

## ORIGINAL RESEARCH



# Cost Analysis Study of Patients Treated With Percutaneous Coronary Intervention

*Real-World Data From a Single Tertiary Center in Greece*

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## Abstract

**Background:** Percutaneous coronary intervention (PCI) is the only treatment for patients with acute coronary syndrome (ACS). This study aimed to estimate the total procedural cost of PCI in Greece. **Methods:** A single-center, prospective, cost-analysis study was conducted. In total, 150 consecutive patients were recruited and subjected to PCI. Resource usage data were assessed during the procedure. Afterward, from the hospital's perspective, the PCI total procedure cost (including the costs of medical supplies, pharmaceuticals, and personnel time) was calculated using the micro-costing method and the bottom-up approach. **Results:** Out of the total of 150 patients, 128 (85.3%) were men with a mean age of 65.24 years. Regarding the type of ACS, 86 (57.3%) patients were diagnosed with non-ST-elevation myocardial infarction (NSTEMI), 35 (23.3%) with STEMI, and 29 (19.3%) with unstable angina (UA). The mean average length of stay in hospital was 5.04 days ( $P < .001$ ). The mean (95% confidence interval) total procedure cost was estimated at €812.62 (€259.55-€2717.66) (US \$877.19 [\$280.17-\$2933.61]); for patients with STEMI, €799.92 (€259.55-€2385.43) (US \$863.48 [\$280.17-\$2574.98]); for patients with NSTEMI, €806.19 (€272.29-€2717.66) (US \$870.25 [\$293.93-\$2933.61]); and for patients with UA, €847.05 (€291.30-€2335.76) (US \$914.36 [\$314.45-\$2521.36]) ( $P = .912$ ). **Conclusions:** This study provides unique, real-world data regarding the total procedure cost of PCI in Greece depending on the type of ACS.

## Introduction

Despite significant improvement in treatment outcomes in recent decades, atherosclerotic cardiovascular disease (ASCVD) remains a leading cause of mortality and morbidity worldwide.<sup>1</sup> Lifestyle as well as environmental and genetic factors are the main causes of risk for the development of CVD.<sup>2</sup> Recently, education has been recognized as a determinant factor in improving the lifestyle and eating habits of patients.<sup>3</sup>

The 2019 report from the European Society of Cardiology (ESC), Cardiovascular Disease Statistics 2019,<sup>4</sup> looked at member states of the ESC and was based on data from the World Health Organization (WHO),<sup>5</sup> the Institute for Health Metrics and Evaluation, and the World Bank. The report shows that CVD is the most common cause of death in ESC member countries and is the main reason

for more than 1 from the total of 3 years of life lost. According to WHO, heart disease was the leading cause of death from 2000 to 2019 and was “the number 1 killer” numerically, with more than 2 million deaths in 2000, which rose to nearly 9 million deaths in 2019.<sup>6</sup>

According to the findings of the SCORE project, based on data from 12 European countries, among a total of 7934 deaths from cardiovascular causes, 5652 were due to coronary heart disease (CHD).<sup>7</sup>

Crucial in reducing mortality and morbidity of CHD is primary prevention before the onset of symptoms, as well as secondary and tertiary prevention to limit their progression. At the same time, prevention is a powerful factor in reducing the waste of financial resources from the perspective of the health care system.<sup>8</sup>

According to several guidelines, CHD (depending on the extent of symptoms) can be treated conservatively with medication, with percutaneous coronary intervention (PCI) and, in extensive cases, with surgery.<sup>9-12</sup>

Monitoring and follow-up treatment of patients with CVD are challenges for all health care systems, and they come with an economic impact.<sup>13-15</sup> Inequalities have been identified for patients with CVD patients across the 56 ESC member countries in terms of access and coverage of health services; their reduction is a major goal of ESC.<sup>16</sup>

