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Cost Analysis of Medical Procedures: A Case Study on Interventional Radiology

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Abstract:

Purpose: *This article aims to establish a comprehensive methodology for calculating the costs of medical procedures, focusing on interventional radiology. The study provides precise financial insights to enhance decision-making, optimize resource allocation, and improve financial stability in healthcare organizations.*
Design/Methodology/Approach: *A mixed-methods approach was applied, incorporating, case study analysis of a private hospital in Poland ("Hospital X"), community-based participant observation (CBPO) involving medical staff, analysis of operational, medical, and financial documentation, unstructured interviews with medical staff conducted over a three-year research period (2021-2024).*
Findings: *The study presents a structured cost-accounting system tailored to coronary angiography and intravascular ultrasound (IVUS). Key findings include, accurate cost categorization into direct and indirect costs, application of advanced costing methods (e.g., activity-based costing, process costing), improved operational efficiency and internal communication following system implementation.*
Practical implications: *The findings offer actionable strategies for healthcare entities to enhance cost management and minimize financial risks. The developed methodology supports precise procedure valuation and informed strategic decisions, such as investments in advanced medical technologies.*
Originality/Value: *This study bridges theoretical cost-accounting frameworks and their practical application in real-world healthcare settings. It highlights the value of participatory research methods in refining cost analyses and optimizing financial management systems.*

Keywords: *Management accounting, activity based costing (ABC), healthcare management, interventional radiology.*

JEL codes: *I15, M41, H51.*

Paper type: *Research article.*

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1. Introduction

Technological advancements in medical procedures have necessitated the adoption of new management solutions, enabling proper planning and control of such procedures. Financial stability within healthcare entities poses a significant challenge for most organizations, directly stemming from the unique nature of medical services. In many European countries, healthcare funding predominantly originates from state sources.

However, the valuation of healthcare services is often a subjective assessment made by the very institutions responsible for allocating financial resources for healthcare. Consequently, the valuation of some medical procedures is significantly underestimated. Nevertheless, these procedures must be performed regardless of their economic feasibility, as they directly impact the health and lives of patients.

In academic literature, many authors seek answers to how revenues and costs can be effectively managed under these described conditions. For instance, Xu *et al.* (2021) examine micro-costing as an accurate tool for assessing medical costs, though they note its time-intensive nature. Similarly, Rao *et al.* (2023) highlight predictive models as effective tools for financial planning in medical facilities. In another study, Morid *et al.* (2020) emphasize the importance of time-based model in predicting healthcare costs. Meanwhile, Andru and Botchkarev (2008) explore the role of neural networks in modeling the complexity of data on medical entities' operations.

These issues and challenges in the healthcare sector motivated in-depth research aimed at establishing a set of principles and rules for calculating medical procedure costs, providing practical and reliable information about the costs incurred in carrying out such activities. Invasive cardiology procedures were chosen as the research example. This decision stemmed from the observed rapid technological development in this field over the past decade.

As a result, many procedures previously conducted solely in cardiac surgery wards as traditional surgeries can now be performed using less invasive techniques. However, these techniques require modern and expensive medical equipment, such as digital angiography systems.

To achieve these research objectives, the study employed, in addition to case analysis, the Community-based Participant-observation (CBPO) method, which combines observational immersion with active collaboration in the research process. Numerous observations and interviews were conducted, engaging the medical staff of the analyzed entity.

As a result, a team led by the author of this paper developed a concept of a managerial accounting system, which included rules for calculating the full costs of medical procedures, among other procedures. This concept was subsequently implemented using several integrated IT systems. The research concluded two years after the

system's launch with final analyses to confirm the effectiveness of the managerial accounting tools applied.

2. Literature Review

As noted in the introduction, the area of cost calculation in medical activities is an area of interest of numerous authors who present various approaches, concepts, and methods to address its issues.

