

The Cost of an Elective Coronary Angiogram at the National Hospital of Sri Lanka

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Abstract: *Introduction:* Coronary angiograms are expensive invasive cardiac imaging performed to diagnose coronary artery diseases. It was emphasized to optimize the spending on care services at government hospitals to sustain free healthcare services in Sri Lanka. Optimization of services cannot be achieved without understanding the present through detailed cost analysis. The NHSL has no mechanism to measure the cost incurred for coronary angiograms. *Objectives:* The study's objective was to estimate the per-procedural cost of diagnostic angiograms at the Cardiac Interventional Unit I (CIU I) of NHSL and compare that with the private sector tariffs. *Method:* It was a single-setting bottom-up micro-costing study combined with a top-down approach conducted at NHSL. The costs of medical consumables, pre-procedural investigations, premedication, and hospital stay were considered to be direct costs, and the rest of the expenses including human resources were indirect costs. *Results:* The per-procedural direct cost for diagnostic angiograms at CIU I of NHSL was SLR.32719. The indirect cost per procedure was estimated to be SLR.8490. *Conclusion:* The per-procedural cost of diagnostic coronary angiograms at CIU I of NHSL was estimated to be SLR.41209, contributed 79.4% by direct costs and 20.6% by indirect costs. The tariff of the leading private hospital network was found to be much higher (113.3%) than the per-procedural cost at NHSL. *Recommendation:* Considering the unchanged nature of direct costs within a provided health technology and fiscal environment, effective utilization of resources like operating time and manpower could minimize indirect costs and the overall per-procedural cost of diagnostic coronary angiograms.

Keywords: Per-procedural cost, Coronary angiogram, National Hospital of Sri Lanka.

1. Introduction

A. Coronary Angiogram

A coronary angiogram is a special X-ray procedure performed by the Cardiac Catheterisation Laboratory (Cath lab) to see if the coronary arteries are blocked or narrowed [1] [2]. It defines coronary anatomy, the degree of luminal obstruction, blood flow, and the presence and extent of collateral vessels [3]. It is the gold standard in diagnosing coronary artery disease and its severity [4].

B. Need to Estimate Angiogram Costs in State Hospitals of Sri Lanka

Hospitals are consuming a larger portion of healthcare resources that are otherwise assumed to be scarce [5]. It was estimated that 74% of total healthcare expenditure across Sri

Lanka was incurred by hospitals [6]. Healthcare policymakers and managers are keen on measuring the cost of services they provide to make comparisons among institutions. This cost-based comparison helps them improve the efficiency, effectiveness, quality, and sustainability of the care services they are spending [5]. The same thing is emphasized for not-for-profit hospitals or state hospitals to overcome the criticism against them over the inefficiency in operations [7]. People's reliance on free health services multiplied following the economic crisis as they couldn't afford private health services [8]. The situation is predicted to have increased cardiovascular morbidity and efficient management of resources is suggested to government hospitals to sustain free health services amidst the rising out-of-pocket expenditures in Sri Lanka [9].

C. The National Hospital of Sri Lanka (NHSL)

The National Hospital of Sri Lanka (NHSL) is the apex referral center of the country with a bed capacity of 3404 and is managed by the state [10]. The Cardiac Center of NHSL performed 3839 diagnostic coronary angiograms and 2436 percutaneous coronary interventions (PCIs) in the year 2022 [11]. The Cardiac Center of NHSL has three interventional units (I, II, & IV) with exclusive Cath lab facilities. Cardiac Interventional Unit I (CIU I) have been providing round-the-clock angiogram and PCI services if elective or emergency. The medical consumables used for the procedures are supplied by the Medical Supplies Division (MSD) of the Ministry of Health, Sri Lanka.

D. Research Problem

Coronary heart disease (CHD) is the single largest cause of death in developed countries and is one of the leading causes of disease burden in developing countries. In 2001, there were 7.3 million deaths due to CHD worldwide. Ischaemic heart diseases are accountable for the highest number of deaths in Sri Lanka [12]. Cardiovascular diseases, specifically coronary heart diseases impose greater financial challenges on low and middle-income countries [13]. Imaging plays a crucial role in diagnosing and triaging coronary artery diseases, thus determining the further management of patients [13]. Difficulties in accessing cardiac imaging facilities contribute to the rising morbidity and mortality due to cardiovascular diseases [13]. Extremely high installation and maintenance

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costs of equipment and consumables rendered the angiogram and cardiac catheterization services scarce and beyond the reach of the average patient in developing countries [13].

