

Time driven activity-based costing as a strategy to increase value: a case from cardiac interventional procedure

Ana Paula Beck da Silva Etges

Instituto de Avaliacao de Tecnologia em Saude <https://orcid.org/0000-0002-6411-3480>

Luciane N Cruz

Hospital Moinhos de Vento

Rosane Schlatter

Hospital de Clinicas de Porto Alegre

Jeruza Neyeloff

Hospital de Clinicas de Porto Alegre

Ricardo B Carodso

Instituto de Avaliacao de Tecnologia em Saude

Luciane Kopittke

Grupo Hospitalar Conceicao

Altacilio Nunes

Universidade de Sao Paulo Hospital das Clinicas da Faculdade de Medicina de Ribeirao Preto

José Alburquerque Neto

Universidade Federal do Maranhao

José Nogueira

Hospital das Clinicas da Universidade Federal de Minas Gerais

Renata de Assis

Universidade Federal do Maranhao

Joilma Tobias

Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto

José Marin-Neto

Universidade de Sao Paulo Hospital das Clinicas da Faculdade de Medicina de Ribeirao Preto

Leila Moreira

Hospital de Clinicas de Porto Alegre

Carisi Anne Polanczyk (✉ carisi.anne@gmail.com)

Universidade Federal do Rio Grande do Sul (UFRGS) <https://orcid.org/0000-0002-2447-2577>

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Abstract

Background

Adopting value-based health care management strategies requires monitoring of real costs and care delivered to patients. In unified health systems, recognizing institutions that provide high-quality services, demands understanding their processes of care and costs. This study aimed to evaluate processes and costs of interventional coronary procedures performed in public academic hospitals of a middle-income country.

Methods

Data from 90 patients submitted to the coronary angioplasties were evaluated in five hospitals in Brazil. Time-driven activity-based costing (TDABC) was used to assess real-world costs and time spent over the care pathway. Descriptive cost analyses were followed by a labor cost-saving estimate potentially achieved by the redesign of the ICP pathway, considering the benchmark of patient care cycle identified in the sample of hospitals studied.

Results

The mean cost per patient of interventional angioplasties was \$1,677 (SD \$881). The procedure phase duration per patient was similar between the hospitals, while the post procedure presented the highest length of time variation. However, it was possible to demonstrate that the highest direct cost saving opportunities are concentrated in the procedure phase, due to the way that labor and non-labor resources are consumed. The physician involvement redesign can account for a 51% ICP cost decrease.

Conclusion

This study demonstrated how the level of detailing provided by microcosting methods such as TDABC can contribute to driving health care management to value. In a public health system, turning transparent how resources are allocated in an individual level basis along an entire episode of care might allow managers to identify cost-saving opportunities and ways to improve the health service delivery.

Highlights

Evaluating the efficiency of a health care process from an economic perspective without understanding its behavior may limit the ability to identify practices associated with greater operational performance for health institutions;

Direct cost-saving opportunities associated with the ICP redesign are more evident at procedure phase.

Timesaving opportunities are concentrated in less costly phases, pre- and post- interventional coronary procedure, and improvement actions on these phases could translate into indirect cost savings and better

patient enhance experiences;

Value-based health care initiatives require investment in technologies to support the ability to control the processes of care delivered and its costs;

Background

Accurately measuring real-world costs of health care is a critical component for implementing value-based health care principles, considering its association with quality outcomes and patients' perceptions of care^{1 2}. Recent scientific advances have shown that the net costs of patient care delivery remain a core element of value assessments³ amidst a set of other eleven elements aimed at capturing patients' perceptions and experiences.

Coronary artery disease is the leading cause of death worldwide, and interventional coronary procedure (ICP) is a standard therapy for acute and chronic case. For this study, elective ICP was chosen considering its high prevalence, not high individual variability, high volume and cost. In 2018, 78,428 percutaneous coronary procedures were performed, and total amount spend was R\$494.835.000 by the public Brazilian system. Assessing the real cost using micro-costing methods allows a better estimation of the economic impact that health care procedures represent⁴. Recently, when analyzing the real cost per microcosting technique of a cohort of 27 patients undergoing heart transplantation in Brazil, an average cost per patient of 74,341 international dollars was observed, and the reimbursement practiced in the country is 18,012 international dollars per patient⁴. For bone marrow transplantation, in a similar study, the average cost of 155,843 international dollars was encountered, and the reimbursement practiced by the national health system is 26,124 international dollars⁵.

