Time-driven activity-based costing as a strategy to increase value: the case of interventional procedures

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)

National Institute of Science and Technology for Health Technology Assessment (IATS)- CNPq/Brazil

<https://orcid.org/0000-0002-2447-2577>

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Abstract

Background: Adopting value-based health care management strategies requires monitoring the real costs and care delivered to patients. This study aimed to evaluate the cost-saving opportunities of interventional coronary procedures (ICPs) by assessing patients' processes of care and costs in five public academic hospitals.

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

Results: The mean cost per patient of interventional angioplasty was \$1,677 (SD \$881). The length of the procedure phase per patient was similar among the hospitals, while the post- procedure phase presented the highest variation in length. However, it was possible to demonstrate that the highest direct cost saving opportunities are concentrated in the procedure phase in which labour and non-labour resources are more consumed. Physician involvement redesign can account for a 51% decrease in procedure cost.

Conclusion: This study demonstrated how the level of detailing on cost information provided by the TDABC can contribute to driving health care management to value by identifying cost-saving opportunities in 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 of implementing value-based health care principles, considering its association with quality outcomes and patient perceptions of care ¹
². Recent scientific advances have shown that the net costs of care delivery remain a core element of

value assessments³ amidst a set of eleven other elements aimed at capturing patient perceptions and experiences.

Coronary artery disease is the leading cause of death worldwide, and interventional coronary procedure (ICP) is a standard non-surgical therapy for acute and chronic cases performed for myocardial revascularization. For this study, elective ICP was chosen considering its high prevalence, low individual variability, high volume and cost. In 2018, 78,428 percutaneous coronary procedures were performed, and the total amount spent was R\$494,835,000 by the public Brazilian system. Assessing the real cost using microcosting methods allows a better estimation of the economic impact that health care procedures represent⁴. Recently, when analysing 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 practised in the country was 18,012 international dollars per patient⁴. For bone marrow transplantation, in a similar study, the average cost of 155,843 international dollars was observed, and the reimbursement practised by the national health system was 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 were 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 health care service delivery are needed⁸. Given the level of cost information accuracy that time-driven activity-based costing (TDABC) can provide, in terms of bottom-up costs and process analysis, the application of TDABC might enable payers and providers to design, to evaluate, and to expand value-based initiatives^{9 8 10}.

TDABC is a patient-centred approach that allows for detailed direct and indirect cost accounting by identifying patient-specific resource consumption over the course of a 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 quantity of resources required to perform a transaction or an activity¹². TDABC might contribute to identifying opportunities for improvement in the delivery of care by adjusting activities according to patient needs¹³. The method has been applied as a successful microcosting technique in medical research^{14 15} and has been suggested in the literature as a methodology that can be useful in value-based initiatives^{9 14}.

The present study aimed to apply the TDABC to identify cost-saving opportunities for ICP by evaluating patient processes of care and costs in five public academic hospitals.

Methods

Costs of ICPs were retrospectively collected in five public academic hospitals that are considered national centres of excellence (A, B, C, D, and E), located in four states of Brazil. Participating centres were selected based on their expertise in 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 listed in Table 1. The study perspective was that of the public health system. This study was approved by the Ethics Committees of the participating hospitals.

DATA COLLECTION

Between March and October 2018, all patients submitted to an ICP were added to the sample analysis, which was limited to a maximum of 20 patients per centre. Center E was the only one that did not reach the maximum (total of 10 patients). Patients were eligible if they had an elective ICP during this period and had a hospital account reimbursed by the unified health system. All centres followed the same data collection process and received instructions on data collection, and a database was created on REDCap web-based software (Vanderbilt University, Nashville, TN, USA)¹⁶.

A multidisciplinary team composed of physicians, industrial engineers and professionals with business backgrounds was formed to apply the TDABC method. All suggested operationalisation steps of the method were strictly followed, starting with the design of the entire patient care pathway and finishing with cost analyses oriented to identify opportunities to decrease costs^{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 centre over a one-week period, followed by validation by the remaining participating centres. The resulting validated map was used to identify all resources consumed during the care pathway (Figure 1). Pre-procedure, procedure, and post-procedure macrophases were observed as described in previous studies^{18 19 15}. At the pre-procedure phase, the patient is admitted and prepared for the procedure at the haemodynamic unit; the procedure phase is substantially performed by physicians with the support of nurses and nurse technicians at the haemodynamic unit; and the post-procedure phases include the period of patient stabilisation after ICP in the haemodynamic unit before transfer to another unit.