Being managed by the government and providing services free of care, the institutions under the Ministry of Health, Sri Lanka don't have systems to trace expenditures on a patient or activity basis. Despite being the largest hospital in the nation with a heavy turnover for cardiac imaging and interventions, NHSL has no mechanism to measure the cost incurred for each procedure or identify the contributors to the cost. Following the economic crisis, the compelling need felt in the recent past, to optimize the spending on care services at government hospitals to sustain free healthcare services in Sri Lanka [10]. Optimization of services by efficient and effective utilization of resources cannot be achieved without understanding the present situation through detailed cost analysis.

E. Objective

The study's objective was to estimate the per-procedural cost of diagnostic coronary angiograms at CIU I of NHSL and compare that with the private sector tariffs.

2. Methods

The single-setting costing study was conducted at CIU I of the NHSL from August to September 2023. The bottom-up micro-costing method was applied with the combination of a top-down approach to calculate indirect costs [14]. The coronary angiogram and other cardiac interventions for the year 2022 were scrutinized. The total number of procedures performed during the period was obtained from hospital records. The diagnostic process is mapped from patient admission to the cardiology ward to discharge from the ward. The complete list of resources (cost elements) utilized in the process was identified and documented. Those resources were quantified and valued [15], [16]. The cost was estimated for an elective procedure without concern for the management of comorbidities and complications.

A. Process Mapping

1) Preparation for the procedure

The task was done mainly by nursing officers with the support of healthcare assistants under the supervision of Cardiologists.

Admission to cardiology ward (day before the procedure) → Pre-procedure investigations (Serum creatinine, Full blood count, ECG, Hepatitis B, and HIV) and confirmation of the procedure → Preparation for the procedure → Transfer to the cardiac interventional (Cath lab) unit → Intravenous cannulation (will be used for the administration of IV drugs and fluids during the procedure if necessary) → Preparing the site for arterial catheterization (groin for femoral artery and wrist for radial artery)

2) Procedure

Done by Cardiologists with the support of nursing officers, radiographers, cardiographers, and healthcare assistants.

Make the patient lie at the table of the Cath lab → Connect to a cardiac monitor (cardiac function is observed by a

cardiographer throughout the procedure) → Pre-medication with IV Heparin and IV GTN (for radial access only) → Apply local anaesthesia to the puncture site (femoral/radial) → Make a small skin incision and palpate the artery → Puncture the artery with the puncture needle → Place a femoral/radial sheath → Insert the guidewire → Insert the cardiac catheter and place it correctly at coronary artery → Inject the contrast media with the help of a manifold syringe → Film (X-ray) the coronary artery system portray by the contrast → Make the diagnosis → Remove catheters → Apply manual pressure for 20minutes at the puncture site to achieve haemostasis → Apply a tight dressing

3) Post-procedure

Transfer the patient back to the ward → Hydrate adequately with oral fluids and ensure adequate urine output (to flush out the contrast) → Observe the patient for four to six hours → Discharge the patient if everything normal

B. Cost Categories

1) Direct cost

The cost of medical consumables (supplied by the MSD), the cost of pre-procedural investigations, the cost of premedication, and the cost of inward stay are the costs straightforwardly attributable to the per-procedural cost of each angiogram procedure. As these costs are exclusively incurred by the angiogram procedure of a particular patient, they are considered direct costs [17]. The costs of medical consumables and drugs were extracted from the procurement prices of the MSD. The costs of pre-procedural investigations and inward stay were estimated based on the updated charges of NHSL for paying wards.

2) Indirect costs

These are the costs that cannot be directly attributed to the angiogram procedure of a single patient. Instead, these costs are shared by a group of patients and procedures [17]. Therefore, the monthly/daily average indirect costs are estimated and divided by the monthly/daily average number of angiograms performed. Resultant amounts are added to the per-procedural cost of each angiogram procedure.

The PCIs performed at the CIU are weighted with coronary angiograms with the help of experts in the field based on the resources consumed for the procedure [18] (then cross-checked and verified with the tariffs of the private sector). The weightage was given as 1:5 between coronary angiograms and PCIs respectively. Accordingly, all PCIs are converted into coronary angiogram procedures and added with diagnostic angiograms to facilitate the costing process. Thus, 7328 coronary angiograms were performed by CIU I in the year 2022.

