PCI provision is the availability of a full-fledged cardiac catheterization laboratory (CL). The CL must be equipped with sophisticated angiogram machines and full resuscitation facilities for the purpose of treating CAD patients. Besides investment in capital assets, human resource organization such as the staffing of CL is also a determinant of the PCI cost.

Ideally, a multidisciplinary team that consists of cardiologists, nurses and technicians who are highly trained should be in place to provide high quality care for PCI patients. There should be at least 2 or more trained interventional cardiologists within a PCI centre. In a study conducted in Japan, it was found that hospitals with a higher number of cardiologists tended to utilize more intensive treatment such as PCI, thus leading to higher healthcare spending among patients admitted with myocardial infarction. Nevertheless, the patient outcomes were more favourable and the mortality rate was lower among these hospitals (Park, Lee, Ikai, Otsubo, & Imanaka, 2013). Therefore, the cost and capacity of human resource is vital information for the establishment and expansion of a PCI service.

Cost of medical procedures and hospitalization also depend on the type of hospitals. Studies have reported cost differences between public- or private-owned hospitals, teaching or non-teaching institutions. The cost differences may be due to the inherent hospital charges, the casemix of patients, and the outcomes of procedures at each centre.

In many countries, university or teaching hospitals provide undergraduate medical training or postgraduate specialty training for practicing doctors who wish to further their qualifications. These centres are also known as academic centres and often serve as tertiary referral hospitals. Patients treated here are generally sicker on average, and the treatment approach tends to be more intensive and utilizing more advanced medical equipment, thus driving up the operation cost of the hospitals. For example, comparison between teaching and non-teaching hospitals in the state of New York, United States revealed that patients with myocardial infarction admitted to teaching hospitals were more likely to undergo invasive cardiac procedures such as PCI, and incurring higher hospital charges compared to non-teaching hospitals (Polanczyk et al., 2002).

Another risk-adjusted resource utilization study sampled 1,748 patients with acute myocardial infarction admitted to 10 large, private teaching hospitals between 2001-2004 in Japan and found that the average cost of PCI was 21,147 Euros (USD 27,068), a much higher figure than known records. The authors reasoned that the high cost could be attributed to the teaching hospital status and the heterogeneous patient population. Among the variables tested, choices of treatment and length of stay (LOS) were found to be strong predictors of the hospital cost (Evans et al., 2007).

Similar findings were seen in several European studies that examined the variations in hospital costs. The studies concluded that higher LOS and urban location of the hospitals predicted high hospital cost among ACS patients who underwent PCI (Etemad & McCollam, 2005; Soekhlal, Burgers, Redekop, & Tan, 2013; Tiemann, 2008). As with any other diseases that require inpatient hospitalization, LOS was identified as a major influencing factor of the cost of PCI procedure. In a cost effectiveness analysis of early discharge after uncomplicated acute MI undergoing PCI, hospitalization beyond 3 days was uneconomical by conventional standard (Newby et al., 2000). In another study, index hospitalization cost increased by a margin of 30% with a longer hospital stay, leading to recommendation of reducing LOS in an effort to reduce PCI cost among the Scottish cardiac centres (Denvir et al., 2007).

In many instances, the hospitalization period and choices of therapy, two of the commonly identified cost determinants for PCI patients, are closely dependent on the health status of the patients. As a result, many published literature identified the risk factors of CVD, namely age, gender and comorbidities such as hypertension, diabetes and obesity, as the predictors of high cost among patients with ACS who may require PCI (Bramkamp, Radovanovic, Erne, & Szucs, 2007; Etemad & McCollam, 2005).

In short, there are a variety of patient, procedure and hospital factors that influence the cost of PCI service. Alongside the already burgeoning demand for PCI procedures, the use of newer generation of expensive stents will create significant economic pressure on the healthcare budgets. The cost of PCI can be a constraining factor towards its service establishment and delivery in resource-limited countries. Thus, it is of fundamental importance to evaluate the costs of PCI and its associated determinants.

2.6 Development of Malaysian Healthcare system

Malaysia inherited the British healthcare system due to our colonization history. Unlike market-based systems, for example, in the United States, healthcare in Malaysia is highly regulated and mainly publicly funded. The Malaysian national healthcare system is a mixed system of public and private healthcare providers. The Ministry of Health (MOH) is responsible for building, establishing and operating the publicly funded healthcare system. MOH provides curative, preventive, rehabilitative, promotive and regulatory health services. It is also the largest healthcare provider in the country in terms of number of facilities, personnel staffing and service utilization. The main funding of public health services is via general taxation. The Treasury allocates the funds to the MOH based on spending in the past years plus any additional increment determined by the estimated inflation in Consumer Price Index. The public health services are highly subsidized; all publicly financed health centres and most common medications are universally accessible at the point of service for all citizens.

The MOH has healthcare facilities in all the 13 states and 3 federal territories. The public sector healthcare sector comprises three tiers at the district, the state and the national level. The first point of contact is the primary care providers at the local community clinic or health clinics; who serve as the gatekeepers to the secondary and tertiary referral centres in district and state hospitals. The place of residence is the main determining factor of which hospital patients will be first admitted to when in need of healthcare. If needs arise, patients can be referred to state-level or national-level tertiary hospitals. Approximately 65% of the population sought treatment and up to 83% of the hospitalizations occur at public healthcare facilities (Institute for Public Health, 2008).

Besides MOH healthcare facilities, tertiary healthcare services are also provided by university hospital under Ministry of Education (MOE). These MOE hospitals are often affiliated with the faculty of medicine of the said university. In Malaysia, there are currently 3 full-fledged university hospitals, namely University Malaya Medical Centre (UMMC), National University Medical Centre (HUKM), and Hospital Universiti Sains Malaysia (HUSM). Other recent additions to the list are International Islamic University Malaysia (IIUM) Medical Specialist Centre, UiTM Sungai Buloh Campus Hospital and Universiti Putra Malaysia (UPM), whereby its teaching hospital building is due to complete by 2018. These university hospitals operate through government subsidies.

Apart from public healthcare providers, the rapidly growing private sectors are also providing many much-needed services especially from curative and rehabilitative aspects. In Malaysia, private healthcare providers were a minority until the 1980s. Under the 4th Malaysia Plan for 1981-1985, a comprehensive privatization policy was put in place as part of the government's initiative in economic liberalization. As a result, the numbers of private hospitals and clinics grew rapidly after the 1980s.

In contrast to public healthcare professionals being the main provider for the less affluent population in the rural areas, the private sectors were mainly located in urban areas and do not receive any subsidization from the government (Juni, 1996). They were the preferred choice by those who can afford to pay out of pocket or receive medical benefits from employment. With the escalating healthcare cost, private healthcare insurance by commercial insurance companies rapidly gained popularity (Kananatu, 2002). As a result, Malaysians often opt for public or private healthcare facilities based on their financial status or insurance coverage.

Despite being conducted with the intention to improve efficiency, the act of privatizing and leaving healthcare to the market forces may have resulted in the opposite of the intended aim. Many opponents of privatization of healthcare argued that private healthcare centres are likely to engage in opportunistic behaviours, especially in view of information asymmetry between patients and providers, leading to providers-induced demands. This could inadvertently led to higher cost and inequity due to the profit-oriented business models by the private healthcare providers (Rosenthal & Newbrander, 1996).

From the perspective of general public, private for-profit hospitals are often perceived to be more efficient in terms of service. Pro-private-care advocates believe that private healthcare provision ensures an up-to-date and high quality of care at competitive prices. This contrasts with substandard public health service that is inequitable and inefficient as a result of bureaucracy, politicization, limited workers' incentives and financial constraints (Hasan, 1996). Despite so, there has been no clear evidence to support the perception that private hospital ownership is associated with higher efficiency compared to public hospital ownership (Herr, Schmitz, & Augurzky, 2011).

With the increasing number of private healthcare facilities offering better remuneration in the late 1980s, there was a rapid outflow of medical professionals from public sector to private sector. During the same period, corporatization became a growing trend around the world (Salmon, 1985). It was envisioned that more flexibility in terms of administration and financial autonomy for government-owned entities would encourage healthy competition and better performance.

The concept of corporatization was first implemented in Malaysia in the 1990s. Corporatization refers to the incorporation of public hospitals as government-owned but profit-oriented entities (S. Barraclough, 1997). In other words, the entity would be operated like a private organization with the aim of improving efficiency, productivity and quality of care to the public. Corporatized entities are allowed greater flexibility and autonomy in terms of the use of resources. Under this scheme, the national tertiary referral centre for cardiac care in Hospital Kuala Lumpur at that time was converted into the National Heart Centre, or Institut Jantung Negara (IJN), a government-owned but profit-oriented corporatized body. It became the first corporatized healthcare institution in the country.

University hospitals also undertook similar effort to curb brain drain to the private sector whereby staff was allowed to tend to private patients and charge consultation fees based on the fee schedule during non-working hours (Wong, 2008). Private hospitals or private wings were established at university hospitals, such as University Malaya Specialist Centre (UMSC), Universiti Kebangsaan Malaysia Specialist Centre (UKMSC), USAINS Hospital University Science Malaysia (USAINS), and UiTM Private Specialist Centre.

By 2015, several public hospitals in Klang Valley launched similar Full Paying Patient scheme (FFPS) so that senior specialists woule be better renumerated and not moved to the more lucrative private sectors. Under this scheme, private healthcare practices such as selection of preferred physicians, timing of elective medical procedures, access to first class ward and diet are available to patients at prescribed Fee Schedule rates set by the MOH. However, one of the drawbacks of this arrangement is the possible neglect of public patients in preference for FFPS patients (K. L. Phua & Barraclough, 2011).

In the backdrop of the reorganization of healthcare delivery and the roles of the various types of providers involved, the healthcare expenditure in Malaysia continues to escalate over the past few decades. One of the best methods to estimate the healthcare expenditure of a nation is to compare total expenditure on health with the national gross domestic product (GDP). During the study period in 2014, the total expenditure on health in Malaysia as a percentage of GDP was 4.2%. It showed an increment from 3.0% in 2000, to 3.8% in 2011, and 4.0% in 2013 (Malaysia National Health Accounts Unit, 2014; World Health Organization, 2014). Even though by international comparison, this figure was still far below the average of 9% in OECD countries, and the 6.1% for upper middle-income countries, the health expenditure as a percentage of GDP in Malaysia over the years has been rising steadily at rates that exceed the actual GDP growth. This has raised issues over its long-term sustainability, making economic evaluations to identify cost effective healthcare services a pressing matter.

In the same WHO Database, it was documented that more than half or 55.2% of the total health expenditure in 2014 was incurred in the public sector. This translated to an amount equivalent to RM 26.7 billion (USD 7.8 billion, USD1= RM 3.40 in 2014). Among the different types of services in public sector, curative care provision at hospital level accounted for the biggest portion of expenditure. This is of great relevance to this study, as cardiology service can be a microcosm representation of the overall healthcare system. It would be expected that majority of the current health expenditure incurred in the cardiology service would be directed towards curative care in the public cardiac centres. Thus, it would be of great interest for the clinicians, healthcare administrators and policy makers at the highest level to be informed of the cost of care and the associated cost-saving factors at various hospitals.

2.7 Development of Cardiology Service in Malaysia

The development of cardiology service in Malaysia took place in an almost parallel manner with the transformation of healthcare services in the country. Before the nation independence in 1957, a missionary hospital known as Lady Templer Hospital was the first centre to provide cardiology and cardiothoracic service. A new university hospital was established in 1968 as part of the Faculty of Medicine for Universiti Malaya, the first university in Malaysia. The hospital, Rumah Sakit Universiti Malaya (now known as University Malaya Medical Centre-UMMC), became the national cardiology referral centre, taking over the services provided at Lady Templer Hospital. Over the next 2 decades, the government allocated more budgets to improve healthcare infrastructure in the country. Gradually, more cardiac units were established at most of the state-level public hospitals.

Back in the 1960s and 1970s, majority of the cardiac cases seen were congenital heart disease and rheumatic heart diseases. By mid 1980s, in view of the increasing prevalence of CAD, services for coronary angiography were slowly incorporated into cardiac units over Malaysia. The procedure of balloon angioplasty was first conducted locally in 1987 at University Hospital and General Hospital Kuala Lumpur. The services started with simple, single vessel disease, coupled with cardio-surgical backup. It gained popularity among the local cardiologists over time with its low invasiveness.

At around the same time, private hospitals with cardiology service started mushrooming in urban locations, operating on fee-for-service basis and catering mainly to middle and high-income population. Subang Jaya Medical Centre, located in one of the more affluent suburb of Klang Valley, was one of the first private hospitals in the country to establish a cardiac angioplasty unit. However, despite increasing private hospitals offering angioplasty services, majority of the work burden still fell on the public cardiac centres. The main reason was due to the exorbitant fees for medical procedures and hospitalization in private sector. With the logistics and cost issues in place, private healthcare centres were not accessible to all. This inequitable distribution of hospitals between urban and rural areas further compromised the quality and accessibility of healthcare services to the rural population (Rasiah, Noh, & Tumin, 2009).

With the implementation of the corporatization concept in the 1990s, the National Heart Institute (IJN) was established as a corporatized body in 1992. It was the intention of the Malaysian government to create "corporatized hospitals, although government-owned, had autonomy in their financial and staff management and were encouraged to compete with one another and also with the private health sector" (Simon Barraclough, 2000).

As mentioned in Section 1.3, IJN operates as both public and private cardiac centres. Fee-for-service arrangement is available for private patients, whereas public patients can also be referred to IJN and charged at a subsidized rate. Furthermore, public sector employees and their dependents and/or parents are entitled to highly subsidized treatment cost and need to pay only minimal rates, far below the prescribed Fee

Schedule rates (Kananatu, 2002) or the rate charged by private hospitals. The discrepancy in the hospital charges of these subsidized public patients are subsequently reimbursed to IJN by government. Therefore, revenue for a corporatized healthcare centres could come from fees from private patients and subsidies from the government for civil servants, pensioners and the poor.

With the establishment of IJN as the national tertiary referral cardiothoracic centre, many complex cardiac treatments such as bypass surgery, angioplasty, organ transplantation, could be conducted at a fraction of the cost charged at private hospitals or overseas cardiac centres. However, the total reimbursement made by the MOH to IJN, which turned into the corporatization's revenue, continued to rise substantially over the years. In a consultation report on healthcare reform initiatives, it was documented that private patients contributed to 24% of IJN revenue, whereas the remaining revenues were paid by governments for the civil servants and their dependents (52%) and the poor (24%) (Shepard, Savedoff, & Phua, 2002). To put it into actual figure, the reimbursements to IJN by the government had been increasing from MYR 31.3 million in 1992 to MYR 65.5 million in 1997 within the 4 initial years of its establishment. The same authors remarked the mismatched equity whereby public patients may be put on longer waiting lists while priority was given to private paying patients in IJN, leading to issue of equity in access to corporatized healthcare service (K. H. Phua & Wong, 2008). By 2004, the reimbursement has risen to RM 144.5 million (Chua, 2005). No published reimbursement values to IJN for recent years could be retrieved but based on anecdotal account, it was estimated to be in the range of RM 200 million in the year of 2012.

Following the corporatization of the Cardiology unit at Hospital Kuala Lumpur into IJN, several public cardiac centres under Ministry of Health were established-Penang Hospital (1994), Sultanah Aminah Hospital in Johor (1996), Sarawak General Hospital (2001), Serdang Hospital in Selangor (2006), Sultanah Bahiyah Hospital in Kedah (2007), Queen Elizabeth Hospital in Sabah (2009). In the east coast of Peninsular Malaysian, 3 centres had been set up respectively, namely in Hospital Raja Perempuan Zainab II Hospital in Kelantan (2009), Hospital Tengku Ampuan Afzan in Pahang (2009) and most recently in Hospital Sultanah Nur Zahirah in Terengganu (2010).

In contract to the corporatized IJN, public cardiac centres are financed by the central Treasury based on global budgeting. Each public cardiac centres receives an annual budget based on previous year's procedural volume. Experiences from previous years showed that most of the centres would have already utilized all allocated budget before end of the fiscal year. As a result, the centres have to turn to the MOH Special Medical Funds (Tabung Perubatan KKM) to secure extra funding for essential devices such as drug eluting stents, pacemaker and closure devices. This highlights the fact that case loads from previous years may not be the best guidance for budget allocation.

As the demand for healthcare services become higher and more diverse, government, private health sectors and insurance companies increasingly seek after cost estimates of different health services for the purpose of financial planning. With the increasing prevalence of CAD in Malaysia, expansion of PCI service across Malaysia is underway. To ensure a year-long smooth delivery of patient care, annual budget allocation should take into account the cost behind the changes in patient demography, medical technology and inflation. Therefore, comprehensive analysis on the cost of PCI can be a stepping-stone towards determining the cost of other relevant cardiology service. This will provide the vital information required for the long-term planning in budget and resource distribution for the various cardiac centres.

2.8 Cost Analysis of Healthcare Intervention

With the rapid escalation of healthcare cost, economic evaluation is fast becoming an important component of modern healthcare delivery. In the face of scarcity, economic evaluation is often necessary to compare health outcomes and costs for policy-making purposes. There has never been a more pressing need for conceptually sound and empirically accurate estimates of healthcare costs. These estimates are used in economic evaluations to assess the impact of investments in disease prevention and treatment, and to guide decision-making in future budget allocation and service planning. (Lipscomb, Yabroff, Brown, Lawrence, & Barnett, 2009).

For economic evaluation, a standardized costing methodology will reduce the possibility of producing unfair comparison and misleading policy makers into making flawed decision. Many researchers have promoted the standardization of methods in economic evaluations to ensure high quality and consistent standard during data collection and result analysis (M. Drummond, Brandt, Luce, & Rovira, 1993; Mullins & Ogilvie, 1998). In many high-income developed countries (HIC) like Australia, Canada and England, there are well-established guidelines and recommendations for general standard and major methodologies for costing in healthcare economic evaluation (Baladi, 1996; M. Drummond, Sculpher, Torrance, O'Brien, & Stoddart, 2005; Oostenbrink, Koopmanschap, & Rutten, 2002; Pharmaceutical Benefits Advisory Committee, 2009). By using the standardized guidelines available, the researchers and healthcare providers in said countries are able to conduct cost studies and incorporate the findings in health service delivery.

Nevertheless, it is impossible to apply one standardized methodology to all studies due to difference in settings, objectives, disease or intervention investigated. Therefore, the best compromise is to reach a balance between the degree of achievable standardization and the necessity to tailor the approach to the individual study setting (Jacobs, Bachynsky, & Baladi, 1995, Oostenbrink et al., 2002). This is especially true for LMIC. These countries face huge challenges in conducting cost studies due to the lack of accurate financial information and electronic health records. As a result, there are few published studies in the area of economic evaluation from LMIC (Mogyorosy & Smith, 2005; Sarowar et al., 2010; von Both, Jahn, & Fleba, 2008).

There are several important methodological differences between HIC and LMIC, leading to various implications for research standards from these countries. To begin with, reference costs derived from a non-patient-specific source, such as diagnosis-related groups based on national administrative databases were readily available in most HIC, thus leading to an application of as high as 78% of economic evaluations sampled from HIC and 45% of upper-middle-income countries, but not in any lower-middle-income countries studies (Griffiths, Legood, & Pitt, 2016). To make up for the lack of reference data, micro costing studies that are more labour-intensive and time-consuming would need to be conducted to obtain cost data via bottom-up approach. Despite being able to produce a more accurate cost estimate of the cost items, the main limitation of bottom-up costing lies within the complexity and cost of its implementation (Emmett & Forget, 2005).

To overcome this issue, some of the published literature advocated striking a balance between the objectives of the costing and the precision of the estimates available when choosing the costing approach (Oostenbrink et al., 2002). In short, it was proposed to apply the more labourious bottom-up micro costing approach only for cost items that are likely to show wide variation between patients (Swindle, Lukas, Meyer, Barnett, & Hendricks, 1999).

Similar to most LMIC, in Malaysia, the local research and environment capacity on health economics is still in an infancy stage. More concerted efforts are required to support widespread practice and application of economic evaluation in the decision-making of health policy. Based on the literature review findings related to costing methodology, it was obvious that certain modifications to the published economic evaluation guidelines would be needed for the purpose of this costing study. This will be further explained in Chapter 3.

2.9 Conceptual Framework

In many countries, the utilization of healthcare services is directly related to the healthcare cost incurred on the system. To gain a better understanding of the healthcare cost, it is necessary to explore to mechanisms that influence healthcare utilization. Multiple individual and contextual factors impact on healthcare utilization. There are several theoretical frameworks in the literature that define the predictors of healthcare access and utilization (Rebhan, 2008; Ricketts & Goldsmith, 2005).

2.9.1 Andersen and Newman Framework

One of the most widely used theoretical frameworks is the model proposed by R. Andersen and J.F. Newman. It was initially called the "Behavioural Model of Health Services Use" in 1968 (R. Andersen, 1968). Multiple individual determinants including predisposing factors (socio-demographic and belief characteristics), enabling factors (support or impedances towards healthcare service use such as income, cost of care, access, location) and illness level were proposed to influence healthcare utilization.

In the 1970s, the model was expanded into the "Societal and Individual Determinants of Medical Care Utilization in the United States" (R. Andersen & Newman, 1973). Figure 2.1 was reproduced from the reprint of the paper (Ronald Andersen & Newman, 2005). The refined framework added in 2 major dimensions, namely social determinants and health services system. Under the health services system, the resource distribution and organization management in terms of labour, asset and budget ultimately influence the structure of health services system and its utilization.

The dimension of societal determinants refers to changes in technology and norms over time. Improvement in medical technology continues to alter the need, length of use and outcome of healthcare utilization. Evolving consensus of beliefs and values in the society, shaped either by formal legislation or new trend development, also play a significant role in the decision for health services utilization. Together, this integrated framework presents a causal explanation of various mechanisms that determine the utilization of healthcare services.

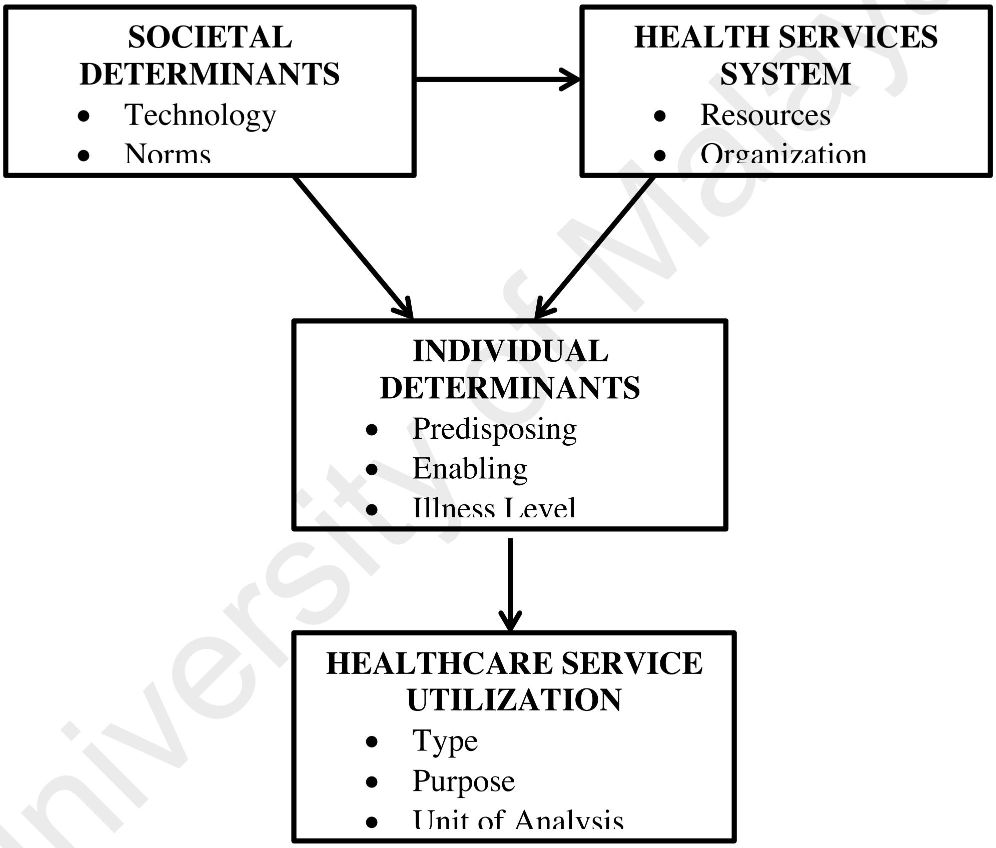

Figure 2.1: Andersen and Newman Framework for viewing health services utilization

2.9.2 Modified Framework

Due to the close relationship between healthcare utilization and healthcare cost, several studies in the literature have incorporated the Andersen's behavioural model in analysis of healthcare costs (Heider et al., 2014; Lehnert et al., 2011). Increasing healthcare utilization will invariably lead to escalation in healthcare cost. However, the interactions between the determinants of healthcare utilization and the eventual impact on the cost outcomes represent a more complex relationship.

This thesis aims to derive the cost of PCI and subsequently to gain better understanding of the components involved in cost variation of PCI. To achieve this, a conceptual framework was developed based on modification made to the Andersen and Newman Behavioural Model (Figure 2.2). Various factors identified in other published studies as outlined in the literature review are included in the analysis to determine the output most relevant to our local setting.

To adapt to the objectives of this thesis, several modifications were made to the model. Individual determinants were substituted with patient-level factors including socio-demographic characteristics, past and current cardiac-related characteristics. As for societal determinants, emphasis was placed on medical advancement in terms of cardiac interventional and device-related technology. This provides a more focused and clinically oriented perspective in line with the main aim of this thesis. Under health service system, attention was directed at the organization of cardiology service in Malaysia and the distribution of resources in terms of finance and labour.

By applying this framework, we hope to be able to evaluate the multi-level determinants on healthcare utilization and subsequently cost in terms of PCI service. The findings could be used to guide the formulation of health policy for sustainable and equitable service delivery.

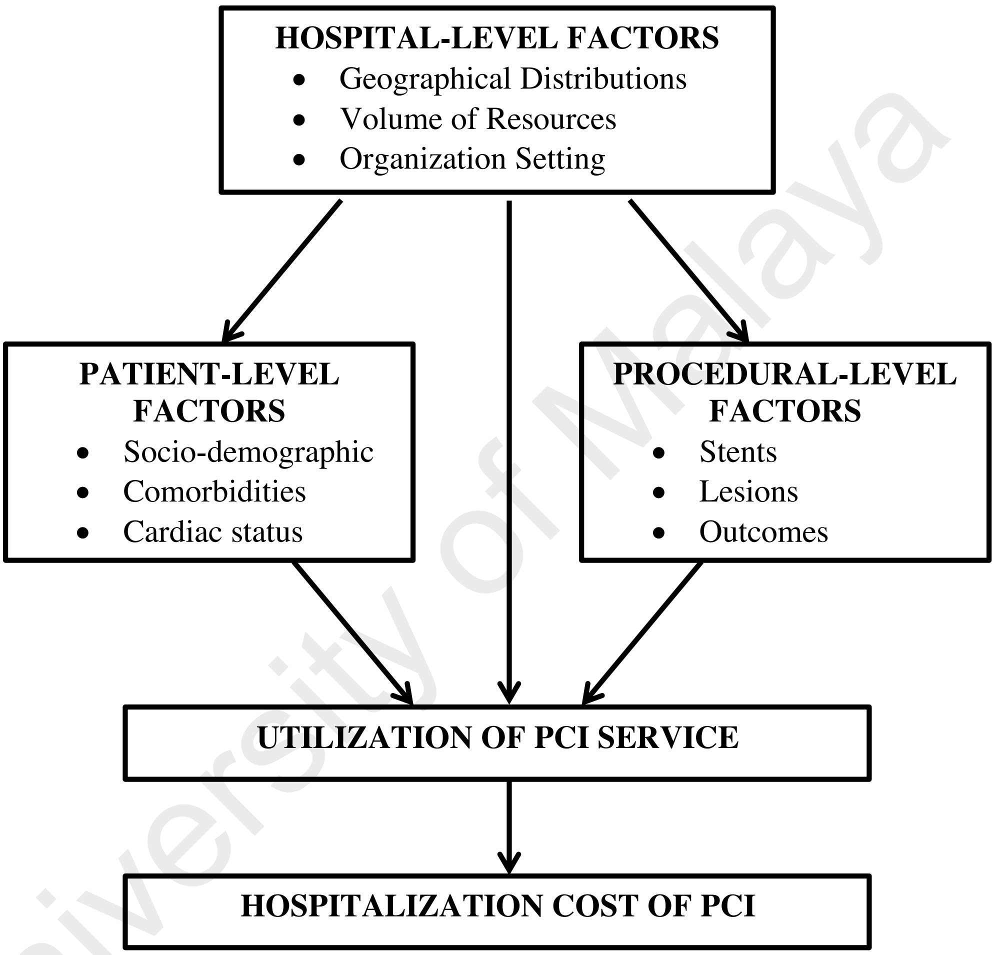

Figure 2.2: Conceptual framework to determine the cost of PCI and its associated factors at various cardiac centres in Malaysia

2.10 Summary

The disease burden of CAD is increasing globally, especially for LMIC like Malaysia. Technological innovation in PCI has led to improved clinical outcome. As with many other medical advancement, it comes with an economic impact on both providers and patients. Studies conducted in various countries have identified the factors associated with utilization and cost pattern of PCI service. Cost drivers for PCI appeared to be different depending on the types of healthcare institutions.

However, published data on the cost of PCI at the various cardiac centres in Malaysia is scarce, and no local evidence is available on the cost driver and cost predictors of the service. To attain reliable cost data, it is necessary to develop a standard costing approach based on the setting of our country. A comprehensive analysis on the utilization and cost of PCI service will provide an insight to the possible reasons behind the variation of costs between the different cardiac centres. This provides important guidance towards the formulation of cost-saving measures to improve efficiency of cardiology service provision in Malaysia.

CHAPTER 3: METHODS AND MATERIALS

This thesis set out as an economic evaluation of PCI, a common intervention for CAD in Malaysia. Ideally, in an economic evaluation, the outcome and cost of intervention will be assessed and subsequent analysis such as cost-effectiveness analysis or incremental cost-effectiveness ratio will be performed if there are several interventions under comparison. The study was initially planned as a cost effectiveness analysis but the outcomes in terms of mortality and post procedure complications were found to be similar with very minimal differences between the centres. Thus, decision was made to conduct a cost analysis at different cardiac centres in Malaysia, in order to determine the resource utilization and cost estimates associated with PCI hospitalization.

With these in mind, cost data was collected with an adapted costing methodology based on modifications made to economic evaluations guidelines published in the literature. Comparison of average costs was made between the different centres. Cost data was then incorporated with patients' clinical and treatment characteristics derived from a nationwide cardiovascular registry to enable further analysis using individual-level patient data.

3.1 Study Design

A cost analysis can be conducted from the perspective of the patients, society or the healthcare providers. The time horizon and subsequent study design very much depend on the type of perspective adopted. In this study, the perspective of the healthcare providers was taken, in which only the costs incurred within cardiac centre was considered. Other cost items from the patients' perspective such as productivity loss, travel cost, and out-of-pocket expenditure were not included.

The adoption of healthcare providers' perspective allowed a shorter time horizon to be set. In this study, cost figure and utilization data from January 1st 2014 to June 30th 2014 were collected. All unit cost estimates were presented in the local currency, Malaysian Ringgit (RM), whereby USD 1=RM 3.60 at the time of study.

In short, this was a hospital-based cross sectional cost analysis. Clinical data for patients was retrieved from a registry database upon completion of data submission for the period of January 1st to June 30th 2014 (See Section 3.4). Cost data was collected from the participating cardiac centres. Cost-related date was obtained via a primary data collection over a course of 3 months from the relevant units and departments after the last day of the stipulated study period of June 30th 2014.

3.2 Study Centres

As of 2014, there were a total of 13 public hospitals and more than 50 private hospitals providing PCI service in Malaysia. The public cardiac centres were well distributed geographically to serve the different regions of the country whereas the private cardiac centres concentrated in the more affluent and urbanized areas. In view of the rapid expansion of the cardiology service in the country since the last decade, the policy makers and the cardiologists realized both the need to establish a cardiac registry.

The Malaysian National Cardiovascular Disease Database (NCVD) was established in 2007 with the support of Ministry of Health (MOH) Malaysia and National Heart Association of Malaysia (NHAM). It consisted of 2 registries; NCVD-ACS Registry and NCVD-PCI Registry. During the study period, there were 13 centres actively providing data to the NCVD-PCI Registry. Further information regarding this registry is discussed in the section 3.4.1.

With the comprehensive clinical data available from this registry, patient-related clinical and procedural data were extracted from the registry and utilized for the purpose of this costing study. As for the cost data, primary data collection was conducted. All of the 13 centres actively providing clinical data to the registry in 2014 were invited to participate in this cost analysis. However, due to the sensitive nature of financial data, there was a lack of interest from most of the centres to collaborate on this project.

In total, 5 cardiac centres agreed to participate and contributed relevant cost data. All these centres are staffed by at least one consultant cardiologist and one cardiothoracic surgeon at all times and are capable of providing full-fledged cardiology and cardiothoracic services. Figure 3.1 is a map of Malaysia showing the locating of each of the participating cardiac centre. Each of this cardiac centre serves as the tertiary referral hospital for the region that they are located in. Of the 5 centres, one is a corporatized entity under a government-linked company; another one is a semi-corporatized university teaching hospital. The remaining 3 hospitals are government public hospitals.

With the different locations and ownership types, the 5 centres would be able to represent variations across the different cost components stemming from the heterogeneity in hospital ownership, patient characteristics and geographical locations. Table 3.1 provides a brief summary on the 5 centres. The subsequent sections 3.3.1 to 3.3.5 describe each of the cardiac centre in greater details.

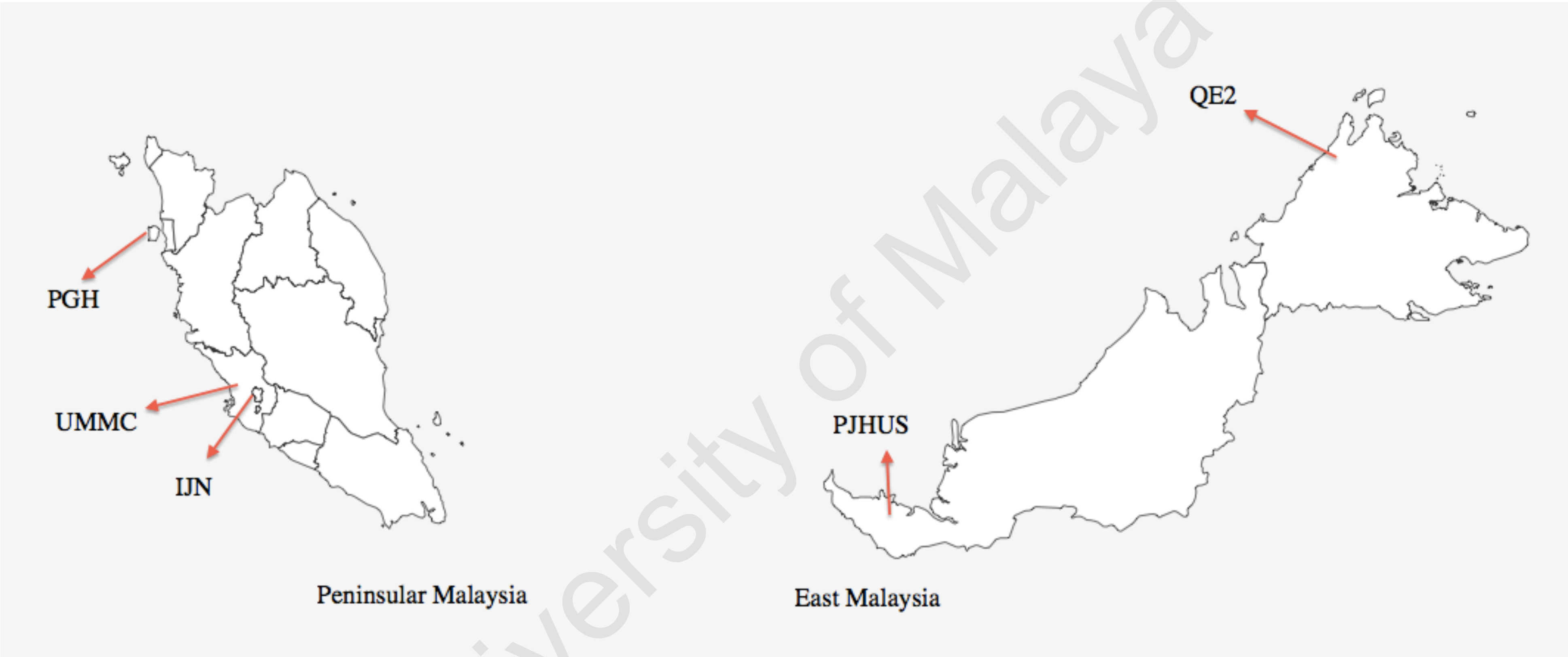

Figure 3.1: Map of Malaysia showing the location of each participating cardiac centre

Note. Map is provided by FreeVectorMaps.com ("Map of Malaysia with Regions-Outline," 2014)
UMMC=University Malaya Medical Centre, IJN=National Heart Institute, PGH=Penang General Hospital, PJHUS=Sarawak General Hospital Heart Centre, QE2=Queen Elizabeth 2 Hospital, Sabah

Table 3.1: Background information of study centres

Centre	**UMMC**	**IJN**	**PGH**	**PJHUS**	**QE2**
Ownership type	Semi-corporatized	Corporatized	Public	Public	Public
Start of PCI operation	1987	1992	1994	2011	2010
Interventional cardiologists	5	15	3	1	1
Fellow cardiologists	12	12	8	7	0
Number of Cardiac Catheterization Laboratory	3	8	2	1	1
Catchment area	National	National	Northern	Sarawak	Sabah
Hospital admission during study	34414	8485	29336	1744	9340

Note. UMMC=University Malaya Medical Centre, IJN=National Heart Institute, PGH=Penang General Hospital, PJHUS=Sarawak General Hospital Heart Centre, QE2=Queen Elizabeth 2 Hospital, Sabah.

3.2.1 University Malaya Medical Centre (UMMC)

UMMC is a tertiary-level teaching hospital affiliated with the University of Malaya. It is located in the heart of Klang Valley and receives patient referral from the whole country. It was originally known as University Hospital (UH) when it opened in 1968. The first PCI in the country was performed in UH in 1983, following the first successful coronary angiogram in 1982.

Due to its status as a teaching hospital, it falls under the purview of Ministry of Education, instead of Ministry of Health (MOH) like other public hospitals. In June 2000, UH was transformed into a semi-corporatized medical centre, kmown as University Malaya Medical Centre (UMMC). Hospital charges for patients were still subsidized by government, but at a lower level if compared to other public hospitals. Later on, a separate privatized entity, known as University Malaya Specialist Centre (UMSC) was established, whereby UMMC consultants are allowed to tend to private patients and charge consultation fees based on the fee schedule.

During the study period, the department of cardiology in UMMC has a total of 17 cardiologists, with 5 of them being fully certified interventional cardiologists. At the end of 2013, the division of interventional cardiology was relocated to the newly constructed complex 'Menara Selatan' meant for day-case procedures. All the elective PCI patients are admitted to Interventional Cardiac Ward (ICW) in the new complex.

3.2.2 National Heart Institute/ Institut Jantung Negara (IJN)

The Malaysian National Heart Institute, or more familiarly known as IJN, is located in the central area of Kuala Lumpur. The IJN today is what used to be the cardiothoracic and cardiology units at the Kuala Lumpur General Hospital. It was converted during the national corporatization drive in the early 1990 to become a corporatized tertiary-level specialized cardiac centre. It is under the ownership of the Ministry of Finance. The centre has a private entity and provides treatment for fee-for-service patients, just like any private hospitals. On the other hand, Malaysian citizens who are retired or in-service government servants can receive care at a subsidized rate in the public wing. The government would reimburse any discrepancy in the treatment charges. Charges for the same treatment vary considerably between government-subsidized and non-subsidized patients. For the purpose of this cost analysis, IJN provided only the cost information related to patients undergoing PCI in the public wing.

Since its establishment, IJN has been at the forefront of using many new devices for coronary interventions, such as rotational atherectomy and intravascular ultrasound. It was also the first cardiac centre in Malaysia to use the drug-eluting stent and drug-eluting balloon. Besides being a main provider of PCI service, IJN has also evolved into a main training and research centre in various aspects of cardiac intervention. During the study period, IJN had a total of 15 interventional cardiologists on board, and another 12 certified cardiologists in other subspecialties. The centre can accommodate up to 460 patients at any one time.

3.2.3 Penang General Hospital (PGH)

PGH is the largest hospital in the Northern region in Malaysia. It serves as the referral centre for patients from the states of Penang, Kedah and Perlis. Its history can be traced as far back as 1854 to the Pauper's Hospital started by the local community leaders to provide healthcare to the poor. The original building of PGH dated back to 1882. The construction and expansion of the PGH complex started as early as 1920s. Currently, it is the second largest public hospital in Malaysia, with a total of 1090 hospital beds.

In 1994, it became one of the first public hospitals in Malaysia to set up a cardiac catheterization laboratory and provide PCI service for patients in need, after Hospital Kuala Lumpur. In 2014, there were 11 cardiologists in the cardiology division; 3 of whom are interventional cardiologists. Elective PCI patients may be admitted to either the Cardiac Rehabilitative Ward or the normal cardiac ward.

