Economia Aziendale Online

Business and Management Sciences
International Quarterly Review

SPECIAL ISSUE
THE MULTIDIMENSIONAL CONTENT OF
ECONOMIA AZIENDALE
Exploring Theories and Applications
of Business Economics and Management
[1 of 3]

An analysis of healthcare processes through an Activity-based Costing approach

Antares D'Achille

Pavia, Aprile 2019
Vol. 10 - N. 1/2019

www.ea2000.it
www.economiaaziendale.it

PaviaUniversityPress

Electronic ISSN 2038-5498
Reg. Trib. Pavia n. 685/2007 R.S.P.

Economia Aziendale Online – Business and Management Sciences International Quarterly Review
Vol. 10.1/2019:93-105 - DOI: 10.13132/2038-5498/10.1.1948

An analysis of healthcare processes through an Activity-based Costing approach

Antares D'Achille [1]

[1] *Researcher*
Università degli Studi di Perugia

Corresponding Author:

Antares D'Achille
Università degli Studi di Perugia
Piazza dell'Università, 1
06123 Perugia (PG)
antares.dachille@unipg.it

Cite as:

D'Achille, A. (2019). An analysis of healthcare processes through an Activity-based Costing approach. *Economia Aziendale Online*, Special Issue, 10(1), 93-105.

Section: *Refereed*

Received: 6 November 2018
Published: 30 April 2019

ABSTRACT

Nella ricerca proposta, sono state analizzate due distinte procedure chirurgiche sui dati dell'ospedale di Perugia, attraverso l'applicazione dell'Activity Based Costing (ABC). Lo scopo principale del nostro studio è quello di analizzare il costo sostenuto tra le due procedure, che hanno medesimo DRG (diagnostic related group), al fine di evidenziare come i costi siano diversi in relazione alla diversa procedura e quali siano le variabili di costo più rilevanti. Si evidenzia come l'applicazione dell'ABC ha l'indubbio vantaggio di determinare il costo di un servizio di cura e fungere da supporto al decision making in ambito sanitario.

We introduce an application of Activity-based Costing (ABC) to specific healthcare procedures. The analyses carried out, using data of the Perugia's hospital. The main purpose of our study is to analyze the cost incurred between two procedures that have the same DRG (diagnosis-related group), in order to highlight how the costs are different in relation to the different cost procedure., highlight cost between the two procedures. Moreover, we identify also differences in the level of resource absorption in both procedures and, therefore, different cost impacts on the procedures are analyzed. In this respect, the application of the ABC has the undoubted advantage of determining the cost of healthcare service and support more objective decisions to be taken by healthcare management.

Keywords: ABC, activity-based costing, healthcare cost, cost management, cost analysis

1 – Introduzione

Nowadays, changes in healthcare create a relevant pressure on national welfare, so this perspective requires greater attention, in particular, with respect to the sustained costs. Cost analysis should be used to promote changes towards correct management and should not for lead to a reduction in the quality of healthcare services.

Improving cost information can increase the healthcare service value and this last aspect, is really relevant for an adequate communication with the "stakeholders", so there is a need for the introduction of more effective cost

management technical approaches. In this situation, the ABC could provide some benefits. The adoption of an ABC model necessarily needs a real case to study, because these models provide best information when applied to a real-case scenario. In particular, the study has been carried out thanks to the collaboration of the Regione Umbria and Perugia's hospital. The aim of the study was to analyze the cost of two different procedures that have the same DRG, which means however that the same pathology has the same complexity. Instead the surgical approach is different, and this aspect is probably reflected in all healthcare processes that allow a different use of resources to treat the same pathological state. This aspect is important if we consider the scarcity of resources and the constant increase in demand for healthcare services because it allows to have greater source of data, both quantitative and qualitative, useful for making decision on healthcare management. It could maximize the usefulness of procedures and reduce the costs. In this way it could be possible to pursue both social and economic objective.