Different variables were selected for evaluation personnel, corporate and divisional allocations (hospital structure), and medications and materials related to each macrophase of the procedure. Data collection techniques included medical record review, direct process observations by researchers, and interviews with hospital staff²⁰. In each hospital, the local researchers followed each individual patient to report the time spent per patient in each phase. These information data were used to calculate the individual costs per phase. The prices and amounts of materials, prostheses and medications were collected from invoices and documents containing the mean acquisition costs of supplies. These prices did not include profit margins, given the public nature of the participating centres.

Non-labour costs included hospital structure fixed costs, such as energy, depreciation, third-party contracts, software licences, taxes and general materials, which were attributed to the haemodynamic unit from each hospital. Labour costs included salaries and were charged per professional class. Financial data were based on a mean expenditure incurred per month over a 12-month period and were obtained from the financial departments of each hospital.

To estimate the cost-capacity rate (CCR) for each resource, the actual capacity was calculated, taking into consideration the number of rooms and working load period of the haemodynamic unit for non-labour costs. For the labour costs, monthly work hours and expected fringe benefit rate were considered.

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 labour and non-labour variables, stratified per phase, 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 prioritise improvement actions²¹. The CCR of each resource observed in the sample of hospitals and the resource time consumption differences were used to explain the variation identified in costs and time in each treatment phase among hospitals.

The analyses aimed to identify cost-saving opportunities in each hospital care process. Because of interstate differences in supply acquisition, which pose analytic challenges, prices of prostheses, materials and medications were excluded from the analysis⁴. The cost composition measured by the mean cost of each resource variable stratified by labour and non-labour costs in each phase was analysed for the cost-saving estimates. A graphical analysis comparing the costliest hospital in ICP to the least costly hospital allowed us 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 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). The mean age was 60 years, and most were male (51

patients). Ninety-four percent of patients 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 hospital. The prosthesis demonstrated a high impact on the total cost as well as divergences in its inter-state acquisition cost. Excluding the materials, medications, and prostheses, the labour costs during the procedure represent the most representative cost variable.

To better understand the cost composition of the ICP in each centre, 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. For all resources, there was a difference in costs per unit of time between hospitals. However, these differences are mostly explained by regional macroeconomic regional conditions; even though a hospital had a more efficient process of care than other less efficient hospitals, higher total costs can still occur.

Figure 2 contains the mean time and costs (excluding those from prostheses, materials and medications). By analysing the charts, it became clear that the procedure phase duration and respective costs were similar between hospitals. The difference between the highest (A) and the lowest (C) mean cost per patient among the centres at the procedure phase was \$71 (interquartile range \$14). In contrast, at the post-procedure phase, the mean cost difference between the highest and lowest cost per patient at the post-procedure phase (hospitals E and B, respectively) increased to \$384 (interquartile range \$94).

The differences in the cost of the post-procedure phase, which were due to the highest time spent per patient at this phase, resulted in a higher cost per patient in hospitals A and E, where the phase represented an average of 59% and 68%, respectively, of the cost estimated per patient (excluding prostheses, materials and medications). However, these higher costs in the post-procedure phase were due to hospital structure use in this phase, as its cost is directly proportional to patient's length of stay. On the other hand, the differences observed during the procedure phase could be explained by the manner in which centres distribute their labour resources. Thus, cost-saving opportunities associated with ICP redesign are more evident in the procedure phase.

When exploring the highest cost differences at the 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). Physician time accounted for 51% of this observed cost difference, followed by nursing 30%. These differences are explained by the time consumed by physician and nurse resources in each hospital, which varied from 0.95 hours in hospital A to 0.64 hours in hospital C for both resources. Regarding the physicians, hospital A also demonstrated the highest CCR. How the CCR and the time contributed to each resource's cost differences can be understood using a variability analysis. In Figure 4, the origin of procedure cost differences between hospitals A and C are detailed. Using the resource, physician, as an example, we demonstrated that the differences in CCR justify 47% of the difference in

costs, and the differences in time justify 53%. If hospital A operates in hospital C's time parameters, it is possible to reduce the physician cost for the procedure by \$18 per patient.