3.2.4 Sarawak General Hospital Heart Centre (PJHUS)

On the Borneo Island of East Malaysia, cardiology services were provided by Sarawak General Hospital in the city centre of Kuching before 2011. Due to the heavy patient load and limited expansion ground in the surrounding area, the cardiology division was relocated to the Sarawak Heart Centre, a new facility in Kota Samarahan on 1st of January 2011. It is a fully public-owned cardiac centre.

Besides being the referral centre for cardiac cases from the state of Sarawak, PJHUS also receives a small number of patient referral from other part of Borneo such as Sabah, Brunei and Kalimantan. It received approximately 4000 admissions in 2014.

During the study period, it had 8 cardiologists, one being an interventional cardiologist. Among the 5 cardiac centres in the study, PJHUS is the only one that has an established day-care centre for PCI patients. Selected patients may be scheduled for same-day discharge after the PCI procedure. Other patients will be admitted to inpatient cardiac ward. This decision is usually dictated by logistics and clinical factors.

3.2.5 Queen Elizabeth 2 Hospital, Sabah (QE2)

In a similar note to PJHUS, QE2 was originally a part of Hospital Queen Elizabeth, the main public hospital in Sabah, another state in East Malaysia. However, major part of the hospital building was declared unsafe in 2008 and reconstruction was necessary. To solve the patient congestion issue in such a short notice, the government bought over a private hospital and renamed it as QE2. Cardiology service was one of the many specialties being relocated to the new hospital at the end of 2009.

Even though the official launching of Sabah Heart Centre in QE2 took place on 2nd February 2012, the cardiac centre started its full operation back in 2010. As a fully government-owned centre, it provides full-fledged interventional cardiology service to patients from Sabah and Labuan. However, there is only one interventional cardiologist. When the need arises, visiting cardiologists will be flown in from other states to relieve his duty.

3.3 Study Population

PCI can be conducted as an elective or emergency procedure based on the disease severity. Patients who undergo emergency PCI procedures tend to have more severe CAD and comorbidities. Thus, they are more likely to consume more resources and incur a higher hospitalization cost. Conversely, elective PCI patients have lower risk profile and often undergo more straightforward procedure in the CL. Thus, they represented a relatively homogenous group and are a better paradigm to highlight the cost and resource utilization at all the cardiac centres.

As such, we restricted our analysis to patients recorded as having undergone PCI as an elective procedure in the NCVD-PCI Registry and excluding all patients with urgent/emergent indication for PCI, or with shock and hemodynamic instability. This definition is compatible with the definition of elective PCI adopted by other studies in the literature (Negassa & Monrad, 2011; Shaw et al., 2002). More specific inclusion and exclusion criteria are as below:

Inclusion criteria

1. All patients who underwent elective PCI in the NCVD-PCI Registry.
2. Patients who received management from admission to discharge within the same cardiac centre.

Exclusion criteria

1. Patients who underwent emergency/urgent PCI.
2. Patients with shock and other haemodynamic instability on admission.
3. Patients with complications post-PCI and required admission to an intensive care unit or a high dependency unit.
4. Patients who required transfer to another cardiac centre within the same episode of disease.

3.4 Clinical Data Collection

Clinical data on patient and procedural characteristics of elective PCI were derived as secondary data from the NCVD-PCI Registry for all the participating centres. This provided an overview of the patient and disease profile for each centre, and allowed comparison of the PCI procedural characteristics and outcomes between the centres.

3.4.1 NCVD-PCI Registry

The National Cardiovascular Disease-PCI Registry (NCVD-PCI) was established in 2007 to record clinical data of PCI for performance appraisal and quality improvement purposes. It was created as a nation-wide prospective observational study on a diverse and multi-ethnic, multi-cultural population of real-world patients admitted for PCI. Clinical information captured included patient demographics, clinical presentation, angiographic severity, treatment and outcomes of all patients, 18 years and above who underwent PCI. The Ministry of Health Medical Research and Ethics Committee (MREC) authorized the NCVD registry under the registration of ID: NMRR-07-38-164.

Participation of cardiac centres in this registry is voluntary. Data collected included socio-demographic and clinical characteristics, angiographic and procedural details, and in-hospital outcomes. An electronic web-based case report form was created for the data collection (APPENDIX B). Data on all PCI cases performed was recorded by trained coordinators stationed at each participating centre and uploaded to an online website application. Collected data was subsequently entered into a web-based centralized database. Data quality was maintained by various measures such as rigorous and uniform data abstraction training, site feedback reports and data validation. Regular data checks were performed and queries were generated for correction to ensure accuracy.

3.4.2 Data Extraction

After completing study registration with the NMRR and obtaining ethical clearance from the Malaysian Research Ethics Committee (MREC), an official request was put forth to the Advisory Board of NCVD-PCI Registry for data release. Upon approval, the full set of requested data was attached as a zip file in an email. The file was encrypted with a password that expired within one week of the email. Due to the large data fields in the PCI registry, the data was exported in Microsoft excel workbooks. Each workbook contained data from different section of the registry case report form.

There were 5 separate files containing all the necessary data for this study. The first file, 'Patient', recorded 8 demographic variables from section 1 of the registry case report form. The second file, 'PCIPatientNotification', included 56 variables from section 2-6 and 8 of the registry case report form. Variables recorded in these sections included comorbidities and cardiac status of the PCI patients. The third file, 'PCIPatientOutcome', recorded the discharge details and outcomes of each patient. The 20 variables pertaining to the details of lesion treated in the PCI procedure were contained in the 'PCILesion' file. By using the unique identifier-*PCIPatientNotificationID*, all the variables in the different files were merged.

The combined dataset from the 8 sections contained a total of 84 variables. However, only clinical variables relevant to this costing study were selected from each section and included in the analysis. The selected clinical variables and their definitions are described in the next section.

3.4.3 Operational Definitions

Gender

Male or female.

Age

Age in years on admission day.

SDPID

The cardiac centre where the PCI procedure for the patient was conducted.

Ethnicity

Malay, Chinese, Indian or others (Punjabi, Iban, Kadazan, Bidayuh, other bumiputera).

Smoking

History confirming any tobacco use currently or in the past. Can be yes (currently smoking or previously smoked), or no (never smoked).

Dyslipidaemia

Diagnosed and treated by physician, and/or cholesterol >5.0 mmol/L, HDL <1.0mmol/ L, or Triglycerides >2.0 mmol/L.

Diabetes

History of diabetes mellitus regardless of duration and treatment.

Hypertension

Diagnosed and treated by physician, and/or Blood pressure of >140 systolic or >90 diastolic on at least 2 occasions.

Family history of CVD

First-degree relative with either CAD or stroke.

Myocardial infarction history

Documented history of previous MI either by ECG changes, elevated cardiac biomarkers or imaging evidence.

Documented CAD

Presence of >50% stenosis on coronary computed tomography angiogram, angiogram or ischaemia on functional cardiac imaging.

Chronic renal failure

Serum creatinine level > 200 micromol/L.

Body mass index

Measured weight in kg/ (Measured height in metre)^2.

History of heart failure

Documented heart failure on chest x-ray or presence of paroxysmal nocturnal dyspnea, dyspnea on exertion or pedal oedema.

Recent onset angina

Reported angina in the past 2 weeks.

Previous PCI

Prior percutaneous angioplasty procedure.

Previous CABG

Prior coronary artery bypass grafting surgery.

NYHA (New York Heart Association) Functional Classification

Class I: Ordinary physical activity does not cause dyspnea.

Class II: Ordinary physical activity results in limiting dyspnea.

Class III: Less than ordinary physical activity causes dyspnea.

Class IV: Dyspnea at rest that increases with any physical activity.

CCS (Canadian Cardiovascular Society) Grading of Angina Pectoris

CCS 1: Ordinary physical activity does not cause angina. Angina with strenuous or rapid or prolonged exertion at work or recreation.

CCS 2: Slight limitation of ordinary activity. Walking or climbing stairs rapidly, walking uphill, walking or stair climbing after meals, or in cold, or in wind, or under emotional stress, or only during the few hours after awakening. Walking more than two blocks on the level and climbing more than one flight of ordinary stairs at a normal pace and in normal conditions.

CCS 3: Marked limitation of ordinary physical activity. Walking one or two blocks on the level and climbing one flight of stairs in normal conditions and at normal pace.

CCS 4: Inability to carry on any physical activity without discomfort, anginal syndrome may be present at rest.

Acute coronary syndrome (ACS)

Clinical features comprising unstable angina (UA), Non-ST-elevation MI (NSTEMI) and ST-elevation MI (STEMI), characterized by chest pain or overwhelming shortness of breath, defined by accompanying ECG and biochemical features.

Single Vessel Disease

Lesions of >50% in only one coronary system.

Multi-Vessel Disease

Lesion of >50% in 2 or more coronary system.

Percutaneous entry

Arterial vascular access via brachial, femoral or radial artery.

TIMI flow

TIMI (Thrombolysis in Myocardial Infarction) classification is used to assess coronary artery perfusion based on angiographic grade flow seen during PCI.

TIMI-0: no perfusion

TIMI-1: Partial, but incomplete filling of the coronary bed distal to the obstruction

TIMI-2: Partial perfusion. Contrast material passes across the obstruction to distal of obstruction, but slower than comparable areas

TIMI-3: Complete perfusion. Antegrade flow rapid from an uninvolved area

Coronary system lesion type (ACC/AHA guidelines)

A: Minimally complex, discrete (<10mm), concentric, readily accessible, lesion in non-angulated segment (<45 degrees), smooth contour, little or no calcification, less than totally occlusive, not ostial in location, no major side branch involvement, absence of thrombus.

B1: Only one of the following type B characteristics: lesion moderately complex, tubular (10-20mm), eccentric, moderately tortuosity of proximal segments, lesion in moderately angulated segment (>45 degrees but <90 degrees), irregular contour, moderate to heavy calcification, total occlusions less than 3 months old, ostial in location, bifurcation lesions requiring double guide wires, some thrombus present.

B2: more than one type B characteristic.

C: severely complex diffuse (>20mm), excessive tortuosity of proximal segment, lesion in extremely angulated segment > 90 degrees, total occlusion greater than 3 months old or bridging collaterals, inability to protect major side branches, degenerated vein graft with friable lesions.

Type B2 and C are classified as complex lesions.

High risk feature within lesion

Ostial lesion-Lesion is within 3mm of the origin of the vessel.

Total occlusion-Lesion has 100% pre-procedure stenosis.

Chronic total occlusion (CTO)-Lesion defined as being >3 months old and/or bridging collaterals. CTO lesions have 100% pre-procedure stenosis.

Calcified lesion-Calcium deposits present in the diseased vessel.

Bifurcation-Division of a vessel into at least two branches, each of which is >2 mm or greater in diameter. In a bifurcation, the plaque extends on both sides of the bifurcation point. It needs not progress down both branches.

Stent type

Drug-eluting stent/ bare metal stent/ drug-eluting balloon/ bio-absorbable vascular scaffold.

Length of stay (LOS)

Hospital LOS was calculated and expressed in days by: LOS = discharge date - admission date. If discharge date = admission date, then LOS = 1 day.

Lesion result

Successful revascularization when <20% residual stenosis detected in stented lesion.

Significant peri-procedural myocardial infarction

The new occurrence of a clinically diagnosed myocardial infarction, with or without positive biomarker, within 6-24 hours post-PCI.

Emergency reintervention

Patient required an ischaemia-driven, unplanned revascularization in the form of PCI or CABG, after the elective PCI, prior to current discharge from hospital.

Post procedural complications

The presence of any of the following; cardiogenic shock, arrhythmia, stroke, tamponade, contrast reaction, worsening heart failure or renal failure, bleeding.

In-hospital mortality

Dead on discharge.

3.4.4 Data Cleaning

After the selected variables of all the elective PCI patients were extracted from the merged file, data cleaning was conducted for detection of missing data. Correction of any gross errors in the study dataset was also made. Attempts were made to contact the original cardiac centres to request for missing data from the dataset. However, not all the missing data could be traced. Thus, imputation was necessary for some variables.

Variables with less than 5% of missing data were not imputed. The missing data among the categorical variables were found to be less than 5% of the total variables. Among the continuous variables, only BMI recorded a high percentage of missing data due to the low number of available weight and height data. Missing data of weight and height were checked to determine if it was Missing At Random using the separate variance t test. A non-significant Little's MCAR test, $p = 0.10$, revealed that the height and weight data were missing completely at random (Little, 1988). The two variables were then imputed using single imputation with a random error term method. The BMI was not imputed directly, but calculated from the imputed height and weight variables.

3.5 Cost Data Collection

For high-income countries (HIC), there are many established health economics guidelines in place for the implementation of healthcare related cost analysis. However, these guidelines often require comprehensive and easily accessible finance information and health records. Therefore, not all the recommendations were feasible for low- and middle-income countries (LMIC) setting like Malaysia.

For this cost analysis, a stepwise process for the cost data collection and analysis was devised based on guidelines published in the literature aimed for countries with limited data availability (Hendriks et al., 2014; Mercier & Naro, 2014). Some modifications made for this study were discussed along each step in this section.

3.5.1 Collection Tools and Process

To ensure data collected for costing study are comparative between different centres, international guidelines recommended the design of a standardized cost collection tool. It should be universally accessible and user-friendly for all involved parties (Batura et al., 2014; M. Drummond et al., 1993). For this study, health economists and interventional cardiologists were consulted during the initial stage to produce a clinically comprehensive yet economically sound data collection form using MS Excel programme. The Excel file contained 8 sheets, with each sheet being designed to retrieve relevant cost information from different departments or units in the hospital, namely engineering, human resource, finance, cardiac ward, cardiac catheterization laboratory, pharmacy, and medical record unit (APPENDIX C).

Pilot study was conducted at one of the centres. Feedbacks gathered and shortcomings identified during the pilot study were taken into consideration to improve the data collection form. Thereafter, site initiation visit at each cardiac centre was conducted to provide hands-on training for data enumerators. A one-day training workshop was conducted and covered topics such as the purpose of the cost analysis, introduction of the data collection tool, clarifications on the definitions of each unit of analysis and cost items, stepwise instructions on how to use the tool, and troubleshooting.

Figure 3.2 outlines the steps of cost data collection. For each centre, a data enumerator and a site coordinator were assigned (Table 3.2). The data enumerator was in charge of the data collection from the respective departments. As many of the data was considered to be of a sensitive nature, the relationship between the enumerators and staff in various other units proved to be an important factor towards a successful data collection. Site coordinators for this study were senior personnel in the respective cardiac centres with vast knowledge on the daily clinical and financial operations of the centre, especially pertaining to cardiology department and PCI procedures.

In some circumstances, there were bureaucratic resistance towards parting with financial data, citing confidentiality issues. This was one of the major challenges faced in this study. Site coordinators had to step in and used their discretion to ensure that staff from other units cooperated and provided complete data to the data enumerator. This highlighted the importance of ensuring access of transparent and quality cost data towards the successful implementation of a cost analysis in any healthcare facility. Upon completion of data collection by data enumerator, site coordinator was responsible of checking the completeness of the data. Face validity check to identify unjustifiable outliers was also conducted before submitting the cost collection form.

The compiled cost data of each cardiac centre was then forwarded to the primary investigator. Data collected at each centre was assessed for its consistency and validity. All unit cost outliers (defined as less than one-tenth or more than 10 times the mean average unit cost) were flagged and queried with the site coordinators. All the cost data was subsequently reviewed in the presence of cardiologists and deemed accurate and justifiable before proceeding on with further calculation and analysis.

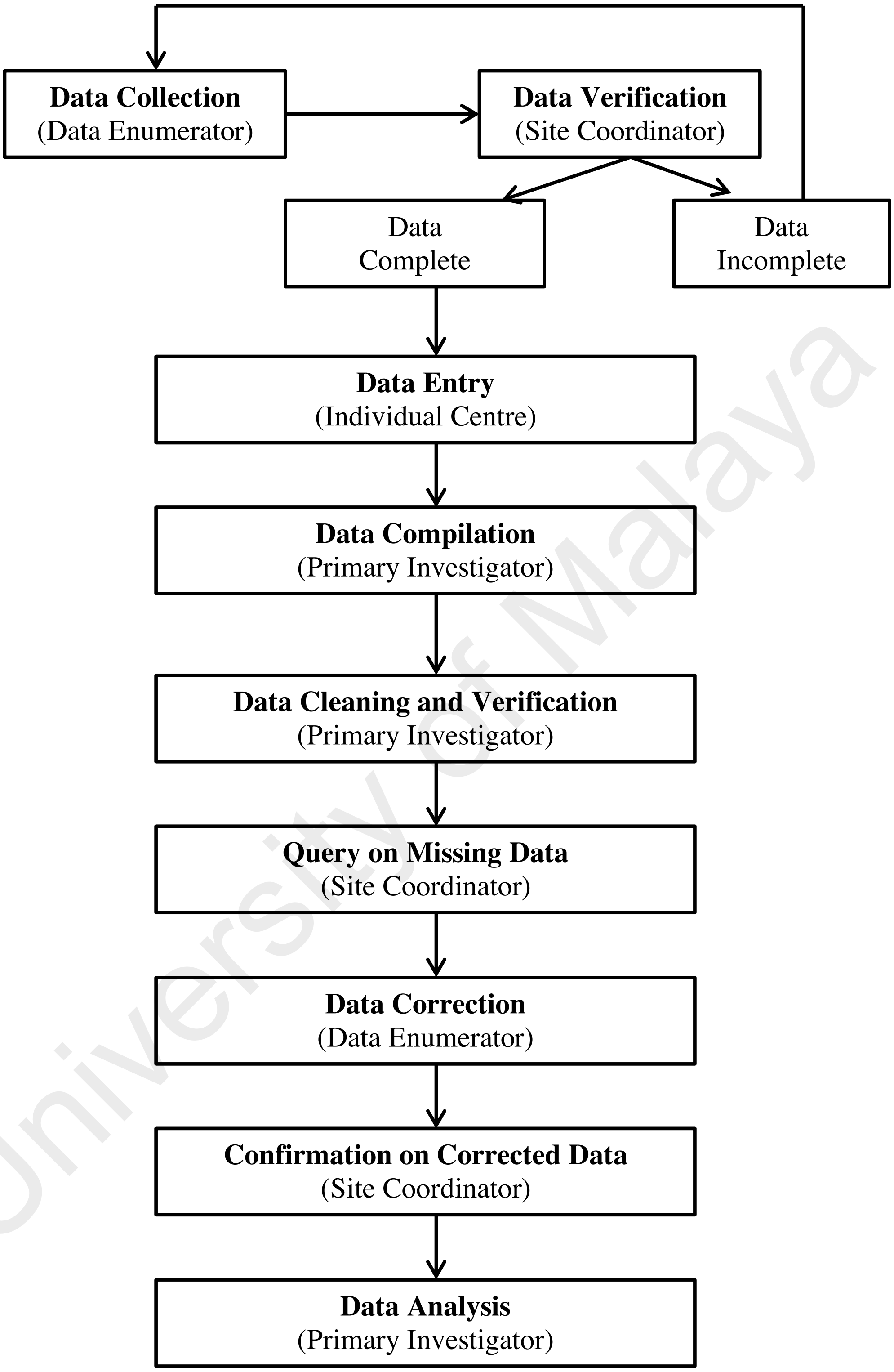

Figure 3.2: Flow chart of cost data collection process at each centre

Table 3.2: Data enumerator and site coordinator personnel at each centre

Centre	Data enumerator	Site coordinator
PGH	Nursing sister	Deputy Hospital Director
PJHUS	Research assistant	Senior Pharmacist
QE2	Nursing matron	Senior Pharmacist
UMMC	Research assistant	Finance Officer of Cardiology Department
IJN	Finance officer	Head of Finance Department

3.6 Clinical Pathway and Unit of Analysis

The cost collection tool was designed based on the steps in the cost data collection process discussed in this section. To achieve the most accurate estimate of PCI cost, it is important to identify all the resources consumed by the patients during hospital admission. Many HIC used Diagnosis Related Group (DRG), a system which classifies acute inpatient episodes based on the main clinical condition, as unit of analysis for illness-specific costing (S.S. Tan et al., 2011).

However, DRG is not practiced in any of the study centres. As an alternative, we outlined the event pathway for the provision of care for PCI patients from admission to discharge to determine the units of analysis involved in the hospital care for elective PCI patients (Figure 3.2).

The standard vignette for the PCI patients in this costing study commenced upon arrival at the cardiac centres, followed by admission to the cardiac ward (CW) before undergoing PCI in the cardiac catheterization laboratory (CL). All of the patient management, including diagnosis and treatment were delivered at the same hospital.

As the rate of complications of elective PCI reported in NCVD-PCI Registry were very low, it was assumed that no serious complications occurred. Any cost that might have been incurred in the Cardiac Care Unit or Intensive Care Unit post procedure was not taken into account in this costing study. The vignette ended upon patient discharge.

Based on the event pathway for this costing study, PCI service rendered to a patient was categorized into the following units of analysis: hospital general services, CW admission and CL utilization. The summation of the 3 units gave rise to the total cost of hospitalization for PCI patients.

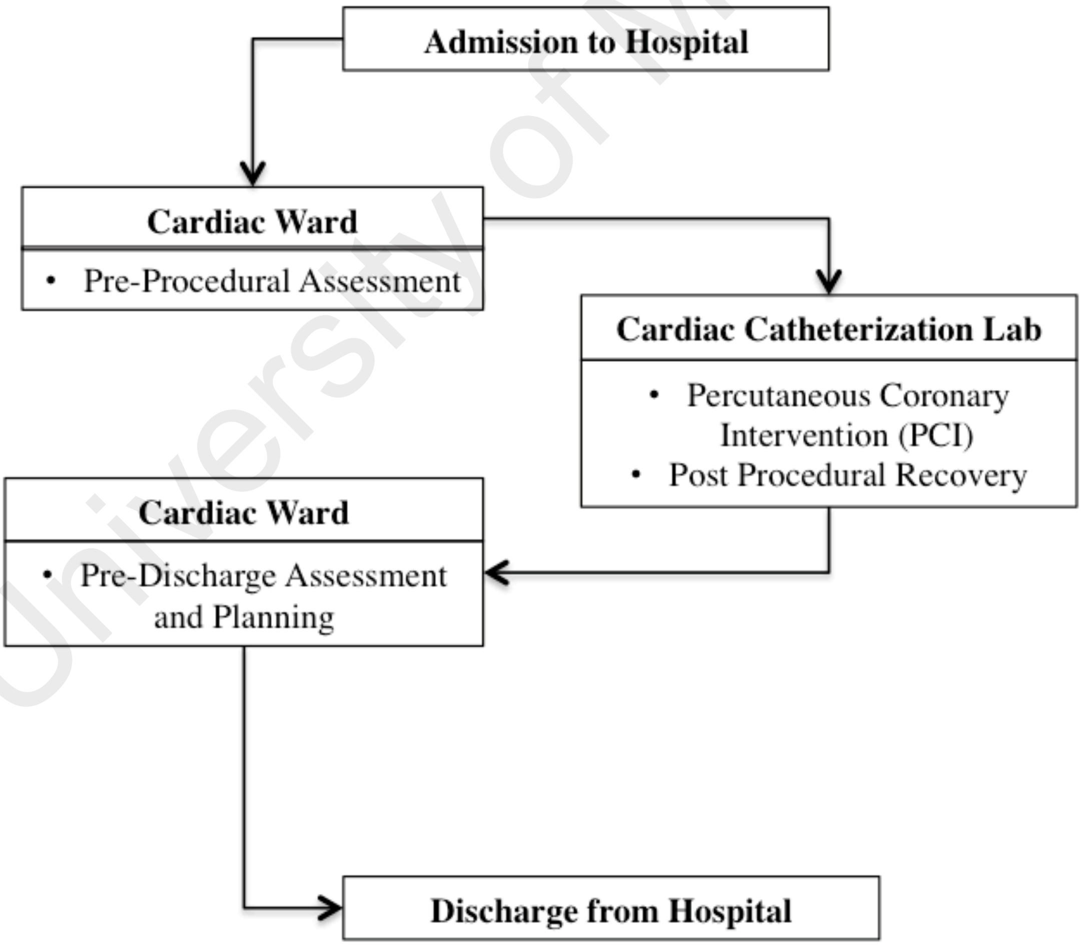

Figure 3.3: Event pathway of patients undergoing elective PCI

3.7 Identification of Cost Centres

A variety of cost items such as labour, utility, and consumables contributed to the total cost of each unit of analysis. These cost items are often categorized under different cost centres to facilitate the costing process. There are several ways to categorize the different types of cost centres in a hospital cost analysis. For the purpose of this study, each of the 3 units of analysis consisted of overhead cost centres and/or direct medical cost centres. This is illustrated in Figure 3.3.

Under direct medical cost centres, cost items that can be directly attributed to patient care are included. This comprised of labour cost of clinical staff, medication and consumables used, and capital cost of asset in CW and CL respectively.

As for overhead costs, it refers to those resources that are used to provide service to more than one department/unit in a hospital, for example hospital administration, laundry and linen, housekeeping, maintenance etc. These shared costs need to be attributed to the individual patient care centre that are being costed (M. Drummond et al., 2005). For the purpose of this study, separate overhead cost centres were created for each of the unit of analysis; namely hospital general overhead, CW overhead, and CL overhead. This separation was carried out as the users of each of this overhead services were of different volume.

Hospital ancillary services refer to the range of supplemental healthcare services that are provided to patients in order to support the doctors in the diagnosis and treatment of conditions. In this study, we categorized services from 4 departments under ancillary services, namely pharmacy, radiology, laboratory, and rehabilitation departments. In many economic evaluations, departments that provide ancillary services are organized separately as intermediate cost centres. However, due to the constraint in time and budget for this costing study, separate cost analysis was not conducted to assign the cost of each respective department to the individual PCI patients. Instead, all costs incurred by the ancillary services were calculated as part of cardiac ward overhead cost. Similar modifications were carried out in a few other published costing studies (Hammad, Fardous, & Abbadi, 2016; Hendriks et al., 2014).

In the subsequent sections 3.7.1 to 3.7.3, detailed description of cost items incurred at each unit cost of analysis was outlined.

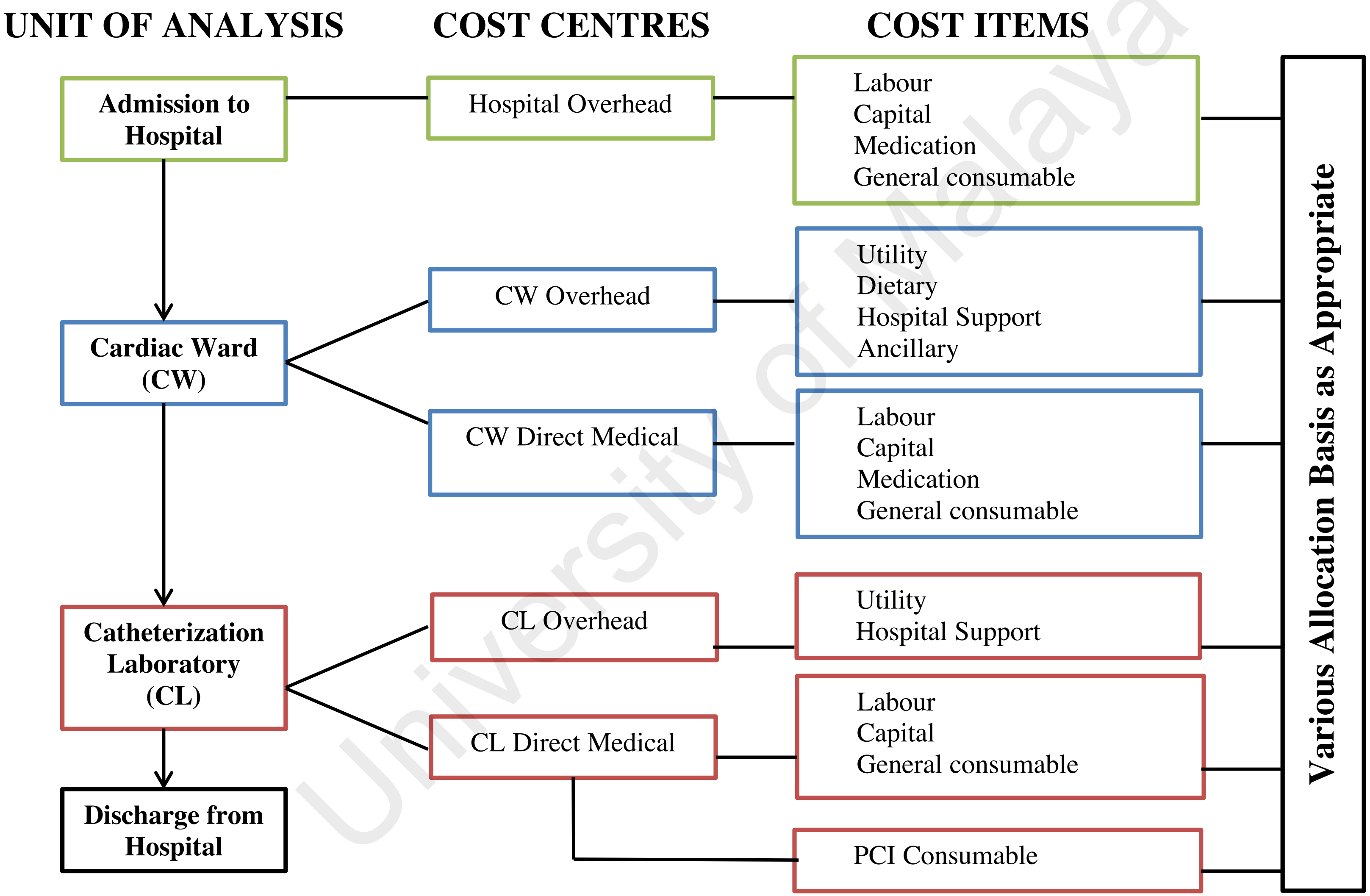

Figure 3.4: Flowchart of cost item identification under each cost centre for all units of analysis

3.7.1 Hospital General Overheads

On arrival to the cardiac centre, elective PCI patients would incur general overhead cost for the non-clinical services they utilized in the general public areas before their admission to the cardiac ward. These services were shared among all the hospital users, regardless of the diagnosis or procedures they were admitted for. General overheads included in this study were labour cost of administrative personnel, consumable cost of office supplies, utility, and support service cost of the non-clinical space in the hospital.

3.7.2 Cardiac Ward

Under the second unit of analysis, cardiac ward (CW) admission, all the PCI patients would incur direct medical cost and overhead cost throughout the duration of their stay. In UMMC, all the elective PCI patients were admitted to the same CW, which is known as the Interventional Cardiac Ward (ICW). Elective PCI patients in QE2 in Sabah were also admitted to only a single ward, which was the Cardiac Rehabilitative Ward (CRW). However, in PGH, the patients may be admitted to CRW or CW, depending on bed availability. In PJHUS, apart from the CW, day-care centre was also available for elective PCI patients. Day-care was available in IJN and PGH, however, less than 2% of the elective PCI patients had same-day discharge from each of the centre. As a result of this under-utilized day-care setting among elective PCI patients, this study did not include the cost analysis for day-care centres at PGH and IJN.

Direct medical cost in CW included labour cost of the medical staff involved in the care of PCI patients, and capital cost within CW. General consumables and medication cost used by the patients were also included under direct medical cost.

Overhead cost of CW included costs incurred by dietary, utility, ancillary, and hospital support services such as laundry and linen cleaning, housekeeping, clinical waste management, and maintenance cost. As each inpatient bed day was considered as a single hospital user, the cost of dietary service and ancillary support service was only counted once under CW and not counted again under cardiac catheterization laboratory. This was to avoid double counting these costs for the same patient.

3.7.3 Invasive Cardiac Catheterization Laboratory

On the day of scheduled PCI, patients would be sent from CW to invasive cardiac catheterization laboratory (CL). Apart from PCI, other interventions conducted in CL included pacemaker insertion, coronary angiography, peripheral angioplasty, intravascular ultrasound, right heart catheterization etc. During the study period, the highest number of procedures being conducted in CL at all the cardiac centres was diagnostic coronary angioplasty, followed by PCI for therapeutic purpose.

Similar to CW, all the patients utilizing the CL incurred direct medical cost and overhead cost, regardless of the interventions being conducted. Direct medical cost in CL included capital cost, general consumable and the labour cost of medical staff. The PCI consumable was categorized as a separate cost item from general consumables as different interventions in the CL required different types of medical devices and consumables. Overhead costs of CL included utility cost, costs of hospital support service such as laundry and linen cleaning, housekeeping, clinical waste management and maintenance cost.

3.8 Identification and Allocation of Cost Items

Upon identifying and classifying the various cost items, the next step in the cost analysis involved sourcing the cost and activity data from the official hospital reports. The most important and informative document for this purpose was the annual financial account of the hospital. Apart from that, data enumerators also approached the relevant personnel in the finance, human resource, and engineering departments to obtain the necessary data.

Data on activity output such as admission numbers and bed days were obtained from the medical records unit. Individual department or unit registers were also used to obtain relevant activity statistics such as number of procedures conducted. The following sections 3.8.1 to 3.8.8 outlined the process of identifying, collecting and allocating the costs of each cost item.

3.8.1 Labour

Labour costs referred to the sum of salary paid to the employees. The full salary included the full wages, housing allowances, social contributions for pension fund, living allowance, critical allowance, and hardship allowance for rural posting. Other costs such as vacations and education are not taken into account. Staff payroll register for all grades and all positions were obtained from the hospital finance department. The maximum and minimum monthly salaries for each grade of every position were summed up and divided by two to derive the average salary for the said staff position in the said grade.

Where a member of staff works in more than one cost centre, an appropriate apportionment was made. For example, a senior doctor may spend time in the cardiac ward conducting clinical rounds, having patient consultation in the outpatient clinics, and performing cardiac procedures in the CL. Thus, the labour costs for the doctors were apportioned based on the working time in each centre, as determined by the head of cardiology department's professional discretion.

3.8.2 Capital

Capital costs included fixed, one-time expenses incurred on the purchase of land, building, and equipment. Most of the cardiac centres were built more than 20 years ago. Furthermore, the main aim of this study was to obtain the operational cost of PCI procedure. Thus, land and building costs were not taken into account as capital asset.

In this study, only equipment such as machines, furniture and instruments were included. Equipment was considered as a capital asset if its purchase cost was higher than RM 1,000 and its economic useful life exceeded 1 year. Any items costing less than RM 1,000 or with a lifespan less than 1 year were considered as consumable items.

Using inventory list in the CW and CL, the complete list of asset, their purchase price and year of purchase were recorded in the cost collection form. The equivalent annual cost (EAC) of each item was calculated by annuitizing the capital outlay using a discount rate with their respective useful life years. Using the straight-line depreciation approach, it was assumed that the services from the capital items were divided equally over the useful life of the asset. A discount rate of 3% was chosen in conformity with most economic evaluation studies conducted. Based on expert opinion and literature review, a useful life of 5 years was applied for equipment (Creese & Parker, 2000).

3.8.3 Consumables

Consumables referred to items or goods that are disposable in nature. They would wear out or be used up quickly, necessitating frequent replenishment. Thus, they are often purchased in huge volumes to enable regular replacement.

In the administrative setting, consumables included office supplies and stationery. In the clinical setting, consumables included general medical supplies such as IV fluids, syringes, cotton swabs, and needles used during hospitalization. The total costs of clinical consumables were obtained from the central procurement section, which is under the purview of pharmacy department.

In the event that actual usage records at the individual cost centre were not available, workload ratio based on hospital users was used as the allocation basis to apportion the total consumable cost.

A separate category of cost item was created for specific consumables used in PCI procedure such as stents, catheters, wires and balloons. The actual cost of purchase was available from the invoice orders dated between 1st January 2014 and 30th June 2014.

3.8.4 Medication

In this study, drugs used in CW were divided into general medication and cardiac specific medication commonly used for heart diseases. The division was made as a result of the drug purchasing mechanism. General medications are often stored as floor stock in the ward. Similar to consumable, hospital workload ratio was the allocation statistics for general medication cost.

On the contrary, cardiac specific medication was purchased by central pharmacy under separate budget. These cardiac specific medications would be distributed to the different cardiac wards under cardiology department. Workload ratio of cardiology department was the allocation basis to determine the cost of CW cardiac specific medication.

3.8.5 Utility

Utility cost referred to expenses incurred on electricity, water, telephone and Internet service during the study period. The total bill was obtained from the January-June 2014 financial account. Hospital blueprints and construction documents from the engineering department were obtained to calculate the space ratio, i.e. the percentage of square metres of physical space occupied by the cost centre in comparison to the total hospital indoors area. Space ratio was the allocation basis for utility cost.

3.8.6 Dietary

This included costs of meal preparation by the in-house dietary unit for patients throughout their admission period in the hospital. The total dietary cost was obtained from the dietary unit and allocated to CW based on inpatient bed days.

3.8.7 Hospital Support Service

For all the cardiac centres, cost items under the hospital support service such as housekeeping, laundry and linen cleaning, waste management, building and equipment maintenance were outsourced as an annual contract to a private company. The annual contract cost for all these services were obtained from the finance department. Space ratio of the cost centre to the hospital indoor area was used as the allocation basis.

3.8.8 Ancillary Service

The 4 main ancillary service departments included as overhead cost in this study were laboratory, pharmacy, radiology, and rehabilitation. The total cost of ancillary services was the summation of the labour cost for all the personnel, the cost of consumables supplied to the departments, and the hospital support and utility cost based on the space area occupied by the 4 departments. We did not include the capital asset at these four departments.

Keeping in mind that the range of ancillary services in a hospital could be used by both inpatient and outpatient hospital users, the total cost must be further apportioned. Based on a survey on public hospitals in Malaysia, 60% of services provided by the ancillary departments can be attributed to inpatient use, whereas the remaining 40% would be attributed to outpatient use (Medical Development Division, 2013). Therefore, this study applied the same 60:40 proportion for the cost of ancillary services dedicated to inpatient and outpatient usage.

After obtaining the inpatient ancillary service cost, workload ratio based on inpatient bed days was used as the allocation basis for ancillary service overhead cost of CW.

3.9 Calculation of Cost Items for Each Unit of Analysis

By incorporating the relevant cost items described in Section 3.8, the direct medical and overhead costs at each cost centres were obtained for the study period of January-June 2014. They were then tabulated to derive the total cost required for the unit cost calculation.

3.9.1 Hospital General Overheads

This section showed the calculation of the allocated cost for the first unit of analysis, hospital general overheads. The actual labour cost of all the administrative personnel was used in the calculation. The utility and hospital support service costs were calculated based on the floor space ratio. The actual consumable cost for administrative and general usage was available from the annual finance account. The calculation of allocated cost for hospital general overheads was shown in separate tables, due to the different space ratio in each centre (Table 3.3-Table 3.7).

Table 3.3: Calculation of cost items of hospital general overhead in UMMC

UMMC	**Cost (RM)**	**Allocation basis**	**Ratio**	**Allocated Cost**
Labour	20,548,614.82	Actual	-	20,548,614.82
Consumable	4,045,956.81	Actual	-	4,045,956.81
Utility	15,001,573.31	Space Area	0.2050	3,075,690.73
Hosp.Support	14,296,989.39	Space Area	0.2050	2,931,233.72
TOTAL				**30,601,496.08**

Table 3.4: Calculation of cost items of hospital general overhead in IJN

IJN	Cost (RM)	Allocation basis	Ratio	Allocated Cost
Labour	15,680,582.63	Actual	-	15,680,582.63
Consumable	3,550,480.52	Actual	-	3,550,480.52
Utility	6,525,563.15	Space Area	0.3909	2,550,600.83
Hosp.Support	11,458,716.02	Space Area	0.3909	4,478,787.46
TOTAL				**26,260,451.44**

Table 3.5: Calculation of cost items of hospital general overhead in PGH

PGH	Cost (RM)	Allocation basis	Ratio	Allocated Cost
Labour	14,246,045.67	Actual	-	14,246,045.67
Consumable	5,617,744.10	Actual	-	5,617,744.10
Utility	10,614,337.58	Space Area	0.0114	120,740.58
Hosp.Support	23,830,916.68	Space Area	0.0114	271,082.27
TOTAL				**20,255,612.62**

Table 3.6: Calculation of cost items of hospital general overhead in PJHUS

PJHUS	Cost (RM)	Allocation basis	Ratio	Allocated Cost
Labour	706,068.66	Actual	-	706,068.66
Consumable	144,446.00	Actual	-	144,446.00
Utility	3,302,303.97	Space Area	0.4005	1,322,867.21
Hosp.Support	6,189,306.14	Space Area	0.4005	2,479,369.01
TOTAL				**4,652,750.88**

Table 3.7: Calculation of cost items of hospital general overhead in QE2

QE2	Cost (RM)	Allocation basis	Ratio	Allocated Cost
Labour	1,588,696.50	Actual	-	1,588,696.50
Consumable	575,838.00	Actual	-	575,838.00
Utility	2,057,979.53	Space Area	0.5002	1,029,448.77
Hosp.Support	7,505,291.44	Space Area	0.5002	3,754,319.67
TOTAL				**6,948,302.94**

3.9.2 Cardiac Ward Direct Medical Cost

Under the second unit of analysis, admission to CW, the first cost centre would be direct medical cost centre. The cost items that can be directly attributed to the care of patients in the CW were included in the calculation. These included labour cost of medical staff, capital cost within CW, consumables and medication used by the patients.

3.9.2.1 Labour

The salary of clinical staffs in the cardiac ward contributed towards the labour costs of cardiac ward. With the exception of doctors, all the clinical staff in the CW were stationed in CW and contributed only towards the care for patients admitted to CW. Thus, labour cost of this group of clinical staff was the summation of their average salaries over the study period.