2 – Literature Review

The ABC is taken into account in the healthcare sector due to the increasing complexity of the modern welfare state. The application of ABC in the healthcare sector is recent but some studies have been published since the development of the ABC in 1990s (Chan, 1993, Ramsey, 1994, Udpa, 1996, Baker, 1997). In 2006 Cao *et al.* introduced a simplified ABC model (defined S-ABC by authors) in a Japanese hospital context to reduce the complexity of its cost system. Other contributions were published in recent years but all of them are characterized by a limited use in specific departments and/or care services (Agyar *et al.*, 2007, Kuchta and Zabek, 2011, Goldberg and Kosinski, 2011, Rajabi and Dabiri, 2012, Hennrikus *et al.*, 2012). The limited use of ABC is due to the relevant difficulties in disseminating this costing system to healthcare institutions. The main problems that hinder an extensive use are: the assessment of performance (considering also patient outcome), the mapping of activities because, in many cases, the healthcare process is not standardized, and finally, the complexity and size of the hospital (Popesko and Novak, 2011, Popesko and Novak, 2013). Moreover, activity-based models are the best choice to increase knowledge on costs sustained because "traditional top-down hospital accounting systems, using ratios of costs to charges and relative value units (RVUs), are often inaccurate and offer little insight to surgeons and clinical staff on how and where to optimally reduce cost" (Najjar *et al.*, 2017).

To manage these issues, we can also consider a "light" approach to ABC, namely the Time-Driven ABC (TDABC), that was introduced in 2007 by Kaplan and recently revised for the healthcare point of view (Kaplan, 2014, Kaplan and Haas, 2014, Kaplan *et al.* 2014, Campanale *et al.*, 2014, Kaplan and Porter, 2011, Demeere *et al.*, 2009). The light approach must be understood as a simplification of the traditional ABC model, since, in order to apply the TDBC, the most relevant aspects concern the definition of the practical capacity of the resources involved (i.e. the time of use), the cost of the resources themselves and the definition of the time necessary to carry out a process or an activity. These last elements can be identified through the elaboration of a time equation. The main advantages compared to the traditional ABC, concern greater objectivity of the measures (practical capacity, cost of resources, execution time of a process) compared to the measurements provided by the ABC that requires significant drivers in the absorption of resources and they are based on the use of interviews and questionnaires for measuring time needs (from which also derives the

distortion of the maximum use of time in the performance of the activities by respondents, known as social desirability). Moreover, the TDABC has hexhibited better chances for adoption because it provides information for decision making to both product and proess levels rather than the traditional ABC (Monroy *et al.*, 2012) , seems to provide more accurate cost information (Everaert *et al.*, 2008) and allows to revise the healthcare process for cost reduction (Yangyang *et al.*, 2017, McLaughlin *et al.*, 2014, Popat *et al.*, 2018). On the other hand, some studies point out that TDABC does not provide relevant benefits with respect to ABC (Gervais *et al.*, 2010) and, as the traditional ABC, also the TDABC is not used extensively (Keel *et al.*, 2017). Taking into account these considerations we have tried to adopt an ABC model with a hybrid approach using both main models offered in literature and more specifically:

- a part of staff costs is allocated by interviews and through process analysis in collaboration with nurses and physicians (this method is used in the ABC approach), but O.R. cost staff costs are allocated on a time basis (TDABC approach);
- when possible, costs are directly allocated, as those for exams and consults (direct costs);
- other costs, as the drugs employed during hospitalization, are allocated on a volume basis.

So, differently from other authors, that are oriented to use purely the TDABC to compare the cost of different procedures (Chipko *et al.*, 2017), we use several methods and by an in-depth analysis we try to allocate directly the more relevant costs. The two procedures considered are quite complex and it is not possible to highlight a standard pattern in the healthcare process: this circumstance reduces the relevance of TDABC (as time-based allocation method). In our contribution, we consider the use of two different surgical procedures for the same pathology having the same DRG, that is the measure of national refunding to subject that performances the healthcare service

So, our main research question is:

- same DRG refunds in correct way the healthcare services?