In recent years, less invasive treatment methods have been developed in the field of invasive cardiology.<sup>9</sup> Thanks to the evolution of technology, new and more reliable materials have been created, helping reduce mortality and improve health-related quality of life—but not without cost. Increasing health spending does not necessarily ensure the effectiveness and improvement of the quality of health services provided. Thus, to sustain health systems, it becomes imperative to set limits on cost increases and analyze the factors that lead to them.<sup>17</sup> Resources are scarce and needs are unlimited, and in this context, decisions should be made after systematic study and evaluation of all the alternatives. Economic evaluation methods are important tools in decision-making to optimize output.<sup>18</sup>

In the era of big data analytics, machine learning, and artificial intelligence, new horizons for access to higher quality health services are emerging in the field of cardiology.<sup>19,20</sup>

The primary aim of this study is to estimate, based on real-world data, the mean total procedure cost of PCI and its components according to the type of acute coronary syndrome (ACS): ST-segment elevation myocardial infarction (STEMI), non-STEMI (NSTEMI), and unstable angina (UA). The secondary aim is to examine the mean total average length of stay (ALOS) in hospital according to the department of hospitalization and the type of ACS.

Economic evaluation methods are valuable tools for informing all stakeholders and formulating public health policies for publicly financed health care systems to ensure sustainability, transparency, and public accountability for taxpayers.<sup>21</sup>

## Patients and Methods

### *Study Design and Study Population*

This study is a single-center, prospective, observational, cost analysis study. Between January 1, 2019, and March 8, 2019, all consecutive patients who were treated with PCI at the Cardiac Catheterization Lab of the Cardiology Department of the University Hospital of Ioannina in Greece were included in the study.

Costing data were collected using the micro-costing method and the bottom-up approach, which provide the most precise level of accuracy in hospital costing.<sup>18</sup> The study was conducted from the hospital perspective.

The study was approved by the Institutional Review Board of the postgraduate program in Health Care Management of the Hellenic Open University, and data were collected after the permission of the Scientific Council of the hospital. Consent was obtained from all patients before their inclusion in the study, and the study was conducted in accordance with the Declaration of Helsinki (1989) of the World Medical Association.

### *Data Collection*

A case report form for every patient was completed. The data collected by the main researcher of the study encompassed sociodemographic characteristics; type of ACS; date and duration of the PCI procedure; and human resources, medical supplies, and medications used during the procedure. The

patients' medical history, department where they were treated, and duration of hospitalization were assessed based on information collected from the hospital information system.

### *Total Cost of PCI Procedure*

The total cost of the PCI procedure includes the medical supplies, human resources, and pharmaceuticals used during the PCI procedure.

It is worth noting that this study assesses the direct medical costs of the PCI procedure as mentioned above. Other direct costs such as administration, equipment acquisition, equipment depreciation, and cleaning; indirect costs such as the patients' productivity loss; and intangible costs such as the pain and suffering associated with the treatment are not included.<sup>18</sup> The cost of the medical supplies includes the cost of diagnostic equipment (diagnostic catheters, etc), interventional equipment (guiding catheter, inflation kit, interventional wires, pressure wire, stents, balloons, over-the-wire balloon, etc) and the cost of closure devices. The cost of pharmaceuticals includes the costs of contrast agents and other medications. The cost of human resources includes the doctors, nurses, and technologists employed in each PCI procedure. To estimate the cost of human resources, the monthly salary for each of the employees (medical, nursing, technological) was divided accordingly by the time each one of them participated in every procedure.

On average, for every PCI procedure, 4 health workers were employed (2 doctors, 1 nurse, and 1 technologist/radiologist). In some cases, 3 doctors, 2 nurses, and 1 technologist/radiologist were employed. Based on the data of the payroll office of the hospital's Financial Department and according to the profile of the specific human resources, the mean salary, in the context of their regular work per minute of work was €0.31 (US \$0.33) for the medical staff, €0.19 (US \$0.21) for the nursing staff, and €0.10 (US \$0.11) for the radiologists. The mean duration of the PCI procedure, for all 150 cases, was 60 minutes (30-150 minutes).