Despite a consensus on the importance of accurate knowledge of real costs, their measurement and control are still limited and require the use of better costing methods⁵. Advances in cost systems that can provide more accurate patient-level costs was highlighted in the studies conducted at the MD Anderson Cancer Center (Houston TX) and Mayo Clinic (Rochester, Minnesota), for example⁶. In health care systems that are continually marked by a significant waste of already limited resources⁷, innovative methods that can guide cost saving initiatives by the redesign of the health care service delivery are much needed⁸. Given the level of cost information accuracy that time-driven activity-based costing (TDABC) can provide, in terms of the bottom-up costs and process analysis, the application of TDABC might enable payers and providers to design, evaluate, and expand value-based initiatives^{9 8 10}.

TDABC is a patient-centered approach that allows for detailed direct and indirect cost accounting by identifying patient-specific resource consumption over the course of care trajectory¹¹. TDABC was proposed as an improvement to activity-based costing, because it makes accurate cost analyses faster and easier to update by using estimates of two-parameters: (i) the unit cost of resource inputs and (ii) the time and the quantity of resources required to perform a transaction or an activity¹². When well-designed and applied, TDABC might contribute to identify opportunities for improvement in the delivery of care, by

adjusting activities according to patients needs ¹³. The method has been applied as a successful microcosting technique in medical research ^{14 15}, being suggested in the literature as a methodology that can be useful in value-based initiatives ^{9 14}.

The present study aimed to evaluate patient's processes of care and costs between five public academic hospitals and to recognize cost saving opportunities for the ICP procedure.

Methods

Costs of ICP procedures were retrospectively collected in five public academic hospitals that are considered national centers of excellence (A, B, C, D, and E), located in four States of Brazil. Participating centers were selected based on their expertise on health technology assessment projects, on whether they were members of the Brazilian Network for Health Technology Assessment (REBRATS), and on their technical capabilities in terms of human resources. Additionally, hospital characteristics are posted on Table 1. The study perspective was that of the public health system. This study was approved by the Ethics Committee of the participating hospitals.

Table 1
Hospitals characteristics

	A	B	C	D	E
Number of beds	831	1013	506	915	504
Number of employees	6061	6628	3377	6032	3200
Number of interventional coronary procedure per year	521	234	148	520	258
Annual budget (\$)	648,116,645	748,129,627	228,645,500	273,813,716	92,029,785

Data Collection

Between March and October 2018, all patients submitted to an ICP were added to the sample analysis, limited to a maximum of 20 patients per center. Center E was the only one which did not reach the maximum (total of 10 patients). Patients were eligible if they have had an elective ICP during this period and had a hospital account reimbursed by the unified health system. All centers received instructions on data collection and a database was created on the REDCap ¹⁶.

A multidisciplinary team composed of physicians, industrial engineers and professionals with business background was formed to apply the TDABC method. All suggested operationalization steps of the method were strictly followed (Fig. 1) ^{14 17}. Applying this microanalytic approach, it is possible to

measure the costs of all the resources used to treat a patient's medical condition over a complete cycle of care.

Process maps were developed by direct observation of a selected center over one-week period, followed by its validation by the remaining participating centers. The resulting validated map was used to identify all resources consumed during the care pathway. Pre-procedure, procedure, and post-procedure macro phases were observed, as described in previous studies^{18 19 15}. Different variables were selected for evaluation personnel, corporate and divisional allocations (hospital structure), and medications and materials related to each macro phase of the procedure. Data collection technics included of medical record, direct process observations by researchers, and interviews with hospital staff²⁰. The prices and amounts of materials, prostheses and medications were collected from invoices and documents containing acquisition costs of supplies. These prices did not include profit margins, given the public nature of the participating centers.