Our hypothesis is that different procedures have different costs and DRG could be overpaying in one case and insufficient in another, so more precise costs could be compare with national fees and open discussion about reimbursement adequacy (Schroeder *et al.*, 2018).

The second research question is specific to two procedures considered (thoracotomy and thoracoscopy) and analyses which variables are relevant, eventually, to explain cost differences:

- which variables are statistically significant to explain costs? Furthermore, which cost drivers are most important in both procedures?

We expected that the two surgical procedures have different impact on an healthcare institution's costs, even if the associated DRG is the same, because thoracotomy is more invasive than thoracoscopy, but thoracoscopy uses a lot of expensive surgical devices. The analysis will increase the awareness on costs to support of management's decision making (Menendez *et al.*, 2018).

3 – Methodology

In order to test our hypotheses, we have carried out an empirical study collecting data from 138 lobectomies for lung cancer, executed through two different procedures: thoracotomy and thoracoscopy (or Vats - Video-assisted thoracoscopic surgery). The study was carried out in the Surgical Thoracic Unit of Perugia's Hospital. The assessment was performed analytically for each medical record available on paper. Thus, we have considered 138 patients hospitalized in the years 2014-2017.

As a first analysis, we have highlighted a limited importance of the consumption of drugs and consumables in general while nursing care was greater for patients undergoing more invasive procedure because the lengths of stay were longer. However, the duration of two thoracic procedures is not particularly different in the Operating Room (O.R.). Moreover, the length of stay is lower in the case of thoracoscopy and this results in lower costs in hospitalization but, on the other hand, costs of medical resources are higher.

We have separated the absorption of resources for both procedures using a mixed ABC model, introducing some evaluations instead of the real costs because the process is really complex and some resources are used continuously in time. Therefore, whenever possible a direct allocation was used (for example, drugs for O.R.), otherwise resources were allocated by time (for example, working time for personnel) and, finally, allocated for length of stay when the resources are linked to days of stay (for example, meals per day).

In this way the complexity of approach was reduced and more attention was given to resources that are not predictable and/or have an important impact in the total cost: in other words, less importance was given to resources that are less expensive.

The study was based on previous research (D'Achille, 2017), that analysed the specific costs of two procedures regardless of common costs. By the previous results we identified in detail some resource costs, introducing a time-driven approach and, finally, allocating direct costs.

Annual staff costs in 2016 were:

- 589,540 euros for medical staff;
- 597,538 euros for nursing staff;
- 101,297 euros for auxiliary staff;
- 156,359 euros for other staff.

Knowing the hours actually worked (data provided from hospital controller) we obtain the value of cost per hour (and minute).

Using the duration of the surgical procedure and personnel used we obtain the cost of each specific procedure in terms of healthcare personnel.

In particular, as the following mean times for the two procedures and lengths of stay were obtained:

- time for O.R. thoracoscopy: 5:53:18;
- time for O.R. thoracotomy: 6:02:11;
- length of stay for thoracoscopy: 9.06 days;
- length of stay for thoracotomy: 12.59 days.

Staff used is the same in both procedures, that is: 2 surgeons, 1 anesthesiologist, 2 nurses. So, the staff cost in O.R. is 1,327 euros for thoracotomy and 1,309 euros for thoracoscopy.

Using the same approach for other staff, as absorption of human resources per day, the relative cost for the two procedures is shown as follows in Table 1.

Through interviews and analysis of the data of medical records, we know the time spent in the pre and post-operative period, so for each individual activity we can allocate staff costs.

Staff	*Cost per day*
Other graduated personnel	11.45
Administrative staff	6.00
Nurses	103.00
Physicians and academic physicians	80,26
Auxiliary staff (OTA/OSS)	20.79
Technical staff	14.62
Total cost per day	*236.11*

Table 1 - Staff cost per day

As mentioned before, other not relevant costs are allocated through an assessment with healthcare personnel, as in the case of common drugs used during hospitalization and the consumables that are used for all surgical patients. Drugs in O.R., exams and post-operative consults are instead directly allocated to specific patient/surgical procedure. Other costs as laundry and meals are allocated per day without particular bias in this case and in any case these resources have little impact to the total cost.