On the contrary, doctors worked in multiple cost centres, including the CW, the CL, and clinics. Therefore, expert opinion of the head of cardiology department was sought to determine the portion of time spent on each cost centre. The apportionment of working hours via expert opinion was based on the assumption that all staff was equally productive in delivering patient-related care and no idle time was spent. It was at best a gross approximation, and acceptable for top-down approach. The apportioned time of the respective clinical duties by different grades of medical doctors were then taken into account while calculating labour cost for doctors in CW. The following section outlines the calculation of labour cost in CW at all the 5 cardiac centres.

UMMC

In UMMC, a teaching hospital, the working hours of doctors can be apportioned towards research and training activities, conducting procedures in catheterization laboratory, seeing patients in the clinic, and conducting ward rounds in all the cardiac wards. There are 3 main cardiac wards in UMMC. Patients undergoing elective PCI would be admitted to only one ward, the interventional cardiac ward (ICW). Table 3.8 shows the proportion of working time spent for each activity based on the seniority of the doctors.

Table 3.8: Proportion of working time for doctors in UMMC

Proportion of Working Time For Doctors in UMMC	**Junior Grade UD 47-51**	**Senior Grade UD 53 and above**
Teaching and Research	35%	45%
Catheterization Laboratory	15%	20%
Outpatient Clinic Consultations	30%	20%
Inpatient ward rounds	20%	15%
Interventional Cardiac Ward (ICW)	*(6.6.7%)*	*(5%)*
Cardiac Care Unit (CCU)	*(6.67%)*	*(5%)*
Cardiac Ward 4U	*(6.67%)*	*(5%)*

Based on the proportion of working hours spent on inpatient wards, junior and senior medical officers (MO) between grade 47-51 were estimated to be spending one-third or 6.67% of their total working hours in UMMC ICW. As for cardiologists grade UD 53 and above, 5% of their total working hours can be attributed to patient care in ICW. Based on the working time, the apportioned salary of each grade of doctors was calculated.

Apart from medical doctors, there were 1 nursing matron, 4 nursing sisters, 19 nurses, 2 ward clerks and 9 health attendants in total working in the ICW. As these clinical staff only worked in ICW, their average salaries over the 6-month study period were summed up in total.

Subsequently, the apportioned salaries of the doctors were added up together with the total salaries of the rest of the clinical staffs. In UMMC, the labour cost of cardiac ward totalled RM 666,064.92. Table 3.9 details the allocated labour cost for the CW of UMMC.

Table 3.9: Calculation of labour cost in ICW of UMMC

Staff	**Apportioned Work Time**	**Average Monthly Salary**	**Apportioned Salary**	**n**	**Total Salary Payout**
Doctors					
Consultant	5.00%	12,898.56	644.93	1	3,869.57
Specialist	5.00%	8,959.00	447.95	11	29,564.70
Senior MO	6.67%	8,465.50	564.65	4	13,551.57
Junior MO	6.67%	7,848.50	523.49	1	3,140.97
Subtotal					46,738.92
Others					
Matron	100.00%	5,508.00	5,508.00	1	33,048.00
Sister	100.00%	3,994.00	3,994.00	4	95,856.00
Nurse	100.00%	3,242.50	3,242.50	19	369,645.00
Attendant	100.00%	1,758.50	1,758.50	9	94,959.00
Clerks	100.00%	2,151.50	2,151.50	2	25,818.00
Subtotal					619,326.00
Total Labour Cost					**666,064.92**

Note. MO=medical officer, n=number of staff in each category

IJN

As a semi-corporatized centre, the IJN cardiologists placed more focus and spent more time on the outpatient clinic consultations. The proportion of working time of doctors in IJN based on the expert opinion of consultant cardiologists working there are as Table 3.10.

Table 3.10: Proportion of working time for doctors in IJN

Proportion of Working Time For Doctors in IJN	
Catheterization Laboratory	20%
Outpatient Clinic Consultations	60%
Inpatient ward rounds	20%

As IJN was a semi-corporatized organization, the study team was not privy to the finer financial details, especially of the staff salary. For the purpose of this costing study, IJN provided only final value of the labour cost item. However, similar top-down costing method was applied to calculate the labour cost of doctors based on the proportion of working time.

The apportioned salaries of the doctors were added up together with the total salaries of the remaining clinical staffs to produce the total ward labour cost in IJN.

Labour Cost of Doctors	RM 633, 592.52
Labour Cost of Other Clinical Staff	RM 700, 012.26
Total Ward Labour Cost in IJN	**RM 1,333,604.78**

PGH

As for the 3 remaining public centres; namely PGH, PJHUS, and QE2, it was agreed by all their consultant cardiologists that a doctor's working time was to be apportioned equally to the cardiac laboratory, the cardiac specialist clinic, and the cardiac wards. The only exception was for house officers in the wards, whereby 100% of their working time was dedicated to the inpatient ward duties. Table 3.11 shows the apportionment of the working time for doctors in PGH.

Table 3.11: Proportion of working time for doctors in PGH

Proportion of Working Time For Doctors in PGH	
Catheterization Laboratory	33.3%
Outpatient Clinic Consultations	33.3%
Inpatient ward rounds	33.3%
Cardiac Rehabilitative Ward (CRW)	*(11.1%)*
Cardiac Care Unit (CCU)	*(11.1%)*
Cardiac Ward C8	*(11.1%)*

PGH CRW

There were 3 main cardiac wards in PGH during the study period, namely CRW, C8 and CCU. Based on the proportion of working hours spent on inpatient ward rounds, doctors in the cardiology department of PGH were estimated to have spent 11.1% of their total working hours in each ward. However, patients undergoing elective PCI were admitted only to CRW and C8.

Table 3.12 details the labour cost in the CRW of PGH. The total salary of the other clinical staff including 1 nursing matron, 3 nursing sisters, 18 nurses, and 10 health attendants were added to the apportioned salaries of the doctors to derive the total salary payout during the 6-month study period.

Table 3.12: Calculation of labour cost in CRW of PGH

Staff	Apportioned Work Time	Average Monthly Salary	Apportioned Salary	n	Total Salary Payout
Doctors					
Consultant	11.1%	18,587.54	4,126.43	2	24,758.60
Specialist	11.1%	15,976.00	14,186.69	8	85,120.13
Senior MO	11.1%	13,289.00	19,176.03	13	115,056.16
Junior HO	100.0%	8,491.50	8,491.50	1	50,949.00
Subtotal					277,827.51
Others					
Matron	100.0%	4,991.28	4,991.28	1	29,947.65
Sister	100.0%	4,081.44	4,081.44	3	73,465.92
Nurse	100.0%	3,353.60	3,353.60	18	362,188.26
Attendant	100.0%	2,178.46	2,178.46	10	130,707.30
Subtotal					596,309.13
Total Labour Cost					**874,136.64**

Note. MO=medical officer, n=number of staff in each category

PGH C8

Apart from CRW, patients who underwent PCI in PGH could also be admitted to ward C8. Similar calculations were made to derive the labour cost in the ward C8 of PGH. Based on the proportion of working hours spent on inpatient ward rounds, doctors in the cardiology department of PGH were estimated to have spent 11.1% of their total working hours in Ward C8. During the study period, there were 1 nursing matron, 3 nursing sisters, 24 nurses and 9 health attendants in total stationed in ward C8. To obtain the labour cost of ward C8, the total average salaries of these staff over the study period were added to the apportioned salary of the doctors (Table 3.13).

Table 3.13: Calculation of labour cost in Ward C8 of PGH

Staff	Apportioned Work Time	Average Monthly Salary	Apportioned Salary	n	Total Salary Payout
Doctors					
Consultant	11.1%	18,587.54	4,126.43	2	24,758.60
Specialist	11.1%	15,976.00	14,186.69	8	85,120.13
Senior MO	11.1%	13,289.00	19,176.03	13	101,203.36
HO	100.0%	8,491.50	8,491.50	3	152,847.00
Subtotal					375,516.87
Others					
Matron	100.0%	4,991.28	4,991.28	1	29,947.65
Sister	100.0%	4,081.44	4,081.44	3	73,465.92
Nurse	100.0%	3,353.60	3,353.60	24	482,917.68
Attendant	100.0%	2,178.46	2,178.46	9	117,636.57
Subtotal					703,967.82
Total Labour Cost					**1,079,484.69**

Note. MO=medical officer, HO=house officer, n=number of staff in each category

PJHUS

Similarly for PJHUS, the consultant cardiologists decided that a doctor's working time was to be apportioned equally to the cardiac laboratory, the cardiac specialist clinic, and the cardiac wards. However, the time spent in cardiac day-care unit would be half of that spent in the inpatient wards of CRW and CCU (Table 3.14).

Table 3.14: Proportion of working time for doctors in PJHUS

Proportion of Working Time For Doctors in PJHUS	
Catheterization Laboratory	33.3%
Outpatient Clinic Consultations	33.3%
Inpatient ward rounds	33.3%
Cardiac Rehabilitative Ward (CRW)	*(13.3%)*
Cardiac Care Unit (CCU)	*(13.3%)*
Day Care	*(6.7%)*

PJHUS CRW

As previously mentioned, patients undergoing elective PCI can be admitted to CRW or Day-care in PJHUS. Based on the proportion of working hours spent on inpatient ward rounds, doctors in the cardiology department of PJHUS were estimated to have spent 13.3% of their total working hours in CRW.

As for the remaining clinical staff, there were 4 nursing sisters, 33 nurses and 16 assistant nurses and 6 health attendants in total. Table 3.15 shows the total labour cost in CRW of PJHUS.

Table 3.15: Calculation of labour cost in CRW of PJHUS

Staff	**Apportioned Work Time**	**Average Monthly Salary**	**Apportioned Salary**	**n**	**Total Salary Payout**
Doctors					
Consultant	13.3%	17,000.00	2,266.67	1	13,600.00
Specialist	13.3%	16,449.00	2,193.20	5	65,796.00
Senior MO	13.3%	11,608.50	1,547.80	1	9,286.80
Junior MO	13.3%	8,041.50	1,072.20	7	45,032.40
Subtotal					**133,715.20**
Others					
Sister	100.0%	6,446.10	6,446.10	4	154,706.40
Nurse	100.0%	3,779.30	3,779.30	33	748,301.40
Ass. Nurse	100.0%	2,577.50	2,577.50	16	247,440.00
Attendant	100.0%	1,826.50	1,826.50	6	65,754.00
Subtotal					1,206,910.60
Total Labour Cost					**1,340,625.80**

Note. MO=medical officer, n=number of staff in each category

PJHUS Day-care

Due to the nature of day-care unit, the time spent by doctors there was less than in the other two cardiac wards. Based on the expert opinion provided by PJHUS consultant cardiologist, approximately 6.7% of the working time of doctors in the department was dedicated to the operation of day-care unit. There were also slightly less number of clinical staff in the Day-care unit. There were only 2 nursing sisters, 8 nurses, 2 assistant nurses and 2 health attendants in total. Table 3.16 details the labour cost in the Cardiac Day-care unit of PJHUS.

Table 3.16: Calculation of labour cost in cardiac day-care unit of PJHUS

Staff	Apportioned Work Time	Average Monthly Salary	Apportioned Salary	n	Total Salary Payout
Doctors					
Consultant	6.7%	17,000.00	1,132.20	1	6,793.20
Specialist	6.7%	16,449.00	1,095.50	5	32,865.10
Senior MO	6.7%	11,608.50	773.13	1	4,638.75
Junior MO	6.7%	8,041.50	535.56	7	22,493.08
Subtotal					66,790.13
Others					
Sister	100.0%	4,666.10	4,666.10	2	55,993.20
Nurse	100.0%	3,779.30	3,779.30	8	181,406.40
Ass. Nurse	100.0%	2,577.50	2,577.50	2	30,930.00
Attendant	100.0%	1,826.50	1,826.50	2	10,956.00
Subtotal					279,285.60
Total Labour Cost					**345,683.73**

Note. MO=medical officer, n=number of staff in each category

QE2

In QE2, the consultant cardiologist decided that a doctor's working time was to be apportioned equally to the cardiac laboratory, the cardiac specialist clinic, and the cardiac wards. There were 2 cardiac wards in QE2, whereby expert opinion by consultant cardiologist in QE2 deemed that equal time was spent between the 2 wards by all the senior doctors in the cardiology department. However, for house officers, 100% of their working time was spent in the ward that they were assigned to.

Table 3.17: Proportion of working time for doctors in QE2

Proportion of Working Time For Doctors in QE2	
Catheterization Laboratory	33.3%
Outpatient Clinic Consultations	33.3%
Inpatient ward rounds	33.3%
Cardiac Rehabilitative Ward (CRW)	*(16.7%)*
Cardiac Care Unit (CCU)	*(16.7%)*

As for the remaining clinical staff, there were 2 nursing sisters, 22 nurses and 8 health attendants. Table 3.18 shows the calculation of the total labour cost in cardiac ward.

Table 3.18: Calculation of labour cost in cardiac ward of QE2

Staff	Apportioned Work Time	Average Monthly Salary	Apportioned Salary	n	Total Salary Payout
Doctors					
Consultant	16.7%	12,215.32	2,039.96	1	12,239.75
Specialist	16.7%	9,764.80	1,630.72	2	19,568.66
Senior MO	16.7%	7,345.14	1,226.64	1	7,359.83
HO	100%	6,842.84	6,842.84	8	328,456.32
Subtotal					367,624.56
Others					
Sister	100.0%	6,471.64	6,471.64	2	77,659.68
Nurse	100.0%	5,285.33	5,285.33	22	697,663.56
Attendant	100.0%	2,125.63	2,125.63	8	102,030.22
Subtotal					877,353.46
Total Labour Cost					**1,244,978.02**

Note. MO=medical officer, HO=house officer, n=number of staff in each category

The labour cost of the 5 cardiac centres as calculated above are compiled and compared in the Results Chapter 4.

3.9.2.2 Capital

The capital cost was the total EAC of assets based on the inventory records in CW, as discussed in the section 3.9.2. Based on a discount rate of 3% and a useful life of 5 years, the straight-line depreciation approach was used to calculate the total capital cost at the respective admission wards of each cardiac centre (Table 3.19).

Table 3.19: Capital cost of cardiac ward at all centres

Centre	Total EAC of assets (RM)
UMMC	382,311.39
IJN	222,997.80
PGH CRW	94,791.64
PGH CW	27,674.28
PJHUS CRW	193,787.82
PJHUS Day-care	250,095.62
QE2	86,215.03

3.9.2.3 Consumable

Table 3.20 shows the consumable cost at the CW of each cardiac centre. The most accurate cost data would be the actual consumable cost incurred by the respective CW. For IJN, PJHUS and QE2, the actual consumable cost can be obtained from the financial record.

However, at UMMC and PGH, the actual costs of consumable supplied to the cardiac ward were not available from all the sources. For UMMC, the next best available data was the total cost of consumables for inpatient wards. Workload ratio was used as the allocation basis to apportion the total inpatient consumable cost. The ratio was determined by the total inpatient days of ICW over total hospital bed days during the study period.

As for the 2 admission wards in PGH, the next best available data to estimate the consumable cost was the total cost of consumables supplied to all inpatient cardiology wards. Therefore, the allocation basis used was slightly different from UMMC. The total inpatient consumable cost was allocated based on inpatient cardiology ward bed days ratio. The ratio was determined by the total inpatient days of CRW over total bed days of all the cardiology ward inpatient during the study period. Similar calculation was conducted for ward C8.

Table 3.20: General consumable cost of cardiac wards of all centres

Centre	Consumable Cost	Ratio Used	Allocated Consumable Cost
UMMC[a]	8,040,094.67	0.014	116,035.54
IJN	63,584.90	NA	63,584.90
PGH CRW[b]	1,253,881.80	0.171	214,708.34
PGH Ward C8[c]		0.735	921,706.71
PJHUS CRW	64,321.29	NA	64,321.29
PJHUS Day-care	47,716.53	NA	47,716.53
QE2	19,857.02	NA	19,857.02

Note. NA=Non-applicable
[a] For UMMC, next best consumable cost available is total hospital inpatient consumable cost. Ratio used was ICW bed days: Total hospital bed days
[b] For PGH, next best consumable cost available is total cardiology department inpatient consumable cost. Ratio used was CRW bed days: Total department bed days
[c] Ratio used was Ward C8 bed days: total department bed days

3.9.2.4 Medication

The costs of medication used in CW were calculated in similar manner to consumable costs discussed above (Table 3.21). Actual medication cost supplied to the cardiac wards in IJN, PJHUS, and QE2 were available from the financial record.

However, the actual general medication cost of CW was not available in UMMC and PGH. The next best available cost to estimate the medication cost in UMMC would be the summation of total general medication provision and total cardiology medication provision in the centre. Therefore, different workload ratio was used as the allocation basis to allocate the medication cost.

For general medication cost, the allocation basis used was workload ratio of UMMC ICW based on hospital inpatient bed days ratio. For cardiology medication, the total cost of cardiac-specific medication spent by all the cardiac inpatient wards was available. To calculate the cost of cardiac specific medication in CW, workload ratio in the cardiology department was used as the allocation basis. The ratio was determined by the total inpatient days of CW over total bed days in all the three cardiac wards during the study period.

In PGH, the next best available data to estimate the CW medication cost was the total cost of medication supplied to all inpatient cardiology wards. Therefore, the allocation basis used was inpatient cardiology ward bed day ratio.

Table 3.21: Medication cost of cardiac wards of all centres

Centre	Medication Cost	Ratio Used	Allocated Medication Cost
UMMC[a]	15,773,581.91 [b]	0.014	227,646.08
	2,615,119.03 [c]	0.317	828,293.09
IJN	12,697.27	NA	12,697.27
PGH CRW [d]	1,677,474.14	0.171	287,242.14
PGH C8 [e]		0.735	1,233,082.08
PJHUS CRW	558,577.96	NA	558,577.96
PJHUS Day-care	62,189.01	NA	62,189.01
QE2	575,258.55	NA	575,258.55

Note. NA=Non-applicable
[a] For UMMC, the medication allocated to ICW were supplied via hospital general medication and cardiology department medication.
[b] The ratio of ICW: total hospital bed days was used to allocate the total hospital general medication cost.
[c] For cardiology medication, ICW: total department bed days was the ratio used to allocate the cardiology medication cost.
[d] For PGH, next best medication cost available is total cardiology department inpatient medication cost. Ratio used was CRW: Total department bed days.
[e] Ratio used was C8: total department bed days.

3.9.3 Cardiac Ward Overhead Cost

Overhead costs of CW included costs incurred by utility, dietary service, ancillary support service and hospital support service such as laundry and linen cleaning, housekeeping, clinical waste management and maintenance of the equipment.

As these overhead costs are shared between many patient care centres in the hospital, it is necessary to allocate these overhead costs accordingly. In this study, direct allocation method was applied based on to usage of the overhead item. Allocation criteria applied included space ratio and workload ratio.

3.9.3.1 Utility

The utility cost in CW was calculated based on the floor space ratio to the hospital area. Table 3.22 shows the allocated utility cost of CW at each centre.

Table 3.22: Utility cost of cardiac wards of all centres

Centre	Total Hospital Utility Cost	Space Area Ratio[a]	Allocated Utility Cost
UMMC	15,001,573.31	0.0058	87,132.83
IJN	13,225,641.63	0.0117	154,201.25
PGH CRW	13,500,989.22	0.0072	97,277.64
PGH C8		0.0008	10,998.59
PJHUS CRW	3,476,083.32	0.0359	124,948.95
PJHUS Day-care		0.0180	62,473.17
QE2	2,057,979.53	0.0056	11,603.16

[a] Space Area Ratio used was ward space area: total hospital indoor space area

3.9.3.2 Dietary

The cost of operation of in-house kitchen that prepared inpatient meals was obtained from the dietary department. Workload ratio based on total inpatient days of CW over total hospital bed days was used as the allocation basis to derive the dietary cost at CW (Table 3.23).

Table 3.23: Dietary cost of cardiac wards of all centres

Centre	Dietary Cost (RM)
UMMC	26,075.00
IJN	118,721.94
PGH CRW	95,143.27
PGH C8	408,434.00
PJHUS CRW	58,374.60
PJHUS Day-care	43,305.00
QE2	26,269.15

3.9.3.3 Hospital Support Service

The annual contract cost paid to the private company that provided the hospital support services was obtained from the finance department of each cardiac centre. It was divided half to derive the cost during the study period of January to June 2014. Space ratio of the CW area to hospital indoor area was used as the allocation basis (Table 3.24).

Table 3.24: Hospital support service cost of cardiac wards of all centres

Centre	Total Hospital Support Service Cost	Space Area Ratio[a]	Allocated Support Service Cost
UMMC	14,296,989.39	0.0058	83,040.43
IJN	9,676,613.94	0.0117	159,664.13
PGH CRW	23,902,027.03	0.0072	35,375.00
PGH C8		0.0008	19,413.87
PJHUS CRW	6,197,120.61	0.0359	222,476.63
PJHUS Day-care		0.0180	111,235.99
QE2	9,358,962.77	0.0056	52,784.55

[a] Space Area Ratio used was cardiac ward space area: total hospital indoor space area

3.9.3.4 Ancillary Service

The 4 main ancillary service departments included as overhead cost in this study were laboratory, pharmacy, radiology, and rehabilitation. The total cost of ancillary service comprised of the labour cost for all the personnel, the cost of consumables supplied to the departments, and the hospital support and utility cost based on the space area occupied by the 4 departments.

Table 3.25 shows the tabulation of ancillary service cost for UMMC. The total cost of ancillary services was then apportioned to inpatient and outpatient services based on the 60:40 utilization proportions. Based on this, the inpatient ancillary service cost for ICW in UMMC was equivalent to RM 29,132,182.90. In the next step, the CW to hospital inpatient bed day workload ratio was used as allocation basis to derive the ancillary service cost of CW in UMMC (Table 3.26).

Table 3.25: Total cost of ancillary service at UMMC

Ancillary Service	Total Cost	Allocation basis	Ratio[a]	Allocated Cost
Labour	19,808,970.00	Actual	NA	19,808,970.00
Consumable	22,298,984.37	Actual	NA	22,298,984.37
Utility	15,001,573.31	Space Area	0.2200	3,300,346.13
Hospital Support	14,296,989.39	Space Area	0.2200	3,145,337.67
Total Ancillary Service Cost at UMMC				48,553,638.16
Ancillary Service Cost for Inpatient Services at UMMC[b]				**29,132,182.90**

[a] Ratio used was the space ratio of total space area of the 4 ancillary departments: hospital indoor space area
[b] Total ancillary service cost is apportioned based on utilization ratio of 60:40 for inpatient: outpatient services.

Similar steps were repeated for the other 4 cardiac centres. The final allocated cost of ancillary service to CW at the 5 cardiac centres can be seen in Table 3.26.

Table 3.26: Calculation of ancillary cost of cardiac ward of all centres

Centre	Hospital Inpatient Ancillary Cost	Workload Ratio[a]	Allocated Cost
UMMC	29,194,750.69	0.014	420,404.41
IJN	1,714,364.08	0.147	126,005.76
PGH CRW	11,773,789.90	0.009	106,302.47
PGH C8	11,773,789.60	0.039	456,338.57
PJHUS CRW	3,129,678.16	0.199	622,613.16
PJHUS Day-care	3,129,678.15	0.148	461,883.47
QE2	1,865,379.08	0.043	80,074.16

[a] Workload ratio used was the cardiac ward inpatient days: hospital inpatient bed days

3.9.4 Cardiac Catheterization Laboratory Direct Medical Cost

The next unit of analysis contributing to the total cost of PCI hospitalization was the cardiac catheterization laboratory (CL). The direct medical cost of CL included cost items that can be directly attributed to patients during the utilization of CL, such as labour cost of CL staff, utility and capital costs in CL, and consumables used during PCI. Medication for PCI patients was prescribed and served from the cardiac ward, thus no separate category for medication was created for CL.

3.9.4.1 Labour

The salary of doctors and other clinical staffs in the CL contributed towards the labour costs. Similar to the calculation of labour cost for doctors in the CW, different apportionment of working time for medical doctors was used to calculate the labour cost of doctors in CL. As for the remaining clinical staff, their labour cost was the summation of their total average salaries. Using similar steps as shown in Section 3.10.2.1, the labour cost in CL was calculated for each centre.

UMMC

As shown in Table 3.8, expert opinion of the head of cardiology department in UMMC was sought to determine the portion of time spent on separate cost centres by different grades of medical doctors. It was deemed that cardiologists spent 20% of their working time on CL-related work, whereas medical officers spent 15% in CL. In UMMC, besides doctors, clinical staffs who worked in CL included 1 nursing matron, 2 nursing sisters, 8 nurses, 3 senior and 7 junior laboratory technicians, 2 senior and 6 junior radiographers, 2 senior and 1 junior clinical clerks and 4 health attendants. As these clinical staff only worked in CL, their average salaries over the study period were summed up in total. Subsequently, the apportioned salaries of the doctors were added up together with the total salaries of the rest of the clinical staffs. The total labour cost in the CL of UMMC was RM 878,721.52. Table 3.27 outlines the calculation of labour cost in CL of UMMC.

Table 3.27: Calculation of labour cost in cardiac catheterization laboratory of UMMC

Staff	Apportioned Work Time	Average Monthly Salary	Apportioned Salary	n	Total Salary Payout
Doctors					
Consultant	20.0%	12,898.56	2,579.71	1	15,478.27
Specialist	20.0%	8,959.00	1,791.80	11	118,258.80
Sr. MO	15.0%	8,465.50	1,269.83	4	30,475.80
Jr. MO	15.0%	7,848.50	1,177.28	1	7,063.65
Subtotal					171,276.52
Others					
Matron	100.0%	5,170.00	5,170.00	1	31,020.00
Sister	100.0%	3,994.00	3,994.00	2	47,928.00
Nurse	100.0%	3,242.50	3,242.50	8	155,640.00
Sr. Radiographer	100.0%	3,994.00	3,994.00	2	47,928.00
Jr. Radiographer	100.0%	3,242.50	3,242.50	6	116,730.00
Senior Lab. Tech.	100.0%	3,994.00	3,994.00	3	71,892.00
Junior Lab. Tech.	100.0%	3,242.50	3,242.50	7	136,185.00
Health Attendant	100.0%	1,758.50	1,758.50	4	42,204.00
Senior Clerks	100.0%	3,227.00	3,227.00	2	38,724.00
Junior Clerks	100.0%	3,199.00	3,199.00	1	19,194.00
Subtotal					707,445.00
Total Labour Cost					**878,721.52**

Note. MO=medical officer, Sr.=Senior, Jr.=Junior, n=number of staff in each category

IJN

Based on the expert opinion of consultant cardiologists in IJN, doctors in the cardiology department spent 20% of their working time on CL-related work. As explained earlier, IJN provided only final value of the labour cost item. Using similar top-down costing method, labour cost of doctors was calculated based on the proportion of working time.

Labour Cost of Doctors	RM1,063,207.77
Labour Cost of Other Clinical Staff	RM1,467,271.19
Total Labour Cost OF CL in IJN	**RM2,530,478.96**

PGH

Based on the expert opinion of the head of cardiology department in PGH, cardiologists and senior medical officers spent one-third of their working time on CL-related work. Junior MO and house officers are usually not involved the CL activities. The apportioned salary of the doctors is calculated based on the proportion of the working time. As for the remaining clinical staff, they worked only in the CL. Therefore their average salaries over the study period were summed up in total. Table 3.28 outlines the calculation of labour cost of CL of PGH.

Table 3.28: Calculation of labour cost in cardiac catheterization laboratory of PGH

Staff	Apportioned Work Time	Average Monthly Salary	Apportioned Salary	n	Total Salary Payout
Doctors					
Consultant	33.3%	18,587.54	4,126.43	2	24,758.60
Specialist	33.3%	15,976.00	14,186.69	8	85,120.13
Senior MO	33.3%	13,289.00	19,176.03	13	115,056.16
Subtotal					187,396.92
Others					
Matron	100.0%	4,991.28	4,991.28	1	29,947.65
Sister	100.0%	4,081.44	4,081.44	1	24,488.32
Nurse	100.0%	3,353.60	3,353.60	8	160,972.56
Sr. Radiographer	100.0%	3,939.05	3,939.05	2	47,268.54
Jr. Radiographer	100.0%	3,316.00	3,316.00	8	159,167.26
Senior Lab. Tech.	100.0%	4,281.68	4,281.68	3	77,070.24
Junior Lab. Tech.	100.0%	3,742.50	3,742.50	5	112,275.00
Health Attendant	100.0%	2,178.46	2,178.46	6	78,424.56
Subtotal					689,614.70
Total Labour Cost					**880,833.45**

Note. MO=medical officer, Sr.=Senior, Jr.=Junior, n=number of staff in each category

PJHUS

In PJHUS, the consultant cardiologist decided that a doctor's working time was to be apportioned equally to the cardiac laboratory, the cardiac specialist clinic, and the cardiac wards. Therefore, it is estimated that doctors in the cardiology department of PJHUS spent 33.3% of their total working hours in CL. Table 3.29 details the calculation of labour cost in the CL of PJHUS.

Table 3.29: Calculation of labour cost in cardiac catheterization laboratory of PJHUS

Staff	Apportioned Work Time	Average Monthly Salary	Apportioned Salary	n	Total Salary Payout
Doctors					
Consultant	33.3%	17,000.00	5,661.00	1	33,966.00
Specialist	33.3%	16,449.00	5,477.52	5	164,325.51
Senior MO	33.3%	11,608.50	3,865.63	1	23,193.78
Junior MO	33.3%	8,041.50	2,677.82	7	112,468.42
Subtotal					333,953.71
Others					
Sister	100.0%	3,994.00	3,994.00	2	47,928.00
Nurse	100.0%	3,242.50	3,242.50	10	194,550.00
Sr. Radiographer	100.0%	3,256.50	3,256.50	4	78,156.00
Senior Lab. Tech.	100.0%	3,242.45	3,242.45	5	97,273.50
Health Attendant	100.0%	1,483.35	1,483.35	3	26,700.30
Subtotal					444,607.80
Total Labour Cost					**778,561.21**

Note. MO=medical officer, Sr.=Senior, n=number of staff in each category

QE2

In QE2, a doctor's working time was apportioned equally to the cardiac laboratory, the cardiac specialist clinic, and the cardiac wards based on the expert opinion of the consultant cardiologist. Thus, 33.3% of the working time of doctors in the department can be attributed to CL. The number of clinical staff in CL of QE2 was much lower compared to other cardiac centres in the study. Table 3.30 details the allocated labour cost for doctors in the CL.

Table 3.30: Calculation of labour cost in cardiac catheterization laboratory of QE2

Staff	Apportioned Work Time	Average Monthly Salary	Apportioned Salary	n	Total Salary Payout
Doctors					
Consultant	33.30%	12,215.32	4,067.70	1	24,406.21
Specialist	33.30%	9,764.80	3,251.68	2	39,020.14
Senior MO	33.30%	7,345.14	2,445.93	1	14,675.59
Subtotal					78,101.94
Others					
Sister	100.0%	6,471.64	6,471.64	1	38,829.82
Nurse	100.0%	5,285.33	5,285.33	10	317,119.80
Sr. Radiographer	100.0%	4,339.76	4,339.76	1	26,038.56
Senior Lab. Tech.	100.0%	4,523.33	4,523.33	1	27,193.98
Health Attendant	100.0%	2,125.63	2,125.63	1	12,753.78
Subtotal					421,935.94
Total Labour Cost					**500,037.88**

Note. MO=medical officer, Sr.=Senior, Jr.=Junior, n=number of staff in each category
The complete labour cost results of all centres are outlined in Chapter 4.

3.9.4.2 Capital

The capital cost was the total EAC of assets based on the inventory records in CL, as discussed in the section 3.9.1.

Table 3.31: Capital cost in cardiac catheterization laboratory Cost at all centres

Centre	Total EAC of assets
UMMC	2,839,335.96
IJN	3,619,363.29
PGH	614,370.96
PJHUS	687,789.25
QE2	782,479.78

3.9.4.3 Consumable

There were 2 categories of consumables used in CL. The first category refers to general supplies, for example IV drips, branula and syringes. All the users of CL, regardless of their diagnosis or the intervention being conducted in the CL, shared these general consumables. The actual cost of general consumable items was available from the CL invoice record at each respective centre (Table 3.32).

Table 3.32: General consumable cost in cardiac catheterization laboratory at all centres

Cente	General Consumable Cost
UMMC	201,404.15
IJN	5,130,845.80
PGH	359,953.93
PJHUS	398,523.57
QE2	334,733.31

The second category of consumables used in CL refers to PCI consumables such as stents, catheters, wires and balloons. Contrary to general consumables, these items were only used for patients who underwent PCI procedures. As these items were purchased directly by the cardiology department, up-to-date purchasing record and total cost was readily available from the CL.

A wide range of cardiac stents were used in each centre, and they can be broadly categorized as drug-eluting stent (DES), bare metal stent (BMS), bio-absorbable vascular scaffold (BVS) and drug-eluting balloon (DEB). Table 3.33 records the total cost of all the stents purchased and used during the study period, regardless of the types of stents.

Table 3.33: PCI consumable cost in cardiac catheterization laboratory at all centres

Centre	Stent Cost	Other PCI consumable Cost	Total PCI consumable Cost
UMMC	3,634,900.00	869,950.00	4,504,850.00
IJN	8,137,097.50	4,605,949.00	12,743,046.50
PGH	1,905,950.00	872,604.00	2,778,554.00
PJHUS	1,664,434.50	715,030.00	2,379,464.50
QE2	1,528,828.50	623,515.00	2,152,343.50

3.9.5 Cardiac Catheterization Laboratory Overhead Cost

Under CL, the overhead cost included only utility cost and hospital support service cost. As each inpatient bed day was considered as a single hospital user, the cost of dietary service and ancillary support service was only counted once under CW to avoid double counting these costs for the same PCI patient.

3.9.5.1 Utility

The utility cost in CL was calculated based on the floor space ratio of CL to the total hospital indoor area.

Table 3.34: Utility cost of cardiac catheterization laboratory at all centres

Centre	Total Hospital Utility Cost	Space Area Ratio[a]	Allocated Utility Cost
UMMC	15,001,573.31	0.0076	114,473.40
IJN	13,225,641.63	0.0082	109,094.76
PGH	13,500,989.22	0.0017	22,559.11
PJHUS	3,476,083.32	0.0142	49,302.66
QE2	2,057,979.53	0.0075	15,417.61

[a] Space Area Ratio used was CL area: total hospital indoor space area

3.9.5.2 Hospital Support Service

Similar to Section 3.10.3.3, the contract cost paid to the private company during the study period for providing the hospital support services were obtained from the finance department. The hospital support service cost in CL of each cardiac centre was calculated based on the space ratio of CL to hospital indoor area.

Table 3.35: Hospital support service cost of cardiac catheterization laboratory at all centres

Centre	Total Hospital Support Service Cost	Space Area Ratio[a]	Allocated Hospital Support Service Cost
UMMC	14,296,989.39	0.0076	109,096.89
IJN	9,676,613.94	0.0082	112,959.66
PGH	23,902,027.03	0.0017	34,634.59
PJHUS	6,197,120.61	0.0142	87,785.37
QE2	9,358,962.77	0.0075	70,137.06

[a] Space Area Ratio used was CL area: total hospital indoor space area

3.10 Average Cost via Top-down Approach

To derive the unit cost of interest, bottom-up or top-down costing approaches can be applied. Bottom-up approach multiplies actual utilization volume to the unit price to derive the cost of each cost item, providing the actual cost of resource consumption at individual patient level. A full bottom-up micro costing approach was deemed to produce the most accurate unit cost estimates. However, it is a labour intensive and costly exercise, thus not practical in view of our time and budget constraint.

Top-down approach allocates a total budget for a specific service obtained from the hospital financial and administration level to the number of products or services, assuming that every procedure consumes equal amount of resources. Thus, it is cheaper and more straightforward to conduct.

To derive the unit cost of interest in this study, top-down approach was used. The result would represent centre-specific resource use and unit cost for an average PCI patient. This approach enabled the comparison of resource consumption and costs at various levels between the 5 centres.

3.10.1 Average Cost of Each Unit of Analysis

By using top-down approach, the total cost of each cost centres tabulated in Section 3.10 was divided by appropriate activity output to derive the unit cost of interest, namely cost of hospital general overhead per user, cost per bed day in cardiac ward that would lead to cost per admission for elective PCI patient, cost per cardiac catheterization laboratory utilization, and cost of PCI consumable per PCI procedure. The latter two would give rise to the cost per PCI procedure in CL. Figure 3.5 outlines the calculation pathway for each unit of analysis.

For the first unit of analysis, hospital general overhead, the total cost of hospital general overhead was divided by the total number of hospital users during the study period to produce the cost of hospital general overhead per user.

For the second unit of analysis, CW admission, the summation of direct medical cost and overhead cost gave rise to the total cost at CW. To calculate the unit cost of CW, the average method was used, whereby the total cost of CW was divided by the total inpatient bed days during the study period to derive the cost per bed day in CW.

The CW cost per bed day was then multiplied by average length of stay (ALOS) to produce the cost of cardiac ward admission per elective PCI patient. The ALOS was decided to be 3 days via consensus by all the interventional cardiologists. For PGH and PJHUS where there were more than one ward accommodating PCI patients, weighted cost of admission was calculated using the ratio of patients admitted to the respective wards. This was done to facilitate the comparison of average admission cost with other centres.

For the third unit of analysis, utilization of CL, the sum of direct medical cost and overhead cost was divided by the total number of procedures conducted in the CL during the study period to derive the cost per CL utilization, regardless of type of procedures.

Lastly, the total cost of PCI consumables was divided equally with the number of PCI procedures to obtain the cost of PCI consumable per PCI. By adding this to the cost per CL utilization, the cost of PCI procedure in the CL was obtained.

The average cost for each unit of analysis at all centres will be presented in Chapter 4.

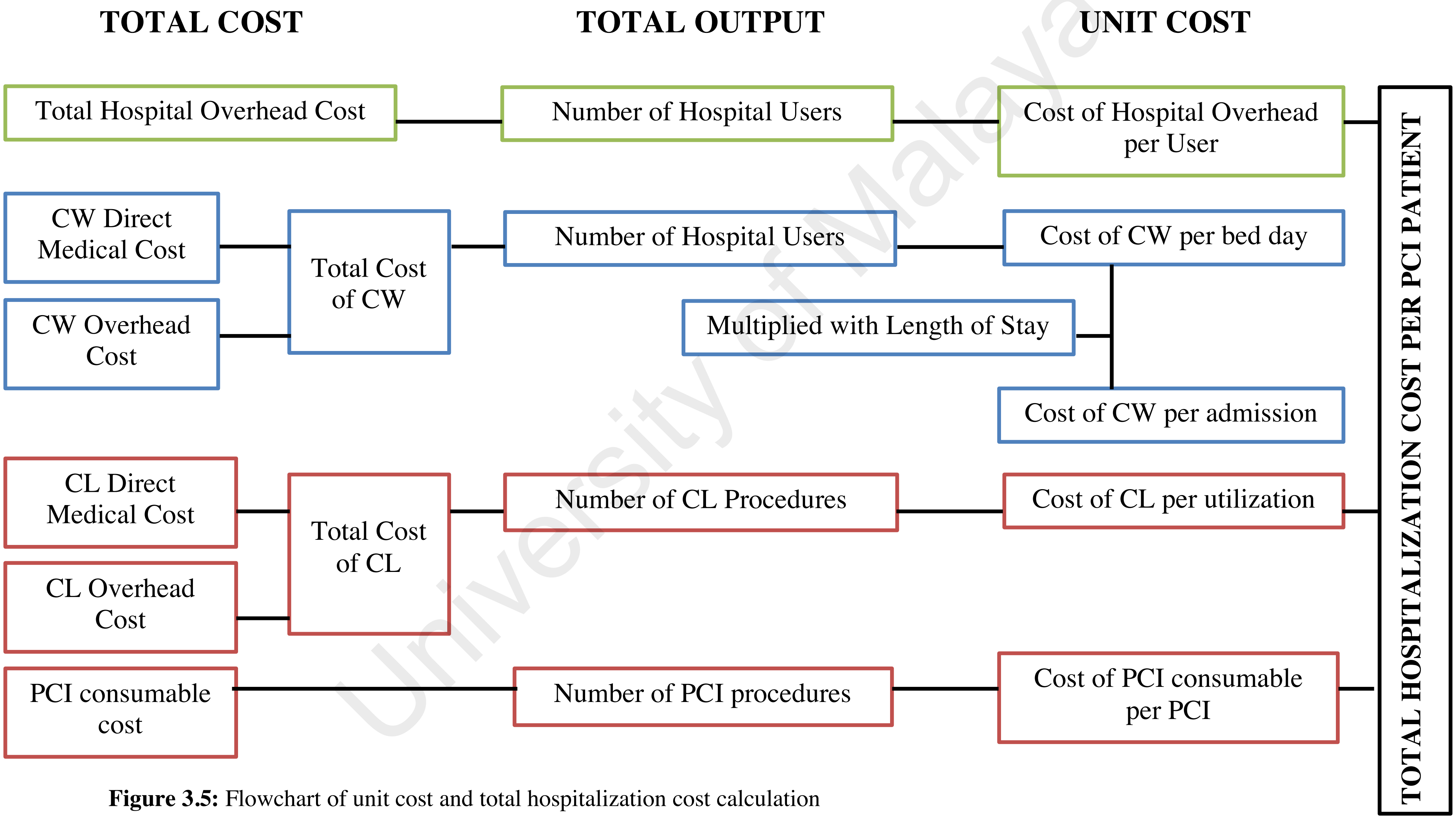

Figure 3.5: Flowchart of unit cost and total hospitalization cost calculation

3.10.2 Average Hospitalization Cost for Elective PCI

The unit costs calculated as shown in Section 3.11.1 would be taken into account for the calculation of the average hospitalization cost of PCI patients at each cardiac centre.

