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Titolo della tesi

The application of Time-Driven Activity Based Costing in Total Joint Replacement

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Al mio Babbo e la mia Mamma,
che ci hanno sempre creduto

INDEX

ABSTRACT

In the Value Based Healthcare era, the goal of healthcare delivery is to provide high value to patients. This is what matters to patients and what binds the interests of all system stakeholders; as the healthcare system′s economic sustainability improves, patients, payers, and providers will all benefit. According to this viewpoint, the healthcare delivery process has shifted from a quantity-based to a value-based efficiency.

As a result, there is a growing interest in the efficiency of health-care processes, which must provide the most value at the lowest feasible cost. The study of health expenditure, as the sum of actual costs incurred by providers for the delivery of healthcare services, has become especially important in order to investigate how actual costs of delivery can be significantly decreased. This definition is also helpful in determining the strategic effectiveness and operational efficiency of hospitals and healthcare providers.

Time-Driven Activity Based Costing (TDABC), from this perspective, provides information that offers credible support for improving the operational efficiency and strategic efficacy of the healthcare system.

Based on this premise, the broad research question (BRQ) of this dissertation is the following:

"How might time-driven activity-based cost accounting systems improve the orthopaedic delivery process?"

To answer this general research problem, this work is structured in three sub-research questions (RQ). Infact, an alternative format for writing-up the results of three years' PhD research is to submit the "three papers model". The three separate, publishable, papers are each free standing (in the sense that each can be read and understood independently) but they are on related themes.

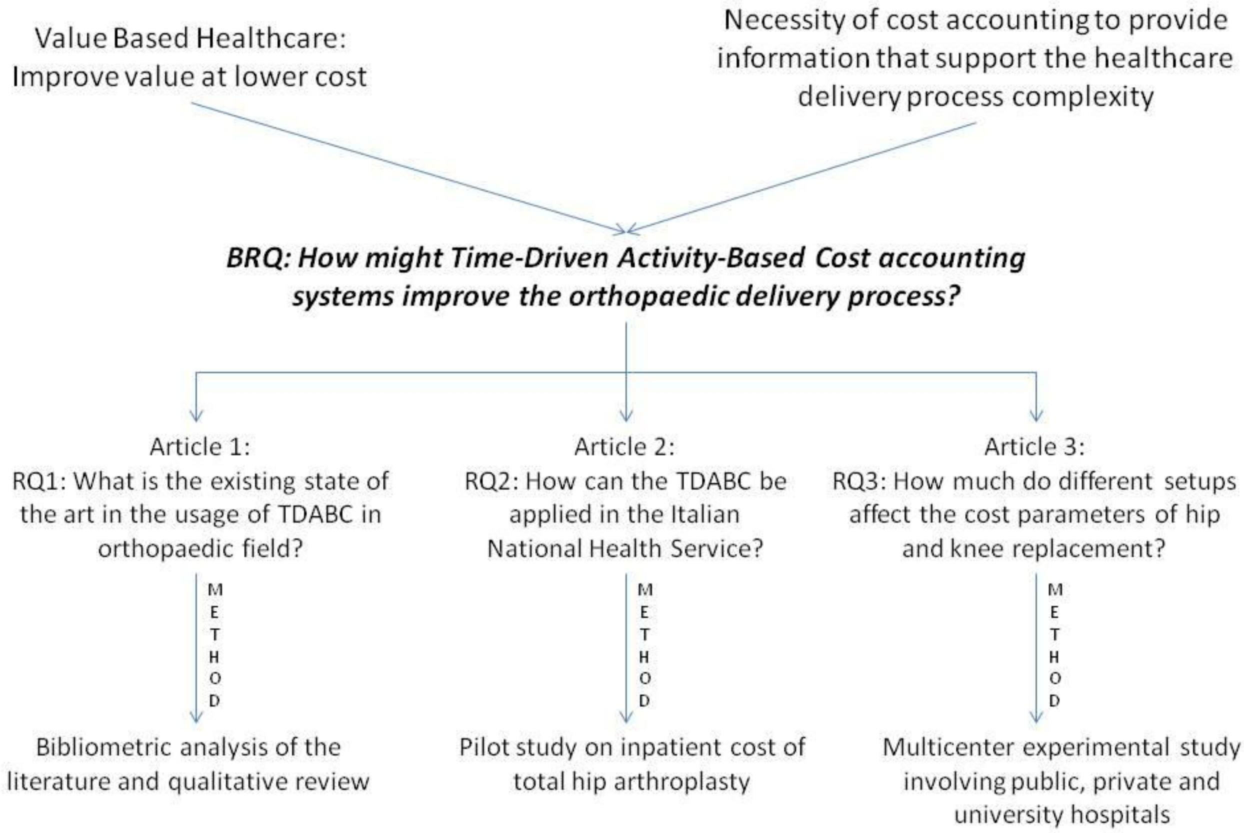
The three research questions are listed below:

RQ1: What is the existing state of the art in the usage of TDABC in orthopaedic field?