A greater complexity was the assessment of medical devices absorption because they are cost relevant and difficult to track in the specific surgical procedure. In this case we need the support of physicians and analyzing the theoretical procedure we consider about 1000 items to take into account in the two procedures. Medical devices are therefore allocated by in-depth assessment.

In table 2 we show the cost for the two procedures in terms of average values.

	Thoracotomy	Thoracoscopy
Operating room staff	1,327.01	1,309.04
Total staff for length of stay	2,912.65	2,080.85
Meals and laundry	262.78	189.17
Operating room drugs	258.89	283.34
Operating room devices	1,212.04	2,225.82
Post-operative exams and consults	155.94	111.52
Drugs and consumables in thoracic surgery	298.24	213.07
Consumables in common with three surgical departments	127.35	127.35
Total	*6,554.90*	*6,540.16*

Table 2 - Total cost for procedure

The differences between two procedures in terms of costs is really small. In particular, as we expected, the thoracotomy, being a more invasive procedure, requires longer stays for patients to recover, increasing costs linked to time factor. In the thoracoscopy we have instead the use of more expensive medical devices as trocar and trocar's accessories that have an important impact on O.R. cost.

The DRG associated to two surgical procedures for treatment of lung cancer is the 75c that provides a standard reimbursement tariff of 8,150 euros. The reimbursement is more than sufficient for both procedures, but we have to consider also the common costs or, in other terms, the overheads, all the costs that for their features cannot be allocated to a cost object. The ABC approach is not suitable to manage the overheads when these costs have not specific associated cost driver, and then, we cannot change them from common to specific cost. In our case, we have an important portion of common cost but every allocation has to be considered discretionary. We have chosen to allocate the common costs per day splitting them in three groups depending on the greater or lesser relation to the healthcare process, as shown in Table 3.

Related	blood transfusion, hospital staff, etc.
Partially related	consults, training, other healthcare services, etc.
unrelated	amortization, financial costs, consults, etc.

Table 3 - Relation of common costs to healthcare process

Using the sum of these costs we obtain for both procedures a common cost allocated per length of stay (also the allocation to the whole healthcare institution was performed by same factor of patients discharge per year):

- average thoracotomy common costs: 6,555 euros;
- average thoracoscopy common costs: 4,719 euros.

Finally, we report in the following Table 4 the criteria of cost allocation of the two procedures. Overheads are considered common costs and divided into three levels according to their greater or lesser connection with the analyzed procedures. This categorization allows to take into account different cost "degrees", finally obtaining a full cost, but taking in into account the critical issues that may arise with respect to the definition of a "full cost" when ABC is in use.

The total cost of the two procedures, adding also the common cost as a function of the length of stay, shows that DRG covers only partially the total costs and using as parameter the length of stay, it is possible to overestimate common costs for the procedures with long hospitalization or, on the other hand, to underestimate the common costs for the procedures that need shorter hospitalizations.

Moreover, there is the risk of cross-subsidization so less complex procedures (or routine healthcare processes) turn out to be more expensive than more complex procedures. In this respect, it is not possible to decrease the uncertainty without applying the ABC extensively to the whole institution.

Resource	Process	Allocation criteria	Data	Cost	Type
Personnel	Length of stay	Time absorbed	Medical records / controller data	Time absorbed by Practical capacity/personnel cost per year	Specific cost
Personnel	Operating room	Time absorbed	Medical records / controller data	Time absorbed by Practical capacity/personnel cost per year	Specific cost
Drugs (O.R.)	Operating room	Direct	Medical records / controller data	Effective absorption per tariff	Specific cost
Medical devices	Operating room	Assessed	Medical records / interviews / controller data	Standard absorption per cost sustained	Specific cost
Exams & Consults	Lenght of stay	Direct	Medical records	Effective absorption per tariff	Specific cost
Drugs and Consumables	Lenght of stay	Assessed	Controller data	Cost sustained allocated for day	Specific cost
Meals and Laundry	Lenght of stay	Direct	Controller data	Cost sustained allocated for day	Specific cost
Structure	Lenght of stay	Volume-based	Accounting data	Allocation per day (as ratio allocation: hospitalization days of Thoracic surgical unit/hospitalization days whole hospital)	Common cost