The first group of publications analyzes different accounting tools in connection with the use of modern information technologies. For example, Andru and Botchkarev (2008) compare various algorithms for estimating the costs of medical procedures, including linear regression methods and more advanced algorithms like neural networks. The authors emphasize the importance of appropriately matching the algorithm to the specificity of the data. Their conclusions suggest that these methods can better capture the complexity of data than more basic statistical approaches.

Another example is the work of Taylor *et al.* (2020), which describes the use of electronic health records (EHRs) for modeling healthcare costs. This is an example of automation in processing large volumes of data. Similarly, Xu *et al.* (2021) conducted an analysis of micro-costing, which enables precise estimation of costs associated with specific medical procedures and resource utilization. They noted the high degree of precision achieved with this technique compared to macroeconomic approaches, while also emphasizing its time-consuming nature and high implementation costs. Meanwhile, Rao *et al.* (2023) proposed using open health data and advanced predictive models for healthcare cost estimation.

These models, leveraging machine learning algorithms such as XGBoost and Random Forest, predict costs based on patient patterns. However, these tools are not suitable for calculating the costs of individual medical procedures, as they rely on aggregated data encompassing the costs of several diverse medical services.

The second group of publications consists of articles, primarily in medical journals, which analyze the costs of specific surgical procedures. In one such study, Mercier and Naro (2014) examine differences between "bottom-up" and "top-down" costing methods in surgery. The bottom-up method, based on Activity-Based Costing (ABC), allows for more precise cost estimation but is difficult and expensive to implement. The top-down method, based on average costs, is simpler but less accurate.

The authors conclude that applying the bottom-up method in labor-intensive surgeries could improve cost management. In another study, Vieira *et al.* (2022) developed a cost model for surgical hospitalizations based on actual patient flows.

Their top-down micro-costing approach estimates both direct costs (e.g., materials, drugs) and indirect costs (e.g., equipment depreciation). Christou *et al.* (2022) offer a

practical guide for surgeons on estimating surgical costs. They highlight the differences between top-down and bottom-up costing methods and their application in various contexts, proposing the use of hybrid models as a compromise between precision and cost efficiency. Lastly, Gray *et al.* (2024) compare the costs of repairing thoracic aortic aneurysms using endovascular (TEVAR) and open surgical (OSR) techniques. TEVAR is more expensive when considering the procedure (mainly due to stent costs) but cheaper in terms of hospitalization and postoperative care. Their findings showcase the importance of considering the entire treatment cycle in cost analyses.

The authors of the analyzed publications clearly highlight the need for further research into cost calculation methods in medical activities, particularly empirical studies based on case analyses. This supports the relevance of the article's objective as outlined in the introduction.

3. Research Methodology

To achieve the objective outlined in the introduction, the following research methods were employed:

Literature Analysis: A comprehensive review of the literature on the subject, particularly regarding the cost calculation of medical services, was conducted. The findings from this review are presented in section 2.

Case Study: A case study was conducted in a large, private hospital in Poland, which has several specialized departments, including a Cardiology Department. Within this department operates the Interventional Cardiology Department, which performs the medical procedures analyzed for cost calculation in further chapters of this paper. To maintain confidentiality, the hospital is referred to as "Hospital X" throughout the study.

Community-based Participant-observation (CBPO): This research method combines participant observation with participatory research[2]. Its purpose was to understand how different staff groups perceive and influence cost generation and management within the organization. As part of this study, the author participated as an observer during the medical procedures described in this paper as well as conducted numerous interviews with medical personnel, including doctors, nurses, and medical

[2]*This method is described, among others, by Clark et al. (2009), who analyzed the use of participant observation in studying public spaces, emphasizing its participatory nature. According to their findings, participatory methods can significantly enhance the quality of data and the engagement of the studied community. Similarly, Roque et al. (2024) present the Community-based Participant-observation (CBPO) method as a tool that combines participant observation with participatory research, enriching ethnographic studies.*

technicians. By involving the staff in the research process, it was possible to develop precise principles for calculating the costs of medical procedures.

Documentation Analysis: For the purposes of this study an analysis of the source documentation from the studied organization was performed, including medical records, financial documents, and analytical reports prepared by the medical staff.