RQ2: How can the TDABC be applied in the Italian National Health Service?

RQ3: How much do different setups affect the cost parameters of hip and knee replacement?

Three different methodologies were used to achieve these goals: a bibliometric analysis of the literature and qualitative review of the forty most cited articles; a pilot study on the application of TDABC in an Italian public hospital; a multicenter experimental case study involving public, private and academic hospitals.



Findings from each paper steer the design and writing of the subsequent one. The suitability of TDABC to the orthopaedic field and, in particular, to arthroplasty context revealed by the bibliometric reviews guided the selection of the pilot study on the inpatient cost of hip replacement. Finally, the TDABC was applied to map the delivery process of two orthopaedic procedures in separate hospitals to understand how its implementation could improve the delivery process. The preference for total hip and knee arthroplasty was due to the high frequency and demand for the two surgical procedures. The aim of the study is to understand the elements that most divert the cost of these procedures and to learn how to improve clinical decision-making. Having the mechanism by which to identify true costs at the local level by building a process map of the patient pathway and having a mechanism to reduce costs without negatively impacting outcomes, are necessary steps to reduce healthcare expenditures and improve value globally, while safeguarding or even improving patient outcomes and care.

This study arises from a collaboration with Dr. Irene Schettini, M.Sc., PhD (agreement stipulated with the MESVA Department for support and consultancy activities for the interpretation of organizational variables, resolution no. 169 of 16 July 2019).
The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of University of L'Aquila (Italy) - authorization number 22/2022.

BACKGROUND

The cost of health care continues to rise rapidly worldwide, with a notable increase over the past decade, although increases in health care prices over the past year pale in comparison to those seen in the rest of the economy, suggesting that the healthcare sector is thus spared so far from the full impact of rapid inflation in 2022 also due to the COVID19 emergency [1]. In the United States, national health care spending collectively sponsored by private business, households, and other private revenues is projected to account for 53 percent of total spending by 2025 [2]. According to Keehan S. et al., economists at the Centers for Medicare and Medicaid Services at Baltimore, Maryland, there is considerable uncertainty about how the nation's health care will be provided and paid for moving forward: indeed, growth in health care spending is projected to average 5.6 percent annually over the period 2016-25 and reach 19.9% of GDP by 2025 [2].

In Italy, current healthcare expenditure in economic accounting in the period 2002-2019 increased from 78,977 million EUR to 117,338 million EUR, with an increase in absolute value of 38,361 million EUR and an average annual growth rate of 2.4%. Although the performance of the Italian National Health System (INHS) ranks first in the European and world context, for the quality of services, as well as for the equity and universality of access to treatment [3], maintaining the quality standards achieved makes essential to address the sustainability of public health spending, also in light of the 20 billion EUR investment in Health Mission of the National Recovery and Resilience Plan (PNRR) [4].

The growth in health expenditure is also due to technological progress and greater health awareness of citizens. To meet demand, offer service, health care organizations face an ongoing challenge to balance limited resources and prices while providing the theoretically best level of quality at the lowest possible cost [5].

In this sense, by knowing the costs of an organization's resources and activities in order to make appropriate and timely decisions, healthcare managers aim for optimal efficiency as a fundamental part of managing the healthcare system [6]. As a result, in recent decades various information tools have been introduced in the healthcare sector, such as economic and financial accounting and cost accounting, which attempt to determine the overall cost but in significantly different manners. In particular, the use of cost accounting provides valuable assistance in improving the operational efficiency and strategic effectiveness of the healthcare system, being composed of planning, scheduling and control systems, which offer an indispensable self-regulation tool to assist management company in the creation and articulation of strategic objectives, as well as the evaluation of the results obtained [7,8].

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Article 1

The Dark Side Of Joint Replacement Costs:

A Quantitative And Qualitative Analysis

INTRODUCTION

The most sophisticated analytical accounting systems, such as Activity Based Costing (ABC), are able to correctly describe the costs incurred, including the "behind-the-scenes" activity. ABC was developed in the late 1980s in the United States as an alternative method to increase cost effectiveness without compromising quality of service. It points out a flow of information that helps managers maximize their resources and create new options for improving service quality development [1].