Table 4 - Cost allocation criteria

The application of the ABC methodologies to the whole institution would allow to reduce the discretionary divisions of the common costs, as a part of the value of those structural resources (with reference to the two analyzed procedures) could be allocated as specific cost to other processes (for the most part those connected with health processes), therefore reducing the "uncertainty zone" that leads to a cost allocation based on the length of hospitalization.

In other words, the actual costs incurred by the structure and without a no clear link with specific treatment process are part of common costs. The following tables (5 and 6) exemplify this concept.

All processes analyzed

	Cost for resource consumption	
Healthcare process 1	Specific costs	allocated
Healthcare process 2	Specific costs	allocated
Healthcare process 3	Specific costs	allocated
Healthcare process …	Specific costs	allocated
Healthcare process n	Specific costs	allocated
Structure	Common costs	assessed / estimated and allocated from process 1 to n

Table 5 – Cost per resource consumption (all processes)

Partially processes analyzed

	Cost for resource consumption	
Healthcare process 1	Specific costs	allocated
Healthcare process 2	Specific costs	
Healthcare process 3	Specific costs	
Healthcare process …	Specific costs	
Healthcare process n	Specific costs	
Structure	Common costs	assessed / estimated and allocated to process 1

Table 6 - Cost per resource consumption (partially processes)

In the table 5, through the allocation of costs for each healthcare treatment process, the cost of the resources absorbed is reached and therefore the remaining structural costs are only a residual part referable to the healthcare structure. In the table 6, the attention is placed only on a single process (or a limited number of them) and we can see a distribution of the common cost that requires an allocation that is not always consistent. In the case examined, this distribution took place in relation to the weight of the days of hospitalization in Thoracic Unit on the total days of hospitalization in healthcare institution, but on closer inspection implies that in all those cases in which the hospitalization is high, in a particular healthcare process, this implies a greater weight of the common costs and, on the other hand, when the hospitalization is shorter would have a reduced distribution of the common costs. A more coherent criterion, knowing all the specific costs of the processes, could be a distribution based on the relative cost of the same processes, in which it is assumed that a greater use of resources also is associated a greater benefit in the existence of the healthcare structure itself. The second research question leads us back to the specific costs. In particular, we will analyze which are the most important cost in the procedures and if there are relevant differences between the above-mentioned procedures.

	Mean	Std. Deviation	N
Total cost	1,703.8983	297.12415	48
O.R. Staff cost	1,309.0394	237.29287	48
O.R. drugs	283.3415	166.12436	48
Exams	98.5996	83.97318	48
Consults	12.9167	18.67509	48

Table 7 - Descriptive statistics in Thoracoscopy

Looking at the previous results the most important costs seem to be staff costs and medical devices costs, but we have to consider that both of them are linked to hospitalization so their amount changes depending on the increase or decrease of the length of stay. So, we focused our attention on costs that are not linked to time factor, in particular: O.R. staff cost, O.R. drugs, exams and consults.

Thus, we analyzed the costs minus the variables linked to time, so total cost of procedure is only the sum of the variables previously mentioned.

	Mean	Std. Deviation	N
Total cost	1,741.8359	329.70855	90
O.R. Staff cost	1,327.0114	223.65045	90
O.R. drugs	258.8866	182.60194	90
Exams	139.7160	115.21212	90
Consults	16.2222	28.74052	90

Table 8 - Descriptive statistics in Thoracotomy

According to the descriptive statistics (Tables 7, 8) the mean values are similar but the variance is more relevant in the thoracotomy procedure except for drugs in O.R.; so thoracotomy results show a greater impact of consultant and exam costs in the post-operative stage: this could be explained considering that the procedure is more invasive and the patient recovery is slower than in the thoracoscopy procedure (we can also assume that infection diseases are more frequent).