Different strategies were implemented to calculate non-labor and labor capacity cost rates (CCR). Hospital structure fixed costs, such as energy, depreciation, third party contracts, software licenses, taxes and general materials were estimated per department used by each patient. Salaries per professional class were considered as labor costs. All financial information was based on an average expenditure incurred per month over a 12-month period. To calculate the CCR for each resource, actual capacity was calculated, taking into consideration the characteristics of each department. For inpatient areas, in which workload can be considered proportional to physical space, the number of beds were included in the calculation. For the professionals, monthly work hours and expected fringe benefit rate were considered. Department's capacity was based on hospital productivity reports and employee allocation scales and complemented by interviews with each department's manager.

DATA ANALYSIS

Sample data were consolidated in a Microsoft® Excel spreadsheet for Mac 2019 and exported to IBM SPSS® for Mac 2019 for analysis. Time and cost databases were created for each resource under analysis. Patient-level cost mean, standard-deviation (SD), minimum, and maximum values per site were reported descriptively. Next, a comparison between the mean time and cost per phase allowed the identification of connections between time and cost during the procedure. The TDABC equation, which suggests the sum product of the CCR of each resource and the time consumed of each resource, was applied considering the labor and non-labor variables and allowed us to calculate the mean cost per procedure phase, resource and hospital.

The analysis of costs per phase is an advantage of the TDABC method and it has been used to prioritize improvement actions²¹. The CCR of each recourse observed in the sample of hospitals and the resources time consume differences were used to explain the variation identified in costs and time during the patient trajectory among hospitals.

The analyses aimed to identify cost-saving opportunities in each hospital care process. Due to inter-state differences in supply acquisition, which poses analytic challenges, prices of prosthesis, materials and medications were excluded from the analysis⁴. The cost composition measured by the mean cost of each resource variable stratified by labor and non-labor costs in each phase was analyzed for the cost-saving estimates. A graphical analysis comparing the costliest hospital in ICP to the less costly, allowed to identify the resource variables that contribute the most to the cost difference and, because of that, concentrate the highest cost-saving opportunity.

Cost data were collected in Brazilian currency (*Reais*, in 2019) and converted into international dollars according to the purchasing power parity (PPP) data for 2018 from the Organization for Economic Co-operation and Development.

Results

During the study period, 90 patients undergoing elective ICP were included in the study (hospitals A to D, 20 patients each, and hospital E, 10 patients). Mean age was 60 years, and most were male (51 patients). Ninety four percent had systemic arterial hypertension and 60% had diabetes mellitus. The total cost of treatment for all 90 patients was \$151,004. Mean cost per patient was \$1,677 (SD \$881). Table 2 shows descriptive costs, stratified by hospitals. It is possible to observe the prosthesis's impact on the total cost as well as the divergencies in inter-state supply acquisition of each institution. Excluding the materials, medications, and prosthesis, the labor costs during the procedure represent the most representative cost variable.

Table 2
Interventional coronary procedure cost detailing

Hospitals		A	B	C	D	E
Cost composition (\$)						
Pre procedure	Labor cost	40	10	15	7	26
	Non labor cost	39	2	62	77	9
	Total	79	12	77	84	35
Procedure	Labor cost	145	90	76	81	123
	Non labor cost	14	2	13	11	23
	Total	159	92	89	92	146
Post Procedure	Labor cost	95	13	19	2	-
	Non labor cost	250	1	55	19	399
	Total	345	14	74	21	399
	Materials and Medications Cost	89	165	204	83	50
	Prosthesis cost	1,967	1,487	830	527	1,491
	Total	2,056	1,652	1,034	610	1,541
	Estimated mean cost per patient	2,639	1,770	1,274	807	2,121
	SD	739	606	425	467	762
	Maximum	3,681	3,278	2,313	2,616	3,302
	Minimum	1,307	1,286	680	458	1,143
	Median	2,191	1,493	1,275	691	2,023
	Interquartile range	1,268	774	399	166	1,172

In order to better understand the cost composition of the ICP in each center, Table 3 presents the mean values of time and process costs for each resource at each phase of the care pathway as well as the mean cost per patient. On all resources, there was a difference in costs per unit of time between hospitals. Due to this, even though a hospital had a more efficient process of care, it can result in a higher total cost when compared to others less efficient ones.