Unstructured Interviews: These interviews were conducted at various stages of the research project. Initially, at the beginning of the project, interviews were used to assess the state of the existing managerial accounting system in the studied organization. Subsequent interviews focused on identifying the processes involved in delivering medical services.

After designing the new system (which took approximately 7 months), the implementation phase followed (approximately 3 months), culminating in the system's operational launch. Two years after this launch, the final round of unstructured interviews was conducted with medical staff, managerial accounting personnel, and the hospital's management. These interviews aimed to evaluate the effectiveness and utility of the proposed solutions. Collectively, the interviews spanned the years 2021-2024.

4. Research Results and Discussion

To achieve the article’s objective, a case study was conducted on Hospital X. Within its structure, among others, the Interventional Radiology Department is distinguished, comprising three laboratories: Laboratory of Angiocardiography and Hemodynamics, Laboratory of Electrophysiology and Hemodynamics and Laboratory of Cardiac Stimulation Systems Implantation. Each of these is similarly equipped, primarily with rooms housing digital angiographs (procedure room, technical room, and control room).

An angiograph is a medical device equipped with an X-ray source and detectors that capture real-time images of the vascular system. The angiograph records contrast flow in blood vessels, creating images that show their shape, diameter, and potential abnormalities, such as stenoses, blockages, or aneurysms. This examination also enables real-time blood flow assessment, which is crucial for diagnosing many diseases.

The Interventional Radiology Department also utilizes various mobile devices tailored to specific procedures (e.g., an intra-aortic balloon pump, flow measurement systems with thermal options, etc.).

Invasive cardiology procedures performed at the studied facility include: coronary angiography, angioplasty, coronary atherectomy (rotablation), intravascular ultrasound (IVUS), fractional flow reserve (FFR) measurement, electrophysiology

(ablation), pacemaker implantation (insertion or replacement of pacemakers), and closure of PFO (patent foramen ovale) or ASD (atrial septal defect).

The primary medical procedure conducted in the Interventional Radiology Department is coronary angiography[3]. Approximately 2,500-3,000 such procedures are performed annually. Coronary angiography is a diagnostic procedure during which the physician decides on further medical management. This often involves performing a subsequent therapeutic procedure, such as angioplasty, stent implantation, ablation, etc.

For some patients, coronary angiography alone is insufficient for a comprehensive diagnosis, as it provides only a macro-level localization of abnormalities and procedural efficacy.

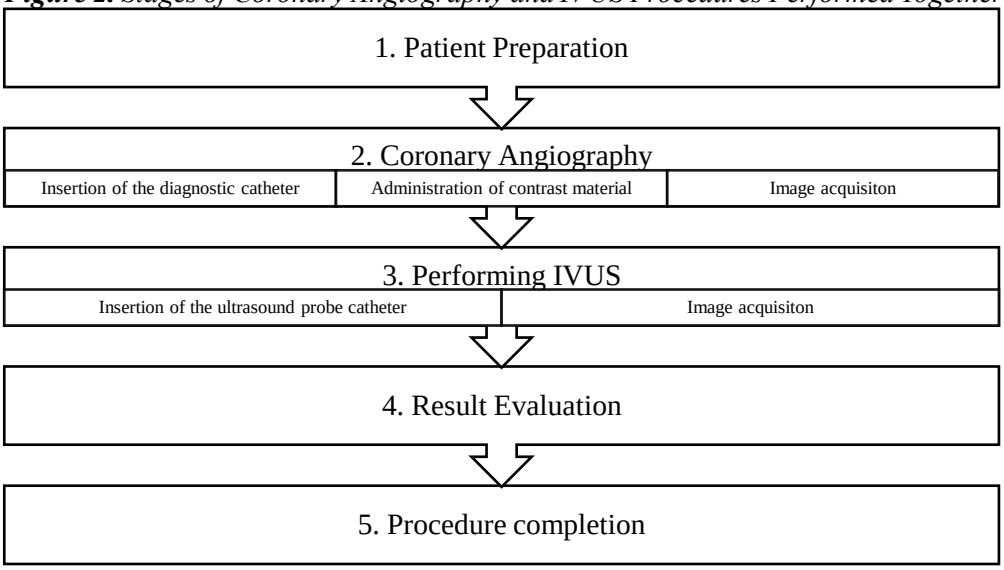
In such cases, an additional diagnostic procedure—IVUS (intravascular ultrasound)—is usually employed. IVUS complements coronary angiography by allowing precise evaluation of the internal structure of blood vessels. In this article, these two procedures are analyzed in detail to establish cost calculation.