All the above costs (medical supplies, human resources, and pharmaceuticals) were calculated using the micro-costing method and the bottom-up approach.

### **Statistical Analysis**

Quantitative variables are summarized as mean + standard deviation (SD), and categorical variables are reported as percentages. ANOVA test was applied to evaluate the association between means of different types of ACS.

For the test of significance between mean values of different samples, student's t-test was performed; between categorical variables, Chi-squared test was performed.

Cost data are presented as means [5% confidence interval (CI)]. The 95% CI for mean costs was obtained from 5000 nonparametric bootstrapped resamples because cost data are truncated at 0 and do not follow normal distributions (it is skewed because there are often small numbers of very costly cases, and because they are bounded by 0).

A probability value of 5% was considered statistically significant. All statistical calculations were performed using Statistical Package for the Social Sciences (SPSS) software version 26.

### **Results**

#### *Patient Demographic Characteristics*

In total, 154 patients were treated with a PCI procedure during the study period. The procedure was not completed in 3 patients because 2 of them showed extensive damage that required cardio surgery assessment and treatment, and 1 showed small lesions. One patient died during the PCI procedure.

Data from 150 patients, in which PCI was completed, were analyzed. Of the 150, 128 (85.3%) were men and 22 (14.7%) were women ( $P=.757$ ). The mean age of all patients was 65.24 years (31-87 years); the mean age of the men was 64.5 years, and the mean age of the women was 69.5 years (**Table 1**).

**Table 1. Baseline demographic and clinical characteristics of patients treated with percutaneous coronary intervention procedure (N = 150).**

	<b>Total N = 150</b>	<b>STEMI N = 35</b>	<b>NSTEMI N = 86</b>	<b>UA N = 29</b>	<b>P-value</b>
<b>Gender</b>					<b>0.757</b>
<b>Male</b>	128 (85.3%)	31 (88.6)	72 (83.7%)	25 (86.2%)	
<b>Female</b>	22 (14.7%)	4 (11.4%)	14 (16.3%)	4 (13.8%)	
<b>Mean age (years)</b>	65.24	66.43	65.50	63.03	<b>0.408</b>
<b>SD</b>	10.43	10.23	9.34	13.39	
<b>Min/max (years)</b>	31-87	46-87	43-86	31-84	

PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction; NSTEMI = non-ST-segment elevation myocardial infarction; UA = unstable angina

Regarding the mean age per type of ACS, the mean age of the patients with STEMI was 66.43 years (men, 65.84 years; women, 71.00 years); the mean age of the patients with NSTEMI was 65.50 years (men, 64.83 years; women, 68.93 years); and the mean age of the patients with UA was 63.03 years (men, 61.92 years; women, 70.00 years) (P=.408) (**Table 1**).

#### *Types of ACS (STEMI, NSTEMI, UA)*

From the total of 150 patients, there were 86 (57.33%) patients with NSTEMI, 35 (23.33%) with STEMI, and 29 (19.33%) with UA. (**Table 1**).

Of the 35 patients with STEMI, 31 (88.6%) were men and 4 (11.4%) were women; of the 86 patients with NSTEMI, 72 (83.7%) were men and 14 (16.3%) were women; and of the 29 patients with UA patients, 25 (86.2%) were men and 4 (13.8%) were women (P=.757) (**Table 1**).

#### *Mean Total Average Length of Hospital Stay*

For all patients, the mean ALOS in the cardiology department was 3.57 days (0-6 days, SD 0.87). For patients with STEMI, mean ALOS was 3.66 days (0-6 day, (SD 1.11); for patients with NSTEMI, the mean ALOS was 3.57 days (2-6 days, SD 0.81); and for patients with UA, the mean ALOS was 3.45 days (2-5 days, SD 0.74) (P=.635) (**Table 2**).