3) Human resources

Human resources are mostly deployed in two shifts (day and night). A team consisting of Cardiologists, Nursing officers, Radiographers, Cardiographers, and healthcare assistants runs the operations of the CIU (Table 1). Their monthly average salaries, allowances, and extra duty payments were estimated by the pay information from the Accounting Department of NHSL.

Table 1
Human resources of CIU I at NHSL in 2022

Staff Category	No. of staff for a day shift	No. of staff for a night shift
Cardiologist	02	02
Radiographer	02	01
Nursing Officer	04	02
Cardiographer	01	01
HCA	04	02

4) *Cleaning materials, stationery, and printing cost*

Average monthly consumptions were estimated by the data from relevant stores. Their prices were extracted from the Supplies Department of NHSL.

5) *Electricity*

The electricity consumption was estimated with the help of experts, based on the daily average power consumption of electrical appliances used (e.g. Cath lab, air conditioners, refrigerators, etc.). It was divided by daily average procedures (total procedures per day) and the cost was equally distributed.

6) *Maintenance cost of equipment*

The repairs and maintenance of the Cath lab are covered by a service agreement between the supplier of the equipment and the Biomedical Engineering Services division of the Ministry of Health. The agreement cost was equally shared among the procedures performed in that year. The maintenance cost of other appliances was found to be negligent.

7) *Depreciation cost of Cath lab and other appliances*

The Straight-Line method (SLM) was applied to estimate the depreciation/replacement cost of equipment used per procedure [19] [20]. The equipment procurement cost was adjusted to the cost of current equivalent machines [21]. The depreciation period of the Cath lab was determined as 15 years [20] and other appliances as 8 years [5] based on experts' opinions.

8) *The opportunity cost of building space*

The building has an estimated space of 750 square feet. The opportunity cost was estimated according to the commercial rent-out price of the area.

9) *Other indirect costs that were ignored*

The overhead costs of administrative, logistics, and maintenance units of the hospital were not added to angiogram expenditures as it was negligible in such a massive multi-specialty hospital. Likewise, the telecommunication, laundry, and water expenses were also found to be ignorable.

C. *Total Cost Per Procedure*

Total cost per procedure was calculated by adding direct cost per procedure with indirect cost per procedure. Finally, the total cost per procedure was compared with the tariff of the largest private hospital network in Sri Lanka.

3. Results

A. *Direct Costs*

The direct cost of performing a diagnostic coronary angiogram test at CIU I of NHSL was SLR.32719 (79.4% of the total cost), contributed by: pre-procedural investigations SLR.2350 (5.7%), pre-medications SLR.900 (2.2%), medical consumables SLR.27969 (67.9%), and the cost of inward stay SLR.1500 (3.6%) (Table 2).

B. *Indirect Costs*

The indirect cost of having a diagnostic coronary angiogram test at CIU I of NHSL was SLR.8490 (20.6% of the total cost), contributed by: salaries and allowances SLR.2798 (6.8%), extra duty payments SLR.2337 (5.7%), general consumables SLR.65 (0.2%), services and repairs of Cath lab SLR.818 (2%), electricity charges SLR.982 (2.4%), depreciation cost of equipment SLR.1163 (2.8%), and the opportunity cost of the building space SLR.327 (0.8%) (Table 2).

C. *Total Cost*

The total cost of a diagnostic coronary angiogram procedure at CIU I of NHSL was estimated to be SLR.41209, in the year 2022. When compared with the tariff of the country's leading private hospital network, the tariff was 112.3% higher than the cost of a coronary angiogram at CIU I, NHSL (Table 3).

4. Discussion

A. *Methodology*

The study adopted the bottom-up micro-costing approach to estimate the per-procedural cost of diagnostic coronary angiograms at NHSL, even though a systematic analysis said that 86% of healthcare costing studies followed a top-down approach [14]. However, there were critics that the top-down method was used to make arbitrary assumptions in the apportionments of overhead and indirect costs to final cost centers, without considering the inputs and outputs of activities performed [22]. Yet, the same study accepted the difficulties in generalizing the methodologies of a bottom-up approach to other hospitals as they are less flexible and more context-specific. A research paper highlights the usage of the bottom-up micro-costing method when the cost data is collected at the unit level and detailed elements are identified for costing [14] [23]. It recommends the approach to measure a single cost object (e.g. coronary angiogram test). Still, the study accepts the need for a top-down method for measuring indirect costs. Therefore, it proposes a new method for the future with the combination of both bottom-up and top-down approaches. The costing studies are known to adopt particular methods for a long time to estimate per-test costs for laboratory investigations [17]. Each costing method has its purpose and complements each other [24]. There are arguments that the bottom-up method is for accuracy and the top-down method is for simplicity [25].