Table 3: Cost Capacity Rate, mean time consumed per resource in each phase and cost per resource per hospital.

Hospitals	PRE PROCEDURE						PROCEDURE					POST PROCEDURE			
	Reception assistant	Nursing technician	Nursing	Physician	Cleaning assistant	Hemodynamic unit cost	Physician	Nursing	Nursing technician	Fellow Physician	Hemodynamic unit cost	Nursing technician	Nursing	Physician	Hemodynamic unit cost
	CCR Time (\$ (h))														
A	14 0.17	23 0.6	44 0.25	79 0.13	9 0.28	15 2.59	79 0.95	44 0.95	23 0.95	6 0.95	15 0.95	23 1.58	44 0.69	79 0.36	15 16.66
B	7 -	14 0.32	33 0.07	73 0.04	4 0.22	3 0.5	73 0.71	33 0.71	14 0.71	6 0.71	3 0.71	14 0.1	33 0.21	73 0.06	3 0.41
C	12 0.2	17 0.45	32 0.11	61 0.01	11 0.11	20 3.09	61 0.64	32 0.64	17 0.64	8 0.64	20 0.64	17 0.22	32 0.26	61 0.12	20 2.73
D	7 0.02	10 0.65	13 -	64 -	7 0.08	13 5.77	64 0.85	13 0.85	10 0.85	8 0.85	13 0.85	10 0.08	13 0.08	64 -	13 1.44
E	8 0.17	11 0.63	34 0.25	66 0.12	5 0.3	22 0.39	66 1.06	34 1.06	11 1.06	6 1.06	22 1.06	11 -	34 -	66 -	22 18.19

Hosp.	PRE PROCEDURE (\$)						PROCEDURE (\$)					POST PROCEDURE (\$)			
	Reception assistant	Nursing technician	Nursing	Physician	Cleaning assistant	Hemodynamic unit cost	Physician	Nursing	Nursing technician	Fellow Physician	Hemodynamic unit cost	Nursing technician	Nursing	Physician	Hemodynamic unit cost
A	2.51	13.72	10.91	10.08	2.57	38.77	75.36	41.89	21.89	6.17	14.28	36.36	30.39	28.65	249.51
B	-	4.37	2.22	2.82	0.83	1.6	51.91	23.26	9.77	4.58	2.26	1.35	6.97	4.65	1.33
C	2.42	7.51	3.58	0.51	1.21	61.85	39.31	20.64	10.86	5.2	12.86	3.64	8.26	7.03	54.57
D	0.14	6.56	-	-	0.59	76.63	54.44	11.05	8.59	7.13	11.25	0.84	1.09	-	19.11
E	1.39	7.11	8.48	8	1.47	8.58	69.41	35.8	11.95	6.32	23.12	-	-	-	398.59

Figure 2 contains mean time and costs (excluding those from prosthesis, materials and medication). By analyzing the charts, it becomes clear that the procedure phases duration and respective costs were similar between hospitals. The difference between the highest and the lowest mean cost per patient among the centers at the procedure phase was \$71 (interquartile range \$14). In contrast, at the post-procedure phase, mean cost difference increased to \$ 384 (interquartile range \$ 94). This increase resulted in higher cost per patient in hospitals A and E, where post-procedure phase represented in average 59% and 68% respectively of the cost estimated per patient (excluding prosthesis, materials and medication). However, these higher costs at post-procedure phase could be justified by the consume of hospital structure as a resource at this phase, as its cost is directly proportional to the length of stay of the patient. On the other hand, the differences observed during the procedure phase could be explained by the manner in which centers distribute their labor resources. Thus, cost-saving opportunities associated with the ICP redesign are more evident at procedure phase.