To properly determine the costs of medical procedures, the associated costs were categorized into three designed cost structures: generic, organizational, and procedural. Cost recording is conducted based on the division into direct costs and indirect costs.

Direct costs are those that can be unequivocally assigned to a specific cost carrier based on source documents. Indirect costs include costs incurred within a cost center that are not classified as direct costs, as well as costs of auxiliary activities allocated using appropriately selected allocation criteria and cost carriers. The cost of producing a medical procedure is the sum of direct and indirect costs.

[3]*Based on interviews conducted with medical staff, it was determined that coronary angiography is a key tool in modern cardiology, enabling effective diagnosis and treatment of coronary artery diseases. It is an invasive diagnostic procedure used to image the coronary arteries, which supply blood to the heart muscle. The procedure allows for a precise assessment of the arteries' condition, detection of narrowing, blockages, or other pathologies that may lead to coronary artery disease, heart attack, or other cardiac issues. It involves puncturing an artery (typically the radial artery in the wrist or the femoral artery in the groin), inserting a catheter into the coronary arteries, and administering a contrast agent that makes the coronary vessels visible through X-ray imaging.*

Figure 2. *Stages of Coronary Angiography and IVUS Procedures Performed Together*



Source: *Author's compilation based on participant observation and unstructured interviews with medical staff at Hospital X.*

The objective of calculating the production cost is:

1. Determining the value and structure of individual costs incurred for each medical procedure.
2. Monitoring the incurred costs.
3. Ensuring accurate valuation of medical procedures.

The calculation of production costs for medical procedures executed by Hospital X is carried out in three stages:

Stage I: Recording direct costs based on the generic criterion.
Stage II: Allocation of indirect costs from auxiliary activities.
Stage III: Allocation of indirect costs from primary activities.

For the purposes of this study, the production costs of two linked procedures—coronary angiography and intravascular ultrasound (IVUS)—were calculated. Due to the complexity of the described procedures, different cost calculation methods were used at various stages of cost allocation:

1. Allocation-based calculation with coefficients.
2. Job-order costing.
3. Process costing.
4. Activity-Based Costing (ABC).

In the first step (Stage I), direct costs were recorded. These include the items presented in Table 1, which lists the most significant cost components.

Table 1. *Direct Costs of Coronary Angiography and Intravascular Ultrasound (IVUS) Procedures Performed Together*

No.		Cost in EUR / operational time
A.	**Direct Material Consumption**[4]	**1.018,00**
A.1.	Coronary angiography kit	46,00
A.2.	Diagnostic catheter for coronary angiography	7,00
A.3.	ACIST[5] kits	82,00
A.4.	IVUS catheter	39,00
A.5.	IVUS probe	798,00
A.6.	Iodine-based contrast material	46,00
B.	**Direct Personnel Costs**[6]	**220 min.**
B.1.	Operating physician	40 min.
B.2.	Clean nurse	60 min.
B.3.	Scrub nurse	60 min.
B.4.	Technical nurse	60 min.

Source: *Author's compilation based on source documentation from Hospital X.*

The subsequent stages of cost calculation for the analyzed medical procedures involve the allocation of indirect costs from auxiliary activities and primary activities (Stage II and Stage III). Based on observations and interviews, the indirect cost items identified are presented in Table 2.