By understanding the origin of the differences in cost, all care pathways could decrease costs by redesigning how professionals are organized to deliver care to patients. Translating these findings to practical terms, pre- and post-phase costs could be reduced by standardising the length of time in the recovery room, and most importantly, the number of physicians and nurses during the procedure had a significant impact on the results. The time parameters observed in hospital A could be assumed as benchmarks to guide the redesign initiatives for hospital C and the others. The post-procedure phase should focus on decreasing the length of time spent in the haemodynamic unit, as a care process improvement action to make it less costly.

Discussion

Through a multicentre 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 behaviour may limit the ability to identify optimal care practices and opportunities for cost savings.

Longer time does not necessarily lead to higher costs both as a function of the time and 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. Reengineering and redesigning methods have been used to increase efficiency and to 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, in comparison to only considering financial results, the value behind the effort of the detailed comprehension of how patients consume resources from the health care service. For instance, standardization of pre- and recovery phases among hospitals, assuming the shortest length of stay, could have an impact on total cost. Also, limiting the number of health care professionals during elective procedures could translate into lower costs and similar outcomes. As demonstrated by others, hospitals and payers could use these data to review health care 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 multiple hospitals from the same health system, this study identified that the way that labour and non-labour resources are

consumed during the procedure phase can concentrate great cost-saving opportunities, with physicians receiving more attention to achieving higher cost-decrease results.

Another important driver of TDABC costs was related to the time spent in the 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 influence the operational performance and costs of health care organizations positively^{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 reimburses 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 operationalisation 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, and 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 analysed to assess differences in the process of care between health institutions in terms of costs and time. Although the influence of the costs of materials, medications and prostheses was removed for the cost-saving analyses, institutions operate in different macroeconomic contexts. Future economic analyses could explore in more detail the origin of differences in CCR. In addition, this study aimed to evaluate costs 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 universal public health system, understanding how individual patients consume resources through their entire care pathway allows managers to identify where they should act to identify opportunities for direct cost savings and hospital process outcome improvements. This study demonstrated how the level of detail 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 expenditures and local resource consumption, not only financial results.

The current report represents the first multicentre 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 health care decision-making.

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

PPP - Purchasing Power Parity

Declarations

Ethics approval and consent to participate:

This study was approved by the Ethics Committee of the Hospital de Clínicas de Porto Alegre (Project reference number - CAAE: 89332618.1.0000.5327), followed by approval agreed upon by the Ethics Committees of 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. Individual questions were not asked, which made the need for consent waived by the Ethical Committee.

Consent to publish:

Not applicable

Availability of data and material:

The tables presented throughout the entire article contain most of the 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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Not applicable.

Author Contributions

APBSE: Organized and conducted data collection and analysis and was involved in the writing process.

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

RS: Organized and conducted data collection and analysis.

JN: Organized and conducted data collection and analysis.

RBC: Was involved with data analysis and writing process.

LK: Was the principal researcher from one centre and was responsible for the data collection at this centre.

AAN: Was the principal researcher from one centre and was responsible for the data collection at this centre.

JAN: Was the principal researcher from one centre and was responsible for the data collection at this centre.

JLN: Was the principal researcher from one centre and was responsible for the data collection at this centre.

RMA: Was a researcher from one centre and was responsible for the data collection at this centre.

JSPT: Was a researcher from one centre and was responsible for the data collection at this centre.

JAM: Was the principal researcher from one centre and was responsible for the data collection at this centre.

LBM: Was the principal researcher from one centre and was responsible for the data collection at this centre.

CAP: Designed the study methods, managed the researchers, reviewed the methods and results and was involved in the writing process.

All authors have read and approved the manuscript

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Tables

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

Table 2: Interventional coronary procedure cost detailing

Hospitals		A	B	C	D	E
Cost composition (\$)						
Pre-procedure	Labour cost	40	10	15	7	26
	Non labour cost	39	2	62	77	9
	Total	79	12	77	84	35
Procedure	Labour cost	145	90	76	81	123
	Non labor cost	14	2	13	11	23
	Total	159	92	89	92	146
Post-Procedure	Labour cost	95	13	19	2	-
	Non labour cost	250	1	55	19	399
	Total	345	14	74	21	399
Materials and Medications Cost		89	165	204	83	50
Prostheses 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

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))	CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))		CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))	CCR Time (\$ (h))	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

Figures

Figure 1

Physician's cost-saving opportunities

Figure 1

ICP general process map

Figure 1

ICP cost detailing

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

Figure 1

Comparison between process cost patient profiles and time consumption patient profiles