**Table 2. Mean total average length of stay in hospital of patients treated with percutaneous coronary intervention procedure in Greece (N = 150).**

Mean ALOS (hospital department)		PCI N = 150	STEMI N = 35	NSTEMI N = 86	UA N = 29	P-value
<b>CD</b>	Mean	3.57	3.66	3.57	3.45	0.635
	SD	0.87	1.11	0.81	0.74	
	Min-max	0-6	0-6	2-6	2-5	
<b>CICU</b>	Mean	1.47	2.26	1.33	0.97	<b>&lt;0.001</b>
	SD	0.79	0.78	0.60	0.63	
	Min-max	0-4	1-4	0-2	0-2	
<b>Total</b>	Mean	5.04	5.91	4.90	4.41	<b>&lt;0.001</b>
	SD	1.13	1.33	0.92	0.83	
	Min-max	2-8	2-8	4-8	3-6	

ALOS = average length of stay; PCI = percutaneous coronary intervention; CD = cardiology department; CICU = cardiac intensive care unit; STEMI = ST-segment elevation myocardial infarction; NSTEMI = non- ST-segment elevation myocardial infarction; UA = unstable angina

For all patients, the mean ALOS in the cardiac intensive care unit (CICU) was 1.47 days (0-4 days, SD 0.79). For patients with STEMI, the mean ALOS was 2.26 days (1-4 days, SD 0.78); for patients with NSTEMI, the mean ALOS was 1.33 days (0-2 days, SD 0.60) and for patients with UA, the mean ALOS was 0.97 day (0-2 days, SD 0.63) ( $P < .001$ ) (**Table 2**).

For all patients, the mean total ALOS in hospital was 5.04 days (2-8 days, SD 1.13). For patients with STEMI, the mean total ALOS was 5.91 days (2-8 days, SD 1.33); for patients with NSTEMI, the mean total ALOS was 4.90 days (4-8 days, SD 0.92) and for patients with UA, the mean total ALOS was 4.41 days (3-6 days, SD 0.86) ( $P < .001$ ) (**Table 2**).

#### *Mean Cost of Medical Supplies for the PCI Procedure*

The mean cost for medical supplies for the PCI procedure was €700.50 (€157.47-€2620.70) (US \$756.16 [\$169.98-\$2828.94]) (SD 479.57). The mean cost for patients with STEMI was €669.47 (€157.47-€2254.22) (US \$722.67 [\$169.98-\$2433.34]) (SD 491.03); the mean cost for patients with NSTEMI was €700.01 (€175.09-€2620.70) (US \$755.32 [\$189.00-\$2828.94]) (SD 462.98); and the mean cost for patients with UA was €739.39 (€194.34-€2238.80) (US \$798.14 [\$209.78-\$2416.70]) (SD 526.86) ( $P = 0.847$ ) (**Table 3**).

#### *Mean Cost of Pharmaceuticals During the PCI Procedure*

The mean cost for pharmaceuticals for the patients treated with the PCI procedure was €52.62 (€28.09-€235.72) (US \$56.80 [\$30.32-\$254.45]) (SD 32.42); the mean cost for patients with STEMI was €64.88 (€42.36-€235.72) (US \$70.04 [\$45.73-\$254.45]) (SD 50.99); the mean cost for patients with NSTEMI was €48.38 (€28.09-€164.58) (US \$52.22 [\$30.32-\$177.66]) (SD 50.99); and the mean cost for patients with UA was €50.45 (€28.93-€143.71) (US \$54.46 [\$31.23-\$155.13]) (SD 24.75) ( $P = .036$ ) (**Table 3**).