A more recent derivation of the ABC, the Time-Driven Activity Based Costing (TDABC), as advocated by Kaplan in 2011 [2], is a valuable tool for linking and summarizing the information held by the various actors involved in the provision of health care services, in addition to providing more accurate information about the use of resources. This method is an essential component of the newly defined value-based healthcare (VBHC) agenda [3-5], which strives to analyze the patient's complete usage of resources across healthcare departments and organizations [6,7]. Specifically, the value-based approach seeks to develop a new universal language in healthcare administration centered on the patient's value, to balance the interests of all stakeholders [5]. The specific application of TDABC plays an important role in this field [8,9]. Not surprisingly, the TDABC requires more local detailed accounting data, which necessitates an increase in the 'bottom-up' micro-costing technique capable of bringing even the slightest waste and consumption out of the shadows. A bottom-up strategy will promote insight and, as a result, autonomy and controllability [7,10, 11].

Ultimately, agreeing on the most accurate approach to costing and its key drivers can implement strategies to bend the cost curve and increase value for patients: having an accurate cost accounting method allows to illuminate the main cost drivers of orthopaedic care. Only then it will be possible to truly improve the value of healthcare, defined as health outcomes achieved per dollar spent over the entire care cycle [12].

The purpose of this study is to bring to light the current state of the art of the international TDACB literature in the orthopaedic field, highlighting which orthopaedic topic deriving from the clinical/economic interdisciplinarity is of greater interest.

METHODS

To achieve the aim of the study, a bibliometric analysis of the literature was performed. Bibliometry is a statistical-quantitative tool for analyzing textual and editorial data [13]. Bibliometric analysis represents a systematic, transparent, and reproducible literature review process [14], which allows a recognition of the existing literature on a single topic through the definition of an interconnected system of keywords established on the basis of the main contributions deemed relevant. This

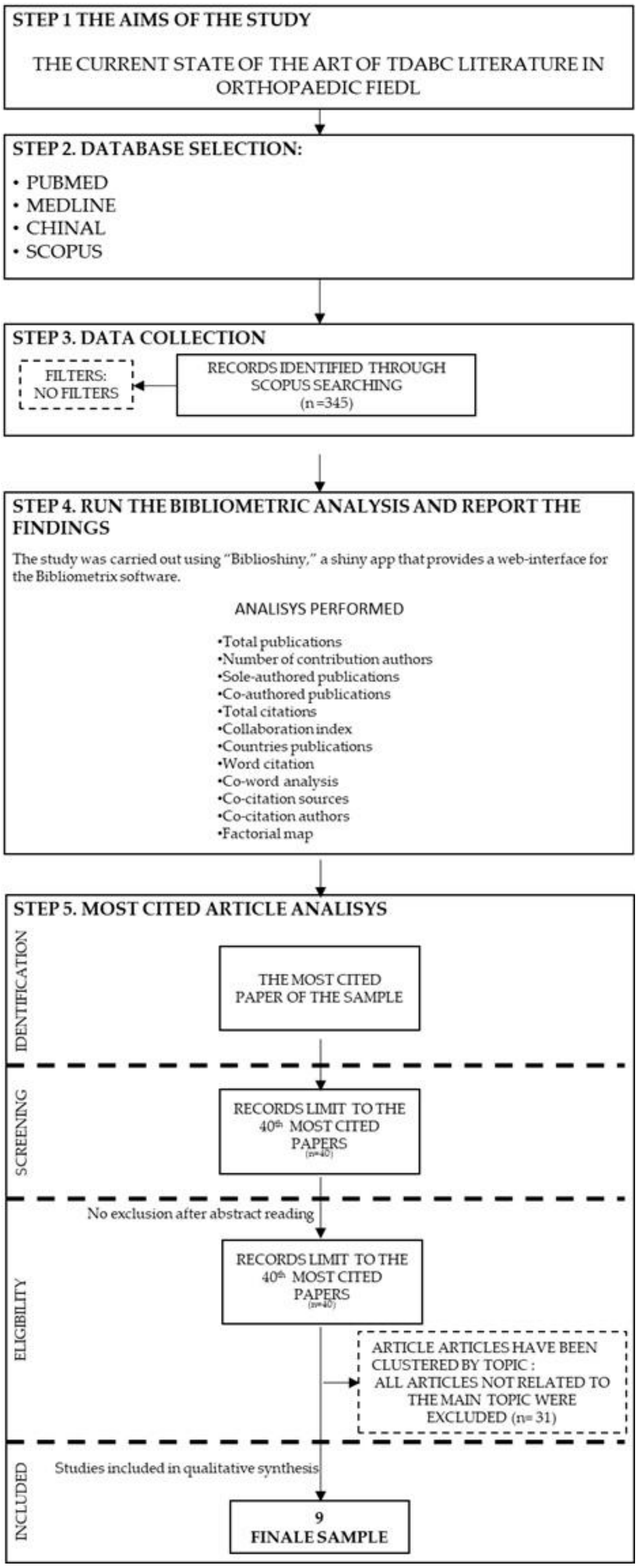
methodology is suitable for broad aims (e.g., summing up a lot of literature) and was chosen due to the scope of this study and the sample size.
The databases used for the research were Pubmed, Medline, Cinahls and Scopus, while the program used to analyze and summarize the data was Bibliometrix R-Package. For the first part of the research, the keywords used were chosen in accordance with the paper's goal of representing the state-of-the-art of the TDABC in the international literature. **Table 1** contains a list of them.