When exploring highest cost differences at procedure phase (hospitals A and C) as a redesign opportunity in cost-saving estimates, it becomes clear that hospital A could decrease costs from adapting its processes to operate at hospital C organizational parameters.

Figure 3 presents the broken-down cost difference between the highest and lowest total mean costs of procedure phases (Hospital A and C respectively). Physicians time accounted for 51% of this observed cost difference, followed by nursing 30%. Thus, all care pathways could decrease costs by redesigning the manner in which professionals are organized to deliver care to patients. The post-procedure phase should receive focus on decreasing the length of time spent in the hemodynamic, as care process improvement actions to make them less costly.

Discussion

Through a multicenter study across different regions in Brazil, our results were able to demonstrate the importance of assessing net costs and time data separately to identify similar patterns of care. The results showed that, evaluating the efficiency of a process from an economic perspective without understanding its behavior may limit the ability to identify optimal care practices and opportunities for cost-saving.

Longer time does not necessarily lead to higher costs both as a function of the time and of the intensity of how each resource is being consumed and the respective cost-per-time base value of this resource. The differences identified can be used to better guide the redesign of health care delivery. Re-engineering and redesign methods have been used to increase efficiency and improve patient experience in different health care fields^{22 23 24}. Understanding how each patient consumes resources requires methodologies that allow us to design clinical pathways considering all of the relevant flows of care and resources, outcomes, experience, and costs²⁵. Our results demonstrate the value behind the effort of the detailed comprehension of how patients consume resources from the health care service in comparison to only considering financial results. It highlights the value of TDABC in regard to its requirement of enable researchers, clinicians and health care managers to real comprehend the health care routine service delivery²⁶.

Some authors point out that any approach that evaluates hospital performance requires the identification of a reference institution, a benchmark, for comparisons aimed at continuous efficiency improvement²⁷. In recent scientific publications, the need to look at this topic from a systemwide context and not just focus on one or two components of the system has been set as a premise for the identification of inefficient and low-value points that need to be reformulated²⁸. By involving multiples hospitals from the same health system, this study identified that the way that labor and non-labor resources are consumed during the procedure phase can concentrate great cost-saving opportunities, being the physicians the resources that may receive more attention to achieve higher cost decrease results.

Another important cost driver of TDABC was related to time spent on recovery room. Time reduction time opportunities are concentrated in pre- and post-ICP. Investing in redesign actions that allow for a reduction in post-procedure time, as observed in hospitals A and E, can provide indirect benefits linked to opportunity costs, such as hospital capacity increase. Comparison of processes of care, while not always associated with a great impact on the reduction of direct costs, is a valuable method to identify improvement opportunities that can have an impact on elements of patient perception³ or opportunity costs²¹. Others have demonstrated that microcosting studies with TDABC provided the opportunity to optimize processes of care and to positively influence the operational performance and costs of health care organizations^{29 15}.

As in the care process analyses, in which the importance of not assessing value by isolated components was discussed, the monitoring and control capacity of the agency that regulates and reimburse the system deserves attention with respect to high-cost technologies used during the procedure. The inability of information systems to monitor processes and costs has been reported as a barrier to the

operationalization of value-based management and payment models^{11 30}. Especially in unified health systems, this can be extended further to include the importance of traceability and control, at the individual level, the differences in deliver of care throughout the treatment of patients. Adopting technologies such as radiofrequency identification is seen as an option, with positive results reported in the literature, particularly regarding controllability and organizational management³¹. The use of these technologies, linked to a digital system that allows for an accurate cost assessment, can contribute to correctly managing treatments delivered to patients and their respective costs, thus enabling value-based control mechanisms for health systems³².

This study has some limitations. First, only one procedure was analyzed to assess differences in process of care between health institutions in terms of costs and time. Although the influence of costs of material, medication and prosthesis was removed for the cost-saving analyses. In addition, this study aimed to evaluate cost and time consumed assuming similar clinical outcomes among institutions. Regarding the suggestions on how process improvements may impact patient experience and opportunity costs, it should be noted that they were presented in this paper as hypotheses to guide future studies aiming to improve methods to assess value in health care.