**Table 3: Mean total procedure cost (in €) of patients subjected to percutaneous coronary intervention, per type of ACS (N=150).**

Mean Cost (€)	PCI N = 150 Mean (95% CI*)	STEMI N = 35 Mean (95% CI*)	NSTEMI N = 86 Mean (95% CI*)	UA N = 29 Mean (95% CI*)	P-value
Medical supplies	700.50 (157.47-2620.70)	669.47 (157.47-2254.22)	700.01 (175.09-2620.70)	739.39 (194.34-2238.80)	0.847
Pharmaceuticals	52.62 (28.09-235.72)	64.88 (42.36-235.72)	48.38 (28.09-164.58)	50.45 (28.93-143.71)	<b>0.036</b>
Human resources	59.50 (54.60- 84.60)	65.57 (54.60-84.60)	57.80 (54.60-73.20)	57.21 (54.60-73.20)	<b>&lt;0.001</b>
<b>Total cost</b>	<b>812.62</b> (259.55- 2717.66)	<b>799.92</b> (259.55-2385.43)	<b>806.19</b> (272.53-2717.66)	<b>847.05</b> (291.30-2335.76)	0.912

ACS = acute coronary syndrome; STEMI = ST-segment elevation myocardial infarction; NSTEMI = non- ST-segment elevation myocardial infarction; UA = unstable angina; CI = confidence interval.

\*CI has been derived by using the percentile bootstrap method.

### *Mean Cost of Human Resources for the PCI Procedure*

The mean cost of human resources for the patients treated with the PCI procedure was €59.50 (€54.60-€84.60) (US \$64.23 [\$58.94-\$91.32]) (SD 54.60); the mean cost for patients with STEMI was €65.57 (€54.60-€84.60) (US \$70.78 [\$58.94-\$91.32]) (SD 10.73); the mean cost for patients with NSTEMI was €57.80 (€54.60-€73.20) (US \$62.39 [\$58.94-\$79.02]) (SD 5.87); and the mean cost for patients with UA was €57.21 (€54.60-€73.20) (US \$61.76 [\$58.94-\$79.02]) (SD 5.34) (P<.001) (**Table 3**).

### *Mean Total Cost for the PCI Procedure*

The mean total cost for the patients treated with the PCI procedure was €812.62 (€259.55-€2717.66) (US \$877.19 [\$280.17-\$2933.61]) (SD 483.22); the mean total cost for patients with STEMI was €799.92 (€259.55-€2385.43) (US \$863.48 [\$280.17-\$2574.98]) (SD 509.80); the mean total cost for patients with NSTEMI was €806.19 (€272.53-€2717.66) (US \$870.25 [\$293.93-\$2933.61]) (SD 461.45); and the mean total cost for patients with UA was €847.05 (€291.30-€2335.76) (US \$914.36 [\$314.45-\$2521.36]) (SD 528.21), (P=.912) (**Table 3**).

## **Discussion**

This single-center, observational, prospective study, was conducted to estimate the total PCI procedure cost in patients with ACS (STEMI, NSTEMI and UA), in Greece. To the extent of our knowledge, there are limited data regarding the procedure cost of PCI in Greece. This cost analysis study is unique insofar as it addresses the cost of the PCI procedure according to the type of ACS. The findings indicate a relatively small economic burden of the PCI procedure.

Out of the total of patients (N = 150), 128 (85.33%) were men and 22 (14.73%) were women. The percentage of men (85.3%) is higher than the corresponding percentage of women (14.7%). The ratio of men to women in our sample (5.8:1) is higher than the literature ratio from other studies.<sup>22,23</sup>

The mean age of the patients was 65.2 years, similar to the mean age of another study<sup>24</sup> where the mean age was 66.3 years. The mean age of the men was 64.5 years and women, 69.5 years, which is in accordance with other studies.<sup>22,25</sup>

The main comorbidities recorded are CHD (69.33%), diabetes mellitus (61.33%), hypertension (57.33%), and dyslipidemia (46.00%), as well as the existence of CHD in other members of the patient's family (30.00%). These data are reported as major risk factors in the results of other studies.<sup>13,26</sup>

Regarding the type of ACS, of the 150 patients, 86 (57.33%) had NSTEMI, 35 (23.33%) STEMI, and 29 (19.33%) UA.