		Total cost	O.R. Staff cost	O.R. drugs	Exams	Consults
Pearson correlation coefficient	Total cost	1.000	.788	.505	.318	-.022
	O.R. Staff cost	.788	1.000	-.052	.057	.041
	O.R. drugs	.505	-.052	1.000	-.007	-.165
	Exams	.318	.057	-.007	1,000	-.090
	Consults	-.022	.041	-.165	-.090	1.000

Table 9 - Correlations in Thoracoscopy

The Pearson index is particularly high, but this is an obvious result depending on the equation model because the independent variable is the perfect sum of dependent variables. The R-squared is also high for the same reason. Anyway, the more interesting results came from the measures explained for the model and the collinearity tests.

All the independent variables are related to total cost except for consults in thoracoscopy. As above mentioned, maybe this aspect is of little relevance for the less invasive procedure, and the greater part of total cost is affected by staff cost in O.R. in both procedures.

		Total cost	O.R. Staff cost	O.R. drugs	Exams	Consults
Pearson correlation coefficient	Total cost	1.000	.690	.611	.473	.328
	O.R. Staff cost	.690	1.000	.008	.006	.059
	O.R. drugs	.611	.008	1.000	.136	.046
	Exams	.473	.006	.136	1.000	.503
	Consults	.328	.059	.046	.503	1.000

Table 10 - Correlations in Thoracotomy

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Test	
		B	Std. Error	Beta			Tolerance	VIF
1	(Costant)	.002	.005		.444	.659		
	O.R. Staff cost	1.000	.000	.799	305575.532	.000	.993	1.007
	O.R. drugs	1.000	.000	.559	211493.527	.000	.970	1.031
	Exams	1.000	.000	.283	107877.429	.000	.988	1.012
	Consults	1.000	.000	.063	23683.592	.000	.963	1.039

a. Dependent variable: Total cost

Table 11 - Coefficients[a] in Thoracoscopy

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Test	
		B	Std. Error	Beta			Tolerance	VIF
1	(Costant)	.004	.003		1.461	.148		
	O.R. Staff cost	1.000	.000	.678	455251.850	.000	.996	1.004
	O.R. drugs	1.000	.000	.554	368885.312	.000	.981	1.020
	Exams	1.000	.000	.349	201304.505	.000	.734	1.363
	Consults	1.000	.000	.087	50549.473	.000	.743	1.345

a. Dependent variable: Total cost

Table 12 - Coefficients[a] Thoracotomy

As expected, the Beta predictors are statistically significant for both procedures while the collinearity test is positive because tolerance and VIF are below of critical value.

4 – Results

The costs thus allocated could already highlight which of the two procedures is more convenient (only in terms of costs). So, having available a reference value of both procedures, the management could for example consider the introduction of diagnostic tests and sustain cost for them in order to make early diagnoses and make more extensive use of thoracoscopy (that requires more expensive medical devices but allows savings in terms of length of stay) or, on the other hand, reduce medical devices that needs the VATs, saving financial resources for other issues and therefore using thoracotomy as a first choice (that has minor costs for medical devices and savings for no introduction of diagnostic tests but is more expensive in terms of length of stay of). In other words, with a full costing approach for single patient we could resolve the concerns from cost overestimating or underestimating with respect to the effective absorption of resources. Using a statistical approach, we could answer to the second research question highlighting the most important costs in terms of resource absorption between the two procedures and if the differences have statistical significance. In particular, we have found that most relevant variables are personnel cost, costs related to length of stay and the relevant differences in the medical devices. These results are expected because the procedures have different impact in relation to use of devices and patient hospitalization. In general, the costs that are not linked to the duration of hospitalization are similar, with lesser variance in thoracoscopy than thoracotomy, meaning a greater predictability in planning future resources.