Conclusion

In a national wide public health system, the comprehension of how individual patients consume resources through their entire care pathway allows managers to identify where they should act to identify opportunities for direct cost-saving and hospital process outcomes improvements. This study demonstrated how the level of detailing provided by microcosting methods such as TDABC can contribute to driving health care management to value. Hence, if we were to set efficiency benchmarks, it would be wise to consider time expenditure and local resource consumption, not only financial results.

The current report represents the first multicenter study of the costs of ICP in Brazil. Therefore, the costs reported here can be used as a benchmark to measure true costs in future economic analyses for decision-making in health care.

Abbreviations

TDABC – Time-driven Activity-based Costing

VBHC – Value-based Healthcare

ICP – Interventional Coronary Procedure

REBRATS - Brazilian Network for Health Technology Assessment

CCR - Capacity Cost Rates

SD - Standard-Deviation

Declarations

Ethics approval and consent to participate:

This study was approved by the Ethic Committee of the Hospital de Clínicas de Porto Alegre (Project reference number - CAAE: 89332618.1.0000.5327), followed by approval agreed by the Ethical Committees from all the participating hospitals.

This research did not interview patients directly and the need for consent was waived by the Ethical Committee. The managers and clinical staff interviewed in the research were invited to collaborate sharing their knowledge about the service routine.

Consent to publish:

Not applicable

Availability of data and material:

The tables presented along the entire article contains most data used to develop the article analysis. Additional datasets used during the current study are available from the corresponding author on reasonable request.

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Competing Interests:

The authors declare that they have no conflicts of interest.

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Authors Contributions

APBSE: Organized and conduced data collection and analysis and has been involved with all the writing process.

LNC: Organized the communication with centers and has been involved with data collection and analysis, and with the writing process.

RS: Organized and conduced data collection and analysis.

JN: Organized and conducted data collection and analysis.

RBC: Has been involved with data analysis and writing process.

LK: was the principal researcher from one center, being responsible for the data collection at this center.

AAN: was the principal researcher from one center, being responsible for the data collection at this center.

JAN: was the principal researcher from one center, being responsible for the data collection at this center.

JLN: was the principal researcher from one center, being responsible for the data collection at this center.

RMA: was a researcher from one center, being responsible for the data collection at this center.

JSPT: was a researcher from one center, being responsible for the data collection at this center.

JAM: was the principal researcher from one center, being responsible for the data collection at this center.

LBM: was the principal researcher from one center, being responsible for the data collection at this center.

CAP: designed the study methods, managed the researchers, reviewed the methods and results, has been involved with all the writing process.