The following equation showed the actual calculation involved:

Average Cost per CW admission

= Average Cost per bed day in CW * Average length of stay (3 days)

Average Cost of PCI consumables

= Average cost of cardiac stents + Average cost of other specific consumables

Average Cost of PCI in CL

= Average cost of CL utilization + Average cost of PCI consumables

Average PCI Patient Hospitalization Cost

= Hospital General Overheads Cost per user

+ Average Cost per CW admission

+ Average Cost of PCI in CL

It is important to note that the cost produced is via a top-down approach and it represented the average cost estimates for a patient admitted for an elective PCI procedure, assuming an average length of stay of 3 days, with no complications post-PCI that required intensive care. This cost also did not reflect any difference in the type and number of stents used for each patient.

3.11 Individual Cost via Mixed Method Approach

The unit cost per PCI patient calculated via the top-down approach in Section 3.11 produced an average estimate of PCI hospitalization per patient. While this average cost enables an objective baseline comparison of resource consumption and hospitalization cost between the cardiac centres, it is insufficient for more comprehensive analysis such as patient-level comparison and determination of cost predictors via statistical analysis.

Due to the time and resource constraint, a full bottom-up micro costing approach was not possible for this costing study. Instead, a mixed method of top-down and bottom-up costing approaches was applied to obtain individual-level patient cost data. Bottom-up approach was reserved for certain cost items deemed to have significant impact on the final cost output.

For cost items to be costed with bottom-up approach, certain clinical and cost data were needed at the individual patient level. In some studies, secondary data from cardiac registries have been used to derive the cost data required to study the impact of health financing on healthcare system (Ryan, 2010). As described in Section 3.5.1, NCVD-PCI Registry contains clinical information such as patient demographics, clinical presentation, angiographic severity, treatment and outcomes of all patients who underwent PCI. Therefore, relevant patient data from the registry was retrieved and incorporated to the bottom-up micro costing approach to determine the individual cost of PCI patients.

3.11.1 Cardiac Ward Admission

Based on literature review, it was shown that inpatient LOS were major determinants in the difference of total costs calculated using top-down and bottom-up approach (Emmett & Forget, 2005; S. S. Tan, Rutten, van Ineveld, Redekop, & Hakkaart-van Roijen, 2009; Wordsworth, Ludbrook, Caskey, & Macleod, 2005). In Section 3.11, an average LOS of 3 days was applied for all cardiac centres to calculate the average cardiac ward admission cost. For bottom-up approach in this section, actual LOS of each patient was retrieved from the NCVD-PCI Registry and used in the calculation of CW admission cost.

Hospital LOS was calculated by the difference between the date of discharge and the date of admission in the NCVD-PCI Registry. If the date of discharge and the date of admission were the same, then the LOS would be taken as 1 day. Actual LOS of individual patient was multiplied to the admission cost per bed day in cardiac ward to derive the individual admission cost per patient for elective PCI procedure.

3.11.2 PCI consumables

The second cost item recalculated with bottom-up approach was the cost of cardiac stents under PCI consumable. A wide range of cardiac stents were used in each centre, and they can be broadly categorized as drug-eluting stent (DES), bare metal stent (BMS), bio-absorbable vascular scaffold (BVS), and drug-eluting balloon (DEB). Due to the broad variety of stent types and the high purchase price of stent, it was postulated that cardiac stent cost usage would have a significant impact on the total costs when different costing approaches were applied.

To apply the bottom-up approach for cardiac stent cost, the types and quantity of cardiac stents used by each patient were extracted from the NCVD-PCI Registry. The purchase price of each type of stent was obtained from the invoice orders kept by the cardiology department. By multiplying the purchase cost with the quantity of stent used, the cardiac stent cost of an individual patient was calculated. The cost of the remaining PCI consumables i.e. coronary catheters, wires and angioplasty balloons followed the average cost calculated in Section 3.10.4.3.

3.11.3 Individual Patient Hospitalization Cost

The summation of the 3 units of analysis, namely hospital general overheads cost per user, individual patient admission cost, and cost per PCI in CL produced the individual patient hospitalization cost.

Individual Cost per CW admission

= Cost per bed day in CW * Individual length of stay

Individual Cost of PCI consumables

= Individual cost of cardiac stents + Average cost of other specific consumables

Individual Cost of PCI in CL

= Average cost of CL utilization + Individual cost of PCI consumables

Individual PCI Patient Hospitalization Cost

= Hospital General Overheads Cost per user

+ Individual Cost per CW admission

+ Individual Cost of PCI in CL

The final cost derived from the calculation represented the hospitalization cost of individual PCI patient recorded in the NCVD-PCI Registry during the study period. In comparison to the average hospitalization cost calculated as shown in Section 3.11, this mixed method approach took into account the cost items with high heterogeneity between the patients. The individual patient hospitalization cost generated with this approach provided the cost distribution of each unit of analysis and also facilitated the identification of significant cost predictors in regression analysis.

3.12 Statistical Analysis

This section provides an overview of the statistical testing used to achieve the different objectives of the study.

3.12.1 Clinical Data

For the data on clinical and treatment characteristics of PCI patients extracted from NCVD-PCI Registry, statistical analysis was conducted using IBM® SPSS® Statistics version 20.0.0. For each centre, descriptive analysis was performed on the clinical variables. Categorical variables were described as numbers and percentages. Continuous variables were described based on the normality of the distribution. Normality distribution was examined using the stem-and-leaf plot and Kolmogorov- Smirnov test. If the clinical data was normally distributed, the variables were described as mean and standard deviation. If the data distribution was skewed, the variables were described as medians (with 25th and 75th percentiles).

3.12.2 Cost Data

All the cost data collected from the 5 cardiac centres was entered into Microsoft Excel 2010. Average cost and its breakdown was compiled for each centres and then described in percentages in separate excel sheet for each centre. A system of linked Excel spreadsheets was then used in the cost calculation for comparison purposes between the 5 cardiac centres.

The unit cost data obtained from the Microsoft Excel was then inserted into the NCVD-PCI patient file to derive individual hospitalization cost of each patient. Goodness of fit test was used to test the normality of the individual cost obtained. In this study, Kolmogorov-Smirnov statistic was used as the reference as the sample size is large. Any *p-value* of more than 0.05 will indicate normal distribution of the data. If the cost data was normally distributed, the variables were described as mean and standard deviation. In the event that the data was skewed, which is almost always for cost-related data, the variables were described as medians and interquartile ranges.

Although it is common practice to report skewed data with median and IQR for general statistical practices, but for medical-related cost data, it is useful to report means and standard deviation alongside. This is because mean can be used to recover the total cost, which reflects the entire expenditure on healthcare in a given patient population. The arithmetic mean cost, when multiplied by the number of patients to be treated, produces the total cost estimates that would be incurred if the said treatment were implemented. This information would be more important for policy decisions. Therefore, for cost-related output in the results section, both mean and median values were reported.

Further analysis was conducted to delineate the similarities and differences in the patient characteristics, treatment details, resource consumption, and cost of elective PCI at the 5 participating cardiac centres. Analyses were conducted using chi-square for categorical variables, and ANOVA for continuous variables. All comparisons were 2 tailed and the significance level was taken at *p-value* of <0.05. The individual patient-level hospitalization cost calculated as shown in Section 3.12.3 would be used to compare the mean and median costs between the 5 cardiac centres.

3.12.3 Predictors of Total Hospitalization Cost

Multiple linear regression was used to predict significant predictors of total hospitalization cost from the independent variables. Despite the fact that the dependent variable, total hospitalization cost, was likely to be positively skewed, standard methods for regression are known to be fairly robust to non-normality, especially in studies with large sample size.

By law of large numbers and the central limit theorem, the ordinary least square (OLS) estimators in linear regression technique would be approximately normally distributed around the true parameter values, which implied that the estimated parameters and their confidence interval estimates remain robust (Li, Wong, Lamoureux, & Wong, 2012). Therefore, for studies with sufficiently large samples, violations of normality in the dependent variables may not be an issue in the use of a linear regression technique. Previous simulations studies showed that "sufficiently large" is often under 100, and even for some studies with extremely non-normal medical cost data, the sample size was less than 50 (Lumley, Diehr, Emerson, & Chen, 2002). With 2260 patients in our study, a linear regression model can thus be accepted as an useful default prediction tool.

In view of the large number of independent variables on patient and treatment characteristics, bivariate analysis was first conducted with Spearman's rank-order correlation. Only variables with statistically significant correlations ($p<0.05$) were inserted in the linear regression analysis.

Stepwise linear regression analysis was chosen to determine the best combination of independent variables to predict the individual patient hospitalization cost. Before presenting the results of the stepwise linear regression, the information on the examination of the extent to which the assumptions for linear regression were met are also outlined. The assumptions checked included independence of errors, homoscedasticity of errors, linearity and normality. Statistical significance is taken at $p<0.05$.

3.12.4 Predictors for Long Hospital Stay

Further analysis was conducted based on hospitalization period of the patients. The LOS for patients who were admitted for elective PCI may be associated with the underlying health status and the disease severity.

For this section of analysis, the hospitalization period was dichotomized into early discharge or short hospital stay group (LOS$\leq$ 3 days) and non-early discharge or long hospital stay (LOS > 3 days). A LOS of 3 days was chosen as a cut-off point as the median LOS calculated was 3 days. The interventional cardiologists involved in this costing study also unanimously agreed that the average LOS for elective PCI patients would be 3 days.

Comparisons were made between patients with long and short hospital stay to determine any differences in the patient and treatment characteristics. Analysis was performed with chi-square for categorical variables and independent t-test for continuous variables to identify differences in study variables between the 2 patient groups based on LOS.

Following that, a logistic regression analysis was used to identify the predictors of long hospital stay among the various patient and treatment characteristics. Variables that showed significant association on Chi-square testing were included in the logistic regression. Odds ratio and its 95% confidence intervals were reported.

3.13 Ethical Approval

This study is registered in the National Medical Research Register of Malaysia and received ethical approval from Medical Research and Ethics Committee, of the Ministry of Health (ID: NMRR-13-1403-18234 IIR) (APPENDIX D). Ethical approval was also obtained from the Medical Ethics Committee of University of Malaya Medical Centre, Kuala Lumpur (IRB Reference number: 1038.19) (APPENDIX E).

3.14 Summary

To achieve the objective of this thesis, 2 main sets of data were required. This chapter covered in great details the methods used for both sets of data collection. The first set of data was clinical data concerning patient and treatment characteristics extracted as secondary data from the NCVD-PCI Registry. The second set of data was the cost data obtained via primary data collection from all the participating cardiac centres. Due to the limitations on the cost data available, modifications were made to economic evaluation guidelines based on local scenario.

For the first phase of cost analysis, average cost by centre was calculated using top-down approach to determine dominant cost drivers at each centre. In the second phase, mixed method of top-down and bottom-up costing approaches was applied to calculate individual-level patient cost data. This enabled a more comprehensive cost analysis and facilitated the identification of predictors of length and cost of hospitalization. In the final section, data analysis and ethical consideration were outlined.

CHAPTER 4: ANALYSIS OF AVERAGE COST BY CENTRES

In view of the multitude of patient, physician and hospital factors involved in the PCI service, variation in PCI practices may exist between different cardiac centres. It is necessary to identify these variations, as they would have an impact on the outcomes and costs of PCI procedures. In this study, it is presumed that the variations caused by physicians' preference were minimal and negligible as there are up-to-date clinical practice guidelines for the selection of treatment modality and stent usage. For the hospital and patient factors, the results are presented in Chapter 4 and 5 respectively.

In the first section of this chapter, the results of the tabulation of all the cost items listed in Section 3.9 were presented. They were then compiled to derive the average costs, based on steps shown in Section 3.10. Comparison was made between the centres and dominant cost drivers at each step were identified.

4.1 Total Cost of Each Unit of Analysis by Cardiac Centre

In this section, the cost output from each centre was presented. The results were tabulated separately for the 3 units of analysis, namely hospital general overhead cost, cardiac ward admission cost, and cardiac catheterization utilization cost. The total cost of these units of analysis served as the numerators for the calculation of average cost.

4.1.1 Total Cost of Hospital General Overhead

The 4 main cost items included in the calculation of total cost of hospital general overhead were labour, consumable, utility and hospital support service costs (Table 4.1). The total cost is related to the scale and workload of the cardiac centre, and also the ownership type of the centre, whether it is a public centre or corporatized centre.

The 3 centres in Peninsular Malaysia topped the total costs of hospital overhead in the study. The cost at UMMC, totaling RM 30.6 million, was the highest among all the cardiac centres, followed by IJN at RM 26.3 million, and PGH at RM 20.3 million. The cost was relatively low at the two East Malaysian centres.

Figure 4.1 showed the contribution of cost items under each category towards the total hospital overhead cost at the 5 cardiac centres. For UMMC, IJN and PGH, as high as 60-70% of total hospital overhead cost was attributed to labour cost. Consumable cost accounted for the second highest expenditure in the 3 centres. On the contrary, hospital support service constituted more than half of the total cost in QE2 and PJHUS.

Table 4.1: Cost items contributing towards total cost of hospital general overhead

Cost Items	**UMMC**	**IJN**	**PGH**	**PJHUS**	**QE2**
Labour	20,548,614.82	15,680,582.63	14,246,045.67	706,068.66	1,588,696.50
Consumable	4,045,956.81	3,550,480.52	5,617,744.10	144,446.00	575,838.00
Utility	3,075,690.73	2,550,600.83	120,740.58	1,322,867.21	1,029,448.77
Hosp.Support	2,931,233.73	4,478,787.48	271,082.27	2,479,369.01	3,754,319.67
TOTAL	**30,601,496.08**	**26,260,451.44**	**20,255,612.62**	**4,652,750.88**	**6,948,302.94**

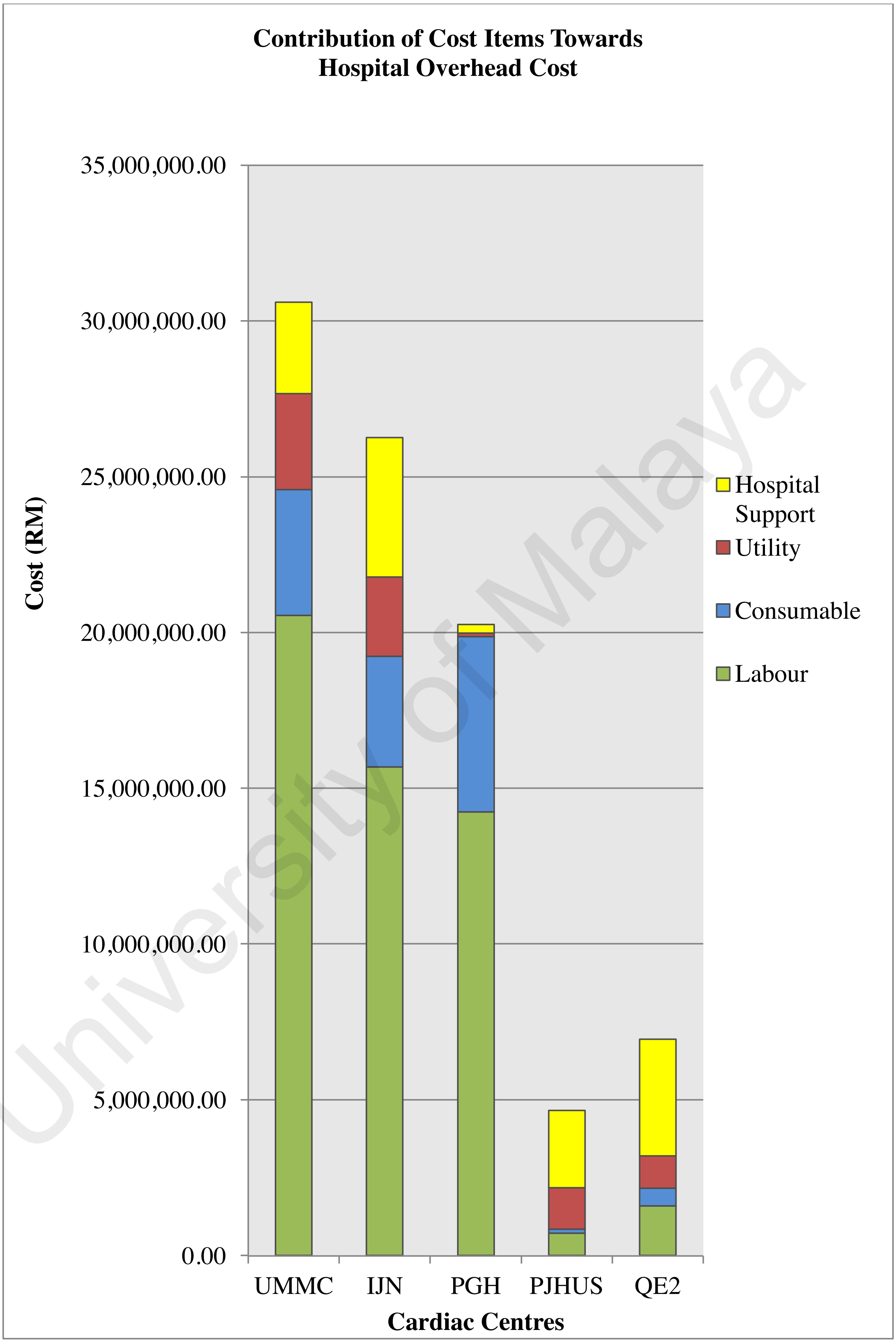

Figure 4.1: Contribution of cost items towards total hospital overhead cost at all centres

4.1.2 Total Cost of Cardiac Ward Admission

The second unit of analysis contributing to the total hospitalization cost of a PCI patient was cardiac ward admission. For UMMC and QE2, all elective PCI patients were admitted and discharged via the cardiac rehabilitative ward (CRW).

In IJN, elective PCI patients may be admitted to any one of the 8 second- or third-class wards. Each of this consisted of different numbers of 3, 4 or 5-bedded rooms. Cost analysis based on staff ratio, space ratio and bed day ratio for each individual ward was conducted before the average weighted cost of all the wards were worked out for IJN and presented as a single value for each item.

It was important to point out that for PGH, there were 2 cardiac wards that PCI patients may be admitted to, namely CRW and Ward C8. In PJHUS, apart from CRW, there is also a special day-care unit for patients who were deemed stable enough to discharge on the same day after the procedure was conducted. The 2 wards at these 2 cardiac centres differed in several aspects including staffing ratio and space area, thus their cost items were presented separately.

Table 4.2 outlined each cost item under the direct medical and overhead costs. The overall cost incurred can be dependent on various factors, including unit price paid for attaining each cost item and overall workload of the ward. The total cost of all cost items in CW was the highest in Ward C8 in PGH, followed by CRW in PJHUS and UMMC.

Table 4.2: Cost items contributing towards total cost of cardiac ward admission

Cardiac Ward Cost Items	**UMMC**	**IJN**	**PGH CRW**	**PGH C8**	**PJHUS CRW**	**PJHUS Day-care**	**QE2**
Direct Medical							
Labour	666,064.92	1,333,604.78	874,136.64	1,079,484.69	1,340,625.80	345,683.73	1,244,978.02
Capital	382,311.39	222,997.80	94,791.64	27,674.28	193,787.82	250,095.62	86,215.03
Consumable	116,035.54	63,584.90	214,708.34	921,706.71	64,321.29	47,716.53	19,857.02
Medication	1,055,939.18	12,697.27	287,242.14	1,233,082.08	558,577.96	62,189.01	575,258.55
Total	*2,220,351.03*	*1,632.884.74*	*1,470,878.76*	*3,261,947.76*	*2,157,312.87*	*705,684.89*	*1,926,308.62*
Overhead							
Utility	87,132.83	154,201.25	97,277.64	10,998.59	124,948.95	62,473.17	11,603.16
Dietary	26,075.00	118,721.94	95,143.27	408,434.00	58,374.60	43,305.00	26,269.15
Hospital Support	83,040.43	159,664.13	35,375.00	19,413.87	222,476.63	111,235.99	52,784.55
Ancillary support	420,404.41	126,005.76	106,302.47	456,338.57	622,613.16	461,883.47	80,074.16
Total	*616,652.67*	*558,593.07*	*334,098.38*	*895.185.03*	*1,028,413.34*	*678,897.63*	*170,731.02*
Total Ward Cost	**2,837,003.70**	**2,191,477.81**	**1,804,977.14**	**4,157,132.79**	**3,185,726.21**	**1,384,582.52**	**2,097,039.64**

For all the centres, the direct medical cost items contributed to majority of the total cardiac ward admission cost. The proportion was the highest in QE2 (91.9%). It was the lowest in PJHUS day-care (51.0%). The difference in the proportion of overhead and direct medical costs for all the cardiac centres is illustrated in Figure 4.2.

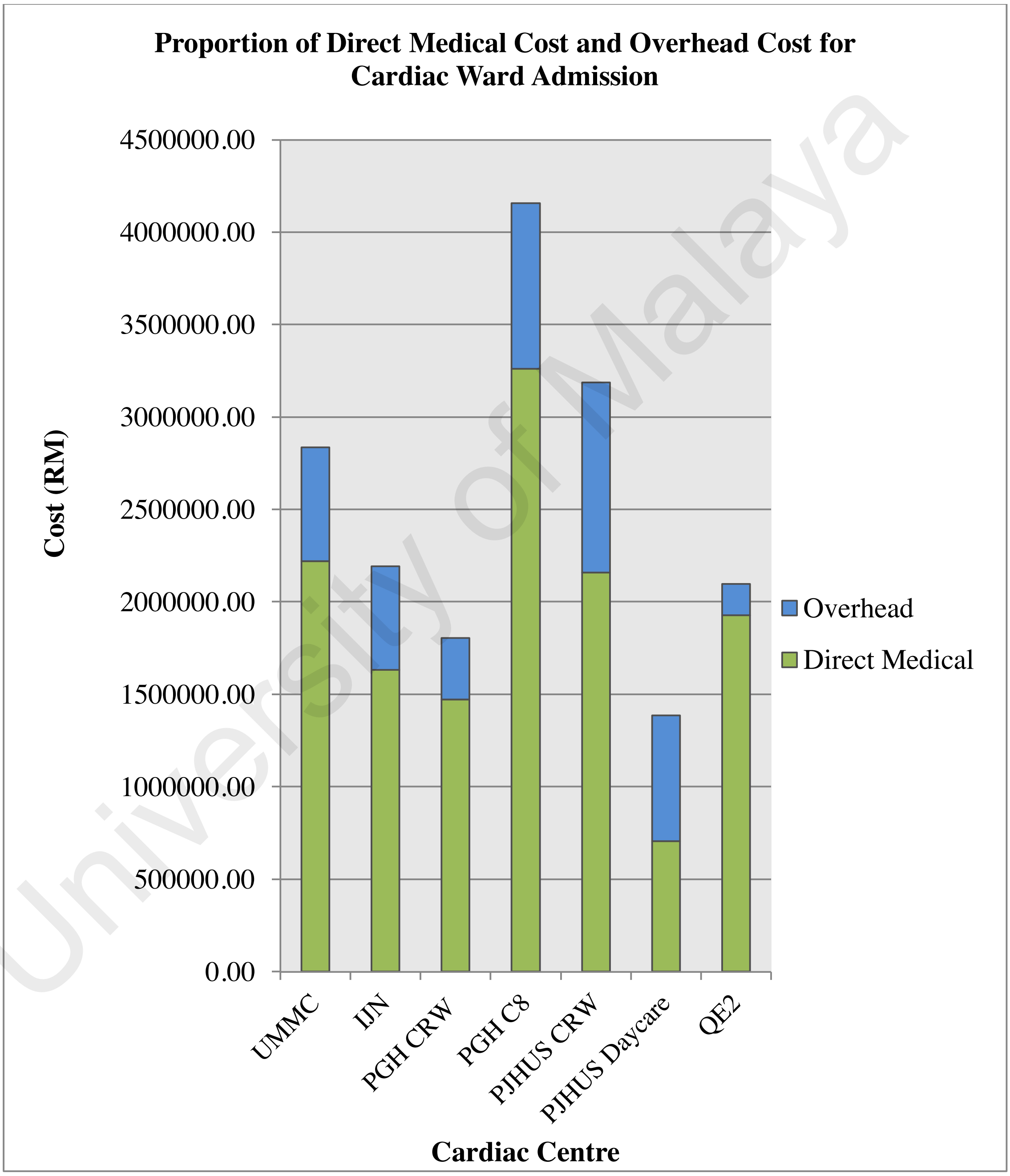

Figure 4.2: Proportion of direct medical cost and overhead cost towards total cardiac ward admission cost at all centres

A closer scrutiny on cost items under direct medical cost revealed that all the centres recorded labour cost as the highest contributor of direct medical cost, except for UMMC. For UMMC, labour cost was the second highest cost driver in CW after consumable cost. There were great discrepancy between the medication cost in UMMC as compared to the other centre, with the biggest difference seen between UMMC and IJN. This could be partially attributed to the allocation basis used to obtain the medication cost in the top-down approach, as explained in section 3.9.2.4. Capital and consumable costs were relatively low compared to other cost items for most centres (Figure 4.3).

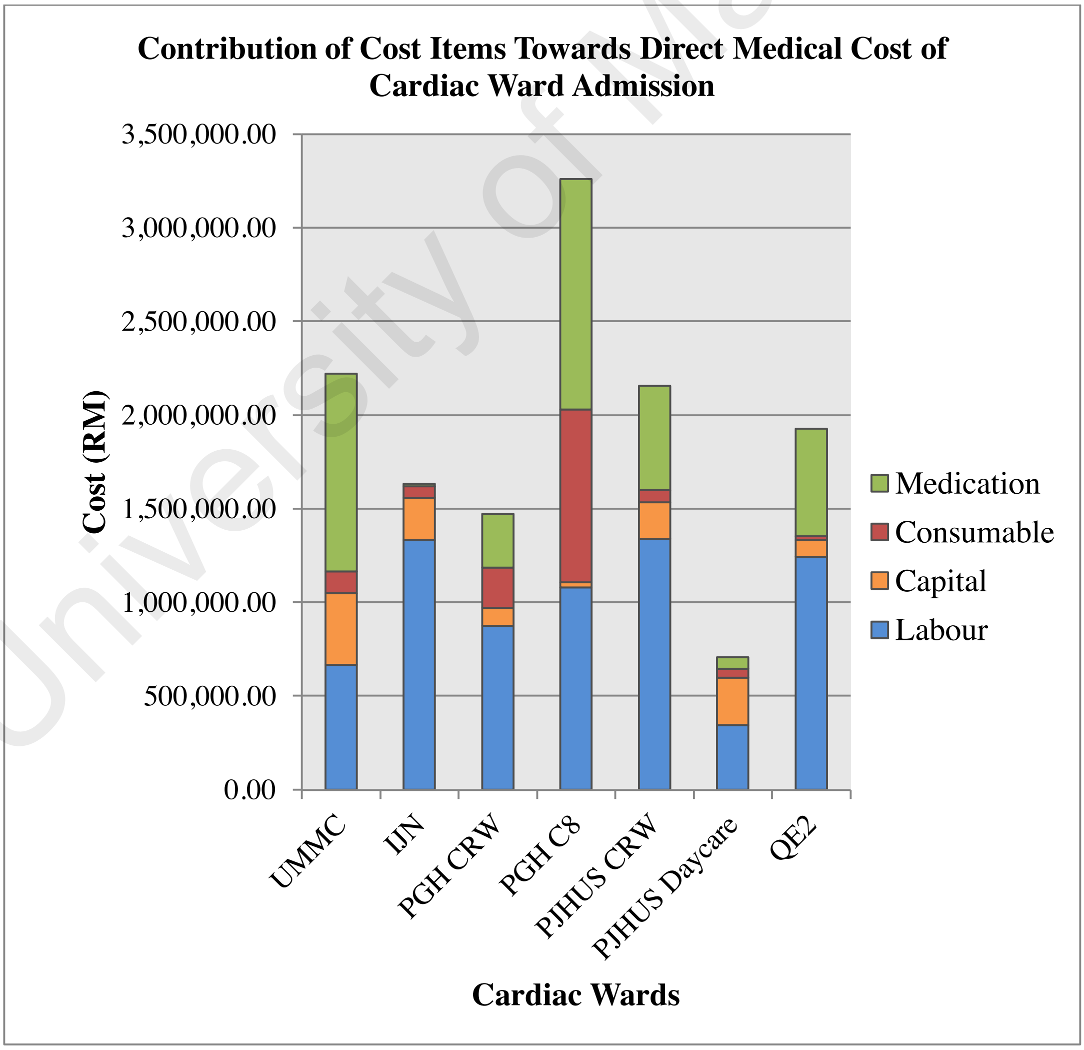

Figure 4.3: Contribution of different cost items towards the direct medical cost of cardiac ward admission at all centres

Figure 4.4 showed the contribution of different cost items towards the CW overhead cost. The overhead cost was the lowest in QE2. Among all the cost items, ancillary support service accounted for the largest proportion of cost at all the cardiac centres, ranging from 22.6% of total cost in IJN to 78.4% of total cost in PGH C8. The remaining cost items showed a wide range of differences between the centres.

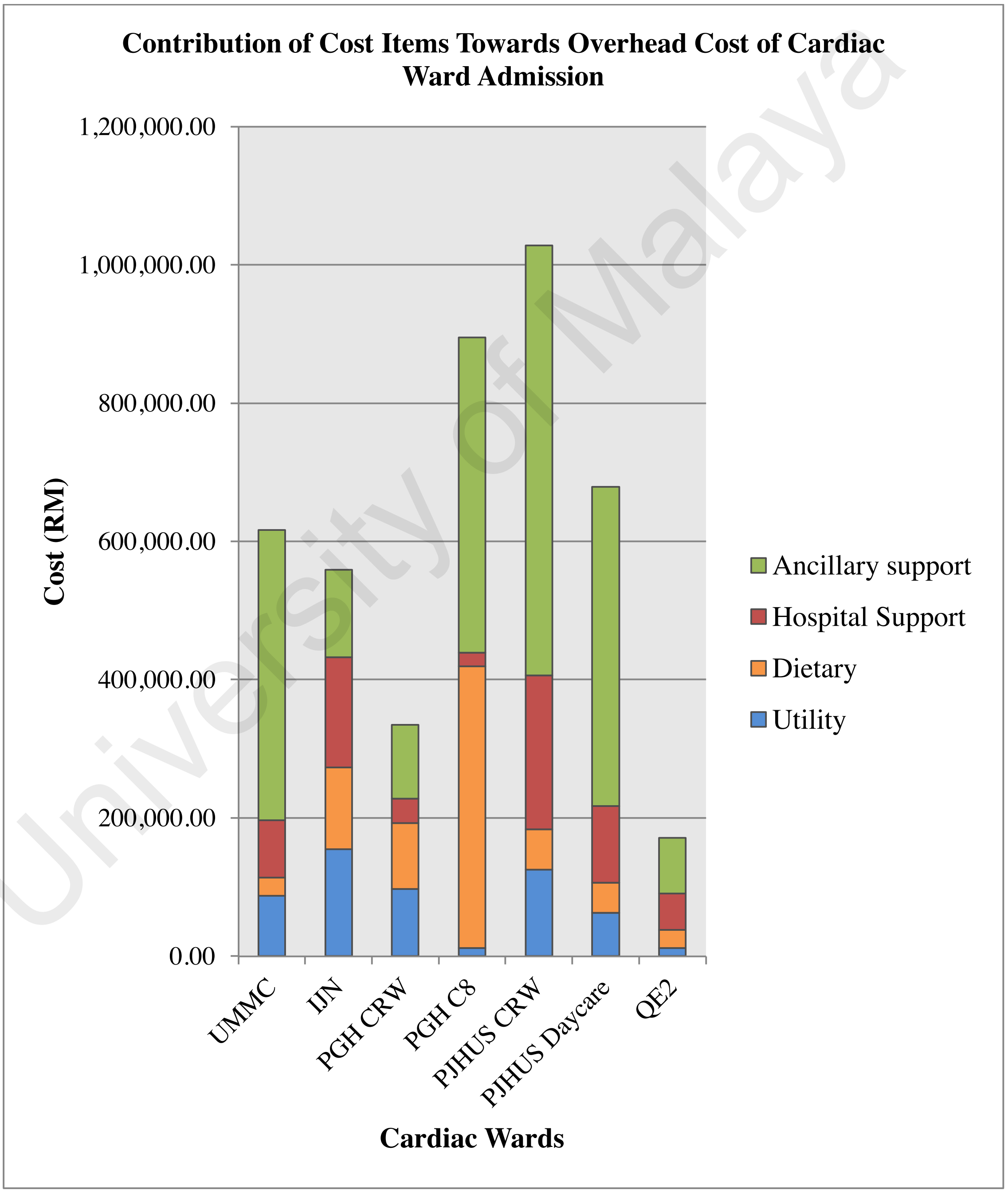

Figure 4.4: Contribution of different cost items towards the overhead cost of cardiac ward admission at all centres

4.1.3 Total Cost of Cardiac Catheterization Laboratory Utilization

The third unit of analysis in the total hospitalization cost of elective PCI patients was the cardiac catheterization laboratory (CL) utilization.

A closer scrutiny on Table 4.3 revealed that IJN had the highest cost of CL utilization amounting to RM 11.5 million during the study period. The second highest cost was incurred by UMMC, approximately one-third of the cost at IJN (RM 4.1 million).

The cost of CL utilization at the remaining 3 public cardiac centres ranged from RM 1.7 million to RM 2.0 million. Similar to the cost of CW admission, the overall cost of CL utilization would increase with higher number of case volume in the CL, or higher cost of attaining each cost individual cost item. This would be further analyzed in the next section of 4.2.

Table 4.3: Cost items contributing towards total cost of cardiac catheterization laboratory utilization

Cost Items	UMMC	IJN	PGH	PJHUS	QE2
Direct Medical					
Labour	878,721.52	2,530,478.96	880,833.45	778,561.21	500,037.88
Capital	2,839,335.96	3,619,363.29	614,370.96	687,789.25	782,479.78
Consumable	201,404.15	5,130,845.80	359,953.93	398,523.57	334,733.31
Total	*3,919,461.63*	*11,280,688.04*	*1,855,158.34*	*1,864,874.03*	*1,617,250.97*
Overhead					
Utility	114,473.40	109,094.76	22,559.11	49,302.66	15,417.61
Hosp.Support	109,096.89	112,959.66	34,634.59	87,785.37	70,137.06
Total	*223,570.29*	*222,054.42*	*57,193.70*	*137,088.03*	*85,554.67*
Total Cost	**4,143,031.92**	**11,502,742.46**	**1,912,352.04**	**2,001,962.06**	**1,702,805.64**

As shown in Figure 4.5, direct medical cost items constituted more than 90% of total cost of CL utilization at all 5 cardiac centres. In contrast, overhead cost items constituted to a very small percentage of the total CL utilization cost.

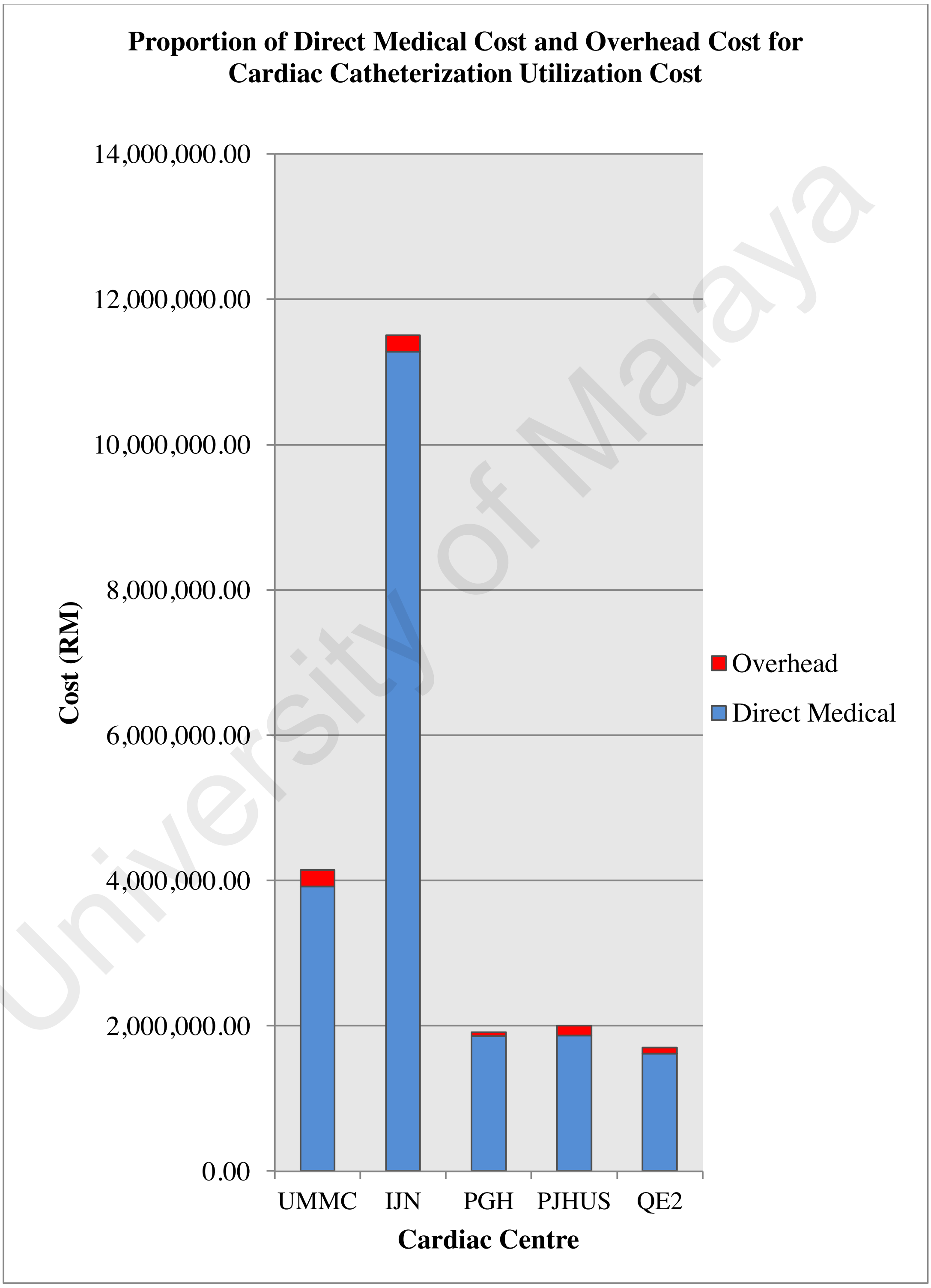

Figure 4.5: Proportion of direct medical cost and overhead cost towards cost of cardiac catheterization laboratory utilization at all centres

Under direct medical cost, capital costs accounted for the biggest proportion of cost in UMMC (72.4%). At PGH and PJHUS, it was predominantly driven by high labour cost. On the contrary, the main contributor in IJN was the cost of general consumable (44.5%). Figure 4.6 shows the contrast between the costs incurred towards the direct medical cost of CL utilization at each centre.

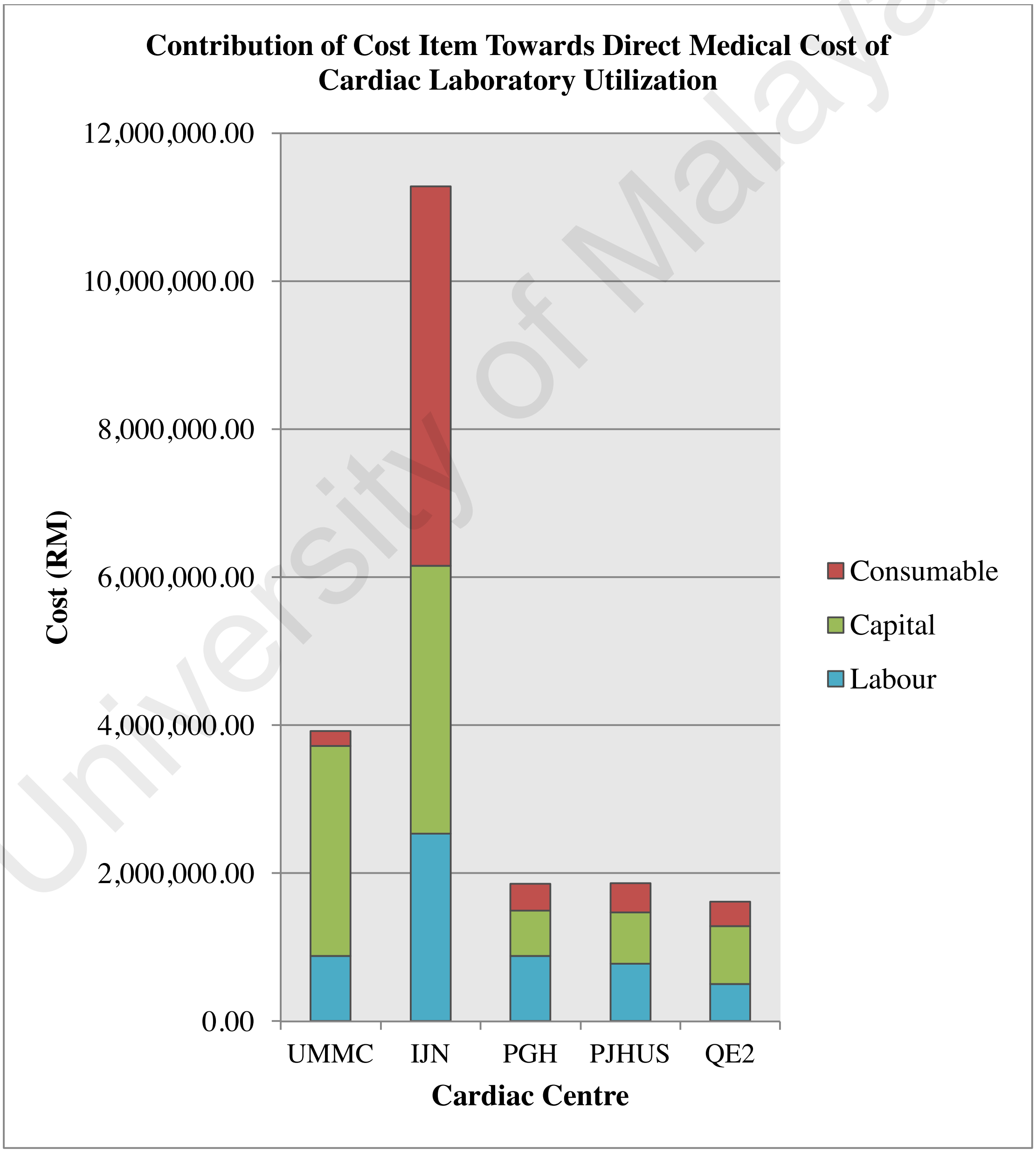

Figure 4.6: Contribution of different cost items towards the direct medical cost of cardiac laboratory utilization at all centres

For the overhead cost of CL utilization, only 2 cost items were included; hospital support service and utility costs. Hospital support accounted for a bigger proportion of cost at all the centres (Figure 4.7).