Table 1: Keywords used for the first inquiry

1st Keyword	"time driven activity based costing" OR "TDABC"	Pubmed: 62 results Medline: 66 results Cinahls: 20 results Scopus: 345 results
AND		
2nd Keyword	"orthopaedic" OR "orthopedic"	

The search was initially performed on the biomedical databases and finally Scopus was selected, as it returned the largest number of published articles.
All languages and all document types were considered eligible for this search. All articles published from 2011 (date of first publication in this field) to December 2022 were considered.
The **Figure 1** depicts the steps conducted during the entire investigation.
Specifically, the data were loaded and translated into a R dataframe in Bibliometrix based on the final sample returned by Scopus in bibtex format, to build two primary levels of analysis: bibliometric and qualitative analysis. The bibliometric analysis illustrates the characteristics of the sample and measures its main performances by evaluating the research field identifying the most important actors and analyzing groups of scientific actors and their impact [15, 16].
Within bibliometric analysis a citation analysis and a spatial representation of the relationships between disciplines, fields, specialties, and individual papers or authors [15, 17] were also undertaken. All the data illustrated in the figures in the results paragraph were generated using “Biblioshiny” (Bibliometix-R software).
Furthermore, an in-depth analysis of the 40 most cited articles was carried out to spotlight the area of greatest interest in the orthopaedic field, and from which to extrapolate a qualitative analysis.

Figure 1: Flowchart of the methodology used for this quantitative and qualitative systematic review



RESULTS

This section, in tandem with the method steps (Figure 1), presents the results of the review by first reporting the bibliometric results and finally the results of the qualitative analysis.

Quantitative analysis

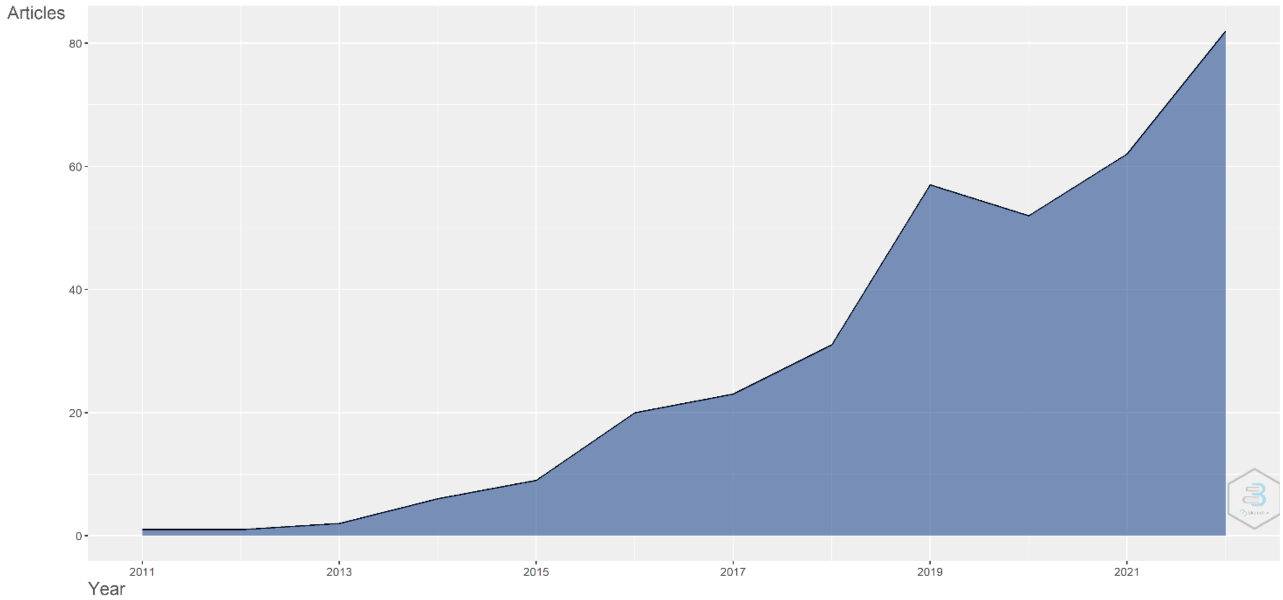
The entire survey was conducted on the final sample consisting of 346 documents.
In particular, 72% of the documents are articles, 18% reviews and 10% a mix of conference papers, books, editorials. With 1544 authors and a collaboration score of 4.63 (i.e., a Co-authors per Article index calculated just using the multi-authored article set), authorship is highly fragmented. There is an average of 4.46 authors per document, with only a few articles by a single author (15 articles, 4,3%).
All the main information about the sample is summarized in **Table 2**.