Moreover, the consults have the weakest relation with the thoracoscopy total cost model, so they are of little importance for the costs of this procedure. On the other hand, staff costs in O.R. is more relevant for this procedure rather than for thoracotomy.

Finally, we can conclude that the adoption of ABC model could improve the cost information and so, the statistical analysis could contribute to best managing most important costs and healthcare resources.

The main value of the study is in-depth analysis on a particular context that has become relevant in our economic context. On the other hand, the study is still limited to a specific case and it has a limited statistical sample. We think that further studies could increase both the extensive adoption inside an organization and represent a way to "intercept" the set of common costs in order to bring them back to the specific cost area, reducing, as much as possible, the uncertainty related to healthcare costs sustained by the national healthcare service.

REFERENCES

Agyar, E., Ersoy, A., Baykara, M., Ucar, M. (2007). A practical application of Activity Based Costing (ABC) in an urology department. *Proceedings of: 7th Global Conference on Business & Economics*, 13-14.

Baker, J., Boyd, G. (1997). Activity-based costing in the operating room at Valley View Hospital. *J Health Care Finance*, 24, 1-9.

Campanale, C., Cinquini, L., Tenucci, A. (2014). Il Time-Driven Activity-Based Costing per la gestione dei costi in logica di spending review: riflessioni da un caso di azienda ospedaliera. *MECOSAN 91*, 9-42.

Cao, P., Toyabe, S., Akazawa, K. (2006). Development of a practical costing method for hospitals. *Tohoku Journal of Experimental Medicine 208*(3), 213–224.

Chan, Y.L. (1993). Improving hospital cost accounting with activity-based costing. *Health Care Manage Rev* 18, 71-77.

Chipko, C., Schutzer, M.E., Serrano, N., Anscher, M.S. (2017). Using Time-Drive Activity-Based Costing in a Cost Analysis of Whole Brain Radiation Therapy Using Clinical Setup Versus CT Simulation Planning. *International Journal of Radiation Oncology• Biology• Physics, 99*(2), E392.

D'Achille, A. (2017). Activity-based Costing Application for Making Decision of Thoracic Surgical Procedures. *Proceedings of 47th International Business Research Conference*.

Demeere, N., Stouthuysen, K., Roodhooft, F. (2009). Time-driven activity-based costing in an outpatient clinic environment: Development, relevance and managerial impact. *Health Policy*, *92*(2-3), 296-304.

Everaert, P., Bruggeman, W., Sarens, G., Anderson, S.R., Levant, Y. (2008). Cost modeling in logistics using time-driven ABC: Experiences from a wholesaler. *International Journal of Physical Distribution & Logistics Management, 38*(3), 172-191.

Gervais, M., Levant, Y., Ducrocq, C. (2010). Time-Driven Activity-Based Costing (TDABC): An Initial Appraisal through a Longitudinal Case Study. *JAMAR The Journal of Applied Management Accounting Research, 8*(2), 1-20.

Goldberg, M.J., Kosinski, L. (2011). Activity-based costing and management in a hospital-based GI unit. *Clinical Gastroenterology and Hepatology, 9*(11), 947–949.

Hennrikus, W.P., Waters, P.M., Bae, D.S., Virk, S.S., Shah, A.S. (2012,). Inside the value revolution at Children's Hospital Boston: time-driven activity-based costing in orthopaedic surgery. *Harvard Orthopaedic Journal*, 14, 50–57.

Kaplan, R.S., McLaughlin, N., Michael A., Burke, M.A., Nisheeta, P.S., Douglas, R.N., Kaplan, A.L., Saigal, C., Mahajan, A., Neil, A.M. (2014). Time-Driven Activity-Based Costing: A Driver for Provider Engagement in Costing Activities and Redesign Initiatives. *Neurosurgical Focus, 37*(5).

Kaplan, R.S. (2014). Improving Value with TDABC. *HFM Healthcare Financial Management, 68*(6), 76–83.

Kaplan, R.S., Haas, D.A. (2014). How not to cut health care costs. *Harvard Business Review, 64*(11), 116–122.