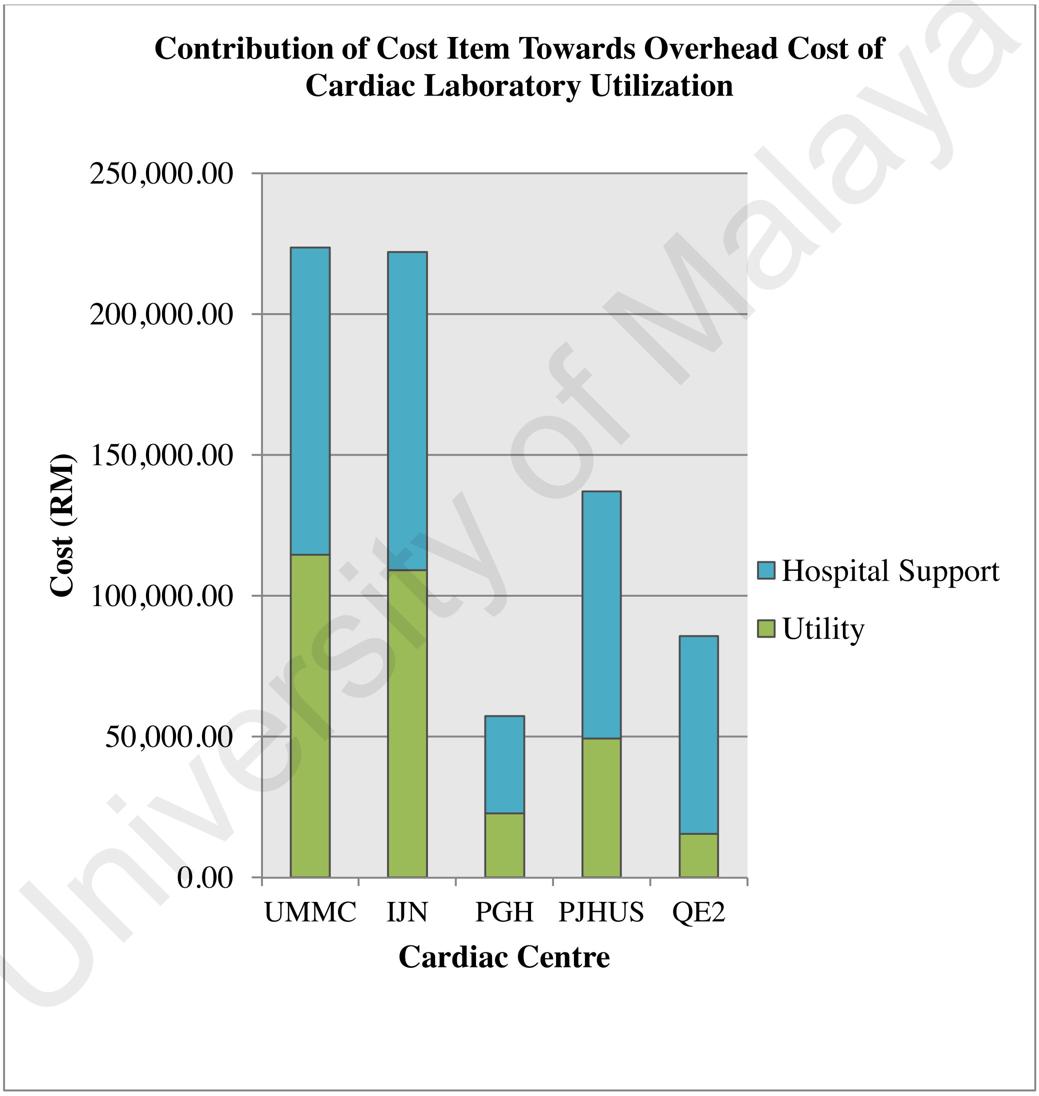

Figure 4.7: Contribution of different cost items towards the overhead cost of cardiac laboratory utilization at all centres

4.1.4 Total Cost of PCI consumable

Consumables used specifically for PCI procedures were accounted separately in this section. This was to provide a better reflection on the resource consumption and cost pattern as not all the procedures conducted in the CL utilized the same consumable items.

For the purpose of this study, we narrowed down PCI consumables to stents, catheters, guide wires, and angioplasty balloons. As stents used in PCI had a high unit cost, it was separated from the remaining three items.

From Table 4.4, IJN was shown to incur a total of RM12.7 millions towards PCI consumable. UMMC spent approximately a quarter of IJN cost (RM 4.5 million). The other 3 cardiac centres were comparable in the total costs, ranging from RM 2.2 millions in QE2 to RM 2.8 millions in PGH. All the centres spent 60-80% of the total cost of PCI consumable on stents alone, compared to only 20-40% on other PCI consumable.

Table 4.4: Cost items contributing towards total cost of PCI consumable

Cost	UMMC	IJN	PGH	PJHUS	QE2
Stents	3,634,900.00	8,137,097.50	1,905,950.00	1,664,434.50	1,528,828.50
Others	869,950.00	4,605,949.00	872,604.00	715,030.00	623,515.00
Total	**4,504,850.00**	**12,743,046.50**	**2,778,554.00**	**2,379,464.50**	**2,152,343.50**

4.2 Average Cost of Each Unit of Analysis

The result of total cost of each unit of analysis at the 5 cardiac centres was outlined in section 4.1. It provided an overview on the contribution of each item in CW and CL. However, the total cost was closely dependent on the utilization volume of each cardiac centre, be it in the CW or CL. An average cost would be a better reflection of the actual expenditure pattern between cardiac centres. The average cost discussed in this section was obtained via top-down approach, using appropriate utilization volumes at each unit of analysis. It represented an average estimate of each cost item.

4.2.1 Average Cost of Hospital General Overheads at All Centres

All hospital users shared the hospital general overhead service, whether as outpatient visit or inpatient admission. In this study, total hospital users were calculated as the sum of outpatient visits, day-care visits, and inpatient bed days. Inpatient bed day was the multiplication of total inpatient number to the average length of stay at each cardiac centre. Table 4.5 shows the tabulation of hospital users for all centres.

Table 4.5: Calculation of total hospital users (Jan-June 2014) at all centres

Type of Users	UMMC	IJN	PGH	PJHUS	QE2
Total Outpatients	561258	131488	675102	13483	39503
Total Inpatients	34414	8484	54809	2544	9340
Average hospital LOS	6.3	2.9	5.6	7.7	5.9
Total Bed Days[a]	216808	49210	308574	19567	58842
Total Day-care Visits	28849	267	34631	62640	1045
Total Hospital Users	**806915**	**180966**	**1018307**	**95690**	**99390**

[a] Total bed days=Total inpatient number*average hospital LOS

Using the total hospital users as denominator, allocated cost for the cost items under hospital general overhead were calculated in the manner reported in Section 3.9.1. By averaging out the total cost of hospital general overhead over the number of hospital users, the cost per hospital user was shown in Table 4.6.

IJN, as a corporatized centre, incurred the highest hospital overhead cost at RM 145.11. This figure was 2 to 7 times higher than the remaining centres. Despite having the third highest overall cost shown in Table 4.1, the cost of hospital overhead per user was the lowest in PGH at RM 19.89, due to the high number of hospital users recorded during the study period.

Table 4.6: Average cost of hospital general overhead per user

	UMMC	**IJN**	**PGH**	**PJHUS**	**QE2**
Total Cost	30,601,496.08	26,260,451.44	20,255,612.62	4,652,750.88	6,948,302.94
Hospital Users	806915	180966	1018307	95690	99390
Cost per User	**37.92**	**145.11**	**19.89**	**48.62**	**69.91**

4.2.2 Average Cost of Cardiac Ward Admission at All Centres

The summation of direct medical cost and overhead cost gave rise to the admission cost in CW. To obtain the average cost per bed day of admission, top-down approach was applied. Total inpatient bed days at the respective wards were used as the denominator. Table 4.7 showed the total inpatient bed days recorded at each cardiac centre during the study period.

Table 4.7: Utilization volume of cardiac ward based on inpatient bed days

	UMMC	IJN	PGH CRW	PGH C8	PJHUS CRW	PJHUS Daycare	QE2
Bed days	3129	3682	2786	11960	3892	2887	2526

The total cost of CW as tabulated in section 4.1.2 was divided with the inpatient bed days to derive the cost per CW bed day. Table 4.8 showed that cost per bed day was the lowest at PJHUS Day-care (RM 479.60) and PGH C8 (RM 570.53). On the contrary, it was the highest in UMMC (RM 906.68), almost 2 times that of the lowest cost.

Among the various cost items, the highest labour cost per bed day was recorded in QE2 (RM 492.87), followed closely by IJN (RM 362.24), and PJHUS CRW (344.46). The cardiac wards in the PJHUS and QE2 had relatively high labour cost. This might be an exogenous price-level effect due to the hardship allowance being allocated for healthcare staffs that served in East Malaysia. As for capital cost, it was extremely high in UMMC, the teaching hospital. Capital cost per bed day in UMMC was RM 122.18, twice as much as IJN, the centre with the second highest capital cost.

The wide disparity of several cost items between CRW and C8 of PGH can be attributed to the application of top-down approach. The unit cost is highly dependent on the activity output, which in this case, was the total bed days. CRW has a fixed number of beds available. C8, on the other hand, often has 'makeshift' extra beds to cope with the high patient load, resulting in high number of total bed days. While this may appear to lead to low unit cost, it does not accurately reflect the acceptable quality of care and level of patient comfort.

As for overhead cost, PGH and QE2 incurred the two lowest cost per bed day. By comparison, the overhead costs at the other centres ranged from RM 151.74 in IJN to RM 264.23 in PGH CRW. Dietary services are provided via different means at the study centres. Some centres utilized in-house dietary centre/kitchen whereas others outsource the patient meal preparation to external catering services, thus the disparity in cost.

Table 4.8: Average cost of various cost items for cardiac ward admission

Cost Items	UMMC	IJN	PGH CRW	PGH C8	PJHUS CRW	PJHUS Day-care	QE2
Direct Medical							
Labour	212.87	362.24	313.76	90.26	344.46	119.74	492.87
Capital	122.18	60.57	34.02	2.31	49.79	86.63	34.13
Consumable	37.08	17.27	77.07	77.07	16.53	16.53	7.86
Medication	337.47	3.45	103.10	103.10	143.52	21.54	227.73
Total	709.60	443.53	527.95	272.74	554.30	244.44	762.59
Overhead							
Utility	27.85	41.89	34.92	0.92	32.10	21.64	4.59
Dietary	8.33	32.25	34.15	34.15	15.00	15.00	10.40
Hospital Support	26.54	43.37	12.70	1.62	57.16	38.53	20.90
Ancillary support	134.36	34.23	38.16	38.16	159.97	159.97	31.70
Total	197.08	151.74	119.93	123.51	264.23	235.16	67.59
Cost per Bed Day	**906.68**	**595.27**	**647.88**	**570.53**	**818.53**	**479.60**	**830.18**

To obtain the admission cost per PCI patient, average LOS of 3 days was assumed at all centres. This was based on the general consensus of the consultant cardiologists. As there are 2 possible wards for PCI patients in PGH and PJHUS, weighted cost of admission was calculated using the ratio of patients admitted to the respective wards. This was done to facilitate the comparison of average admission cost with other centres. Table 4.9 outlined the results.

Based on an average LOS of 3 days, the average admission cost of a 3-day hospitalization was the highest in UMMC (RM 2,720.04), followed closely by QE2 at RM 2,490.54. By comparing the two avenues of admission at PJHUS, it was shown that the cost of admission was approximately 5 times higher for an inpatient admission if compared to day-care admission.

Apart from the PJHUS Day-care, the lowest cost of CW admission over 3 days was recorded at PGH C8. There was no stark difference in the cost of admission for the 2 wards in PGH. The cost of admission for elective PCI patient averaged out to be RM 1895.35 for a 3-day admission in PGH.

Table 4.9: Average cost of cardiac ward admission at all centres

Average Cost	UMMC	IJN	PGH CRW	PGH C8	PJHUS CRW	PJHUS Day-care	QE2
Cost per bed day	906.68	595.27	647.88	570.53	818.53	479.60	830.18
Average CW admission cost	2,720.04	1,785.81	1,943.64	1711.59	2,455.59	NA	2,490.54
Weighted CW Admission Cost	NA	NA	1895.35		1685.09		NA

Note. NA-Not Applicable

4.2.3 Average Cost of Cardiac Catheterization Laboratory Utilization at All Centre

Besides PCI, procedures conducted in CL included pacemaker insertion, implantable cardiac defibrillator insertion, peripheral vessel angiography and stenting. All these procedures share the resources in the CL and thus must be taken into account as the denominator for CL utilization cost. In table 4.3, the number of CL procedures and PCI procedures conducted during the study period were shown.

As previously mentioned in Section 3.9.4-3.9.5, the summation of direct medical cost and overhead cost items gave rise to the total cost of CL utilization. The cost was then divided by the utilization volume of the CL, i.e. the total procedures conducted in CL, to produce the cost per CL utilization.

As shown in Table 4.10, IJN recorded the highest CL utilization volume, approximately at 2-3 times compared to the remaining centres. More than half of the procedures conducted in IJN and UMMC were PCI. As for the other centres, PCI procedures represented only a quarter or less of the procedures conducted in CL. The proportion ranged from as low as 19.0% in PJHUS to 26.7% in QE2.

Table 4.10: User volume of cardiac catheterization laboratory based on number of procedures conducted

Number of Procedure	UMMC	IJN	PGH	PJHUS	QE2
All CL Procedure	1084	2709	1118	1485	940
PCI only	580	1558	257	282	251
Percentage of PCI over all procedures	53.5%	57.5%	23.0%	19.0%	26.7%

Table 4.11 showed the average cost of each cost item that contributed towards the cost of CL utilization. A closer examination showed that IJN and UMMC had the two highest costs. In IJN, the main contributors were the consumable cost (RM 1,894.35) and capital cost (RM 1,336.30). Consumable cost per CL utilization in IJN was 5.3 to 10.2 times higher when compared to the other centres.

UMMC recorded the second highest cost of CL utilization. At UMMC, the main cost items driving up the cost of CL utilization was capital cost. The results of capital cost revealed stark contrast between teaching hospital (UMMC) and the remaining centres. In UMMC, capital cost per CL utilization was RM 2,619.31, which was 68.5% of the total cost per CL utilization. UMMC capital cost was almost twice that of IJN, and about 6 times higher than the lower cost in PJHUS, partially attributed to underutilization of the CL in UMMC due to staffing issue during study period.

The average costs of CL utilization in PGH, QE2, and PJHUS were in the range of RM 1,300 to RM 1,800, with almost similar proportion spent on capital and consumables for all the 3 centres. Labour cost appeared to be higher in PGH than the two East Malaysian centres.

In contrast to direct medical cost, overhead cost per CL utilization constituted to less than 10% of the total cost for all centres. UMMC also recorded the highest overheads cost at RM 206.25 per utilization. This was approximately 2.2 to 4.0 times higher than the other centres. The overhead cost was the lowest in PGH, at only RM 51.16 per utilization.

Table 4.11: Average cost of cardiac catheterization laboratory utilization at all centres

Cost Items	UMMC	IJN	PGH	PJHUS	QE2
Direct Medical					
Labour	810.63	934.27	787.87	524.28	531.96
Capital	2,619.31	1,336.30	549.53	463.16	832.43
Consumable	185.80	1,894.35	321.96	268.37	356.10
Total	3,615.74	4,164.92	1,659.35	1,255.81	1,720.48
Overhead					
Utility	105.60	40.28	20.18	33.20	16.40
Hospital support	100.64	41.71	30.98	59.11	74.61
Total	206.25	81.98	51.16	92.32	91.02
Cost per CL utilization	**3,821.99**	**4,246.91**	**1,710.51**	**1,348.12**	**1,811.50**

4.2.4 Average Cost of PCI consumable at All Centres

As aforementioned, consumable items used specifically for PCI procedures were categorized separately from general consumable. These items were not shared by all the procedures in the CL, thus the output units used to derive the unit cost would be different.

This group of PCI consumables included stents, guide wires, balloons, and catheters. The cost of stents was tabulated separately from the other PCI consumable due to its high unit cost. As these items were only consumed during PCI procedures, the total output used was number of PCI procedures as shown in Table 4.10. This resulted in the average cost of PCI consumable per procedure.

As there was no central purchasing agency of PCI consumable in the country, the unit costs of PCI consumables were not standard across all centres. Even for the same PCI consumable item from the same manufacturing company, there might be some disparity in the purchasing price at each centre. Table 4.12 showed the average costs of stents, other consumables and all PCI consumable per PCI procedure. For the purpose of this part of cost analysis, no differentiation between the 4 major groups of stents, namely DES, BMS, BVS, and DEB, was made when calculating the average cost of the cardiac stents.

The average cost of PCI consumable was cheapest at UMMC (RM 7,766.98) and most expensive in PGH (10,811.48). The costs at the remaining centres were almost similar in the range of RM 8,179 to RM 8,575. After separating the cost of stents from the other PCI consumable, as high as 63.8% to 80.7% of the total cost could be attributed to the cost of stents alone. The proportion was the highest in UMMC.

Table 4.12: Average cost of PCI consumable at all centres

Average Cost	UMMC	IJN	PGH	PJHUS	QE2
Stents	6,267.07	5,222.78	7,416.15	5,902.25	6,090.95
Others	1,499.91	2,956.32	3,395.35	2,535.57	2,484.12
Total	7,766.98	8,179.11	10,811.49	8,437.82	8,575.07

4.3 Total Hospitalization Cost

The next step towards the calculation of the hospitalization cost for an average PCI patient involved the summation of the cost of hospital overhead per user, average cost per CW admission, cost per CL utilization, and cost of PCI consumable per procedure. This cost represented the cost estimates for the average patient who underwent an elective PCI procedure at the respective cardiac centre.

4.3.1 Average PCI Hospitalization Cost at All Centres

By adding up the unit cost of each unit of analysis, the average cost of hospitalization at each centre was tabulated in Table 4.1 and Figure 4.8. The cost ranged from RM 11,519.65 in PJHUS to RM 14,356.93 in IJN. The cost at UMMC (RM 14,346.93) ranked the second highest, closely behind IJN.

The 2 cardiac centres in East Malaysia had relatively lower average hospitalization cost than the 3 centres in West Malaysia. PJHUS, the only centre with a day-care service for PCI patients, appeared as the centres with the lowest hospital cost for PCI patients. By comparison, hospitalization cost for an average patient admitted for elective PCI was approximately 20% higher at UMMC, PGH and IJN compared to PJHUS, the cheapest centre.

Table 4.13: Average hospitalization cost of Elective PCI at all centres

Average Cost	**UMMC**		**IJN**		**PGH**		**PJHUS**		**QE2**	
Hospital Overheads	37.92	0.3%	145.11	1.0%	19.89	0.1%	48.62	0.4%	69.91	0.5%
CW Admission	2,720.04	19.0%	1,785.81	12.4%	1,895.35	10.0%	1,685.09	14.6%	2,490.54	19.2%
CL utilization	3,821.99	26.6%	4,246.91	29.6%	1,710.51	12.3%	1,348.12	11.7%	1,811.50	14.0%
PCI consumable	7,766.98	54.1%	8,179.11	57.0%	10,811.49	77.6%	8,437.82	73.2%	8,575.07	66.2%
Total Hospitalization	**14,346.93**	100.0%	**14,356.93**	100.0%	**13,937.25**	100.0%	**11,519.65**	100.0%	**12,947.02**	100.0%

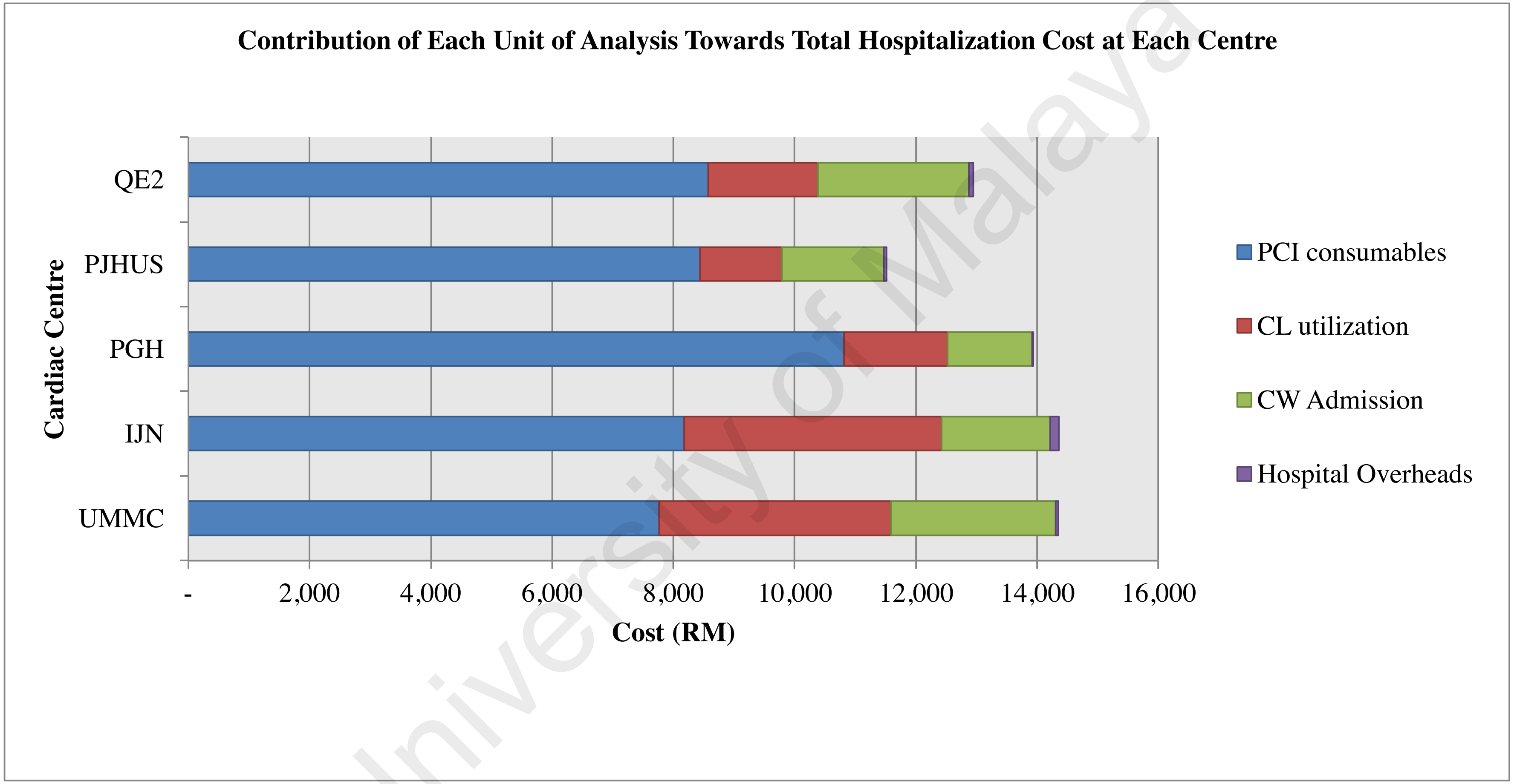

Figure 4.8: Percentage breakdown of units of analysis towards average hospitalization cost by centre

4.3.2 Dominant Cost Drivers for Average Hospitalization Cost

In Figure 4.8, the results of average hospitalization cost for all cardiac centres were summarized in a bar chart to better reflect the contribution of each unit of analysis.

Among all, PCI consumable incurred the highest cost at all centres. It accounted for more than half of the total costs at all the cardiac centres. The proportion was the highest in PGH, accounting for 77.6% of the total costs.

For the 3 cardiac centres in Peninsular Malaysia, the second biggest proportion of hospitalization cost can be attributed to CL utilization. It accounted for 29.6% of the total cost in IJN, 26.6% in UMMC, and 12.3% in PGH.

As for the 2 centres in East Malaysia, the proportion contributed by cardiac ward admission was larger than CL utilization. About one fifth of the hospitalization cost in QE2 was admission cost, and 14.6% in PJHUS. For all the centres, the hospital general overhead costs represented only a minimal proportion (1.0% and less) of the hospitalization cost.

4.4 Summary

In this chapter, the total cost of each cost item under different units of analysis was first outlined. Top-down approach was used to derive the average cost of each cost item. They were then added up to produce the average hospitalization cost. Similar steps were conducted for all 5 cardiac centres and comparison was made. Dominant cost drivers were identified and reported at the final section of this chapter.

CHAPTER 5: ANALYSIS OF INDIVIDUAL PATIENT-LEVEL DATA

In Chapter 4, the results presented focused on average cost of the respective centres to delineate the variation between different centres. Apart from hospital factors, cost variation can also be influenced by heterogeneity in patient and treatment characteristics.

As previously explained, the average cost by centres was insufficient to conduct further statistical analysis to determine the heterogeneity between individual patients. Therefore, bottom-up costing approach was applied on selected cost items in order to derive the individual patient hospitalization cost.

The first section of this chapter reported the baseline demographic, clinical and procedural characteristics of all the patients who underwent elective PCI during the study period using data extracted from the NCVD-PCI Registry. This was followed by the result of the individual-level patient cost data, calculated and compiled under each unit of analysis. Further analysis was conducted to identify the similarities and differences in the practice of PCI among the 5 cardiac centres.

The individual patient-level hospitalization data was also used to compare between patients of long and short hospital stay. Logistic regression analysis was conducted to determine the significant predictors of long hospital stay. Lastly, linear regression analysis was used to identify the significant predictors of hospitalization cost for elective PCI patients.

5.1 Descriptive Analysis of Patient Characteristics

During the study period of January 1st 2014 to June 30th 2014, a total of 2260 patients underwent elective PCI in the 5 cardiac centres. More than half of the procedures (56.9%) were conducted in IJN, followed by another 16.6% in UMMC. The other 3 public cardiac centres, namely PJHUS, QE2, and PGH, accounted for approximately one quarter (26.5%) of all the elective PCI procedures conducted.

5.1.1 Demographic and Clinical Characteristics of All Patients

Table 5.1 outlined the demographic and treatment characteristics of all patients in the study. The mean age of the 2260 patients undergoing elective PCI was 58.7 years (standard deviation of 10.3), with a slight majority of patients aged above 60 years old (54.6%). Every 4 out of 5 patients were male. The distribution of the patients by ethnicity was as follows: 47.3% Malays, 20.6% Chinese, 22.4% Indians, and 9.6% of other ethnicities (representing other indigenous groups including Punjabi, Iban, Melanau, Kadazan etc. and non-Malaysian nationals).

The prevalence of coronary artery disease (CAD) risk factors was high among the patients. Majority had more than two of the following risk factors: hypertension, diabetes mellitus (DM), dyslipidemia, obesity and history of smoking. More than half of the patients were overweight (65.6%) with body mass index (BMI) of more than $25kg/m^2$. A high number of patients had previously smoked or were active smokers (65.8%). As high as 71.0% of patients were hypertensive and 68.4% had dyslipidaemia. Slightly less than half of the patients were diabetic (46.9%). Approximately 1 in every 5 patients (22.5%) had family history of cardiovascular disease (CVD).

Among the 2260 patients, about half of the patients (45.6%) had documented CAD, whereby they were diagnosed with >50% of stenosis via angiographic or imaging evidence. However, only less than one-fifth (19.7%) of patients suffered from new onset of angina within 2 weeks of admission to the cardiac centres. A high percentage of patients (38.7%) had previously experienced a myocardial infarction. Out of these patients, 27.0% had undergone previous PCI, and only 3.4% had previous CABG. Only a mere 4% of the patients suffered from congestive heart failure, a common complication of poorly treated and chronic CAD.

On presentation, symptom severity of CAD can be categorized based on New York Heart Association Classification (NYHA) or Canadian Cardiovascular Score (CCS). Majority of the patients (62.8%) were of NYHA Class I, i.e. the lowest level of symptom severity. Similarly, more than half of the patients (54.5%) were recorded to be either asymptomatic or CCS 1 on admission. On the contrary, patients on the higher end of symptom severity were a minority; only 10.5% of patients were of NYHA III-IV and 16.9% were of CCS 3 or 4.

The distribution of symptom severity can be seen as correlated with the diagnosis of acute coronary syndrome (ACS). As mentioned previously, unlike stable angina, ACS represents the more severe end of the spectrum of coronary artery blockage. It encompasses the potentially fatal manifestations of unstable angina, non-ST segment elevation myocardial infarction (NSTEMI) and ST segment elevation myocardial infarction (STEMI). Among all the patients who underwent elective PCI, only 18.3% were diagnosed as having ACS. It was likely that a higher percentage of ACS would be detected among patients who underwent emergency PCI, in view of the disease severity and critical requirement of immediate intervention.

Table 5.1: Demographic and clinical characteristics of all patients

All Patients (n=2260)	Number	%	Mean	S.D.
Hospital				
UMMC	375	16.6		
IJN	1286	56.9		
PGH	183	8.1		
PJHUS	240	10.6		
QE2	176	7.8		
Demographic				
Age, mean $\pm$ SD, years			58.7	10.3
Age $\geq$ 60	1234	54.6		
Male gender	1846	81.7		
Ethnicity				
Malay	1070	47.3		
Chinese	465	20.6		
India	507	22.4		
Others	218	9.6		
Risk Factors				
History of smoking	1487	65.8		
Dyslipidaemia	1483	68.4		
Hypertension	1552	71.0		
Diabetes mellitus	1011	46.9		
Obesity	1482	65.6		
Family history of premature CVD	487	22.5		
Cerebrovascular disease	46	2.1		
Peripheral vascular disease	13	0.6		
Chronic renal failure	103	4.7		
Cardiac history				
Documented coronary artery disease	991	45.6		
New onset angina in 2 weeks	435	19.7		
Previous heart failure	87	4.0		
Previous myocardial infarction	832	38.7		
Previous PCI	610	27.0		
Previous CABG	76	3.4		
Cardiac Status at Presentation				
NYHA I	1356	62.8		
NYHA II	576	26.7		
NYHA III	204	9.4		
NYHA IV	24	1.1		
CCS- Asymptomatic	277	12.3		
CCS 1	947	42.2		
CCS 2	639	28.5		
CCS 3	324	14.4		
CCS 4	56	2.5		
Acute coronary syndrome	413	18.3		

Note. Risk factors, NYHA, CCS have missing data (<5%). The percentages were determined from the available data.

5.1.2 Treatment Characteristics of All Patients

This section reported on the procedural details and lesion characteristics of all the patients who underwent elective PCI at the cardiac centres (Table 5.2). Percutaneous entry that provides access for the catheters and stents can be done via the femoral, radial and brachial approach. A small number of patients may have more than one vascular access. No brachial access was used among the patients. Between radial and femoral access, the radial approach was the more popular access in our patient population.

Coronary vessels with more than 50% stenosis seen on angiography at the beginning of the PCI procedure would be categorized as diseased vessel. Patients with more than one diseased vessel are labelled as multi-vessel disease. Of the total 2260 patients, 36.1% or 815 patients had multi-vessel disease (MVD). Among the 4 major coronary vessels, the left anterior descending (LAD) artery was the most commonly affected, accounting for almost two-thirds (66.9%) of all the diseased vessels. This was followed by right coronary artery (RCA, 45.7%) and left circumflex artery (LCA, 34.6%).

The atheromatous plaque that led to the stenosis of the major coronary arteries may be the accumulation of several lesions within the same artery. Half of the patients (50.4%) had only a single lesion treated during the PCI procedure; another 36% of patients had 2 lesions treated. The number of patients treated dwindled with the increasing number of lesions treated. Among all the patients, the total number of lesions treated was 3861, giving rise to an average lesion treated per patient of 1.71 lesions.

These treated lesions can be described in several manners with relation to their underlying nature. Calcification and thrombus in lesion are often associated with poorer outcomes. However, only a small percentage of patients were found to have calcified lesion (7.7%) and thrombus in lesion (2.8%) in the study population.

ACC/AHA lesion classification is commonly used to denote the type and severity of the lesion in CAD. This classification has often been used as predictor for angiographic success. Based on this classification system, coronary lesions can be categorized into type A, B1, B2, and C, the latter two being complex lesions. Type C is considered the most complicated type of lesion and associated with high risk of failure. In this study, a high proportion of patients were found to have complex lesions (66.5%), while only 6.2% had type A and 27.3% had type B1 lesions.

The number of stents inserted in a patient ranged from 1 to 7, giving an average of 1.50 stents inserted per patient. As high as 84.1% of the stents inserted were drug-eluting stents (DES). The remaining 15.9% of stents usage included 6.0% of bare metal stents (BMS), 8.3% of drug-eluting balloons (DEB) and 1.3% of bio-absorbable stents such as bio-absorbable scaffolds (BVS). Usage of BVS remained low due to its exorbitant cost. A small percentage of patients (6.2%) underwent PCI without any stent insertion, in a process known as plain old balloon angioplasty (POBA), whereby the balloon catheter was used to compress the atheromatous plaque in the diseased vessel.

The mean length of stay (LOS) was found to be 7.6 days, with a standard deviation of 9.3 days. However, it was better represented with the median value, as the distribution of LOS was skewed. The median LOS was 3 days with an interquartile range of 2-11 days. More than half of the patient (55.6%) was discharged within 3 days.

TIMI (Thrombolysis in Myocardial Infarction) classification was used to assess coronary artery perfusion based on angiographic grade flow after PCI. The score ranks from TIMI-0 as no perfusion to TIMI-3 as complete perfusion. Successful reperfusion after thrombolysis was taken as either TIMI-2 (partial flow) or TIMI-3 (complete flow) post-PCI. There was higher number of lesions with TIMI-2 and TIMI-3 post-PCI compared to TIMI-0 and TIMI-1 in all the centres. Almost all of the lesions treated (96.4%) achieved TIMI-3 flow after PCI.

Successful revascularization was recorded in 96.9% of patients. On the contrary, complication rates were very low. There were only 10 mortalities (0.4%) among the 2260 patients who underwent elective PCI procedures during the study period. Procedural complications such as significant periprocedural MI and the need for emergency reintervention were similarly low, at 0.4% and 0.1% respectively. Another 22 patients (1.0%) were recorded to have suffered from other complications such as arrhythmia, cardiogenic shock, worsening renal impairment, and pseudoaneurysm.

Table 5.2: Treatment characteristics of all patients

All Patients (n=2260)	Number	%	Mean	S.D.
*Percutaneous Entry**				
Femoral	1066	47.2		
Radial	1335	59.1		
*Diseased Vessel**				
Left Anterior Descending	1512	66.9		
Left Circumflex	783	34.6		
Right Coronary	1033	45.7		
Left Main Stem	109	4.8		
Number of Vessels				
Single vessel disease	1445	63.9		
Multi-vessel disease	815	36.1		
*Number of Lesions Treated**				
1	1138	50.4		
2	814	36.0		
3	195	8.6		
4	75	3.3		
5	23	1.0		
6	10	0.4		
7	5	0.2		
Lesions treated per patient, mean ± SD			1.71	0.9
Lesion description				
Ostial	189	8.4		
Total occlusion	128	5.7		
Chronic total occlusion	189	8.4		
Thrombus in lesion	63	2.8		
Bifurcation	160	7.1		
Calcified lesion	173	7.7		
Worst Lesion type				
A	140	6.2		
B1	617	27.3		
B2	276	12.2		
C	1227	54.3		

Table 5.2, continued

All Patients (n=2260)	**Number**	**%**	**Mean**	**S.D.**
*Number of Stents Inserted**				
0	141	6.2		
1	1237	54.7		
2	601	26.6		
3	207	9.2		
4	49	2.2		
5	17	0.8		
6	5	0.2		
7	3	0.1		
Stents placed per patient, mean $\pm$ SD			1.50	0.9
DES placed per patient, mean $\pm$ SD			1.26	1.0
BMS placed per patient, mean $\pm$ SD			0.09	0.3
BVS placed per patient, mean $\pm$ SD			0.02	0.2
DEB placed per patient, mean $\pm$ SD			0.13	0.4
Hospitalization Period				
Length of Stay, mean +/- SD, days			7.62	9.3
Length of Stay, median, IQR, days			3.0	2 to 11
Length of Stay $\leq$ 3 days	1257	55.6		
Outcomes				
TIMI flow post-PCI				
TIMI-0	48	2.1		
TIMI-1	7	0.3		
TIMI-2	26	1.2		
TIMI-3	2179	96.4		
Successful revascularization	2189	96.9		
In-hospital Mortality	10	0.4		
Significant periprocedural MI	9	0.4		
Emergency reintervention	2	0.1		
Other complications	22	1.0		

Note. *Some patients may have more than one percutaneous entry, diseased vessel and/or stent inserted. Percentage breakdown was based on total number of the variable occurrence.

5.2 Individual Patient-level Hospitalization Cost

As stated in Section 3.11, bottom-up costing approach provides a more accurate estimate of each cost item. However, in view of time and resource constraint, only cost items deemed likely to create a large impact on the total cost were calculated using bottom-up approach in this study. For this purpose, we applied actual LOS and the actual number and cost of cardiac stents used in the PCI procedures. This resulted in individual patient cost of cardiac ward admission and PCI consumable cost.

As for the remaining cost items, the same value as calculated with top-down approach was maintained. By incorporating these new individual patient-level cost data, the total hospitalization cost of each individual patient was derived. As with most of the cost data, the distribution of cost output in this section was positively skewed. Both mean and median values were reported in the results. The boxplots showing the distribution of all the cost output in this chapter can be referred to in APPENDIX F.

5.2.1 Individual Patient-level Cardiac Ward Admission Cost

A major determinant of the hospitalization cost is the LOS of each individual patient. Descriptive analysis in Section 5.1 showed a wide range of hospitalization period between the patients. Therefore, actual LOS of individual patient extracted from the NCVD-PCI Registry and used to determine the cost of cardiac ward (CW) admission of each patient.

By incorporating the admission cost per bed day obtained in Section 4.2.2 with the individual LOS recorded in the NCVD-PCI Registry, the admission cost of individual PCI patients was calculated. Overall, the mean cost for all the patients in the study was

RM 4,969.83 with a standard deviation of RM 6,205.39 (Table 5.3). The median cost was much lower than the mean cost of admission, at RM 1,813.36. This showed that the distribution was skewed, as there were fewer patients who incurred particularly high costs for CW admission.

5.2.2 Individual Patient-level PCI consumable Cost

Stent costs have been proven to be a major cost driver in PCI procedural cost in any literature. Furthermore, in view of the different types and number of stents inserted in a patient, stent costs would make significant impact on the total costs when different costing approaches were applied. In this section, bottom-up approach was applied on cardiac stents. The actual type and number of stents inserted in each patient was obtained from NCVD-PCI Registry. It was then incorporated with the unit cost of each stent to obtain the stent cost of each individual PCI patient to derive the cost of PCI consumable.

Table 5.3 showed the overall mean cost of PCI consumable for all patients was RM 8,455.56 with a standard deviation of RM 3,745.36. The overall median cost was RM 7,484.12.

5.2.3 Total Hospitalization Cost of Individual Patients

Mixed method was applied to obtain the total hospitalization cost of each individual PCI patient. The same value of the unit cost for hospital general overhead per user and cost per cardiac catheterization laboratory (CL) utilization calculated with top-down approach were retained. They were incorporated with the CW admission cost and PCI consumable costs of individual PCI patients obtained with bottom-up approach to derive the final hospitalization cost of each patient.

Table 5.3 tabulated the results for the cost items calculated based on the mixed method approach. Total hospitalization cost for each individual patient was obtained by adding up all the cost items. From this study, the mean cost of hospitalization for all the elective PCI patients was RM 16,999.99 with a standard deviation of RM 7,337.36. Due to the positively skewed cost data, the overall median cost was slightly lower than the overall mean cost at RM 15,106.30.

Table 5.3: Mean and median costs of individual patient-level hospitalization cost

Cost	**Patients (*n*=2260)**	
Cardiac Ward Admission		
Mean (SD)	4,969.83	(6,205.39)
Median (IQR)	1,813.36	(1,190.54-7,143.24)
PCI consumable		
Mean (SD)	8,455.56	(3,745.36)
Median (IQR)	7,484.12	(6,185.33-9,414.34)
PCI Procedure in Cardiac Catheterization Laboratory		
Mean (SD)	14,597.84	(3,893.84)
Median (IQR)	13,385.56	(12,621.81-16,617.57)
Total Hospitalization		
Mean (SD)	16,999.99	(7,337.36)
Median (IQR)	15,106.30	(11,767.89-20,230.51)

5.3 Comparison between Different Cardiac Centres

As this study involved patients who underwent elective PCI at 5 cardiac centres, analysis was conducted to identify the differences in terms of patients, treatment, and cost characteristics at the 5 centres. Comparison results between the PCI patients at the 5 cardiac centres were presented with tables and figures as appropriate.