Table 2: Main information of the sample

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2011:2022
Sources (Journals, Books, etc)	186
Documents	346
Average years from publication	2,45
Average citations per documents	10,08
Average citations per year per doc	2,278
References	13248
DOCUMENT TYPES	
article	249
book	1
book chapter	7
conference paper	10
editorial	8
letter	1
note	8
review	62
DOCUMENT CONTENTS	
Keywords Plus (ID)	2070
Author's Keywords (DE)	818
AUTHORS	
Authors	1544
Author Appearances	1921
Authors of single-authored documents	13
Authors of multi-authored documents	1531
AUTHORS COLLABORATION	
Single-authored documents	15
Documents per Author	0,224
Authors per Document	4,46
Co-Authors per Documents	5,55
Collaboration Index	4,63

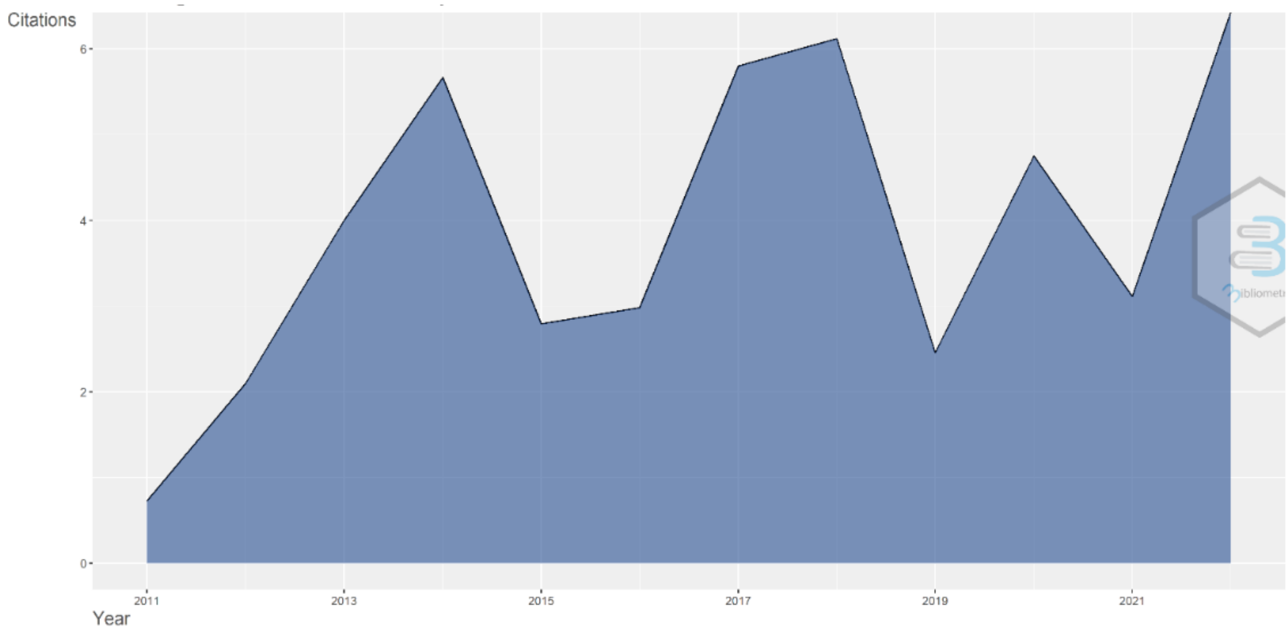
This research field is quite recent with an annual scientific growth rate of 49.27%. As shown in **Figure 2** topic has had a growing interest in the last five years.