The above arguments fortify the adoption of a bottom-up micro-costing method in this study with the combination of the top-down approach to measure indirect costs, the methodology seems to be robust enough to produce valid results.

This study defined the daily/monthly average coronary angiograms at NHSL as a single cost driver to apportion

Table 2
Description of direct, indirect, and total cost per coronary angiogram at CIU I of NHSL in 2022

Cost elements		Cost per test (SLR)	Contribution to total cost (%)
Direct cost			
Investigations (pre-procedural)	Hepatitis B	750	01.82
	HIV	750	01.82
	Creatinine	400	00.97
	Full Blood Count	300	00.73
	ECG	150	00.36
Premedication	(e.g. IV Heparin, GTN)	900	02.18
Consumables (MSD Supplies)	Puncture needle	322	00.78
	Radial/femoral sheath	4439	10.77
	Die syringe and manifold	5292	12.84
	Guidewire	3763	09.13
	Catheter	3153	07.65
	Contrast	10,000	24.27
	Others (less expensive)	1000	02.43
	Inward stay	1500	03.64
Indirect cost			
Salaries & allowances	Cardiologist	1007	02.44
	Radiographer	368	00.89
	Nursing Officer	736	01.79
	Cardiographer	196	00.48
	HCA	491	01.19
Extra duty payments	Cardiologist	1002	02.43
	Radiographer	884	02.15
	Nursing Officer	245	00.59
	Cardiographer	69	00.17
	HCA	137	00.33
Consumables (General)	Stationaries & printing	16	00.04
	Cleaning items	49	00.12
Services & repairs	Cath lab	818	01.99
Electricity charges		982	02.38
Depreciation cost	Cath lab	1128	02.74
	General equipment	35	00.08
Opportunity cost	Building	327	00.79
Total		41,209	100.00

Table 3

Comparison of the cost of a diagnostic coronary angiogram procedure at CIU I of NHSL and the private hospital tariff in the year 2022

Test	Cost at NHSL (SLR)	Private hospital tariff (SLR)	Difference* (SLR)	Difference (%)
Diagnostic coronary angiogram	41209	87500	+46291	+112.33

*Difference = Private hospital tariff (SLR) – Cost at NHSL (SLR)

indirect costs to per-procedural costs. Such an approach made measuring and allocating costs easier [26]. Percutaneous Coronary Interventions (PCIs) and diagnostic coronary angiograms were performed in the same Cath labs without any distinction in time allocation at NHSL. Therefore, the weighted cases method was applied to apportion indirect costs among cases. Weighting was done by experts in the field, based on resources consumed by cases that were calculated by fluoroscopy time, procedural time, X-ray doses received by patients, and even the private sector tariffs [27]. The bottom-up method applied for the estimation of daily/monthly consumption of electricity proved to be an effective and valid method to measure power consumption for a specific setting [28].

B. Findings

Considering the findings, the per-procedural cost of a diagnostic coronary angiogram at CIU I of NHSL was estimated to be SLR.41209. Out of the total cost per coronary angiogram, direct costs were accountable for 79.4% (SLR.32719) of the expenses, and indirect costs (SLR.8490) were for the rest. Such findings contradict another study that valued indirect costs more than direct costs [29]. It seems that

studies that follow a top-down approach without considering resource utilization on an individual patient/process basis tend to overestimate indirect costs [25]. The size and multi-dimensionality of the NHSL and the volume of procedures performed in the cost center (CIU I) together played a pivotal role in down-sizing the indirect costs, as many overhead costs became minimal or negligible when they were apportioned among hundreds of units (cost centers). The effect of the volume of activities was addressed in previous costing studies on angiograms and other healthcare settings in a contradictory manner [2][30]. People argued for and against the economy of scale in determining the per-test costs of procedures in hospitals. However, our findings were convincing that economy of scale plays a big role in massive multi-disciplinary hospitals like NHSL in downsizing indirect/overhead costs on services significantly.