For this study, only patients with elective PCI status in the NCVD-PCI Registry from the 5 cardiac centres were included in the analysis. This was to ensure a relatively homogeneous patient population as a better paradigm to reflect the cost and resource consumption at the participating cardiac centres.

5.3.1 Comparison of Patient Characteristics between Cardiac Centres

Based on the NCVD-PCI Registry, the two national-level tertiary referral centre; IJN and UMMC, recorded the highest number of patients undergoing elective PCI during the study period. More than half of the total patients were treated at IJN. The remaining 3 centres were the referral centres for the regions they were located in. The number of patients who underwent elective PCI was 240 in PJHUS, 183 in PGH, and 176 in QE2. Their patient numbers were approximately 5 to 7 times lower compared to IJN.

Table 5.4 shows the comparison results of patient characteristics between the 5 cardiac centres. Using ANOVA, there was significant difference between the mean ages of patients at the 5 centres (*p-value* <0.05). Patients in UMMC were significantly older with a mean age of 60.1 years. Post hoc test using Tukey method showed that the difference in the mean age was significant between patients at UMMC and QE2. However, further categorization of patients' age revealed no significant differences in the proportion of patients above and below 60 years at the 5 centres. As for gender distribution, no significant difference was detected between the 5 centres. Majority of the patients were male at all 5 centres. The ratio between male and female patients was approximately 4 to 1.

There was significant difference in the ethnicity distribution of the patients between the 5 centres (*p-value* <0.001). For the 3 centres in Peninsular Malaysia, namely UMMC, PGH and IJN, Malay patients were the predominant ethnicity. In QE2, the majority of the patients (64.2%) were of the 'Others' ethnicity.

With regards to the risk factors of CAD, chi-square tests showed significant differences in the prevalence of comorbidities between patients at the different cardiac centres. However, it was a common finding across all centres that the 3 main risk factors, namely hypertension, dyslipidaemia and obesity, were present in more than half of the patients. Among all the centres, IJN had the highest proportion of patients who smoked (71.0%). There was also significant difference in the proportion of patients with diabetes, hypertension, dyslipidaemia between the centres, with PGH recording the highest proportion among the centres. Every 4 out of 5 patients in PGH had dyslipidaemia and hypertension, and half of the patients there were diabetic.

In general, the prevalence of heart failure, renal failure, cerebrovascular diseases, and peripheral vascular diseases were low among all the patients, with no significant difference between the centres. The percentages of patients with these comorbidities were only 3.0% or lower in PGH, QE2, and PJHUS. It was slightly higher in the bigger centres, whereby IJN and UMMC recorded 5.7% and 5.2% of patients with renal failure respectively.

On admission, a high number of patients had documented CAD. Among all the centres, the proportion was significantly higher especially in PGH (59.7%) and UMMC (52.1%). As for history of previous myocardial infarction (MI), the number was highest at QE2 (48.2%), followed by PGH and PJHUS. Despite so, when examining the previous interventions conducted among the patients, the proportion of patients who had previous intervention for CAD was rather low at these 3 centres. These patients might have been treated with pharmacological fibrinolysis during their previous MI.

When examining the numbers of previous PCI and CABG, significant difference was detected between the centres (*p-value* <0.001). Generally, the number of patients who underwent CABG was low across all 5 centres. By comparison, PCI was a commoner intervention than CABG among the patients. UMMC had the highest proportion of patients who underwent previous PCI before current admission (41.6%), whereas the remaining centres recorded only 20.4% to 25.7% patients with previous PCI (*p-value* <0.001). PJHUS had the lowest number of patients with previous CABG and PCI among all the centres. Only 20.4% and 1.2% of the PJHUS patients had previous PCI and CABG.

On admission for elective PCI procedure, the proportion of patients with recent onset of angina in the past 2 weeks were significantly different between the centres, ranging from 14.9% in PGH to as high as 26.7% in QE2 ($p<0.05$). This finding in QE2 correlated with the symptom severity measured on NYHA and CCS. QE2 had the highest proportion patients with of CCS 3-4 patients (22.8%) and ACS (32.4%). In contrast, as high as 85.3% of PJHUS patients were in NYHA Class I, and more than half the patients (67.4%) were asymptomatic by the definition of CCS. It also recorded the lowest prevalence of ACS (13.8%) among all the centres.

Table 5.4: Comparison of patient demographic and clinical characteristics between centres

	UMMC (*n*=375)		**IJN (*n*=1286)**		**PGH (*n*=183)**		**PJHUS (*n*=240)**		**QE2 (*n*=176)**		
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*p-value*
Age, mean ± SD, years	60.10±10.10		58.60±10.30		59.50±10.20		58.20±10.60		56.60±10.70		**0.005**
Age ≥ 60	183	48.8	716	55.7	95	51.9	135	56.2	105	59.7	0.08
Male gender	272	72.5	1056	82.1	155	84.7	208	86.7	155	88.1	0.11
Ethnicity											**<0.001**
Malay	148	39.5	766	59.6	72	39.3	70	29.2	14	8.0	
Chinese	91	24.3	173	13.5	58	31.7	97	40.4	46	26.1	
India	133	35.3	317	24.7	51	27.9	3	1.2	3	1.7	
Others	3	0.8	30	2.3	2	1.1	70	29.2	113	64.2	
Risk Factors											
History of smoking	211	56.3	913	71.0	115	62.8	140	58.3	108	61.4	**<0.001**
Dyslipidaemia	251	71.1	814	65.2	142	81.6	163	72.1	113	68.5	**<0.001**
Hypertension	269	74.7	868	69.2	142	80.7	164	71.6	109	65.7	**0.005**
Diabetes mellitus	183	54.0	600	48.0	95	54.6	73	32.0	60	36.1	**<0.001**
Obesity	243	64.8	861	67.0	113	61.7	143	59.6	122	69.3	0.12
Family history of CVD	130	36.1	186	15.0	62	36.7	65	28.9	44	26.2	**<0.001**
Cerebrovascular disease	10	2.7	28	2.2	4	2.3	2	0.9	2	1.2	0.54
Peripheral vascular	1	0.3	9	0.7	1	0.6	1	0.4	1	0.6	0.90
Chronic renal failure	21	5.7	65	5.2	4	2.2	7	3.1	6	3.6	0.22

Table 5.4, continued

	UMMC (*n*=375)		**IJN (*n*=1286)**		**PGH(*n*=183)**		**PJHUS(*n*=240)**		**QE2 (*n*=176)**		
	n	%	n	%	n	%	n	%	n	%	*p-value*
Cardiac history											
Documented CAD	185	52.1	551	44.0	105	59.7	78	35.0	72	43.6	**<0.001**
Recent onset angina	89	25.1	231	18.3	27	14.9	42	17.7	46	26.7	**0.002**
Previous heart failure	8	2.2	52	4.1	5	2.8	19	8.4	3	1.8	**0.002**
Previous MI	119	33.2	473	37.7	70	42.9	91	42.9	79	48.2	**0.007**
Previous PCI	156	41.6	318	24.7	47	25.7	48	20.4	40	22.7	**<0.001**
Previous CABG	8	2.1	57	4.4	3	1.6	3	1.2	5	2.8	**0.02**
Cardiac Status at Presentation											
NYHA											**<0.001**
I	276	75.0	620	51.6	137	75.3	203	85.3	120	70.2	
II	74	20.1	410	34.1	34	18.7	26	10.9	32	18.7	
III	15	4.1	157	13.1	7	3.8	8	3.4	17	9.9	
IV	3	0.8	14	1.2	4	2.2	1	0.4	2	1.2	
CCS											**<0.001**
Asymptomatic	52	14.0	100	7.8	29	16.0	65	27.2	31	17.7	
CCS 1	105	28.2	638	50.0	47	26.0	96	40.2	61	34.9	
CCS 2	179	48.1	294	23.0	75	41.4	48	20.1	43	24.6	
CCS 3	33	8.9	209	16.4	25	13.8	23	9.6	34	19.4	
CCS 4	3	0.8	35	2.7	5	2.8	7	2.9	6	3.4	
Acute coronary syndrome	78	20.8	203	15.8	42	23.0	33	13.8	57	32.4	**<0.001**

5.3.2 Comparison of Treatment Characteristics between Centres

In this section, procedural and lesion details of patients at each centre were compared to identify the differences between the PCI practices at each centre. LOS and PCI outcomes, in terms of successful revascularization, complication and mortality were also compared (Table 5.5). At the beginning of PCI procedure, vascular access must be established. There are 3 main percutaneous access sites that can be used, namely brachial, femoral, and radial access. It should be noted that certain patients might have more than one percutaneous access. In our study, no brachial access was recorded. Between radial and femoral accesses, analysis revealed significant preference for the radial access site at all the centres except IJN. The ratio of radial access and femoral access were similar in IJN.

The number of vessel affected by stenosis can be seen as an indirect reflection of the disease severity of CAD. Every 1 in 2 patients in IJN had multi-vessel disease (MVD). This was in stark contrast with the remaining centres that mainly treated patients with single vessel disease. At PJHUS, only slightly more than a quarter of patients (27.5%) had MVD, and the numbers were even lower at QE2, UMMC, and PGH.

Depending on the severity of the obstruction seen on the angiogram, a patient can have more than one lesion treated in the same PCI procedure. There was a significant difference in the mean number of lesions treated per patient between the centres (*p-value* <0.001). It was the highest in IJN (1.76 lesions), followed by 1.71 lesions in UMMC. The number was relatively lower in QE2 and PJHUS, with 1.53 and 1.57 lesions treated per patient respectively. More than half of the patients in these two centres had only 1 lesion requiring revascularization.

Among the lesions treated at the 5 cardiac centres, there was a significant difference in the proportion of high-risk characteristics at each centre. QE2 registered a higher proportion of lesion characteristics such as ostial, bifurcation, total occlusion, and calcified lesion. The distribution of high-risk characteristics was spread out among other centres, for example, 12.3% of lesion in UMMC was calcified, while PGH patients had 18.6% lesion with chronic total occlusion. Based on the AHA/ACC lesion classification system, majority of the lesions treated at all the centres are of the complex lesion (type B2 or C). However, the proportion of complex lesion was highest among patients treated in IJN (69.8%) and PGH (66.1%).

For every lesion, revascularization could be achieved with no stent, single stent or multiple stents. For procedure with no stent inserted, it was known as plain old balloon angioplasty (POBA). UMMC had the highest proportion of POBA among all the 5 cardiac centres (11.7%). PGH on the other hand, did not conduct any POBA for the elective PCI patients in the centre.

In this study, the number of stents inserted ranged from one to seven. The difference of number of stents used between the centres was statistically significant. However, at all the centres, the majority of the lesions required only single stent for revascularization. Except for IJN, the other 4 centres had minimal number of patients with more than 3 stents inserted. The mean number of stents inserted was highest in PGH (1.63) and IJN (1.62), and the lowest in PJHUS (1.16). The difference was statistically significant.

Among the types of stents, drug-eluting stents (DES) were the prominent choice at all the centres. More than 50% of the stents used at all centres were DES. However, the proportion of type of stents used differed at different centres. The second commonest type of stent used in QE2 and PJHUS was bare metal stents (BMS), as compared to drug-eluting balloon (DEB) in IJN and UMMC. The usage of bio-absorbable vascular scaffold (BVS) was relatively low at all centres.

The mean LOS was not normally distributed. Kruskal Wallis test showed significant difference between LOS at the 5 centres (*p-value* <0.001). QE2 recorded the longest LOS at 10.3 days, followed by PGH at 9.6 days in PGH. PJHUS patients had the shortest LOS (3.7 days). Median LOS ranged from 2.0 days in UMMC and PJHUS to 7.5 days in QE2. By categorizing the patients into long hospital stay (more than 3 days) or short hospital stay (3 days or less), the result revealed that every 3 out of 4 patients in PJHUS and UMMC had short hospital stay, compared to only 1 in every 2 patients in IJN and PJHUS, and only 1 in 3 patients in QE2 who has short hospital stay. About 1 in 5 of patients in PJHUS had same-day discharge from the day-care centre. IJN and PGH also had day-care setting during the study period. Nevertheless, data from NCVD-PCI registry showed that less than 2% of the patients at these 2 centres had same-day discharge, thus the cost incurred at day-care centres of PGH and IJN were not counted.

While patient and treatment characteristics differ across cardiac centres in this study, there was no significant difference in the post-PCI TIMI flow and successful revascularization rate between the centres. More than 95% of the patients from each centre achieved a post-PCI TIMI-3. The success rate was equally high throughout, ranging from 94.4% in UMMC to 100% in PGH. The rate of mortality and complications were low overall. All patients were discharged alive from UMMC. The overall complication rate post-PCI was very low. For QE2 and IJN, there was a 0.6% of significant periprocedural MI post-PCI and none at UMMC, PGH, and PJHUS.

Table 5.5: Comparison of treatment characteristics between centres

	UMMC n=375		IJN n=1286		PGH n=183		PJHUS n=240		QE2 n=176		
	n	%	n	%	n	%	n	%	n	%	*p-value*
Femoral Access	137	36.5	720	56.0	70	38.3	73	30.4	66	37.5	**<0.001**
Radial Access	255	68.0	674	52.4	117	63.9	169	70.4	120	68.2	**<0.001**
Multi-vessel Disease	56	14.9	653	50.8	14	7.7	66	27.5	26	14.8	**<0.001**
Number of Lesions Treated											
1	168	44.8	634	49.3	90	49.2	142	59.2	104	59.1	**<0.001**
2	167	44.5	441	34.3	74	40.4	77	32.1	55	31.2	
3 to 7	25	6.7	133	10.3	13	7.1	13	5.4	11	6.2	
Lesions treated per patient, mean $\pm$ SD	1.71$\pm$0.81		1.76$\pm$ 0.99		1.67$\pm$0.87		1.53$\pm$0.76		1.57$\pm$0.92		0.001
Lesion description											
Ostial	8	2.1	150	11.7	2	1.1	10	4.2	19	10.8	**<0.001**
Total occlusion	13	3.5	74	5.8	8	4.4	12	5.0	21	11.9	0.002
Chronic total occlusion	26	6.9	103	8.0	34	18.6	8	3.3	18	10.2	**<0.001**
Thrombus in lesion	9	2.4	28	2.2	4	2.2	4	2.2	5	2.1	**<0.001**
Bifurcation	8	2.1	110	8.6	3	1.6	14	5.8	25	14.2	**<0.001**
Calcified lesion	46	12.3	87	6.8	3	1.6	9	3.8	28	15.9	**<0.001**
Complex Lesion by AHA/ACC	216	57.6	897	69.8	121	66.1	132	55.0	111	63.1	**<0.001**
Number of Stents Inserted											
0	44	11.7	70	5.4	0	0	22	9.2	5	2.8	**<0.001**
1	219	58.4	654	50.9	95	51.9	170	70.8	99	56.2	
2	82	21.9	363	28.2	62	33.9	36	15.0	58	33.0	
3	28	7.5	130	10.1	25	13.7	11	4.6	13	7.4	
4 to 7	2	0.6	69	5.3	1	0.5	1	0.4	1	0.6	

Table 5.5, continued

	UMMC n=375		IJN n=1286		PGH n=183		PJHUS n=240		QE2 n=176		
	n	%	n	%	n	%	n	%	n	%	*p-value*
Proportion of Usage by Stent Type											**<0.001**
DES	376	79.0	1797	86.3	288	96.6	240	86.0	5	2.8	
BMS	22	4.6	79	3.8	2	0.7	25	9.0	99	56.2	
DEB	71	14.9	177	8.5	4	1.3	6	2.2	58	33.0	
BVS	7	1.5	30	1.4	4	1.3	8	2.9	13	7.4	
Stents placed per patient, mean + SD	1.27+0.79		1.62+1.03		1.63+0.74		1.16+0.66		1.47+0.70		**<0.001**
DES placed per patient, mean + SD	1.00+0.79		1.40+1.05		1.57+0.78		1.00+0.65		0.88+0.85		**<0.001**
BMS placed per patient, mean + SD	0.06+0.30		0.06+0.26		0.01+0.10		0.10+0.40		0.42+0.72		**<0.001**
BVS placed per patient, mean + SD	0.02+0.17		0.02+0.18		0.02+0.18		0.03+0.22		0.02+0.15		0.43
DEB placed per patient, mean + SD	0.19+0.51		0.14+0.42		0.02+0.15		0.03+0.18		0.14+0.46		**<0.001**
Length of Stay, mean + SD, days	4.80+8.60		8.60+9.30		9.60+11.00		3.7.0+6.30		10.30+9.40		**<0.001**
Length of Stay, median (IQR), days	2.0 (2.0-3.0)		4.0 (2.0-13.0)		3.0 (2.0-17.0)		2.0 (1.0-3.0)		7.5(2.0-15.0)		
Same-day Discharge	2	0.5	21	1.6	3	1.6	44	18.3	5	2.8	**<0.001**
Length of Stay ≤ 3 days	286	76.3	634	49.3	96	52.5	182	75.8	59	33.5	**<0.001**
Outcomes											
TIMI-3 post-PCI	361	96.3	1235	96.0	181	98.9	229	95.4	173	98.3	0.18
Successful revascularization	354	94.4	1246	96.9	183	100.0	231	96.2	175	99.4	0.14
In hospital mortality	0	0	6	0.5	1	0.5	2	0.8	1	0.6	0.62
Significant periprocedural MI	0	0	8	0.6	0	0	0	0	1	0.6	0.29
Emergency reintervention	0	0	2	0.2	0	0	0	0	0	0	0.82
Other complications	3	0.8	13	1.0	1	0.5	0	0	5	2.8	0.06

5.3.3 Comparison of Cost between Patients of Different Cardiac Centres

Table 5.6 outlined the mean and median costs of individual patient for the 5 cardiac centres. Due to the underlying non-normality of the cost data distribution, there was a huge discrepancy between the mean and median values for all the categories. Median value was consistently lower than mean value for CW admission cost, PCI consumable cost, and total hospitalization cost. For the purpose of comparing the cost between the different cardiac centres, we believe that the reporting of mean values would carry a more significant impact for the healthcare providers and policy makers in terms of budget and resource allocation.

However, regardless of mean or median values, the ranking of cost incurred at the 5 centres were the same. Total hospitalization cost was the highest in QE2, mainly driven by the high ward admission cost. The mean cost of cardiac ward admission at QE2 (RM 8,547.08) was the highest among all the centres, almost 3 times higher than the lowest mean cost incurred in PJHUS at RM 3,075.56.

Among the 5 cardiac centres, PJHUS recorded the lowest cost for both admission and PCI consumable costs. As a result, the mean total hospitalization cost was the lowest in PJHUS at RM 12,117.45. The total hospitalization costs at UMMC, IJN, and PGH were close, ranging from RM 16,289.17 in UMMC to RM 17,999.43 in PGH. These figures did not vary much from the overall mean cost of all patients (RM 16,999.99) reported in Section 5.2. PGH incurred the highest mean cost of PCI consumable (RM 11,882.78). This was marginally higher than the remaining centres, which spent only RM 7,645.15 to RM 8,790.37 for PCI consumable.

The bar chart in Figure 5.1 compares the mean cost differences for each unit of analysis at each centre when compared to the overall mean cost of all patients. It provides a better illustration of the relative contribution of each unit of analysis at the respective centres towards lowering or increasing the total hospitalization cost.

Among all the centres, PJHUS and UMMC had a lower mean cost for all units of analysis. The margin of difference is especially wide in PJHUS, ranging from 9.6% lower cost of PCI consumable to 38.1% lower cost of CW admission, resulting in an eventual 28.7% lower total hospitalization cost when compared to the overall mean cost.

The other 3 centres, namely IJN, PGH, and QE2, all recorded a higher mean total hospitalization costs. However, the contributing cost items differed among the 3 centres. In IJN, the CL utilization was the cost item with the widest margin of difference, recording 17.3% higher than the overall mean CL utilization cost. On the contrary, PCI consumable cost was the reason behind the higher total hospitalization cost. The PCI consumable cost in PGH was 40.5% higher when compared to the overall mean cost of all the patients in the study.

As for QE2, the higher hospitalization cost was mainly driven by the difference in the CW admission. It recorded a 72.0% higher admission cost than the overall mean admission cost. As a result, even with a negative margin of difference under CL utilization cost, the mean total cost of hospitalization in QE2 was still 13.1% higher than overall mean cost of all patients.

Table 5.6: Mean and median costs of all individual patients by centre

Cost (RM)	UMMC	(n=375)	IJN	(n=1286)	PGH	(n=183)	PJHUS	(n=240)	QE2	(n=176)
Cardiac Ward Admission										
Mean (SD)	4,344.81	(7,809.66)	5,100.07	(5,532.57)	4,379.25	(5,008.41)	3,075.56	(5,123.15)	8,547.08	(7,804.61)
Median (IQR)	1,813.36	(1,813.36-2,720.04)	2,381.08	(1,190.54-7,738.51)	1,368.36	(912.24-7,754.04)	1,637.06	(818.53-2,355.59)	6,226.35	(1,660.36-12,452.70)
PCI Consumable										
Mean (SD)	8,084.45	(4,329.29)	8,181.49	(3,316.45)	11,882.78	(3,995.34)	7,645.15	(3,551.71)	8,790.37	(3,505.17)
Median (IQR)	7,299.91	(5,999.91-11,099.91)	6,185.33	(6,185.33-9,414.34)	9,195.35	(8,395.35-14,395.35)	7,535.57	(5,135.57-7,810.57)	7,484.12	(5,984.12-12,484.12)
PCI Procedure in Cardiac Catheterization Laboratory										
Mean (SD)	13,406.35	(4,329.29)	15,384.72	(3,316.45)	16,988.64	(3,995.34)	11,528.84	(3,551.71)	13,085.99	(3,505.17)
Median (IQR)	12,621.81	(11,321.81-16,421.81)	13,388.56	(13,388.56-16,617.57)	14,301.21	(13,501.21-19,501.21)	11,419.26	(9,019,26-11.694.26)	11,779.74	(10,279.74-16,779.74)
Total Hospitalization										
Mean (SD)	16,289.17	(8,820.91	17,673.58	(6,570.54)	17,992.43	(6,027.75)	12,117.45	(6,139.60)	19,218.86	(8,905.29)
Median (IQR)	13,173.18	(11,973.18-18,173.18)	15,592.17	(11,767.89-20,949.60)	16,581.87	(12,406.35-21,116.51)	10,569.37	(8,854.59-14,333.70)	17,146.61	(11,856.07-24,929.05)

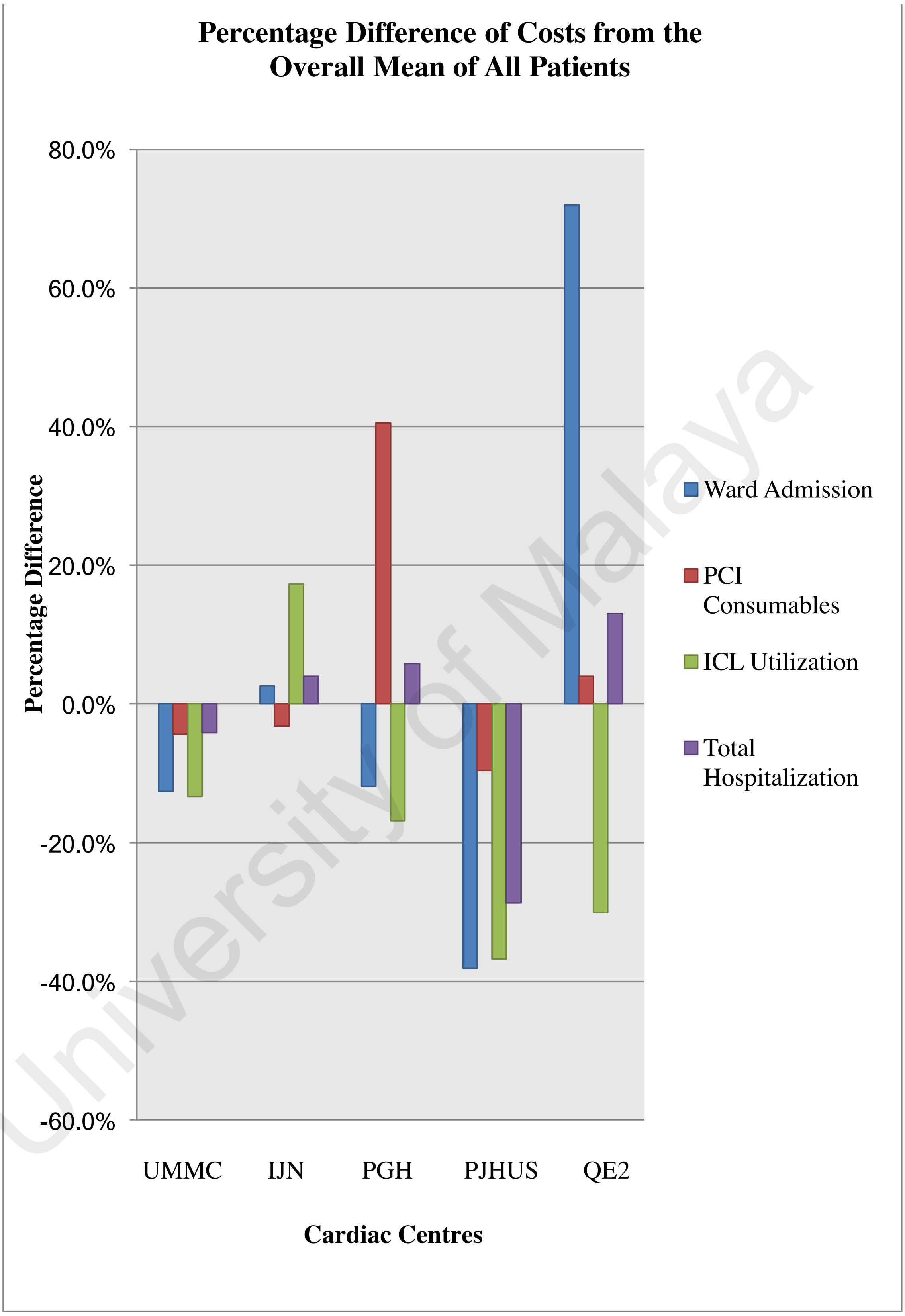

Figure 5.1: Percentage of mean difference for each unit of analysis and total hospitalization cost as compared to overall mean cost of all patients

5.3.4 Hospitalization Cost by Different Costing Approach

The mean total hospitalization cost obtained in Section 5.3.3 showed a wide disparity in terms of highest to lowest cost ranking when compared with the average hospitalization cost calculated using top-down approach in Chapter 4 (Table 5.7). The highly skewed distribution of length of stay, especially in QE2, led to a 48.4% higher hospitalization cost in QE2 when applying patient's actual length of stay.

To enable a fairer comparison, mean hospitalization cost was calculated only for patients with short hospital stay of 3 days of less. When compared with the average hospitalization cost, the ranking of cost incurred by each centre was the same, and the total hospitalization cost closely resembled each other, with minimal differences of 4.0% in UMMC to 11.2 in PJHUS%. Figure 5.2 illustrates the difference between the total hospitalization costs calculated using different approaches.

Table 5.7: Total hospitalization cost of each centre based on different costing approach

Hospitalization Cost (RM)	**UMMC**	**IJN**	**PGH**	**PJHUS**	**QE2**
Top-down Costing Average Cost by Centre	14,346.93	14,356.93	13,937.25	11,519.65	12,947.02
Mixed method Mean Cost of All Individual Patients	16,289.17	17,673.58	17,992.43	12,117.45	19,218.86
Mixed method Mean Cost of Patients with Short Stay (≤ 3 days)	13,769.06	13,590.56	12,681.43	10,234.19	11,739.46

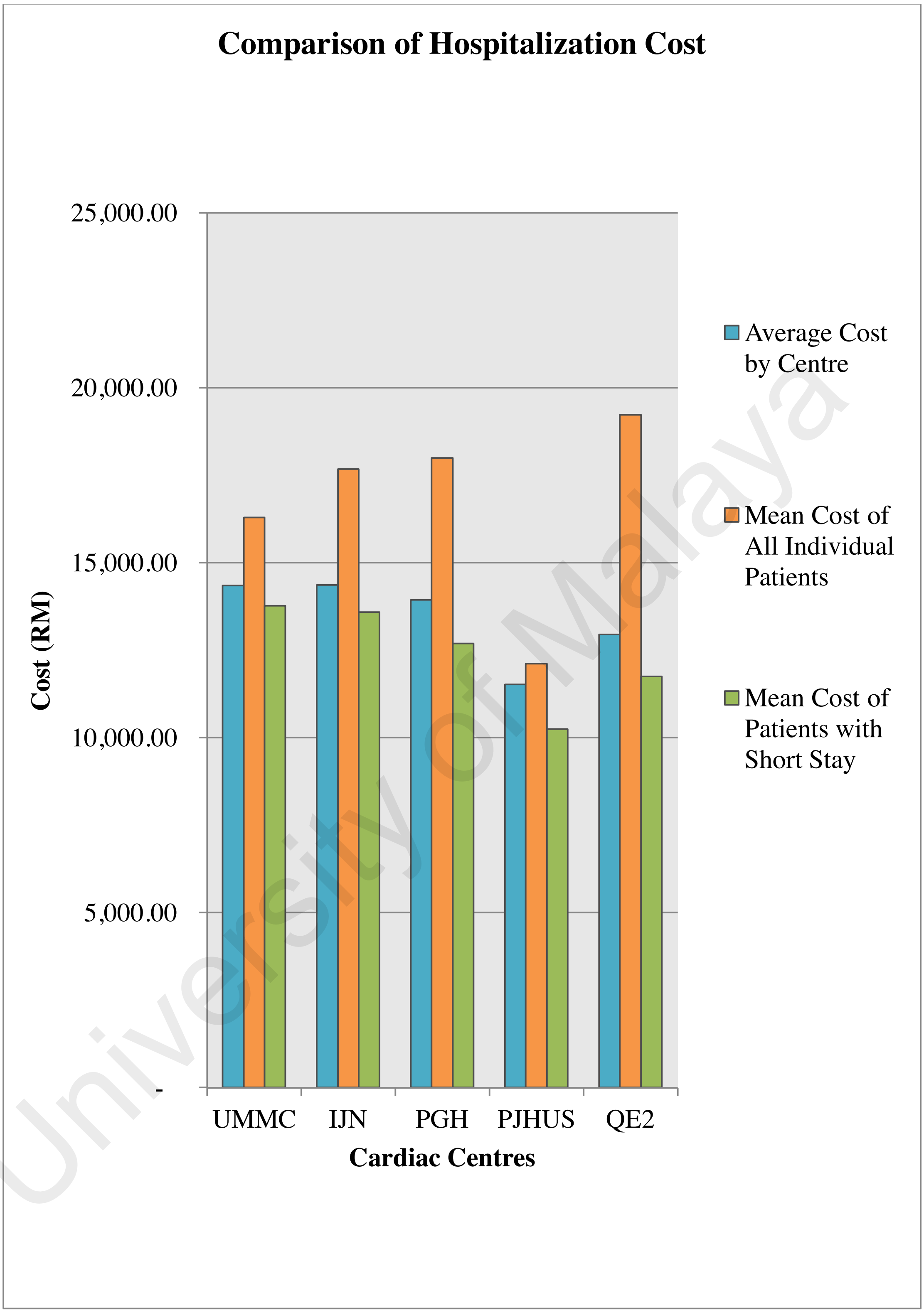

Figure 5.2: Comparison of hospitalization cost between average hospitalization cost (top-down approach), mean cost of all individual patients (mixed method), and mean cost of patients with short stay of 3 days and less (mixed method)

5.4 Comparison based on Hospital Length of Stay

The LOS is closely associated with the underlying health status and disease severity of patients. Thus, it is also a major determinant in the total hospitalization cost, both to the patient and the healthcare system.

For this section of analysis, the study population was divided into early discharge or short hospital stay group (LOS≤ 3 days), and non-early discharge or long hospital stay (LOS > 3 days). A LOS of 3 days was chosen as a cut-off point as the median LOS calculated was 3 days. The interventional cardiologists involved in this costing study also unanimously agreed that the average LOS for elective PCI patients would be 3 days. The clinical and treatment characteristics of the patients with short hospital stay (n =1257; 55.6% of study population) versus patients with long hospital stay are shown in subsequent sections.

5.4.1 Comparison of Patient Characteristics between Long and Short Hospital Stay

Table 5.8 showed the percentage distribution and *p-value* of the comparison between patients with long and short hospital stay at the cardiac centres. Of the 2260 patients from the 5 cardiac centres, slightly more than half of the patients had short hospital stay (55.6%). As IJN had the highest number of patients, a majority of patients who had a long hospital stay were from IJN as well (65.6%). However, the within-centre comparison revealed that QE2 had the highest proportion of long staying patient among all the centres, with every 2 out 3 patients staying more than 3 days. On the contrary, every 3 out of 4 patients in UMMC and PJHUS had short hospital stay. The proportion between patients with short and long hospital stay was almost similar in PGH and IJN.

There were no significant differences in terms of the age and gender distribution between patients with long and short hospital stay. Patients with poorer comorbid status often have longer hospital stay post-PCI procedure. Almost all the risk factors showed no significant difference between the patients with long and short hospital stay, except for smoking status and dyslipidaemia. There appeared to be a significantly higher proportion of patients with short hospital stay among patients who smoke and patients with dyslipidaemia.

Certain cardiac status at presentation appeared to be associated with the eventual LOS of patients. It was found that patients with new onset angina were more likely to have a long hospital stay (24.9%). Among the long staying patients, there were significantly higher number of patients with history of previous MI (42.8%) when compared to only 35.4% of patients with short hospital stay having had a previous MI. There was no difference in the LOS for patients with or without previous PCI, but there were a higher proportion of patients with previous CABG in the long staying group (4.4%) compared to the short staying group (2.6%).

Patients who presented with more severe symptom on admission, namely NYHA II-IV and CCS of 2-4 were more likely to stay longer after PCI procedure. About one quarter (25.9%) of long staying patients were diagnosed with ACS compared to only 11.7% among the short staying patients ($p<0.001$).

Table 5.8: Comparison of demographic and clinical characteristics between patients with long and short hospital stay

	Short Stay n=1257		Long Stay n=1003		
	n	%	n	%	*p-value*
Demographic					
Age > 60	566	45.0	447	45.8	0.716
Male Gender	1033	82.2	789	80.8	0.418
Race					0.217
Malay	574	45.7	487	49.9	
Chinese	287	22.8	170	17.4	
Indian	276	22.0	224	23.0	
Others	120	9.5	95	9.7	
Hospital					**<0.001**
UMMC	286	22.8	83	8.5	
IJN	634	50.4	640	65.6	
PGH	96	7.6	83	8.5	
PJHUS	182	14.5	55	5.6	
QE2	59	4.7	115	11.8	
Risk Factors					
History of smoking	854	67.9	614	62.9	**0.013**
Dyslipidaemia	864	70.6	607	66.1	**0.025**
Hypertension	888	72.0	647	69.9	0.276
Diabetes mellitus	572	47.2	428	46.6	0.776
Family history of CVD	268	22.1	217	23.5	0.449
Cerebrovascular disease	28	2.3	18	1.9	0.562
Peripheral vascular	9	0.7	4	0.4	0.361
Chronic renal failure	51	4.1	48	5.1	0.286
Body Mass Index ≥ 25	827	65.8	633	64.9	0.645
Documented CAD	548	44.8	434	47.0	0.300
Recent angina	190	15.4	237	24.9	**<0.001**
Previous heart failure	43	3.5	43	4.6	0.203
Previous MI	425	35.4	396	42.8	**<0.001**
Previous PCI	351	27.9	252	25.8	0.267
Previous CABG	33	2.6	43	4.4	**0.021**
NYHA II-IV	412	32.8	388	39.8	**0.010**
CCS 2-4	542	43.4	468	48.3	**0.021**
Acute coronary syndrome	147	11.7	253	25.9	**<0.001**

5.4.2 Comparison of Treatment Characteristics between Long and Short Stay

Table 5.9 outlines the comparison of treatment characteristics between patients of long and short hospital stay. Significant association was found between the disease severity and duration of hospital stay. In terms of the distribution of diseased vessels, no significant differences were detected for left anterior descending and left circumflex artery among patients with long and short hospital stay. However, the proportion of patients with right coronary artery and left main stem involvement were significantly higher among long-staying patients.

Of all the patients with long hospital stay, 39.2% of them had multi-vessel disease compared to only 33.7% among patients with short hospital stay (*p-value* <0.05). The mean number of lesions treated was higher for patients with long hospital stay (1.75 lesions), as compared to 1.67 lesions per patient in the short hospital stay group, with a statistically significant difference.

Furthermore, higher proportion of long-staying patients was found to have complex lesions and lesion of high-risk characteristics when compared to short-staying patients. For example, there was twice as much patients with lesions of high-risk characteristics (ostial, total occlusion, thrombus, and bifurcation) in the long staying group. Similarly, based on the ACC/AHA lesion classification system, the proportion of complex lesion type B2 and C was significantly higher in patients who stayed 3 days or more (70.3%).

Analysis showed that the difference in the mean stents inserted per patient was significant. Patients with long hospital stay recorded 1.59 stents inserted per patient compared to 1.43 for patients with short hospital stay. Subsequently, the number of each type of stent used was also significantly higher among patients with long hospital stay.

When comparing patients with long and short hospital stay, there was no significant difference in the outcomes of PCI in terms of success rate and complication rate. Both groups recorded similarly high rate of TIMI-3 flow post-PCI and successful revascularization rate. Despite the slightly higher proportion of patients with in-hospital mortality and post-PCI complications in the long staying group, the difference between the 2 groups was not statistically significant.

Table 5.9: Comparison of treatment characteristics between patients with long and short hospital stay

	Short Stay n=1257		**Long Stay n=1003**		
	n	%	n	%	*p-value*
Percutaneous Entry					
Femoral	600	47.7	451	46.2	0.474
Radial	748	59.5	587	58.8	0.740
Diseased Vessel					
Left Anterior Descending	839	66.7	656	67.2	0.816
Left Circumflex	430	34.2	346	35.5	0.541
Right Coronary	528	42.0	494	50.6	**<0.001**
Left Main Stem	41	3.3	66	6.8	**<0.001**
Multi-vessel Disease (MVD)	424	33.7	383	39.2	**0.007**
Lesions treated per patient, mean ± SD	1.67 ± 0.88		1.75 ± 0.97		**0.042**
Lesion description					
Ostial	86	6.8	100	10.2	**0.004**
Total Occlusion	56	4.5	70	7.2	**0.006**
Chronic Total Occlusion	83	6.6	105	10.8	**0.001**
Thrombus in lesion	22	1.8	40	4.1	**0.001**
Bifurcation	63	5.0	93	9.5	**<0.001**
Calcified lesion	97	7.7	74	7.6	0.905
ACA/AHA Complex Lesion	779	63.6	682	70.3	**0.042**
Stents placed per patient, mean ± SD	1.43 ± 0.88		1.59 ± 0.98		**<0.001**
DES placed per patient, mean ± SD	1.21 ± 0.92		1.33 ± 1.00		**0.002**
BMS placed per patient, mean ± SD	0.07 ± 0.31		0.11 ± 0.39		**0.002**
BVS placed per patient, mean ± SD	0.02 ± 0.17		0.03 ± 0.20		0.311
DEB placed per patient, mean ± SD	0.13 ± 0.42		0.12 ± 0.40		0.562
Number of Stents Inserted					**0.002**
0	91	7.2	49	5.0	
1	716	57.0	504	51.6	
2	308	24.5	285	29.2	
3 or more	142	11.3	138	14.1	
Outcomes					
TIMI-3 post-PCI	1213	96.5	966	96.3	0.716
Successful revascularization	1215	96.7	973	97.0	0.802
In-hospital mortality	3	0.2	7	0.7	0.093
Signficant Periprocedural MI	3	0.2	6	0.6	0.164
Emergency reintervention	0	0.0	2	0.2	0.108
Other complications	8	0.6	11	1.1	0.211

Note. Some patients may have more than one percutaneous entry, diseased vessel and/or stent inserted. Percentage breakdown was based on total number of the variable occurrence.

5.4.3 Predictors of Long Hospital Stay Among the Patients

Logistic regression analysis was conducted to predict long hospital stay among patients who underwent elective PCI. Patients who represented critical outliers of LOS>40 days were removed (n=27). The remaining samples were dichotomized based on the dependent variable of whether the patient had a long hospital stay (more than 3 days) or short hospital stay (0-3 days).

Patient characteristics and treatment details were used as predictors. Only the 22 independent variables that showed significant associations with the dependent variable on Chi-square testing were inserted into the logistic regression model. The logistic regression equation was built with forward, stepwise entry. The likelihood-ratio (LR) test was used as the criterion for determining variable to be removed from the model (Hauck & Donner, 1977; Jennings, 1986). *P*-in was set at 0.05 and *p*-out at 0.10 in order to identify as many possible associations to retention as possible.

A test of the full model against a constant only model was statistically significant, indicating that the predictors as a set reliably distinguished between long and short hospital stay (chi square = 266.840, *p-value* < 0.001 with df = 16). Nagelkerke's R^2 of 0.173 indicated a moderately strong relationship between prediction and grouping. Prediction success overall was 66.9%; 78.6% for short stay and 52.2% for long stay. The Wald criterion demonstrated that 11 variables made a significant contribution at *p-value* <0.05 level to prediction of hospital stay among elective PCI patients (Table 5.10).