The production cost of a medical procedure is the sum of direct and indirect costs. This system enables precise procedure valuation, cost control, and efficient planning. The presented methodology can serve as a model for other medical entities aiming to optimize financial management.

The culmination of the research described in this study involved interviews with the management, managerial accounting staff, and medical personnel. These were conducted two years after the implementation of the new managerial accounting system to assess its usefulness.

[4]*The table presents the estimated costs of material consumption. These costs were calculated in the currency used by Hospital X, i.e., PLN, and then converted to EUR for ease of comparability. The exchange rate applied was: 1 EUR = 4.3 PLN.*

[5]*ACIST kits are components of automatic contrast injection systems used in interventional cardiology and vascular radiology. They are part of the ACIST CVi (Cardiovascular Imaging System) devices, which facilitate precise administration of contrast agents during procedures such as coronary angiography, angioplasty, and vascular studies.*

[6]*Due to the need to maintain confidentiality regarding salary data, the table does not include wage costs. Instead, it provides the working time required to perform the procedure.*

All respondents unanimously indicated that the system's implementation significantly transformed the organizational culture of the unit, improving the efficiency of operational activities and enhancing internal communication across various departments.

Table 2. *Indirect Costs of Coronary Angiography and IVUS Procedures Performed Together*

No.		Cost Allocation Key	Amount	Initial cost in EUR
A.	**Depreciation of Medical Equipment**[7]			
A.1.	Depreciation of the digital angiograph	Operating time	75 min.	800.000
A.2.	Depreciation of the flow measurement device with thermal capabilities	Number of performed procedures	1	25.500
B.	**Allocated Indirect Costs of Cost Centers**			
B.1.	Costs of rooms in the Interventional Radiology Department	m^2		
B.2.	Anesthesiology consultation	Number of consultations	1	
B.3.	Indirect costs of the Interventional Radiology Department	Procedure time	75 min.	

Source: *Own study.*

5. Conclusions, Proposals, Recommendations

Based on the results of the conducted research, several conclusions can be drawn:

1. The implementation of a managerial accounting system based on the cost calculation of medical procedures enabled precise evaluation of both direct and indirect costs, contributing to a better understanding of the cost structure.
2. The analysis of coronary angiography and intravascular ultrasound (IVUS) procedures demonstrated that modern costing methods, such as Activity-Based Costing (ABC) and process costing, provide a more accurate reflection of procedure costs compared to traditional approaches.
3. The efficiency of medical procedures and cost control are key factors influencing the financial stability of medical entities, particularly in the context of underestimation of healthcare service valuations.

[7]*The table presents the estimated initial value of selected fixed assets. These values were originally calculated in the currency used by Hospital X, i.e., PLN, and then converted to EUR for ease of comparability. The exchange rate applied was: 1 EUR = 4.3 PLN.*

In the near future, Hospital X plans to expand the described managerial accounting system by incorporating ex-ante budgeting elements. This will allow for more precise cost and revenue planning as well as monitoring of financial flows. Information obtained from the new managerial accounting system has also enabled optimization of strategic decisions, such as investments in modern medical equipment and staff training in cost management.

Furthermore, based on the research performed and conclusions drawn, the following recommendations for future actions can be made:

1. The implementation of integrated managerial accounting systems is recommended to improve operational and financial efficiency, especially in entities performing advanced medical procedures.
2. Actual costs of medical procedures should be considered in healthcare service valuations to reduce financial risk for medical entities.
3. The adoption of similar systems in other medical entities will facilitate the creation of a standardized approach to cost calculation for medical procedures.
4. Further analysis is needed to explore the application of budgeting systems and cost allocation methods for internal services, enhancing the practical applicability of the results in a broader context.

The solutions and methodologies presented in this article can serve as a model for other healthcare institutions, enabling more effective cost management and improving financial stability. The presented approach provides practical tools for healthcare managers, enhancing operational efficiency.

The study's findings have the potential for further development, particularly in the application of budgeting systems and cost allocation methods for internal services in medical entities.

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