The ALOS in critical care and CICU was 5.04 days, with STEMI patients having almost 1 more day of hospital stay than the other 2 groups, with this time increasing even more (almost double) in terms of hospitalization in the CICU. This fact can be justified due to the severity of the symptoms that occur in STEMI cases compared to the other 2 types, and usually these patients need at least 1 more day of hospitalization in the CICU.<sup>27</sup> Similar data regarding the duration of hospitalization, with patients with

STEMI having a longer stay in hospital than those with NSTEMI, are also reported in the study by Chavalier et al<sup>28</sup> and Cowper et al.<sup>13</sup> In contrast, the study by Soekhlal et al<sup>24</sup> gives longer duration of hospitalization in NSTEMI than STEMI cases.

The mean cost of the PCI procedure was €866.18 (US \$935.01). The highest mean cost was in patients with UA, €898.61 (US \$970.01) and in patients with STEMI, €865.91 (US \$934.72), while the patients with NSTEMI presented the lowest average costs, €855.35 (US \$923.32). Although the difference in cost between the 3 types of ACS is small, it nevertheless contrasts with the fact that STEMI has more serious consequences and therefore greater demands on its treatment. At the same time, the data presented in the present study are in accordance with the findings of Cowper et al<sup>13</sup> and Chevalier and Lamotte,<sup>28</sup> who state that STEMI cases have a higher cost than NSTEMI.

The mean cost of consumables was €700.49 (US \$756.15). In the study of Cowper et al,<sup>13</sup> 45% of the costs that the hospital must cover are consumables. Furthermore, the cost of medicines is presented on average at €52.62 (US \$56.80) for the 3 cases, with STEMI presenting an average cost of €64.87 (US \$70.02), which shows that its treatment is more demanding compared to the other 2 types.

The total mean cost of human resources was estimated at €59.50 (US \$64.23), with a higher mean cost being presented in STEMI cases of €65.57 (US \$70.78) compared to the NSTEMI cases €57.80 (US \$62.39) and UA cases €57.20 (US \$61.75).

Our study has some limitations; it is a single (high volume) center study with a relatively small sample size. Nevertheless, our findings are unique because from the literature review, no similar studies from Greece were found.

## Conclusions

To prevent CVD, further emphasis should be placed on implementing policies in the primary prevention and in controlling all factors<sup>29</sup> that contribute to the onset or progression of the disease. This could mean abstaining from smoking,<sup>30,31</sup> adopting a healthy eating model,<sup>32,33</sup> exercising,<sup>29,34</sup> and other factors.<sup>1</sup>

According to the ESC guidelines, PCI is the only option in a large group of patients with CHD. ESC guidelines are issued with the initial aim of improving the quality of medical services provided for the benefit of patients and are important communication tools between physicians and health systems for all its member countries. The cost of their adoption and implementation is the responsibility for each state to decide which treatments to reimburse and to whom.<sup>21</sup>

This study provides unique cost data regarding the mean total cost of the PCI procedure in one high-volume cardiac catheterization lab of a Greek tertiary (university) hospital, according to the type of ACS. The PCI procedure was in previous years a high-cost medical procedure.

Currently, due to the cost reduction of the medical supplies, PCI is the most effective treatment for patients with CHD to reduce mortality and improve quality of life. Asher et al<sup>35</sup> demonstrate that the reduced cost of PCI, given the many alternatives in medical supplies and equipment, does not affect clinical outcomes.

All stakeholders, especially the physicians who mainly drive the cost, must emphasize lean management and total quality procedures because, as the evidence shows, they achieve better quality with no additional cost.<sup>36,37</sup>

The results of the present study are particularly useful for all decision-makers, physicians, hospital administrators, and the Ministry of Health in Greece. Moreover, the results of this study can develop a series of evidence maps to inform the re-costing of the Greek Diagnostic Related Groups. ■

*The authors have completed and returned the ICMJE Form for Disclosure of Potential Conflicts of Interest. The authors report no financial relationships or conflicts of interest regarding the content herein.*

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