Figure 2: Annual scientific production



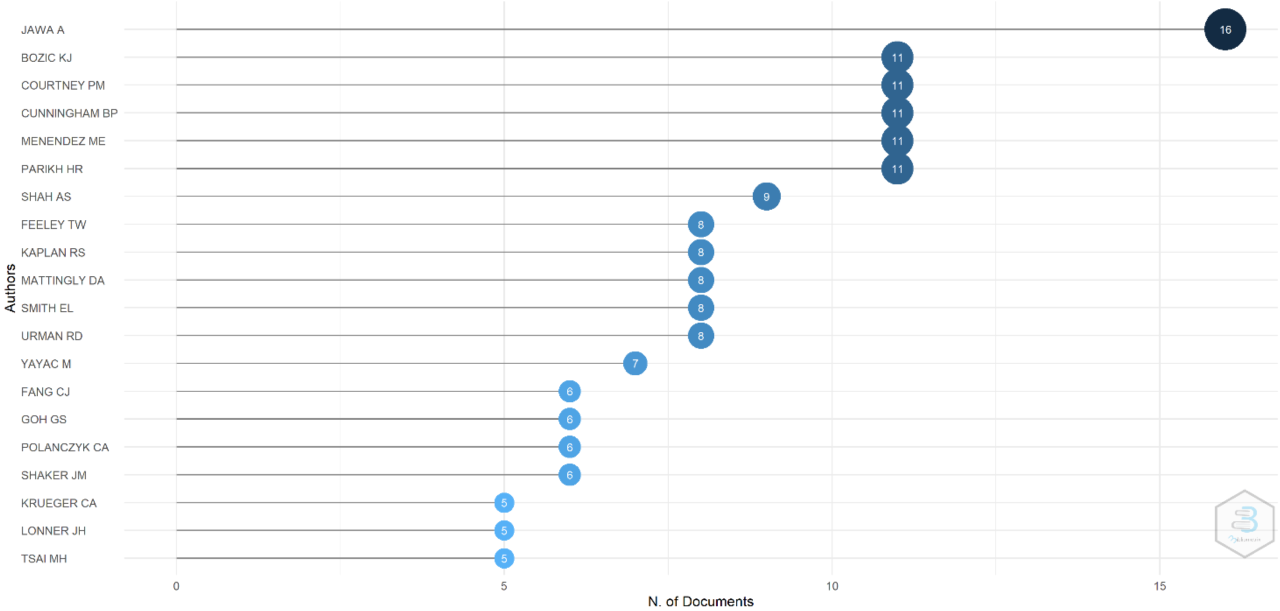
However, the average number of citations collected from articles published in a given year peaked in 2018 (**Figure 3**).

Figure 3: Average article citations per year



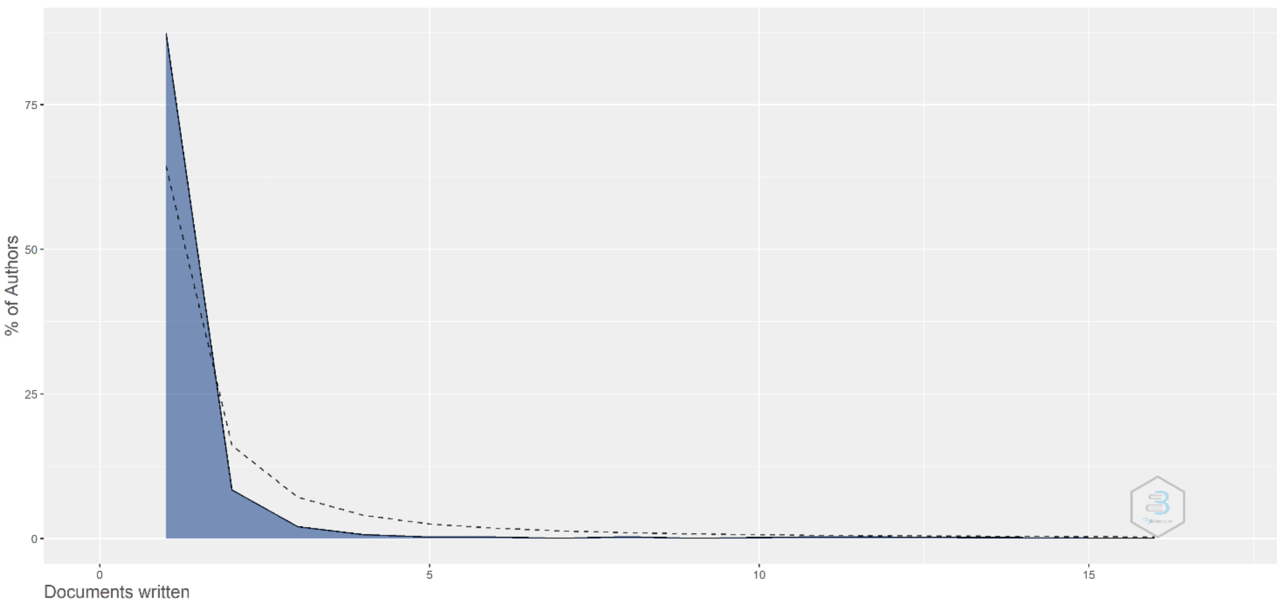
Based on their publication number, the most relevant authors can be identified (**Figure 4)**