All authors have read and approved the manuscript

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Figures

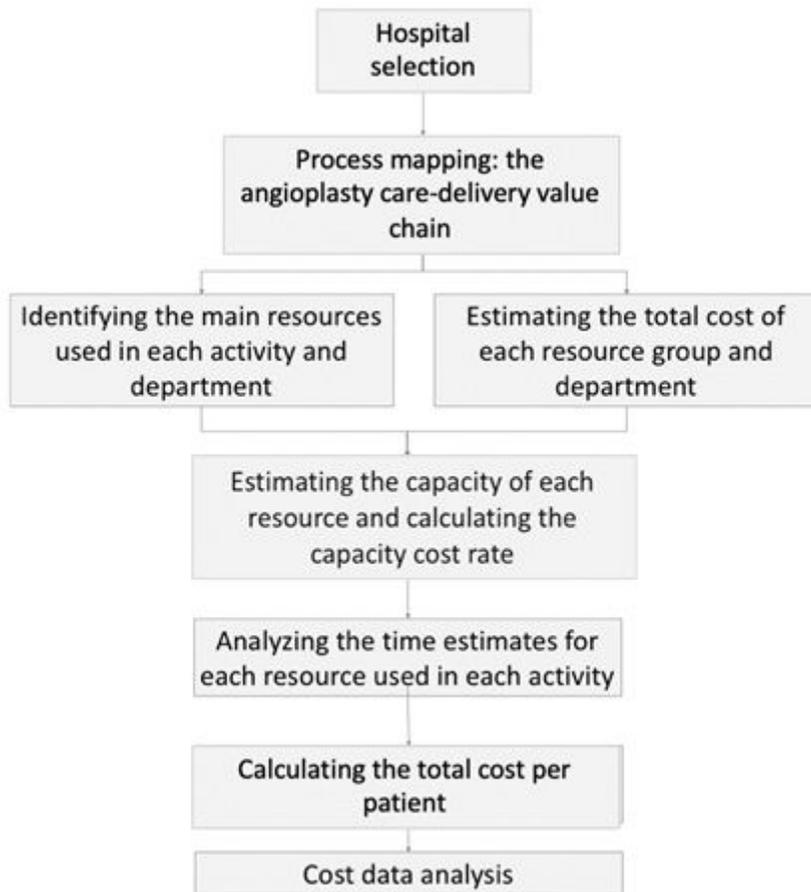


Figure 1

Median costs (A) and median time spend (B) according to procedure phases in participating hospitals.

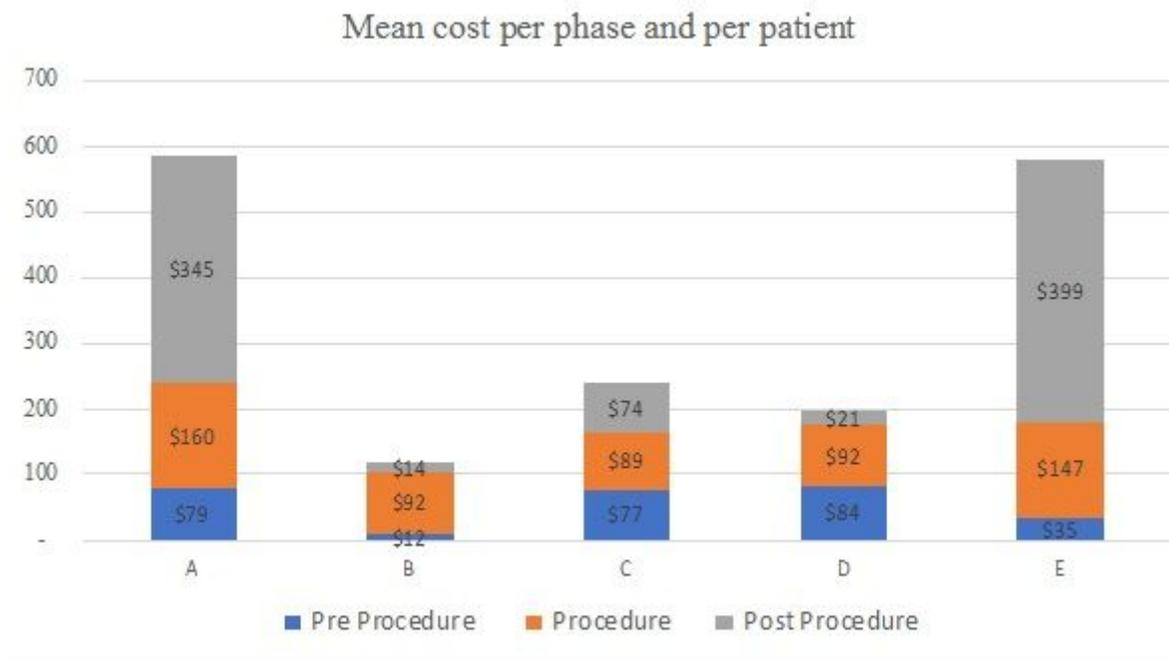
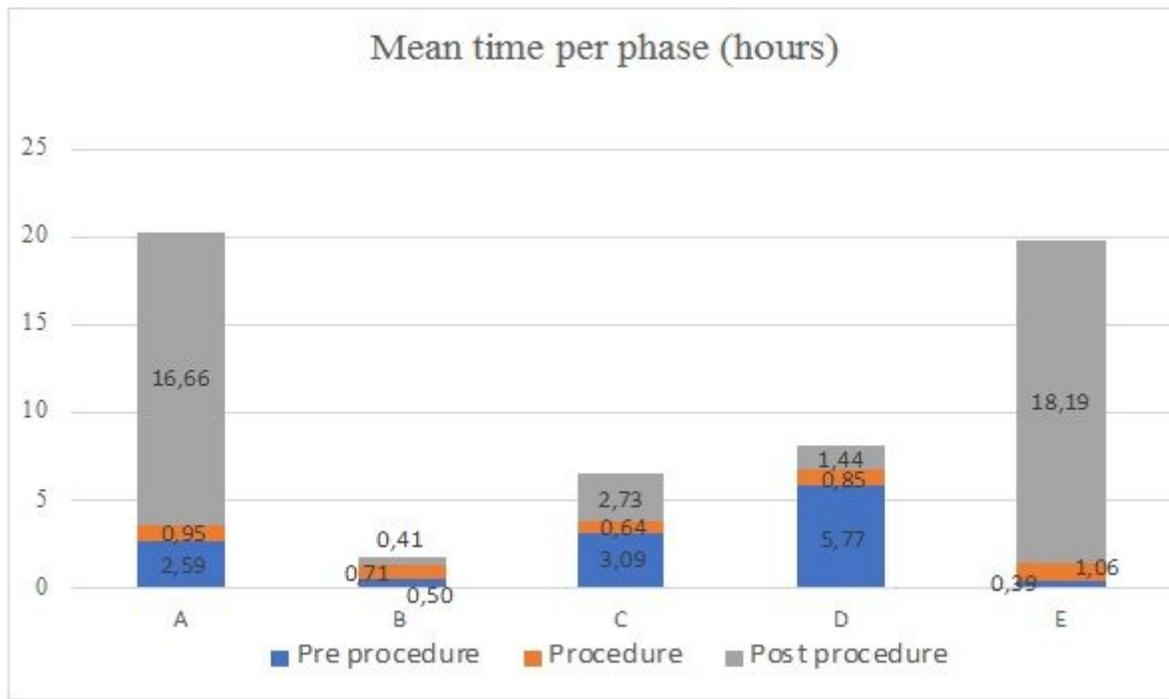