Of the 5 cardiac centres, PJHUS was assigned as the reference because it was the centre with least proportion of patients with long hospital stay. One of the centres, UMMC, was non-significant at *p-value*<0.05 levels. This indicated that patients in UMMC did not have a higher chance of having long hospital stay in relative to patients in PJHUS. Patients from the other 3 centres, however, were 2.3 to 6.5 times more likely to have long hospital stay when compared with PJHUS.

Among the list of CAD risk factors, patients with positive smoking history were 1.5 times more likely to have short hospital stay (Exp (B)=0.705, *p-value*=0.001). On the contrary, patients with ACS and recent onset of angina were 2.2 and 1.5 times more likely to have long hospital stay.

In terms of treatment characteristics, the involvement of right coronary artery and left main stem, posed a higher likelihood of long hospital stay, by 1.3 and 1.9 times respectively. Furthermore, presence of chronic total occlusion and thrombus in the lesion led to an increased likelihood of 1.6 to 1.9 times of long hospital stay.

Several variables included cardiac status at presentation in terms of NYHA and CCS, ACC/AHA classification of complex lesions, number of stents inserted per patient; which were found to be positively associated with long hospital stay in the Chi Square testing, did not register as significant predictors of long hospital stay in the logistic regression analysis. Furthermore, the outcome of PCI procedure also did not appear to be a significant predictor in this analysis. Based on the rather modest Nagelkerke's R^2 value, this model can only account for moderate proportions of explained variations in categorization of long and short hospital stay. Further reasons need to be explored to better predict the possibility of long hospital stay among elective PCI patients.

Table 5.10: Predictors in stepwise logistic regression analysis for long hospital stay

Variables	B	S.E.	Wald	*p-value*	Odds Ratio Exp (B)	95% C.I. Lower	95% C.I. Upper
Centre							
PJHUS (Ref)			123.1	**<0.001**			
QE2	1.9	0.267	49.3	**<0.001**	6.505	3.86	10.97
PGH	0.9	0.252	11.5	**0.001**	2.348	1.43	3.85
IJN	1.0	0.204	25.4	**<0.001**	2.792	1.87	4.16
UMMC	-0.4	0.237	2.2	0.138	0.704	0.44	1.12
Smoking	-0.3	0.105	11.0	**0.001**	0.705	0.57	0.87
Dyslipidaemia	-0.3	0.108	5.6	0.076	0.773	0.63	0.96
Recent onset of Angina	0.4	0.13	11.1	**0.001**	1.540	1.20	1.99
NYHA II-IV	-0.4	0.106	15.1	0.081	0.664	0.54	0.82
Acute Coronary Syndrome	0.8	0.140	33.3	**<0.001**	2.241	1.70	2.95
Right Coronary Artery Involvement	0.2	0.100	5.7	**0.017**	1.270	1.04	1.55
Left Main Stem Involvement	0.7	0.231	8.0	**0.005**	1.919	1.22	3.02
Chronic Total Occlusion	0.4	0.174	6.3	**0.012**	1.551	1.10	2.18
Thrombus	0.6	0.305	4.2	**0.041**	1.867	1.03	3.40

Note. Odds Ratio indicates the likelihood of long hospital stay (more than 3 days)

5.4.4 Comparison of Cost between Patients with Long and Short Hospital Stay

Independent sample T-test was used to compare the cost between patients with a long and short hospital stay. As expected, the cost of CW admission was significantly higher among patients with long hospital stay. The mean difference was large at RM 8,163.98.

Furthermore, the PCI consumable cost was also found to be significantly different between the 2 groups of patients (*p-value* <0.05). Patients with short hospital stay incurred a mean cost of RM 8,276.40 on PCI consumable, compared to RM 8,680.08 among patients with long hospital stay. The mean cost of CL utilization was also significantly higher among the patients with long hospital stay. However, the median and IQR of these 2 costs were similar between the two groups (Table 5.11).

For the total hospitalization cost, the mean difference between patients with long and short hospital stay was significant (*p-value* <0.001). The mean cost was RM 13,139.16 for patients with short hospital stay, as compared to RM 21,838.54 for patients with long hospital stay.

Table 5.11: Mean difference in individual patient cost between short and long hospital stay

	Short Hospital Stay (LOS ≤3 days)		Long Hospital Stay (LOS > 3 days)		Mean Difference	95% CI		*p-value*
						Lower	Upper	
Ward Admission								
Mean (SD)	1,346.61	(517.08)	9,510.59	(7,026.42)	8,163.98	7,727.68	8,600.28	**<0.001**
Median (IQR)	1,190.54	(912.24-1,785.81)	7,738.51	(4,533.40-12,500.67)				
PCI consumable								
Mean (SD)	8,276.40	(3,737.43)	8,680.08	(3,745.04)	403.68	93.10	714.27	**0.011**
Median (IQR)	7,399.91	(6,185.33-9,414.34)	7,535.57	(6,185.33-9,414.34)				
PCI Procedure in Cardiac Catheterization Laboratory								
Mean (SD)	14,274.29	(3,906.12)	15,003.32	(15,003.32)	403.68	93.10	714.27	**0.011**
Median (IQR)	13,388.56	(11,721.81-16,617.57)	13,388.56	(13,388.56-16,617.57)				
Total Hospitalization Cost								
Mean (SD)	13,139.16	(3,821.78)	21,838.54	(7,805.88)	8,699.38	8,171.65	9,227.10	**<0.001**
Median (IQR)	11,767.89	(11,172.62-14,996.90)	20,337.15	(16,299.08-25,711.76)				

Note. Costs of hospital general overheads and cardiac catheterization laboratory utilization remain constant.

5.5 Predictors of Hospitalization Cost for Elective PCI Patients

To determine significant predictors of total hospitalization cost among the independent variables of clinical and treatment characteristics, a multiple linear regression analysis was performed. Preliminary analyses were performed to ensure there was no violation of the assumption of normality and linearity of the variables. However, it was found that the distribution of the dependent variable; total hospitalization cost, was positively skewed.

As outlined in Section 3.12.3, in studies with sufficiently large samples (N>500), violations of normality in the dependent variables may not be an issue in the use of a linear regression technique. By law of large numbers and the central limit theorem, the ordinary least square (OLS) estimators in linear regression technique will be approximately normally distributed around the true parameter values.

With a sample size of 2260 patients, it is assumed that the linear model can be accepted as an useful default prediction tool in this study. Nevertheless, we conducted and reported examination of the extent to which the assumptions of linear regression were met.

In the first step, bivariate correlation was conducted to identify the patients' clinical and treatment characteristics that had a significant (*p-value* <0.01) zero-order correlation with the dependent variable; total hospitalization cost. The linear regression was first conducted with all the patients, and similar steps were repeated for patients with short hospital stay.

5.5.1 Linear Regression for All Patients

In the first step, bivariate correlation was checked for the 53 independent variables. Only 32 variables had significant correlation with total hospitalization cost and were included in the stepwise regression analysis (APPENDIX G).

An analysis of standard residuals was carried out to identify any outliers. Outliers were removed until the minimum and maximum standardized residual values were -3.186 and 3.240 respectively. The data met the assumption of independent errors (Durbin-Watson value = 1.31). Multicollinearity was not a concern as the data met the assumption of collinearity (Tolerance <1, *VIF* <5).

The histogram of standardized residuals indicated that the data contained approximately normally distributed errors, as did the normal P-P plot of standardized residuals, which showed points that were not completely on the line, but close. The scatterplot of standardized predicted values showed that the data met the assumptions of homogeneity of variance and linearity. The data also met the assumption of non-zero variances with the variances of all variables above zero (APPENDIX H).

In Table 5.12, the result of linear regression between total hospitalization cost and independent variables were reported. Using stepwise method, a significant regression equation was found, whereby F (11, 1890) = 515.57, *p-value* < 0.001, R^2 = 0.749, Adjusted R^2 = 0.750. It was found that 8 variables were significant predictors of the total hospitalization cost for elective PCI. The predictor model was able to account for 75% of the variance in total hospitalization cost.

Among all the significant predictors, hospital stay, number of total stents and BVS used had significant positive regression weights. Total hospitalization cost increased RM 4,311 for every additional stent used, and RM 2,951 for every additional BVS used, if other variables are kept constant. Apart from that, patients who had a long hospital stay also incurred RM 6,408 more than patients with short hospital stay.

Patients with ACS, presence of bifurcated lesion, involvement of left main stem artery, and failed revascularization during PCI were also expected to incur higher hospitalization cost based on the regression model. Among all the predictors, only PJHUS has a significant negative weight regression weight, indicating that patients in PJHUS were expected to have lower total hospitalization cost.

From the multiple linear regression analysis, it appeared that baseline demographic and clinical characteristics of the patients in our study were not significant predictors of the total hospitalization cost. Treatment characteristics such as lesion descriptions and stent usage played a more significant role towards the determination of hospitalization cost. This model accounted for approximately three-quarter of the variation in costs. However, there remain some uncertainties in the hospitalization cost and further research needs to be conducted.

Table 5.12: Predictors in stepwise linear regression analysis for total hospitalization cost

Predictor	*B*	*SE B*	Beta	*p-value*
Constant	6809.00	180.29		
Long Hospital Stay	6408.96	141.69	0.54	<0.001
Number of stents	4311.70	93.39	0.58	<0.001
Number of BVS	2951.50	352.14	0.10	<0.001
Acute Coronary Syndrome	570.88	179.73	0.04	0.002
Failed revascularization	1117.17	417.23	0.03	0.007
Bifurcated lesion	817.36	271.88	0.04	0.003
Left main stem	337.33	147.51	0.03	0.022
Cardiac Centre				
PJHUS	-2136.86	231.55	-0.11	<0.001
UMMC	1059.42	203.23	0.06	<0.001
PGH	752.64	259.85	0.03	0.004

Note. The dependent variable was total hospitalization cost.

R^2 = .749, Adjusted R^2 = .750

* $p < .05$, ** $p < .001$

5.5.2 Linear Regression for Patients with Short Hospital Stay

Following similar steps, linear regression was conducted only for patients with short hospital stay in the study (n=1257). Out of the 53 independent variables, 32 variables had significant correlations with total hospitalization cost and were included in the regression analysis (APPENDIX I).

An analysis of standard residuals was carried out on the data to identify any outliers. Outliers were removed until the minimum and maximum standardized residual values were -2.194 and 3.094 respectively. The data met the assumption of independent errors (Durbin-Watson value = 1.89). Multicollinearity was not a concern as the data met the assumption of collinearity (Tolerance <1, *VIF* <5).

The histogram of standardized residuals indicated that the data contained approximately normally distributed errors, as did the normal P-P plot of standardized residuals, which showed points that were not completely on the line, but close. The scatterplot of standardized predicted values showed that the data met the assumptions of homogeneity of variance and linearity. The data also met the assumption of non-zero variances with the variances of all variables above zero (APPENDIX J).

In Table 5.13, the result of linear regression between total hospitalization cost and independent variables were showed. Using stepwise method, a significant regression equation was found, F (10, 1042) = 736.66, $p\text{-}value < 0.001$, $R^2 = .913$, Adjusted $R^2 = .912$.

Among the 5 centres, PJHUS and QE2 had a significant negative weight regression weight, indicating that short-staying patients in PJHUS and QE2 were expected to have lower total hospitalization cost. On the contrary, patients in UMMC and PGH were likely to incur a higher cost when compared to the remaining centres.

Not surprisingly, the number of lesion treated and number of stents used were significant predictors. Total hospitalization cost increased RM 2,641 for every additional stent used. If other variables were kept constant, total hospitalization cost increased RM 1,367 for every additional DES inserted, and RM 3,466 for every additional BVS used. Apart from that, patients with femoral access and history of previous PCI were also more likely to incur higher hospitalization cost.

For patients with short hospital stay, baseline demographic and clinical characteristics of the patients did not exert a substantial influence on the total hospitalization cost. The cardiac centres and the type of stents used were the main significant predictors.

Compared to the predictor model that included all the patients in the previous section, this predictor model was able to account for 91.2% of the variance in total hospitalization cost. By including only patients with short hospital stay, the model accounted for more variation in total hospitalization costs.

Table 5.13: Variables predicting total hospitalization cost of elective PCI among patients with short hospital stay

Predictor	*B*	*SE B*	Beta	*p-value*
Constant	7294.11	180.29		
Femoral Access	229.22	67.81	0.033	0.001
Previous PCI	150.43	74.10	0.020	0.043
Number of lesions treated	91.51	45.94	0.018	0.047
Number of stents	2641.41	113.97	0.582	<0.001
Number of BVS	3466.89	317.70	0.105	<0.001
Number of DES	1367.87	108.79	0.324	<0.001
Cardiac Centre				
PJHUS	-1699.12	102.48	-0.170	<0.001
UMMC	1110.11	88.51	0.128	<0.001
PGH	514.54	123.51	0.040	<0.001
QE2	-383.05	164.53	-0.025	0.020

Note. The dependent variable was Total Hospitalization Cost.

R^2 = .913, Adjusted R^2 = .912

5.6 Summary

In this chapter, individual patient data on clinical and treatment characteristics from NCVD-PCI Registry was analysed. By applying bottom-up approach to selected cost items, individual-level patient cost data was tabulated. Comparison between the 5 cardiac centres was made. Further analysis was conducted by grouping the patients based on length of stay in the hospital. In the last section, linear regression analysis was used to identify significant predictors of hospitalization cost among patients who underwent elective PCI. However, there remains some unexplained variation in the hospitalization cost and further research are warranted.

CHAPTER 6: DISCUSSION

In the face of growing burden of non-communicable disease, cardiovascular disease (CVD) has become the leading cause of morbidity and mortality in developing countries like Malaysia. Increasingly expensive healthcare expenditure from both the perspectives of providers and payers call for the implementation of cost effective and sustainable interventions in the long run, whether it is for population level primary prevention, or advanced therapeutic procedures such as PCI.

This thesis explored the cost of PCI service provision from the perspective of cardiac centres providing interventional cardiac care. This aspect has yet to be examined in the context of our country. Multiple stakeholders in the healthcare system rely on such information to deliver high quality care and to guide policy development.

In this chapter, we set out to review if the objectives proposed have been achieved. The application of a modified costing method was discussed in further details, followed by comparison of the major findings in this study with similar work in the literature. In the final section on public health implications, the main contributions of the thesis were highlighted. The strength and limitations of this thesis were addressed before recommendations for future research were outlined.

6.1 Methodology-related Findings and Contributions

In many developed countries, cost analysis is a built-in component of healthcare delivery system. With easy access to high quality and freely available data in these countries, economic evaluation is commonly applied to assess the impact of investments in disease prevention and treatment, and to guide decision-making in future budget allocation and service planning (Lipscomb et al., 2009).

In 2014, among all the surveyed LMIC, only 20% of upper-middle income countries (UMIC) and 1% of low and low-middle income countries (LLMIC) had any forms of official economic evaluation guidelines (Griffiths et al., 2016). Researchers in developing nations often have to follow the economic evaluation guidelines that were published based on high-income countries settings. Realistically speaking, many of these guidelines in international literature cannot be fully implemented in LMIC setting.

A systematic review on economic evaluations of CVD-related interventions in LMIC showed that majority of the studies used mathematical modelling with data from randomized controlled trials (RCT) as the research designs (Suhrcke, Boluarte, & Niessen, 2012). However, according to the International Society of Pharmacoeconomics and Outcomes Research (ISPOR), it would be more informative for formulation of "sound coverage and reimbursement decisions" using "Real-World data" (Garrison, Neumann, Erickson, Marshall, & Mullins, 2007). LMIC have been hampered by lack of infrastructure and financial support for evidentiary data capture that are indispensable to conduct comprehensive health economic evaluation, as highlighted in a recent editorial (Briggs 2016).

As a middle-income country, we encountered similar predicament during the course of this study. Primary data collection with full adherence to published economic evaluations would be a costly exercise for most LMIC. Therefore, affordable research designs should be considered as alternatives. In the following sections, we identified the essential components required to produce reliable cost-related outcome evidence that are lacking in our setting. From there, we discussed the modifications made to the established guidelines as we designed a cost analysis for PCI patients at different cardiac centres in Malaysia.

6.1.1 Incorporation of Data from Clinical Registry

Many of the published economic evaluations were conducted via primary data collection in a stand-alone costing study or within a RCT. The scope of a cost analysis done via primary data collection may be limited by time and budget factor, whereas costing study within a RCT has led to concern about the generalizability in a real world scenario (Melikian, Morgan, & Beatt, 2005). As compared to RCT that often exclude high-risk patients, registries include a complete and unselected set of patients, thus the data will better represent the real world scenario.

Evaluation of registry data enables clinicians and healthcare administrators to compare disease-specific patterns, management and outcomes. This might lead to changes in national health priorities or strategies of disease management (Alpert, 2000; Fox, 2006). Cardiac registries play an important role in the analysis of cardiac disease epidemiology and management. Some of the well-established cardiac registries around the world include the American College of Cardiology-National Cardiovascular Data Registry (ACC-NCDR), the Euro Heart Survey Program by European Society of Cardiology (ESC) and the Melbourne Interventional Group (MIG) PCI Registry. Information from these registries contributed to quality of care by providing data feedback on a wide range of performance metrics to participating centres and by facilitating local and national quality improvement efforts.

In Malaysia, the initial objectives upon setting up the NCVD-PCI Registry includes stimulating and facilitating research in the field of interventional cardiology in order to improve the level of current practices. Throughout the years, data from the registry have led to the dissemination of many important findings internationally. Past studies focused on clinical aspects and examined the differences between age group, gender, and outcomes of patients who underwent PCI (Asia Pacific Cohort Studies, 2007; C. Y. Lee et al., 2013; Zuhdi et al., 2013). Despite the intention of the collaborative group to calculate the costs of CVD to the nation and to evaluate the cost effectiveness of various treatments in Malaysia (Liew et al., 2008), the data from the registry has not been applied for costing purpose before this.

By incorporating secondary data from the NCVD-PCI Registry in this costing study, we managed to simplify the manual extraction of clinical and utilization data from different units at the cardiac centres. This was especially valuable in view of the time and budget constraint. Furthermore, this study was strengthened by the robustness and breadth of the data from a nationwide registry, a major advantage compared to primary data.

6.1.2 Identification and Valuation of Cost Items

Under each unit of analysis, there are multiple resources being consumed within each cost centre. The identification and valuation of cost items are a major part in economic evaluation. In many high-income countries, Diagnosis Related Group (DRG) is often applied in economic evaluation as appropriate unit of analysis (S.S. Tan et al., 2011). It is a system commonly used to classify patients into resource homogenous group based on the main clinical condition that leads to the acute inpatient episode (Fetter & Brand, 1991; Kobel, Thuillez, Bellanger, Aavikso, & Pfeiffer, 2011). However, DRG is not a widespread practice in Malaysia. None of the centres in this study adopted DRG in the daily clinical practice.

Furthermore, while resource requirements are expected to be similar for patients allocated to the same DRG, in certain therapeutic procedures with high cost of consumable expenditure, the DRG cost estimates may not always be an accurate reflection of resource use (Heerey, McGowan, Ryan, & Barry, 2002). Studies done in Norway during the phase of switching from global budgeting to a DRG healthcare financing services showed that actual cost incurred was significantly lower than the DRG-based cost for patients who underwent liver transplant (Skeie, Mishra, Vaaler, & Amlie, 2002) and thoracic aortic aneurysm repair (Mishra, Geiran, Krohg-Sorensen, & Andresen, 2008).

With the absence of a DRG system in place, and taking into account the likelihood of PCI consumable incurring a high expenditure, we applied actual cost calculation of the cost items in this study. A clinical event pathway on the provision of care for elective PCI patients from admission to discharge was drawn up. The various cost items involved at each step were identified based on the event pathway.

After identifying the various cost items, the next step was to obtain unit cost estimates for each cost item. In most HIC, cost items can be valued in simple steps; based on prices derived from a national database, such as the NHS reference cost in the United Kingdom (Department of Health, 2015), or the standard cost in the Australian costing guide (Pharmaceutical Benefits Advisory Committee, 2009). However, this is a big challenge for Malaysia and most other LMIC, as there is no standard reference cost in place for most of the healthcare services.

Some literatures advocated the use of charges or tariffs for valuation purpose, devising formula such as cost-to-charge ratios to better reflect the actual cost (Shwartz, Young, & Siegrist, 1995). Even though this is relatively simple and less time consuming than calculating the actual cost item, it might not be a true reflection of the value of the cost. Furthermore, public hospital charges are highly subsidized in Malaysia, making it even more of a suboptimal estimate of the actual cost. In view of that, actual calculation of unit cost for all the cost items was conducted in this costing study.

6.1.3 Selection of Costing Approach

As reference data and cost-to-charge ratios are not ideal substitutes for the cost data in Malaysia, actual valuation of each cost item was conducted in this study. There are 2 approaches for the calculation of unit cost: top-down or bottom-up. However, there is no consensus as to which is the gold standard.

Top-down approach divides a total expenditure or budget by total units of product or service to derive a unit cost, assuming that every product consumes an equal amount of resources. This approach is useful in settings with limited availability of cost data and low precision level of utilization data. For example, annual hospital expenditure on outpatient CVD medications divided by number of CVD patients treated at outpatient clinic leads to a cost estimate of CVD medication for the average outpatient. Typically, top-down costing is much more straightforward and less tedious in terms of data collection. However, the trade-off is a lack of sensitivity, especially for cost items that originated from a less homogenous production.

On the contrary, bottom-up approach involves multiplying the unit cost of each cost item with actual patient utilization data to derive the cost of each cost item, providing the actual cost of resource consumption at individual patient level. This can be achieved via direct observation of time spent and resources consumed for each step of the procedure. This micro costing method is also known as time-and-motion studies. It was frequently shown that bottom-up approach for all the cost components would produce the most accurate individual cost estimates and best reflection of the variation in resource use (Berlin & Smith, 2004; Raulinajtys-Grzybek).

Despite being able to produce a more accurate cost estimate, the main limitation of the bottom-up costing lies within the complexity and cost of its implementation (Emmett & Forget, 2005). Being a labourious process, bottom-up approach is rarely conducted in hospital setting as it is more time consuming and expensive to implement. Several authors advocated bottom-up approach but acknowledged that such data may not be easily available, especially in resource-limited setting in LMIC (Clement Nee Shrive, Ghali, Donaldson, & Manns, 2009; Mogyorosy & Smith, 2005; S. S. Tan et al., 2009).

Most of the published literature advocated striking a balance between the objectives of the cost analysis and the precision of the estimates available when choosing the costing approach (Barnett, 2009; Oostenbrink et al., 2002). We followed this recommendation for this study and adopted a mixed method costing approach. Bottom-up approach was only applied to cardiac stents and actual length of hospitalization, which were likely to lead to a significant impact on the total costs. The information needed were extracted from the NCVD-PCI Registry and incorporated into the cost calculation of individual patient-level hospitalization cost.

Labour cost is another cost item commonly identified in literature to be having a significant cost difference between top-down and bottom-up approach (S. S. Tan et al., 2009). However, we lacked the manpower to conduct time-and-motion survey at all the cardiac centres in this study. Therefore, to allocate the labour cost of doctors to each cost centres; we consulted the cardiologists for their expert opinion on the apportioned working hours for each grade of doctors. While this was not as specific as bottom-up approach, it was more refined than averaging the total salary payout over number of staff.

To summarize the contribution of methodology-related findings in this section, it is our opinion that rigid adherence to available economic evaluation guidelines is not always practical in LMIC setting. To encourage the uptake of economic evaluation in LMIC, emphasis should be given to the development of costing methods that are applicable and relevant to local settings. We believe that modifications in this study will be useful for other like-minded researchers in LMIC who are facing the same limitations in data availability.

6.2 Resource Utilization and Average Cost by Cardiac Centres

This is the first multi-centre cost analysis in Malaysia to study the hospitalization cost for cardiology procedure. In this study, 5 cardiac centres of different organization and ownership status were represented. For the first part of the results calculated via top-down approach in Chapter 4, we presented the average cost of each centre at the level of cost items, cost centres and units of analysis. This average cost provided a practical baseline cost comparison between the cardiac centres.

To perform a direct comparison between our findings and other studies would be challenging owing to the different perspectives used in cost estimation, varying cost calculation methods, heterogeneous study populations and vastly different healthcare systems and financial source. However, in the subsequent discussion, we will strive to identify the similarities and differences in the pattern of our hospitalization cost with other published studies in the literature.

6.2.1 Types of Cardiac Centres towards Hospitalization Cost

Overall, the results from this study demonstrated substantial costs associated with the provision of PCI service. The average hospitalization cost ranged from RM 11,519 to RM 14,356 for a Malaysian public cardiac centre to provide the services for patients admitted for elective PCI. IJN, the corporatized centre, recorded the highest cost, followed closely by the semi-corporatized teaching hospital, UMMC.

As explained in Section 3.2.2, IJN provides care for private fee-for-service patients and public-subsidized patients. Data analyzed for the purpose of this study related only to subsidized patients in the public wing of IJN. While private patients have the flexibility to select the type of rooms based on their affordability, all public patients will be admitted to the standard 4-bedded ward. Apart from this difference in accommodation arrangement, there were no other discernible disparities in terms of treatment rendered to the PCI patients during the hospitalization period. The angioplasty procedure was conducted in the same cardiac catheterization laboratory (CL) by the same interventional cardiology team. It would be informative to compare the waiting time for procedural date prior to admission and patient satisfaction towards the care received between the public and private patients. However, this was not within the scope of our research.

Being the centre with the highest average hospitalization cost, the main cost difference between IJN and the remaining centres originated from the direct medical cost incurred at the CL. It was observed that general consumable cost contributed to majority of the differences. As with most private hospitals, all general consumable used in IJN are one-off disposable items. UMMC and the other 3 cardiac centres however, rely heavily on in-house central sterile services department (CSSD) to perform sterilization on equipment and devices that can be recycled for subsequent uses, thus reducing the general consumable cost.

In this study, the total hospitalization cost of UMMC was closely behind IJN. The average ward admission cost in UMMC recorded the biggest difference compared to other cardiac centres in the study. This stemmed from the fact that during the study period, the division of interventional cardiology of UMMC had just been relocated to a newly constructed day-care complex in the South Wing of the hospital. All the elective PCI patients were admitted to Interventional Cardiac Ward (ICW) in the new complex. During the initial period of establishment, there was insufficient staffing to manage the whole ward, thus only 57% or 20 out of the 35 beds were available for patient admission. This indirectly drove up the average cost of ward admission in UMMC. With the staff reshuffling that followed after the study period, the new ward was able to operate at a more optimum efficiency.

In terms of hospital status, UMMC is the only university hospital in our study. While all the 5 cardiac centres provided cardiology training for doctors undergoing specialty training, UMMC is the only teaching hospital in our study. The difference being that, teaching hospitals, or sometimes known as university hospital, generally refer to tertiary care centre in a major city and are affiliated with a medical school for undergraduate and postgraduate training. These teaching hospitals often have with a large academic department and a reputation for excellence in research.

Due to their involvement in teaching and research activities, university teaching hospitals often have greater resource intensity and consequently higher cost of patient care (Rosko, 2004). For example, a Swiss study showed the cost per diem of hospital care in a university hospital was tripled that of a smaller non-teaching hospital (Bramkamp et al., 2007). Several reasons may explain the higher cost of operation in university hospitals such as the severity of diagnosis and patient characteristics presented there (Iezzoni et al., 1990). As patients are generally sicker on average, they would require longer hospital stay, thus consuming more resources. It could also be postulated that university hospitals tend to perform more intensive treatment and utilize more advanced medical equipment. Furthermore, as a referral centre, teaching hospitals need to maintain excess capacity to accommodate a variety of specialized services. The variation of patient and treatment characteristics between centres will be further examined in section 6.3.

6.2.2 Cardiac stents as the Dominant Cost Driver

For the purpose of resource utilization review and budget allocation, it is inherently important to determine the component with the greatest impact on the cost of PCI service. From the literature, the cost drivers differ amongst country. For example, the catheterization laboratory time cost in United States and France had a significant impact on the cost of PCI (Lecomte et al., 2001). Another Italian study found the hospital costs of PCI patient to be 8,992 euros. From this cost, procedural cost that was inclusive of mainly PCI consumable cost and to a lesser extent, cardiac catheterization laboratory cost, accounted for 61.4% of the total cost (Varani, Balducelli, Vecchi, Aquilina, & Maresta, 2007). This was concurred by another study in Italy that reported the greatest use of resources for a patient who undergoes an angioplasty procedure during hospitalization was from the cost of the procedures itself (Manari et al., 2007).

However, this was not the case in Japan, in which the main cost driver for PCI came from higher cost of catheter as shown in an earlier study (Chino, Sakamoto, Sasaki, &

Isshiki, 2004). This was similar to our finding. In our study, a closer scrutiny on the breakdown of average hospitalization cost showed that the major contributor towards the cost of PCI procedure was the cost of PCI consumable, or more specifically the cardiac stents inserted during the procedure. This result was universal across all the 5 cardiac centres.

Among the 4 main categories of stents, drug-eluting stent (DES) was the most preferred stent type across all centres. For all the 5 centres, the proportion of DES usage was more than 50% of the total stents used. By comparison, the usage of bio-absorbable vascular scaffold (BVS) was minimal in all centres, likely resulted from the hefty cost of BVS. Generally speaking, the cost of stent was the highest for BVS, followed by DES and drug-eluting balloon (DEB). Bare metal stent (BMS) has the lowest cost range. While the exact cost of each type of stent may differ across the centres, this cost trend was similar at all centres.

In reviewing the literature, there is a large difference in the costs between stents. In the United States, the costs of DES and BMS are $2700-2900 and $800-900 per stent respectively; making DES about 3 times as expensive as BMS (Bakhai et al., 2006; Cohen et al., 2004). In a Korean study, the cost difference between DES and BMS was less profound, whereby DES was only 21.2% more expensive than BMS (S. Lee, Baek, & Chun, 2014). Based on our study, by taking the average price of stents at all the centres, the price of DES was about 2.5-3 times that of BMS in our study. Among all the centres, PGH recorded the highest proportion of DES stent usage. This invariably led 20-30% higher PCI consumable costs in PGH compared to the remaining centres.

Some literature had reported the effect of stent cost on the overall procedural cost of PCI. Two Italian studies published in the early 2000s economically appraised the cost of angioplasty procedures based on the types of stents inserted. In the first study, it was found that the hospital costs incurred for angioplasty using DES were not covered sufficiently under the reimbursement back then, as compared to plain old balloon angioplasty and bare metal stents (Manari et al., 2007). Another study analyzed the cost of PCI with DES separately for patients with single vessel disease and multi-vessel disease (MVD). The result showed that the cost of multi-vessel PCI with multiple DES was 40% above the reimbursement level (Varani et al., 2007).

The higher costs of newer generation stents have been the major deterrent towards widespread uptake of DES and BVS in the earlier stage. However, in a more recent study, clinical and economic outcomes of PCI before and after DES introduction were compared. It was revealed that despite of the higher initial acquisition cost of DES, overall costs over the long term were more favourable (Rihal et al., 2010). This highlighted the importance of cost analysis in terms of setting short-term and long-term budget allocation in any healthcare system.

In certain countries, other factors contributing towards substantial differences included types of payer. In United States, PCI patients under private insurance scheme were significantly more likely to receive DES compared to patients with Medicaid or without insurance (Epstein, Ketcham, Rathore, & Groeneveld, 2012). In countries with different health financing system from the United States, the ownership types of hospital may have a role to play in the selection of stent. One study specifically pointed out that public hospitals adopted DES more selectively and less readily than private hospitals (Grilli, Guastaroba, & Taroni, 2007). We cannot draw the same conclusion, as we did not include any private hospitals in our study. However, based on the comparison between public centres and corporatized centres, there did not seem to be an obvious variation in the usage of DES among patients undergoing elective PCI. In fact, the highest proportion of DES usage in our study was recorded in PGH, a public hospital.

The purchasing price of cardiac stents is the major determinant of the consumable cost and subsequently the total hospitalization cost. Cardiovascular medical devices are often traded at different prices worldwide. In certain countries, it is extremely difficult to obtain information on market prices of medical devices, which are highly confidential for each medical institution. All the private centres approached during the site recruitment cited confidentiality issue with financial data sharing as the main reason of non-participation in this cost analysis. The 5 public cardiac centres that participated agreed only for the stent cost to be used for compilation of final costs, and not for the individual stent cost to be published.

At present, the acquisition price of the stents differed between centres, as there is no central purchasing agency of PCI consumable in Malaysia. Thus the unit costs of PCI stents were not standard across all centres. Purchasing price may be different even for the same brand of stents by the same manufacturing company. This issue of non-standardized medical device procurement practice is rampant in LMIC.

For any nations, medical devices and equipment are vital in the provision of a high quality healthcare. They should be readily available, accessible and affordable for healthcare facilities, their staff and national governments (World Health Organization, 2012). In most of the high-income countries, device and consumable acquisition is guided by principles of quality care delivery and value for money to ensure containment of rising healthcare costs (Diaconu, Chen, Manaseki-Holland, Cummins, & Lilford, 2014). Decision-making is based on clinical and cost effectiveness evidence, as well as value-based criteria such as equity (World Health Organization, 2010).

On the contrary, strategic use of contracting practices in public procurement of health commodities has not received much attention from the government of most developing countries (Arney, Yadav, Miller, & Wilkerson, 2014). Certain developed countries are not spared of this problem too. For example, cost of cardiovascular devices in Japan had been particularly high. Comparison with the United States showed high price disparities. The market price ratio ranged from 1.2-1.4 for DES, 1.6-2.4 for non-DES and 4.1-5.1 for catheters (Ide, Yasunaga, Imamura, & Ohe, 2007; Yasunaga, Ide, & Imamura, 2007). Apart from the regulation of parallel imports and protectionism under the Japanese Pharmaceutical Affairs Law resulting in higher price range, the other reason was related to the fact that cardiologists at each medical institution individually purchase medicines or medical devices. As a result, business approaches like group purchasing are rare, thus they lack bargaining powers to negotiate for lower purchasing price from the providers (Chino et al., 2004; Kuroda et al., 2003).

In view of its high acquisition cost, the purchase of PCI consumable such as wires, balloons, catheters and stents should undergo continuous and vigorous negotiation via competitive bidding processes (Moscucci et al., 2003). A viable option to control the consumable costs is to consider collaborative purchasing arrangement or centralized procurement scheme. The consumables can then be distributed accordingly to individual centres. A report released by the NHS in England showed that discounts of 10-20% are possible of cardiac devices if the regional health foundation trusts joined together and engage with the market more effectively (National Audit Office, 2011). Bulk purchasing via a group-purchasing organization may render greater negotiation power in terms of pricing, leading to large discounts. This may eventually deliver cost reductions and annual savings.

To further dissect this issue from local standpoint, it should be noted that general consumable items such as branula, needles, gloves etc. are supplied via a central procurement agency to public hospitals in Malaysia. As for specific consumables such as medical devices, current government policy allows hospitals the freedom to manage their operations with minimal intervention from central government. Hospitals and the respective specialty departments are free to buy directly from supplier. This approach was expected to encourage innovation and improvement in the efficiency of services. However, this has led to widely varying unit cost for the same consumable item, such as the stent cost as in this study.

In the past few years, funds allocated to individual public cardiac centres for the procurement of PCI consumable was often depleted before the end of the financial year, leading to disruption in service. In a resource-constrained setting with limited financial capabilities like most LMIC, medical device procurement and prioritization methods is particularly vital. While this study did not provide a comparative analysis between different procurement practices at the study centres, we believe that current procurement process of PCI consumable should be reviewed to ensure greater value-for-money without compromising the flexibility and responsiveness in ordering and delivery. This is crucial to ensure a smooth delivery of service to patients all year long.

6.2.3 Role of Day-care Facility

In this study, CW admission was designated as one of the units of analysis. Among all the centres, the CW admission cost was the lowest in PJHUS, notably because of the availability of day-care facility. This was also partly the reason PJHUS recorded the lowest total hospitalization cost among the 5 cardiac centres. On the contrary, the day-care centre in PGH and IJN were not fully utilized for patients who underwent elective PCI. The ward admission cost and overall hospitalization cost would have been lower at these centres if there had been wider practice of same-day discharge and increased utilization of day-care centres.

Literatures abound on the cost saving effect of same-day discharge for PCI patients (Evans et al., 2007; Gilchrist, 2014; Rinfret et al., 2010). Many previous studies have stated that same-day discharge may represent an important cost-saving strategy for both hospitals and society. Reduction of LOS leads to less consumption of hospital resource per patient and the release of resources to benefit other patients and eventual cost savings as a whole. From a published study, it was postulated that if half of the patients undergoing PCI in the United States were to be discharged on the same day, it would result in a potential economic savings between $200 million and $500 million per year (Gilchrist, 2014).

Although reducing hospital stay plays an important role in reducing overall healthcare costs, this strategy must be adopted without compromising patient safety. Several studies have looked at the feasibility and safety of discharging patients to their home after PCI. Same-day discharge strategy was supported by findings reported in other studies conducted in Canada and the Netherlands (Bertrand et al., 2006; Heyde et al., 2007; Popescu & Weintraub, 2010). Another study from United States reached the same conclusion that selected low-risk patients who underwent elective PCI may be considered for same-day discharge, as there was no significant increased risk for death or readmission (Rao et al., 2011).

A meta-analysis of 12,803 patients, most of whom underwent elective PCI, concluded that same-day discharge in selected patients was associated with a low rate of major complications almost comparable to routine overnight observation (Brayton, Patel, Stave, de Lemos, & Kumbhani, 2013). In another systematic review consisting of 13 studies and 111,830 patients, same-day discharge after uncomplicated PCI was found to be reasonable in selected patients with low risk (Abdelaal et al., 2013).

To establish a same-day discharge strategy, a pathway and protocol needs to be in place, as well as patient education. A recent review recommended a post-procedural observation period of 4-6 hours to be reasonable for low-risk patients, as the likelihood of complication beyond 6 hours is extremely low. By establishing the necessary guidelines at cardiac centres, same-day discharge for PCI patients can potentially improve patient satisfaction, increase bed availability, and bring down hospital costs without compromising patient safety (Shroff, Kupfer, Gilchrist, & et al., 2016)

Despite evidence showing the feasibility and safety of same-day discharge, it is still not a standard practice in many PCI centres. This may be related to reluctance on the part of cardiologists, because of ingrained practice patterns, learning curve associated with new approaches and safety concerns over early PCI complications (Contos, 2016).

Besides that, social and logistical reasons are other main obstacles towards same day discharge. It is imperative that patients must have a social support network at home, and professional healthcare services should be within easy reach in the event of unexpected complication. While the distance limitations in most guidelines are arbitrary, cardiac centres in less urbanized areas would see more patients been kept overnight after PCI, as they are likely to reside in areas with a substantial distance from the cardiac centres. This was observed in QE2, one of the cardiac centres in this study.

Furthermore, it is important to note that while resource and monetary savings are made from the perspective of healthcare providers, the burden indirectly shifted towards societal perspective. Thus, the additional costs to patients and caretakers need to be taken into account too. With these in mind, further research in our local setting need to be carried out to study the feasibility of establishing large-scale day-care service.

6.2.4 Labour Cost of Healthcare Workers

For both CW admission and CL utilization, labour cost was found to be a major contributor towards the total cost. However, a closer examination revealed the rankings of average labour cost under these two units of analysis was different based on the location of the centres. Under CW admission, the two East Malaysian centres, namely QE2 in Sabah and PJHUS in Sarawak, recorded the first and third highest labour costs. Hospital cost analyses have shown that certain cost categories may vary across regions depending on underlying cost differences among regions, either between countries or within countries for hospitals in urban or rural locations. For example, a multi-country cost analysis in Europe found that lower wages of the clinical staff in Hungary, Poland,

and Spain led to lower hospitalization costs for patients admitted for AMI when compared to West European countries such as Germany and France (Tiemann, 2008).

This exogenous price-level effect can be observed in this study, albeit with an opposite effect. In Malaysia, extra stipends known as ‘hardship allowance’ are reimbursed for healthcare workers stationed in Sabah and Sarawak, in an effort to attract more healthcare professionals from Peninsular Malaysia to work in the more distant and less urbanized East Malaysia. A healthcare worker in Sabah or Sarawak may earn a higher monthly salary in comparison to his or her counterparts of the same grade and years of working experience in the Peninsular Malaysia. As a result, this drives up the total labour cost in the two East Malaysian centres in our study. This is especially prominent in QE2, which recorded the highest labour cost in the CW admission category among all the cardiac centres.

However, under the next unit of analysis of CL utilization, higher labour cost was recorded at the cardiac centres in the Peninsular Malaysia. IJN topped the list, followed by UMMC and PGH. It has often been observed that within countries, the distribution of healthcare workers varies by locality. There is typically a higher density of health workers in urban areas because of better standards of living compared with rural regions (World Health Organization, 2006). This is especially evident in the distribution of cardiologists in Malaysia. Majority of the cardiology workforce are concentrated in the bigger cities especially in the west coast of Peninsular Malaysia, with the highest density of cardiologists per capita being found in Klang Valley and Penang (National Healthcare Statistics Initiative, 2015). Using this information, it can be projected to show that study centres in Peninsular Malaysia have more cardiologists in employment, thus accounting for the higher labour costs under the unit of analysis of CL utilization.

While a study in rural Tanzania pointed out increasing the number of health workers did not necessarily reduce the workload or improve the quality of health services (Maestad, Torsvik, & Aakvik, 2010), our study portrayed a slightly different scenario. Based on the ratio of the number of PCI procedures to the number of interventional cardiologist at each centre, the two East Malaysian centres had 2 to 3 times the workload compared to their counterparts in West Malaysia. Another implication from this finding was that the lack of trained staff, especially interventional cardiologists, would render capital assets of catheterization laboratory that are already in place to be under-utilized. Furthermore, in the event that the solo interventional cardiologist becomes unavailable, visiting specialists need to be flown over from Peninsular Malaysia and this represents hidden cost not accounted in this study.