The cost of medical consumables (67.9% of total cost) was found responsible for the exponentially higher direct costs than indirect costs. The price of contrast media alone contributed 24.3% to the total cost. This finding is supported by other studies that named single-use devices or Cath lab expenses as the major cost element for coronary angiograms in Poland and the USA [27], [2]. The expenses for human resources (salaries,

Table 4
Description of costs for coronary angiograms at NHSL (CIU I) in 2022

Cost elements		Cost per month (SLR)	Cost per test (SLR)	
Salaries & allowances	Cardiologist	615000	1007	
	Radiographer	225000	368	
	Nursing Officer	450000	736	
	Cardiographer	120000	196	
	HCA	300000	491	
Extra duty payments	Cardiologist	612000	1002	
	Radiographer	540000	884	
	Nursing Officer	150000	245	
	Cardiographer	42000	69	
	HCA	84000	137	
Investigations (pre-procedural)	Hepatitis B		750	
	HIV		750	
	Creatinine		400	
	Full Blood Count		300	
	ECG		150	
Inward stay			1500	
Premedication	(e.g. IV Heparin, GTN)		900	
Consumables (MSD Supplies)	Puncture needle		322	
	Radial/femoral sheath		4439	
	Die syringe and manifold		5292	
	Guidewire		3763	
	Catheter		3153	
	Contrast		10,000	
	Others (less expensive items)		1000	
	Consumables (General)	Stationaries & printing	10000	16
		Cleaning items	30000	49
Services & repairs	Cath lab System	500000	818	
Electricity charges		600000	982	
Depreciation cost	Cath lab System	688914	1128	
	General equipment	20834	35	
Opportunity cost	Building	200000	327	
Total			41,209	

allowances, and extra duty payments) were identified to be the major contributors to indirect costs (12.5% of total costs). The expenses for Cardiologists were found to be the highest (4.9% of the total cost) in the spending for human resources, followed by Radiographers (3%), Nursing Officers (2.4%), HCAs (1.5%), and Cardiographers (0.6%).

Greater variations were observed between the per-procedural cost of diagnostic angiogram at NHSL and the tariff of the largest private hospital network in the country. The charge for a diagnostic coronary angiogram at the private hospital (SLR.87500) was 112.3% higher than that of the NHSL (SLR.41209). The findings tally with the statement that prices charged at commercial hospitals no way the indicator of the actual cost incurred for those tests [2]. The data shows the average charges for coronary angiograms are considerably higher even in hospitals across India (a neighboring country) than the cost of angiograms at NHSL [31].

C. Limitations

The steep internal and external resource fluctuations over a short period were the study's major limitations, making the costing process extremely difficult. Being a government hospital, there is a huge variation in the grades and remunerations of staff categories. Each staff movement and turnover create greater variation in costs for human resources. This study adopted a method to calculate the average expenses for each category by considering all these variations. The current Sri Lankan economic crisis often instills turbulences in currency value and taxes which is reflected in the prices of all services and goods. Again, multiple adjustments have been

made to calculate the average costs of the elements included.

There were variations among the cardiac interventional units even within NHSL, which might reflect on the costs of angiogram procedures performed in different units. The factors like; type and cost of equipment used, the number of health manpower, and the volume of procedures done could have an impact on the cost of the angiogram. Though respective equal weights were given to each diagnostic angiogram and PCI, there were dissimilarities in the same procedures in the usage of devices and other resources. Anyhow, it's difficult and impossible to accommodate all individual variations in procedures in larger costing studies.

5. Conclusion

NHSL is the largest hospital in the nation with a heavy turnover for diagnostic coronary angiogram procedures, so far has no mechanism to measure the cost incurred for each angiogram procedure or identify the contributors to the cost. Coronary angiograms are highly expensive invasive cardiac imaging procedures performed to diagnose coronary artery diseases. It was emphasized in the recent past following the economic crisis, to optimize the spending on care services at government hospitals to sustain free healthcare services in Sri Lanka. Optimization of services by efficient and effective utilization of resources cannot be achieved without understanding the present situation through detailed cost analysis.

The per-test cost of a diagnostic coronary angiogram procedure was estimated to be SLR.41209 at CIU I of NHSL, with 79.4% contributed by direct costs and 20.6% by indirect

costs. The tariff of the leading private hospital network of the country for the same procedure was found to be much higher (112.3%) than the per-procedural cost at NHSL.

A. Recommendation

The results of the study could apply to hospitals under the Ministry of Health Sri Lanka with provisions for variations due to hospital size & turnover, the volume of procedures done, manpower involved, and the cost of equipment & devices used. Considering that direct costs (incurred by drugs and devices) cannot be diminished unless new healthcare technology provides cheaper alternatives or changes in the greater fiscal environment (currency value, taxes, etc.) reduce the prices as most of them are imported. Therefore, greater concern has to be made on minimizing the indirect costs through effective utilization of resources (operating time, human resources, etc.) and reduction of wastages.

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