Kaplan, R.S., Porter, M.E. (2011). How to Solve the Cost Crisis in Health Care. *Harvard Business Review, 89*(9), 47–64.

Kaplan, R.S., Anderson, S.R. (2007). *Time-Driven Activity-Based Costing: A Simpler and More Powerful Path to Higher Profits*. Boston: Harvard Business School Press.

Keel, G., Savage, C., Rafiq, M., Mazzocato, P. (2017). Time-driven activity-based costing in health care: A systematic review of the literature. *Health Policy, 121*(7), 755-763.

Kuchta, D., Zabek, S. (2011). Activity-based costing for health care institution. *Proceedings of: 8th International Conference on Enterprise Systems, Accounting and Logistics* (8th ICESAL 2011).

McLaughlin N., Burke M.A., Setlur N.P., Niedzwiecki D.R., Kaplan A.L., Saigal C. (2014). Time-driven activity-based costing: a driver for provider engagement in costing activities and redesign initiatives. *Neurosurg Focus* 37, E3.

Menendez, M.E., Lawler, S.M., Shaker, J., Bassoff, N.W., Warner, J.J., Jawa, A. (2018) Time-Driven Activity-Based Costing to Identify Patients Incurring High Inpatient Cost for Total Shoulder Arthroplasty. *JBJS, 100*(23), 2050-2056.

Monroy, C.R., Nasiri, A., Peláez, M.Á. (2014). Activity Based Costing, Time-Driven Activity Based Costing and Lean Accounting: Differences Among Three Accounting Systems' Approach to Manufacturing'. In: Prado-Prado, J., García-Arca, J., *Annals of Industrial Engineering 2012*, 11-17.

Najjar, P.A., Strickland, M., Kaplan, R.S. (2017). Time-driven activity-based costing for surgical episodes. *JAMA surgery, 152*(1), 96-97.

Popat, K., Gracia, K.A., Guzman, A.B., Feeley, T.W. (2018). Using Time-Driven Activity-Based Costing to Model the Costs of Various Process-Improvement Strategies in Acute Pain Management. *Journal of Healthcare Management, 63*(4), 76-85.

Popesko, B., Novak, P. (2013). Activity-Based Costing Methodology as the Tool for Costing in Otorhinolaryngology Department. *Proceedings of: the 6th International Scientific Conference on Finance and the Performance of Firms in Science, Education, and Practice*, 571-579.

Popesko, B., Novak, P. (2011). Application of ABC Method in Hospital Management. *Proceedings of: the 6th IASME/WSEAS International Conference on Economy and Management transformation* (EMT11), 17-19.

Rajabi, A., Dabiri, A. (2012). Applying Activity Based Costing (ABC) Method to Calculate Cost Price in Hospital and Remedy Service. *Iran J Public Health, 41*(4), 100–107.

Ramsey, R. (1994). Activity-based costing for hospitals. *Hospital & Health Services Administration*, 39, 385-395.

Schroeder, G.D., Hilibrand, A.S., Kepler, C.K., McKenzie, J.C., Nicholson, K.J., Stawicki, C., Milhouse, P.W. (2018). Utilization of Time-driven Activity-based Costing to Determine the True Cost of a Single or 2-level Anterior Cervical Discectomy and Fusion. *Clinical spine surgery, 31*(10), 452-456.

Udpa, S. (1996). Activity-based costing for hospitals. *Health Care Management Review, 21*(3), 83–96.

Yangyang, R.Y., Abbas, P.I., Smith, C.M., Carberry, K.E., Ren, H., Patel, B., Lopez, M.E. (2017). Time-driven activity-based costing: A dynamic value assessment model in pediatric appendicitis. *Journal of pediatric surgery, 52*(6), 1045-1049.

Acknowledgements: This research was financial supported by Regione Umbria (Prot. 30852 in 06/25/2015) and we thank the Perugia's hospital staff, who provided insight and expertise that greatly assisted the research.