Figure 4: Most relevant Authors



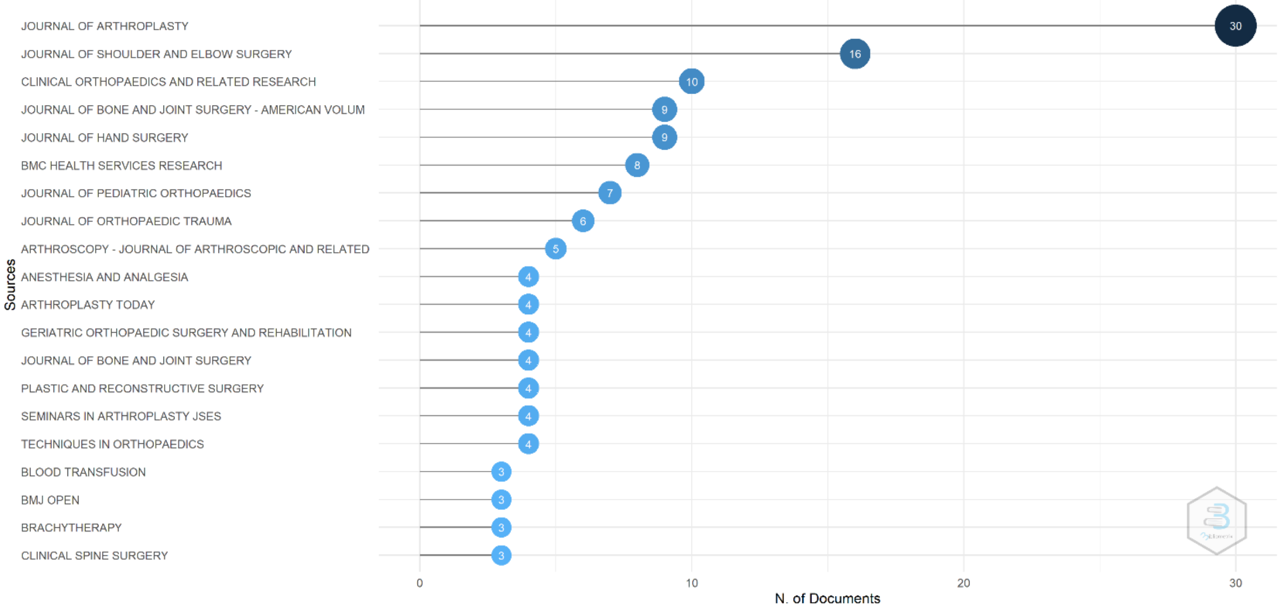
Lotka′s law can also be applied to the data, which states that the number of writers who make "n" contributions to a field is $1/n^2$ those making a contribution [15]. According to this rule, most authors contribute two papers on the field (**Figure 5**).