Despite having an exponential increase in the number of cardiologists over the past 20 years, 78.5% of the total 247 registered cardiologists in the country in year 2012 were based in private hospitals (National Healthcare Statistics Initiative, 2015). At present, the recruitment and training of cardiologists are taking place at a much slower rate if compared to the resignation of cardiologists from the government service to join the private sectors. This 'internal brain drain' of health professionals from public hospitals to private centres has plagued many countries in South East Asia (Kanchanachitra et al., 2011). The loss in the expertise may disrupt the continuous skill and service development in public hospitals, making it harder to sustain quality service delivery. Furthermore, mal-distribution of healthcare workers often results in a shortage of medical staff in rural public hospitals.

To prevent massive migration of skilled healthcare workers to private sectors, the government has taken several steps. Apart from the current incentive of extra allowances for serving in rural areas, more effective and integrated measures need to be formulated. Favourable working condition, fairness in future career development, continuous medical education and social recognition are a few other non-financial incentives that should be implemented.

One of the initial objectives of establishing IJN as a corporatized centre was to curb the migration of cardiologists to the private sectors. This strategy has been successful to a certain extent in retaining some of the specialists. In a newspaper review, it was reported that as a result of higher wages and better work benefits, the centre has a considerably low staff turnover rate of 3% annually and 75% of the consultants have been attached with IJN for more than 10 years. This enables a seamless service provision and manpower training ("IJN doctors: Don't make us scapegoats," 2008). However, this comes at a higher cost, as shown by the higher overall hospitalization cost for PCI procedures in IJN compared to other centres. While the IJN model has proven to be rather effective in retaining doctors in the public sector, whether corporatization of Malaysian public healthcare centres is more cost effective from the perspective of long-term health economics is not within the scope of this study and remains an interesting subject of future research.

In short, the average cost reported for each cardiac centre provides a good reflection of the general practice, resource utilization and costs of elective PCI in the public cardiac centres in Malaysia. We were able to calculate the total costs and identify the differences in costs based on hospital factors such as region, location, teaching status and manpower. In the effort to ensure economic stability within cardiac centres, several recommendations were made towards the viable cost saving strategies. This is important towards the allocation of substantial budget to safeguard the quality of care and sustainability of the cardiology service.

6.3 Individual Patient Characteristics and Hospitalization Cost

The average costs of PCI hospitalization and its cost items enable a baseline comparison in terms of resource utilization and costs of PCI between the cardiac centres. Using the unit cost derived from the calculation in Chapter 4, mixed method was applied to obtain individual patient-level cost. In Chapter 5, the results of individual patient analysis in terms of clinical, treatment and cost characteristics of elective PCI were presented. This enabled a more detailed cost comparison between patients at the various cardiac centres. Furthermore, regression models were used to identify a number of variables associated with length of stay and cost of hospitalization for PCI procedures.

6.3.1 Clinical Characteristics of PCI Patients

This thesis presents an opportunity to examine the variation in characteristics of patients undergoing elective PCI across various cardiac centres in Malaysia. From the NCVD-PCI Registry, the characteristics of the patients who underwent elective PCI in our country can be compared with other similar registries. However, cardiac registries, or more specifically PCI registries around the world varied in their patient population. This may be due to the inclusion criteria for the registry itself, or the indications for PCI in each individual country. In view of that, researchers have called for cross-country collaboration using pooled data in a central registry to enable a more objective comparison on patient and procedural characteristics with associated clinical outcomes for benchmarking of quality performance (Reid et al., 2014).

In this section, we described the similarities and differences in patient clinical characteristics such as socio-demographic, comorbidities, cardiac history and cardiac status between our study and findings from other relevant registries. The mean age of our patients was 58.7 years, which was much younger than mean age of 64.6 years among patients in an Australian PCI Registry (Ajani et al., 2006), but quite comparable to 55.0 years from an Egyptian Angioplasty Registry (El Nagger, Moharam, Taima, & Kamel, 2011). Age has been a strong predictor of outcomes in CAD patients. Certain studies have shown that elderly patients face higher risk of mortality and complications, and possibly higher cost of hospitalization (Bauer et al., 2011). In our study, the highest mean age of patients was recorded in UMMC but the proportion of elderly patients above 60 years old was not statistically different between all the centres.

Similar to most other studies, the preponderance of male PCI patients was detected across all centres in our study. Gender composition showed low proportion of female patients (18.3%). The lower proportion of female patients was also reported in other published registry data, whereby females accounted for only 25-34% patients of the total patients who underwent PCI (Ajani et al., 2006; Anderson et al., 2002). A possible explanation for this is the higher post-procedural risk of complications in women, thus making conservative, non-invasive medical treatment a more preferred option (Fihn et al., 2012). Using data earlier data in year 2007-2009 in NCVD-PCI Registry, it was reported that not only were there less female patients by 1:4 ratio compared to males, women who underwent PCI were also older with more co-morbidities (C. Y. Lee et al., 2013). One of the reasons for this might be the surge in the incidence of CAD commonly seen in postmenopausal women, thus leading to symptom presentation at a later age and worse disease severity in females compared to males (Dosi, Bhatt, Shah, & Patell, 2014).

As a multi-racial and multi-cultural country, Malaysia's population of 30.3 million people consists of 50.3% of Malays, 21.8% of Chinese, and 6.5% of Indian. Other ethnicities such as Iban, Kadazan, Melanau and other aboriginal people represent 11.8% of the total population. However, population in East Malaysia was of the opposite ethnicity distribution, with majority of them (50.9%) being 'Other', followed by 14.7% and 14.4% of Chinese and Malay respectively (Department of Statistics, 2014).

Underlying population ethnicity distribution is often reflected in the patient population. For example, a single-centre registry in Singapore, over half of the patients were of Chinese ethnicity (Koh et al., 2011), closely mirroring the ethnicity distribution in Singapore. Similarly, in this study, about half of the patients in our study were Malays. As for the 2 cardiac centres in East Malaysia, the demography of the patients was significantly different from Peninsular Malaysia. The proportion of Malay, Chinese and Indian combined are considerably smaller in East Malaysia. The distribution of higher proportion of other ethnicities in PJHUS and QE2 was in accordance with the ethnic group distribution in East Malaysia.

Nevertheless, there appeared to be an over-representation of Indian patients in our registry if compared to the national population. The possible reasons were discussed in an earlier paper that detected similar over representation of Indian patients among the NCVD-ACS Registry cohort (Lu & Nordin, 2013). Previous cross sectional surveys had showed that people of South Asian origin from the region of India, Sri Lanka, Bangladesh and Pakistan had higher risk of CAD and its associated morbidity and mortality (P. Joshi et al., 2007; J. Lee et al., 2001). This provided a plausible reason to our observation.

There has been published evidence on ethnicity differences in outcomes following PCI among patients with CAD. However, the studies yielded conflicting results. No differences in mortality following PCI were observed between South Asian and White patients (Jones et al., 2012; Toor et al., 2011). Another study found Chinese and South Asian patients had worse outcomes following PCI for CAD (Gasevic et al., 2013), whereas another study published the opposite results in which higher mortality following PCI were recorded among patients of Western European origin compared to Asian patients in Singapore, Hong Kong and Malaysia (Klomp et al., 2012). In our study, the number of in-hospital mortality and other PCI-related complications were very low to be able to ascertain any significant association with the ethnicity.

Apart from non-modifiable factors, known cardiovascular risk factors such as diabetes and smoking have been associated with poorer outcomes and higher cost of managing CAD. Among patients undergoing elective PCI, increasing BMI was associated with higher risk of procedural complications (Ramirez 2015). In our study, every one in two patients had at least one of the components of metabolic syndrome; namely obesity (65.6%), hypertension (71.0%), and dyslipidaemia (68.4%).

Despite including only patients who underwent elective PCI, the risk factor profile among our patients were comparable with patients from registries that included both elective and emergency PCI patients. In the Singapore registry, prevalence of hypertension, dyslipidaemia, diabetes, and smoking history were at 65.0%, 78.0%, 33.0% and 43.0% respectively (Koh et al., 2011). In contrast, an Australian registry recorded lower rates of diabetes (24.0%) and smokers (22.5%) (Yan et al., 2009).

Many other studies concurred with the same findings that Asian patients with CAD tend to be younger, having a higher rate of hyperlipidaemia and diabetes than their Western counterparts (Klomp et al., 2012; Nguyen, Fujiyoshi, Abbott, & Miura, 2013; Ong, Zeymer, Waliszewski, Tan, & Ho, 2014; Reid et al., 2014; Woodward et al., 2003). This calls for serious attention, as Asian patients would be at a higher risk of developing cardiovascular-related complications at a younger age, leading to substantial socio-economic burden.

Different risk factor profiles may exist in sub-population from geographically distinct areas in the same country. For example, evident variations in cardiovascular risk profiles were reported between southern and northern populations of China (Gu et al., 2005) and among cities of United States (Jarvie et al., 2011). In Malaysia, the cardiovascular risk profile variation and distribution was reported in a paper published in 2012. In the study, the prevalence of cardiovascular risk factor clustering varied across the states. The numbers range from the lowest of 31.9 % in Sabah to the highest of 51.1% in Kedah and 60.1% in Perlis. Overall, the states in northern Peninsular Malaysia showed an overall higher prevalence of clustering (Nuur Amalina, Jamaiyah, & Selvarajah, 2012). This finding was reflected in our study, whereby PGH, as the referral centre in the Northern region, recorded the highest proportion of patients with hypertension, diabetes, dyslipidaemia and smoking history. As for the remaining risk factors of CAD such as cerebrovascular disease, peripheral vascular disease and chronic renal failure, the overall prevalence among our study population was low. This could be attributed to the lower age of our patients and the elective status of PCI procedure.

Apart from that, cardiac status of patients may also affect the LOS and subsequently the cost of PCI procedures. Among the 2260 patients who underwent elective PCI in this study, almost half had documented CAD, and about 1 in 3 had a previous myocardial infarction. However, the number patients with previous CABG or PCI were relatively low. This could be attributed to the fact that these previous episodes were either controlled medically or treated with pharmacological thrombolysis. Other possible reasons for this difference are availability of medical care facilities and health-seeking awareness. UMMC and IJN are located in the heart of the Klang Valley. This region is considered the most economically developed and urbanized area in the country and has a higher density of medical centres within easy reach for the public. Among patients who presented to UMMC and IJN, a higher proportion of those with previous MI had undergone previous PCI or CABG. On the contrary, patients in QE2 and PJHUS recorded higher incidence of previous MI. However, relatively low proportion of patients from these 2 centres had undergone previous cardiac interventions in terms of PCI or CABG.

At presentation, majority of the patients reported the lowest symptom severity on NYHA and CCS. Low proportion of patients had acute coronary syndrome (ACS). In other words, the patients in our study predominantly had stable CAD. In comparison with ACS, mortality rates among stable CAD patients range between 1% and 3%, while rates of non-fatal events are 1–2% annually (Morrow, 2010). In other published registry reports that included both elective and emergency PCI procedures, unstable angina (classified under ACS) was the most prominent indication to undergo PCI. The figure was as high as 61.4% in ECDAR and 62.0% in ACC-NCDR (Ajani et al., 2006; El Nagger et al., 2011).

6.3.2 Treatment Characteristics of PCI Patients

There are 3 types of vascular access for PCI procedure. Brachial access is seldom attempted. Radial access was more preferable in view of lower bleeding risk and shorter recovery period post-PCI. Our analysis also revealed significant preference for the radial access site. In many studies, radial access was associated with lower vascular and bleeding complication rates and also decreased risk of mortality (Agostoni et al., 2004; Baker et al., 2014; Karrowni et al., 2013). Based on a meta-analysis comparing radial and femoral access for patients with ACS, radial access led to reduction in cardiac and safety endpoints in both urgent and elective procedures (Ruiz-Rodriguez, Asfour, Lolay, Ziada, & Abdel-Latif, 2016). By way of reducing vascular complications, early mobilization, and enhanced patient comfort, patients with radial access for PCI are good candidate for same-day discharge.

However, gaining radial access requires higher technical skills. Major adverse cardiovascular events and bleeding are lowest with the radial approach when performed by experienced radial operators at high-volume radial centres (Nathan & Rao, 2012). In our study, radial access was the most popular percutaneous entry point at 4 out of 5 of the cardiac centres. However, there appeared to be no significant difference between the patients with long or short hospitalization period in terms of percutaneous access. Nevertheless, it was difficult to ascertain if patients with radial access in our study were associated with same-day discharge, as only PJHUS provided day-care service for PCI patients at the time of study.

Of the 4 main coronary artery systems, left anterior descending (LAD) vessel was the most commonly diseased vessel among our patients, followed by right coronary artery (RCA). This is in concordance with the common findings of vessel distribution among stable CAD patients (Ong et al., 2014). Apart from this, the number and distribution of diseased vessels can also impact on the choice of treatment and survival outcomes. Based on the number of diseased vessels, CAD patients can be classified as having single vessel disease (SVD) or multi-vessel disease (MVD). MVD patients have stenosis of ≥50% in at least 2 of the 3 major epicardial coronary arteries. In this study, SVD patients outnumbered MVD patients by a ratio of 2:1. This could be attributed to the fact that some patients with MVD in the registry might have undergone emergency PCI or other treatment modalities, such as CABG or pharmacological thrombolysis.

Overall, approximately half the patients in our study had more than one lesion treated during the procedure. The highest number of lesions treated in the same patients was 7 lesions. The number of lesions treated often reflected the number of stents inserted, which in this study ranged from 0 to 7. The highest mean number of stents inserted per patients was recorded in PGH. In a small number of patients, no stent was inserted. This procedure is known as plain old balloon angioplasty (POBA), whereby the balloon catheter was used to compress the atheromatous plaque in the diseased vessel. This could occur in situation whereby the stents could not be delivered across a lesion that are highly calcified or lesions that were located in very small vessels. All the centres in our study conducted a small number of POBA, except PGH which conducted none.

Among the different types of stents inserted, DES was the clear favourite at all centres. According to an international guideline, barring any contraindications of prolonged dual anti-platelet therapy, all patients with stable CAD should have DES insertion during

PCI (Montalescot et al., 2013). By comparison, the overall usage of BMS, DEB, and BVS were much lower. The high cost of BVS was likely the main limiting factor on the use of BVS. The impact of stent cost on the overall hospitalization cost had been discussed in previous section on average hospitalization cost.

Apart from the cost factor, there are other reasons associated with stent selection in a PCI procedure. While patients generally receive the most optimal stent based on the latest clinical practice guidelines, the decision may depend on the operator preference (Tu et al., 2012) and the availability and supply at the cardiac centre (Austin et al., 2008). A closer examination of our results showed that PJHUS has the highest usage of BMS and rather low DES usage compared to the remaining centres. The opposite pattern was observed in PGH, whereby the highest proportion was DES usage was recorded. As there was no standard indication for the choice of stent locally, these differences may be related to local guidelines or policy, funding requirements, or operator selection. Despite evidence on clinical and cost superiority of DES, BMS remains an important option for patients with increased risk of bleeding, those contraindicated for longer duration of anti-platelet therapy, and also more importantly, for patients who cannot afford the price of more expensive stents (Morice, Urban, Greene, Schuler, & Chevalier, 2013). It would be interesting if further casemix-adjusted analysis could be conducted to analyze if any of the above-mentioned reasons lead to the difference in the proportion of stent usage between the cardiac centres.

The associations between angiographic characteristics of the stenosis with LOS and hospitalization cost have also been studied. The procedural complexity for PCI would increase when unfavourable anatomy such as chronic total occlusions, calcified lesion, bifurcation and diffusely diseased small vessels are present. Another classification of angiographic lesions is based on American College of Cardiology/ American Heart Association system. The risk level is categorized into type A, B1, B2, and C based on size, eccentricity, tortuosity, angulation, and calcification of the lesion. Type B2 and C are grouped as complex lesions (Smith et al., 2001). It is known to be a good system to predict angiographic success in a PCI; whereby type A is low risk lesion with a high success rate above 85%, as compared to type C which carries a high risk with less than 60% success rate (Singh, Rihal, Lennon, Garratt, & Holmes, 2004).

The presence of complex lesion and high-risk lesion characteristics has been associated with higher complication and mortality rates among patients undergoing PCI (Endo et al., 2015; Wilensky et al., 2002). However, only less than 10% of patients in our study had these high-risk lesion features. A high proportion of patients in this study were of type C lesion. Despite so, the overall revascularization success rate was high. Revascularization success was achieved in 96.9% of cases. Even though the difference was not significant, the rate of unsuccessful outcomes was higher in IJN and UMMC. This might be attributed to the fact that patients from these 2 centres had worse comorbidities and higher number of lesions requiring revascularization.

Overall, in-hospital complication and mortality rates were low. While it appeared that the 2 centres in East Malaysia had a higher rate of in-hospital mortality post-PCI, the complication and mortality rates were too low and thus underpowered to draw any valid association among the patients in this study. In this study, only short-term in-hospital outcomes were available from the registry data. With the advent of safer interventional technology and newer anti-platelet pharmacological treatment, the short-term and long-term outcomes of PCI have increased tremendously in recent years. Long-term follow up study would provide better insight for the cost and benefits of PCI.

6.3.3 Length of Stay and Hospitalization Cost of PCI Patients

As with many other diseases and clinical procedures, patients with longer hospitalization often incur higher cost of hospitalization. In our study, regression analysis showed long hospital stay to be an independent predictor of total hospitalization cost in this study. Apart from the self-explanatory higher cost of ward admission, patients with long hospital stay also recorded higher costs under the PCI consumable and CL utilization. Therefore, it is vital to identify factors that lead to long hospital stay among patients undergoing PCI.

There are many factors contributing towards the LOS and the hospitalization cost. Different studies in the literature have detected a number of patient and treatment characteristics causing prolong hospitalization. However, direct comparison may not be an accurate reflection due to the underlying variation in hospital policy and physician preferences in different countries.

Most published literature focused on identifying predictors of hospital stay among patients with AMI who underwent primary PCI, rather than elective PCI. In a real life analysis of determinants of costs and length of stay in patients with ACS, gender and age were strong predictors of high costs of hospital care (Bramkamp et al., 2007). However, neither age nor gender turned out to be significant predictors for LOS and hospitalization cost in the multivariate analysis of our study. This could be due to the variation in the patient population whereby our study consisted of more patients with stable CAD than ACS.

Apart from non-modifiable variables such as age and gender, patients' comorbidities also impact on the eventual cost of CAD management. In a recent study on CAD patients who underwent primary PCI, diabetes mellitus and MVD were independent predictors of LOS (Karabulut, Cakmak, Uzunlar, & Bilici, 2011). Another study showed that elderly patients, female sex, patients with MI history, heart failure on admission had longer hospital stay (Schellings et al., 2011). In terms of cost, diabetic patients often incurred a higher hospital cost, as a result of longer LOS and increased resource utilization (Bramkamp et al., 2007; Straka, Liu, Girase, DeLorenzo, & Chapman, 2009).

Among elective PCI patients in our study, several clinical characteristics were found to be significantly associated with long hospital stay. However, only smoking history remained a significant predictor in the final regression model. It was interesting to note that patients who smoked previously or are currently smoking were more likely to have a short hospitalization period after PCI. This could be attributed to the phenomenon of "smoker's paradox" whereby PCI patients who smoked were found to have shorter average LOS, lower in-hospital mortality, and fewer complications than non-smokers (Gupta et al., 2016). However, this modest difference in terms of in-hospital outcomes should not be regarded as an advantage. Smoking cessation must continue to be a main promotive effort in reducing CVD.

In our study, patients diagnosed with ACS were 2.5 times more likely to have a long hospital stay compared to patients with stable CAD. This could explain the high proportion of patients with long hospital stay in QE2, seeing that QE2 recorded the highest proportion of patients with ACS. ACS was also a significant predictor of higher hospitalization cost, whereby patients with ACS were likely to incur RM 570 more if all other predictors were held constant.

In one of the earliest published paper on hospital cost analysis for PCI from the United States, the researchers reported that baseline patient clinical characteristics accounted for nearly half of the explained variance, while the remaining variation can be attributed to procedural-related characteristics (S. G. Ellis et al., 1995). Our study revealed the opposite finding, in which patients' clinical characteristics accounted for very minimal variation in the cost while treatment details such as lesion characteristics and stent usage explained for majority of the variation in total hospitalization costs.

Previously, most studies that reported the procedural costs of PCI were done within the context of RCT. In 2004, a Scottish study compared the real-life costs of PCI procedure at 2 hospitals. The results revealed that the centre that recorded a higher number of stents used and lesions treated had a higher procedural cost (Denvir et al., 2007). This concurred with our study whereby PGH, the centre with the highest number of stents inserted, recorded the highest mean cost of PCI procedure in cardiac catheterization laboratory. Furthermore, the number of lesions treated was a significant predictor of hospitalization cost among patients in our study. This is not unexpected as number of stents required would also be higher with higher number of lesions.

Since the late 1990s, the techniques, devices and concomitant medical therapy of PCI have improved tremendously. This resulted in lower procedure-related mortality and reduced need for emergency reintervention. However, this came at the expense of higher medical costs. Treatment costs are often heavily dependent on treatment strategies and the medical devices used. In a study, CAD patients were followed up for one year and the total medical care cost for each patient treated with elective coronary stenting was significantly higher than for POBA (Cohen et al., 1995). In other words, the cost of PCI would be lower without the use of stent. A more recent study in

Germany also indicated that treatment costs of PCI depended on the type of stent used: the use of BMS led to significant lower average routine care cost of AMI patients compared to DES (Baumler, Stargardt, Schreyogg, & Busse, 2012).

As discussed in Section 6.2.2, our study revealed that PCI consumable especially cardiac stents were the dominant cost drivers in all the cardiac centres. This finding was further strengthened by the multiple linear regression analysis with independent patient-level cost data. The number of stents inserted was an independent predictor of total hospitalization cost. This is especially true for BVS; the type of stents with the highest purchase cost at all the centres. Among all the centres, PGH recorded the highest number of stents inserted and the highest proportion of DES usage among all types of stents. It was also the centre with the lowest number of POBA. Thus, it is not surprising to find the PCI consumable costs to be the highest in PGH.

Besides stent usage, other treatment characteristics may have an impact on the LOS and hospitalization cost. Patients with right coronary artery (RCA) and left main stem stenosis (LMS) tend to have long hospital stay in this study. However, only LMS stenosis led to significant higher hospitalization cost. This can be explained by the fact that LMS stenosis often occurs as part of multi-vessel disease (MVD), and is associated with high-risk lesion characteristics such as bifurcation and calcification (Taggart et al., 2008). Both MVD and high-risk lesion characteristics may drive up the hospitalization cost. In an American study, patients with MVD were associated with higher LOS and cost of care as compared to single vessel disease (Arora et al., 2016). However, we did not reach the same result in our final regression analysis. Patients with MVD were not likely to have a long hospital stay or increased hospitalization cost in our study.

A Japanese study investigated if the characteristics of lesion can be used to predict medical resource use in PCI. The results revealed that total PCI cost was clearly stratified based on the ACC/AHA system, whereby the cost increased according to the order of type A, type B1, type B2, and type C lesions. High-risk characteristics including chronic total occlusion and bifurcation were also significant determinants of high cost (Sakakura, Ako, Wada, Kubo, & Momomura, 2012). In our study, the ACC/AHA classification system did not have any impact on patient hospitalization cost, but bifurcated lesion was found to be an independent predictor of hospitalization cost.

The outcomes of the PCI may also have an impact on the length of stay and hospitalization cost of patients. Some published studies have reported longer hospital stay among patients with unsuccessful procedure and complications (Isik, Ayhan, Uluganyan, Gunaydin, & Uyarel, 2015; Swaminathan et al., 2015). Nevertheless, there was no difference in terms of outcomes between patients with long and short hospital stay in this study, likely attributed to the fact only elective PCI procedures were taken into account. However, from our analysis, failed revascularization was a significant predictor of increased hospitalization cost.

An increase in operator and institutional volume of PCI was found to be associated with a decrease in adverse outcomes, LOS and cost of hospitalization. Many developed countries have published guidelines on the minimum number of annual procedures required for PCI institutions and operators to maintain optimal performance. In the United Kingdom, the British Cardiovascular Intervention Society (BCIS) recommended the minimum centre volume of > 400 interventional procedures per annum for both NHS and private hospitals (Banning et al., 2015). Whereas in the United States, the ACCF/AHA guidelines advocated that PCI operator in a high volume centre

(> 400 procedure/year) should perform at least 75 elective procedures and 36 primary PCI procedures for STEMI in a year (Levine et al., 2011).

In a nationwide study in United States, the primary and secondary outcomes of procedures performed by operators with >100 procedures annually were significantly lower when compared with those by operators of low volume of annual procedures. Similarly operators in the higher quartiles witnessed a significant reduction in LOS and cost of hospitalization (Badheka et al., 2014).

A meta-analysis on the same subject showed studies with larger sample sizes more often showed a relationship between operator volume and outcomes in PCI. Mortality and major adverse cardiac events increase as operator volumes decrease in the cardiac centres. However, the definition of high-volume operators varied with annual PCIs ranging from >11 to >270, with no clear evidence of a threshold effect within the ranges studied (Strom, Wimmer, Wasfy, Kennedy, & Yeh, 2014).

In this study, the disparity between the procedural volumes of the 5 cardiac centres was very wide. IJN recorded the highest volume of PCI procedures; at 3 times the volume of UMMC, and 6 times that of the remaining 3 public cardiac centres. However, no obvious relationship between caseloads and outcomes was detected in our study. With regard to complications and in-hospital mortality, there was no significant difference between the centres. The inclusion selection of patients who underwent elective PCI only in our study might be the reason behind this, as poorer outcomes are more common among emergency PCI.

With regard to the LOS, patients admitted to QE2, the centre with the lowest procedural volume in our study, recorded the longest hospitalization stay. The state of Sabah, where QE2 is located in, is comparatively less developed compared to the remaining states where the other centres are situated in. Due to the vast area and poorer connectivity in the state, patients in Sabah often face more severe logistical issues such as transportation and accommodation. Due to these social factors, some of them might be kept longer than medically necessary in the hospital. This highlighted the importance of taking into consideration such non-clinical factors when determining the feasibility of same-day discharge for PCI patients.

On the other hand, IJN, the centre with the highest procedural volumes, had the third longest mean hospitalization period among the centre. Apart from the small sample of centres in our study, another main explanation for this contrasting observation may be the fact that PJHUS, the centres with the lowest LOS was the only centre providing day-care facilities for PCI patients.

Among the 5 centres, the individual-level patient cost data revealed a wide range of total hospitalization cost between the centres, from RM 12,111 to RM 19,218. Overall, the cost at each centre was much higher than its corresponding average hospitalization cost obtained with top-down approach in Chapter 4. Furthermore, other differences emerged on closer scrutiny. The highest mean hospitalization cost was recorded among patients from QE2, followed by PGH. IJN and UMMC, the 2 centres with highest average hospitalization cost based on analysis in Chapter 4, ranked 3rd and 4th respectively. However, the hospitalization cost remained the lowest in PJHUS regardless of the costing approach applied.

Further analysis showed that the unit of analysis with the greatest discrepancy between these 2 costing approach was CW admission cost. This was not unexpected as the average hospitalization cost was computed with an average LOS of 3 days; whereas individual LOS data were applied to obtain the mean hospitalization cost. Among all the centres, QE2 recorded the highest mean LOS, thus leading to the skewed cost distribution. To enable a better comparison, separate analysis was conducted only for individual patients with short hospital stay (LOS$\leq$ 3 days). With that, the ranking of total hospitalization cost and the ward admission cost shifted to more resemblance with the result output computed with average hospitalization cost.

In short, individual patient-level data provided a better insight towards the disease and treatment profile of elective PCI patients at different cardiac centres in Malaysia. Patients with long hospital stay beyond 3 days led to significantly higher hospitalization cost. Without compromising safety and satisfaction, various strategies can be put in place in order to reduce admission days of PCI patients and utilization of hospital resources. Based on our findings, number and types of stents had a strong impact on the cost of PCI. This further emphasizes the need for efficient consumable purchasing mechanism.

6.4 Research Strength and Limitations

To the best of our knowledge, this was the first multi-centre cost analysis of cardiology service in Malaysia. With the participation of 5 cardiac centres from different regions, the results provided a diverse and comprehensive outlook on the resource utilization and cost of PCI in Malaysia. Furthermore, this thesis was strengthened by the nationwide coverage of study sites and robust clinical data of a relatively large sample size of patient population afforded by the NCVD-PCI Registry.

One of the valid concern was that the cost findings may not be nationally generalizable as hospitals in one region may not be representative of hospitals in other parts of the country. However, due to the similar organizational and financial structures of most public hospitals under the Ministry of Health, the limitation in term of generalizability is likely to be minimal.

Some of the unit cost of cost items showed obvious disparity between centres. This is a study limitation resulted from the potential bias arising from inherent differences in the financial record keeping between the centres. This may not be completely eliminated despite the best effort to standardise the data collection process, as shown in the derivation of consumable and medication costs. To obtain a more refined cost estimates, bottom-up micro costing method should be considered for these cost items in future studies.

The application of economic evaluation in routine clinical practice is not widespread in Malaysia. The lack of familiarity among the staff in healthcare facilities towards the conduct of cost analysis was a barrier. During data collection, there were circumstances of bureaucratic resistance towards parting with cost data of sensitive nature. Misperception of the costing exercise as a performance audit was another reason behind some of the staff reluctance to cooperate. As a result, the relationship between the enumerators and other hospital staff proved to be a vital factor towards a successful data collection. In several instances, site coordinators had to step in and used their discretion to ensure that complete data were provided. This highlighted the importance of ensuring access of transparent and quality cost data towards the successful implementation of a cost analysis.

Another limitation of this study was the possible selection bias due to the lack of involvement from the profit-oriented hospitals. Due to the sensitive nature of the financial data required, private for-profit healthcare centres were reluctant to participate. It would have been interesting to gain insight into the cost of PCI in private health sectors. With the imminent national healthcare transformation in Malaysia, inclusion of all the different healthcare providers can produce a more comprehensive guide the formulation of reimbursement regimens for healthcare providers.

It is unfortunate that cost incurred during pre-admission consultation and post-discharge follow-up were excluded from this study. This was due to the budget and resource constraints in the conduct of this study. Due to the poor follow-up rate in the NCVD registry, we did not include outcome data beyond the index hospitalization. The evaluation of long-term outcomes and associated costs is important in the implementation of a strategy to target patient suitable for same-day discharge. Inclusion of the costs from these two stages of healthcare delivery can perhaps be explored in future research.

Nevertheless, the key strengths of this study lie in the practical applications of its methodological contribution and cost findings. In this thesis, an alternative costing method was devised to overcome barriers in conducting a cost analysis in a LMIC like Malaysia. Modifications were made to existing economic evaluation guidelines based on local setting. Future studies can be built on this effort and like-minded researchers in other LMIC who wish to conduct similar studies can adapt this method to their respective country-specific settings.

PCI is the commonest interventional procedure conducted in most cardiac catheterization laboratory, and majority of the PCI in Malaysia are still conducted as an elective procedure. Another advantage of this research was the ability to present the pattern of patient, treatment and cost characteristics across various cardiac centres by using elective PCI as a proxy.

In addition to producing unit cost estimates per output along the clinical pathway, multiple cost items were aggregated to identify the cost drivers, both within and across the centres. The unit cost at multiple level of the care pathway can also be applied to economic evaluation such as cost effectiveness analysis. Furthermore, this study provided an overlook of cost predictors of cardiology service from the perspective of a multi-ethnic, middle-income developing country. All these are valuable information in the effort to improve resource and budget allocation.

6.5 Public Health Significance

This thesis provides a baseline analysis of the hospitalization cost and its predictors for elective PCI at 5 major cardiac centres in Malaysia. This information is critical for further health economic analysis. It also serves as important guidance in the decision-making regarding the development of cardiology service. Accurate and comprehensive cost data are critical in economic evaluations in healthcare to assist decision makers in ensuring that limited resources are allocated as efficiently as possible.

Universal coverage of healthcare to all citizens is a fundamental human right and a key step towards achieving the Millennium Development Goals. Malaysia has been lauded as a successful example in providing universal coverage at a relatively low cost compared to many other countries. However, with the demographic transition and aging population in the country, Malaysia is facing rising public expectations and increasing health expenditure. The current public healthcare system financing in Malaysia operates on an annual global budgeting manner. In the budget for 2014, the administration allocated RM22.1bn (US$6.9bn) to healthcare spending, out of total expenditure of RM217bn, representing over 10% of total government spending (Ministry of Finance Malaysia, 2014). Policy makers need to deliver an economically-efficient healthcare services without compromising the quality of services provided.

As discussed earlier, the major bulk of workload burden in Malaysia fell on the public healthcare system. Furthermore, public hospital services in Malaysia are heavily subsidized. User fees recoup only very small percentages of hospital costs. The long-term sustainability of the healthcare financing system in Malaysia has often been thrown into the limelight. This has prompted the government to look into alternatives to ensure sustainable financing in the future. Like many LMIC, Malaysia has been planning for a national health insurance system in the last decade. However, lack of robust and transparent evidence on healthcare utilization and cost pattern led to great skepticism and poor support among the public. The results from this study are beneficial in the planning of the government healthcare transformation system at the national level.

At this moment, we do not have adequate knowledge of the costs of procedures in most of our hospitals. In view of the current paucity of health economics data to guide health policy decision-making in the local setting, this procedure-specific cost information would be vital for optimal resource allocation and to ensure appropriate reimbursement of healthcare providers. The findings from this study shed light on pattern of resource utilization and cost incurred for a common low-risk intervention at different cardiac centres. Armed with the knowledge, policy makers will be better informed in the effort to formulate appropriate rate of reimbursement payment for different healthcare providers with the imminent national healthcare transformation in Malaysia.

At the hospital level, this study was able to provide comparative analysis of clinical management and costs of PCI among public cardiac centres to allow for identification of areas of improvement. Massive advancement in the interventional technology have transformed PCI into a routine cardiac procedure. In many countries, the availability of cardiac catheterization laboratory is viewed as a key quality indicator of the healthcare system. The ever-increasing prevalence of metabolic syndrome is likely to lead to more CAD among our population. With the increase in case volume and complexity, coupled with the adoption of new technology, it is an important societal imperative to reduce costs and to improve efficiency of expensive, frequently conducted medical procedures such as PCI.

Efficient cost management can be achieved through modifications of peri-procedural care pathway and consumable procurement practice. Based on this study, one of the major cost reduction strategies that should be taken in serious consideration would be the establishment of day-care centre for patients deemed suitable for same-day discharge. By conducting further research on social and logistical support in local setting, the safety protocol and discharge pathway can be put in place for elective PCI patients. Apart from PCI, the establishment and expansion of day-care service for same-day discharge can be slowly expanded to cardiac patients of other interventions, and also patients from other disciplines.

At all the participating cardiac centres, PCI consumable was the dominant cost driver. In the procurement of essential medicines and health commodities such as these PCI consumable, transparency and consistency are of particular importance. Affordable price and reliable supply of medical devices are crucial for quality health service delivery. A revamp in the current cardiac device procurement practice requires meticulous research and planning in several aspects, including that of national financing structures, stakeholder incentives and power relations. It should be done with the intention of ensuring maximum efficiency and increased value for money in the financing and tendering of medical consumable items.

In short, armed with this information, more evidence on capacity building and financial support can be rendered towards policy planning and service expansion of PCI service at both the national and hospital level. This would be beneficial at patient-level as the equity, accessibility, and affordability of the PCI service can be maintained to fulfil the growing needs of patients with CAD.

Lastly, we believe that many other LMIC face the same barriers in the efforts to conduct healthcare-related economic evaluations. Data availability and accessibility are often the major obstacles during the initial steps of cost analysis. To encourage the uptake of economic evaluation in such countries, costing methods that are applicable and relevant to LMIC settings must be devised. Therefore, this study could serve as a reference to facilitate the cost data collection and analysis for LMIC researchers who intend to conduct economic evaluations.

6.6 Recommendations for Future Research

Although our study is based only on elective PCI, the findings offer valuable insights into the cost of cardiology service delivery in Malaysia. It also provides the foundation for further work on similar topics. The result of this study can be applied as a secondary data source for economic evaluation of PCI such as cost effectiveness analysis and economic modeling purposes. Future research can be expanded to examine other types of cardiology service such as coronary artery bypass grafting and implantations of cardiac devices, and also other healthcare services from different specialties.

In this study, we focused on the cost of hospital care of patients during the index hospitalization episode, from the healthcare providers' perspective. While in-hospital treatment cost may account for a substantial portion of overall cost CAD care, pre-and post-PCI cost to the healthcare providers, patients and society may represent hidden economy burden. This is an important area for future research.

As medical therapy improves, CAD patients would survive longer. Thus, long-term clinical and cost outcomes of the patients are vital for future healthcare planning. Further research to study the trend and changes of the cost of PCI service over time can be conducted.

While this study compared the patient and cost profile at the participating cardiac centres, we did not take into account information related to quality of care and quality of life. Further economic evaluation such as cost benefit analysis and cost utility analysis would be informative. Continuous evaluation and research will be able to provide substantial, sustained and robust evidence towards improvement of the cardiology service in Malaysia.

CHAPTER 7: CONCLUSION

The disease and economic burden of coronary artery disease (CAD) is growing in many LMIC, including Malaysia. PCI is one of the preferred treatment modality for CAD due to its proven clinical effectiveness. Thus, it is widely performed as an elective procedure at local cardiac centres. Although extensive literature on economic evaluations of PCI are available from other countries, there is limited knowledge on the cost of PCI at the cardiac centres in Malaysia. Furthermore, cost drivers and cost predictors of the local PCI service are scarcely explored.

This thesis aimed to determine the treatment practice, resource utilization and cost of cardiac care provision at 5 Malaysian public cardiac centres. Among the different types of cardiac procedures, elective PCI was found to be a suitable starting point for this purpose, in view of its popularity and low heterogeneity among patients and providers.

In order to produce a valid cost output, the ascertainment of the PCI cost must be measured with a standard costing approach. Efforts were made to obtain reliable cost data within the limitations of the financial and clinical record-keeping system of our local healthcare system. By making necessary modification to international guidelines, this thesis illustrated that it is feasible to conduct a comprehensive cost analysis in a LMIC setting using a modified costing method.

The findings from this thesis provided an overview towards the variation in treatment practice and cost pattern for a common cardiac procedure in Malaysia. Using top-down costing approach, average hospitalization cost per elective PCI procedure with an average length of stay of 3 days ranged from RM 11,519 to RM 14,356 at the 5 centres. At all centres, cost of PCI consumable accounted for more than half of the total cost.

By incorporating bottom-up costing approach for selected cost items, individual-level patient cost was calculated. Mean hospitalization cost for all patients was highest in QE2, the centre with the longest mean length of stay. However, when including only the mean hospitalization cost of patients with short hospital stay, the results closely resembled the average hospitalization cost generated by top-down approach. Top-down approach can produce a fairly reliable cost estimates for patients who undergo hospital procedures with short length of stay. Individual-level patient data analysis revealed that high-risk lesion and stent usage were strong predictors of hospitalization cost.

Expansion of cardiovascular service in the country is inevitable with the increasing disease burden. Findings from this thesis presented an opportunity towards formulation of potential cost saving mechanism and quality improvement of PCI. More cost-efficient consumable procurement practices should be considered, in view of PCI consumable being the dominant cost driver at all centres. Day-care establishment is an attractive option to bring down admission cost and subsequently hospitalization cost.

In the face of escalating healthcare expenditure, different stakeholders are increasingly seeking after cost estimates of different healthcare services for the purpose of long term financial planning. The cost information generated from this thesis would provide much needed evidence in the prioritization of resource allocation, in terms of budget and personnel, in the effort of providing quality and sustainable healthcare to the people. In summary, this thesis provided a meaningful insight on cardiology service in the Malaysian public healthcare system and would serve as an impetus for further research in exploring the long-term outcomes and health economics of cardiology service in Malaysia.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

Type	Title	Journal/Venue	Status
Oral presentation	Hospital Cost of Percutaneous Coronary Intervention in a Malaysian Public Cardiac Centre	4th Asia Pacific Conference of Public Health, Malaysia	Presented on 8th Sept 2015
Abstract publication		The Medical Journal of Malaysia	Volume 70 (Suppl.1), Page 77
Poster presentation	Is there any difference in the practice of Percutaneous Coronary Intervention between a teaching hospital and a government hospital?	5th International Public Health Conference Kuala Lumpur, Malaysia	Presented on 26th Aug 2015
Poster presentation	Cost of Elective PCI in a Malaysian Public Hospital	APRU Global Health Workshop 2015 Osaka, Japan	Presented on Oct 30th-Nov 1st 2015
Poster presentation	Cost Analysis of Elective PCI and Clinical Outcomes: A Comparison of Six Tertiary Referral Centres in Malaysia	World Congress of Cardiology 2016 Mexico City, Mexico	Presented on 4th-7th June 2016
Poster presentation	Length of Stay and Hospitalization Cost of Elective PCI -Comparison between a Teaching Hospital and a Government Hospital	10th National Clinical Research Conference Kuala Lumpur, Malaysia	Presented on 27th Jul 2016 Awarded Consolation Prize
Journal publication	Cost of elective percutaneous coronary intervention in Malaysia: a multicentre cross-sectional costing study	Published in **BMJ Open**	BMJ Open 2017;7:e014307. doi:10.1136/ bmjopen-2016-014307
Journal publication	Comparing the treatment practice and hospitalization cost of percutaneous coronary intervention between a teaching hospital and a general hospital in Malaysia: a cross sectional study	Submitted to **PLOS One**. First revision submitted 25th July 2017.	Awaiting Assessment