Figure 2

ICP cost detailing

Differences in procedure phase cost between the hospitals with highest and lowest mean cost in the procedure phase

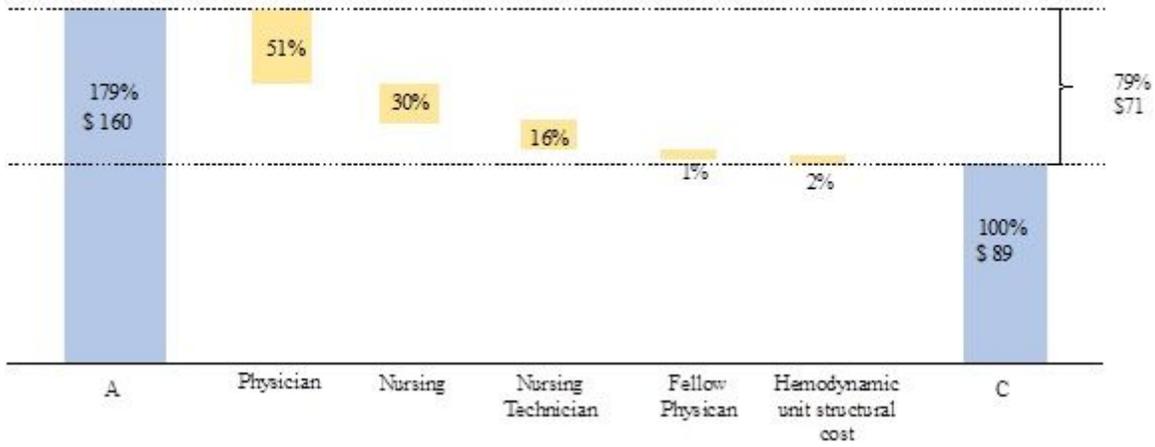


Figure 3

Comparison between process cost patient profiles and time consume patient profiles