Figure 5: The frequency distribution of scientific productivity: Lotka's law



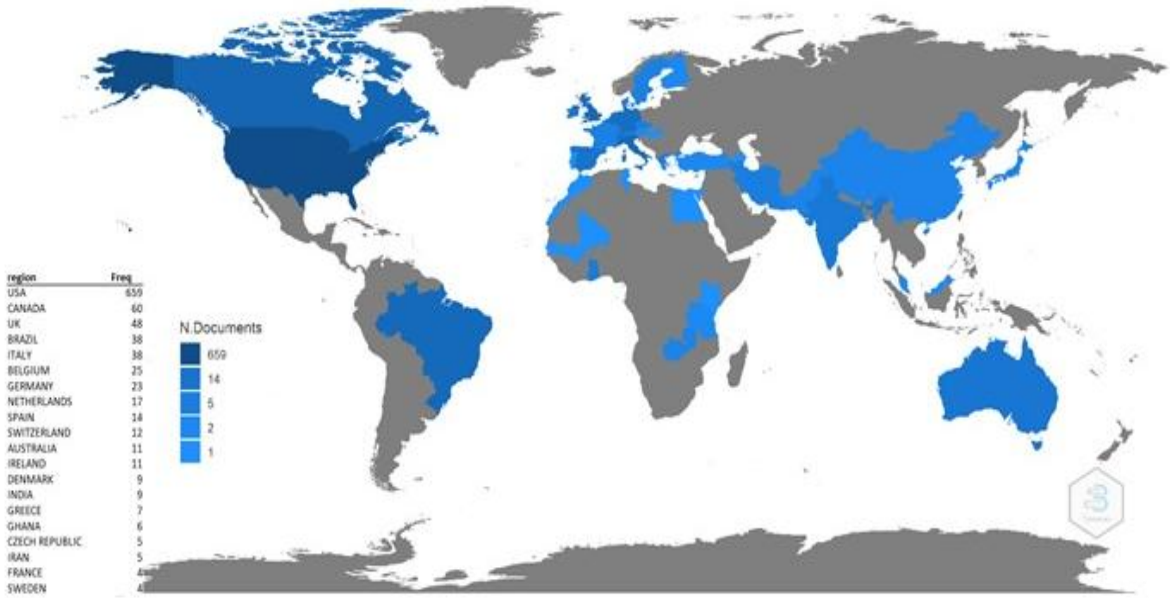
The documents in the dataset were published in 186 journals. **Figure 6** shows the most relevant sources based on the number of articles.

Figure 6: Most relevant sources. The numbers in the circles represent the number of publications.



The **Figure 7** depicts the top countries in terms of scientific output. Based on all authors′ affiliations, the geographical distribution of publications is concentrated in Anglo-Saxon countries (USA, Canada, UK) and other European countries (Italy, Belgium, Germany, Netherlands), more the isolated appearance of Brazil in the Latin area.

Figure 7: Country scientific production

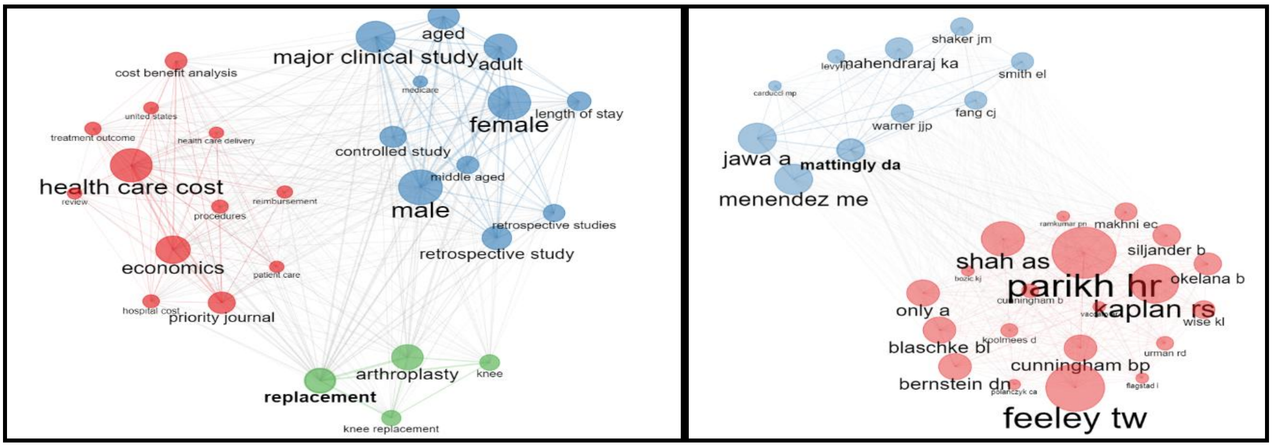


The most frequent words (Author′s keywords) in the sample are value, cost, TDABC, value-based care, cost-effectiveness, total knee arthroplasty etc. The **Figure 8** illustrates the wordcloud of the most frequent keywords.

Figure 8: Most frequent words (Author's keywords).
Word occurrence measure: frequency; Ellipticity: 0,65; Padding: 1

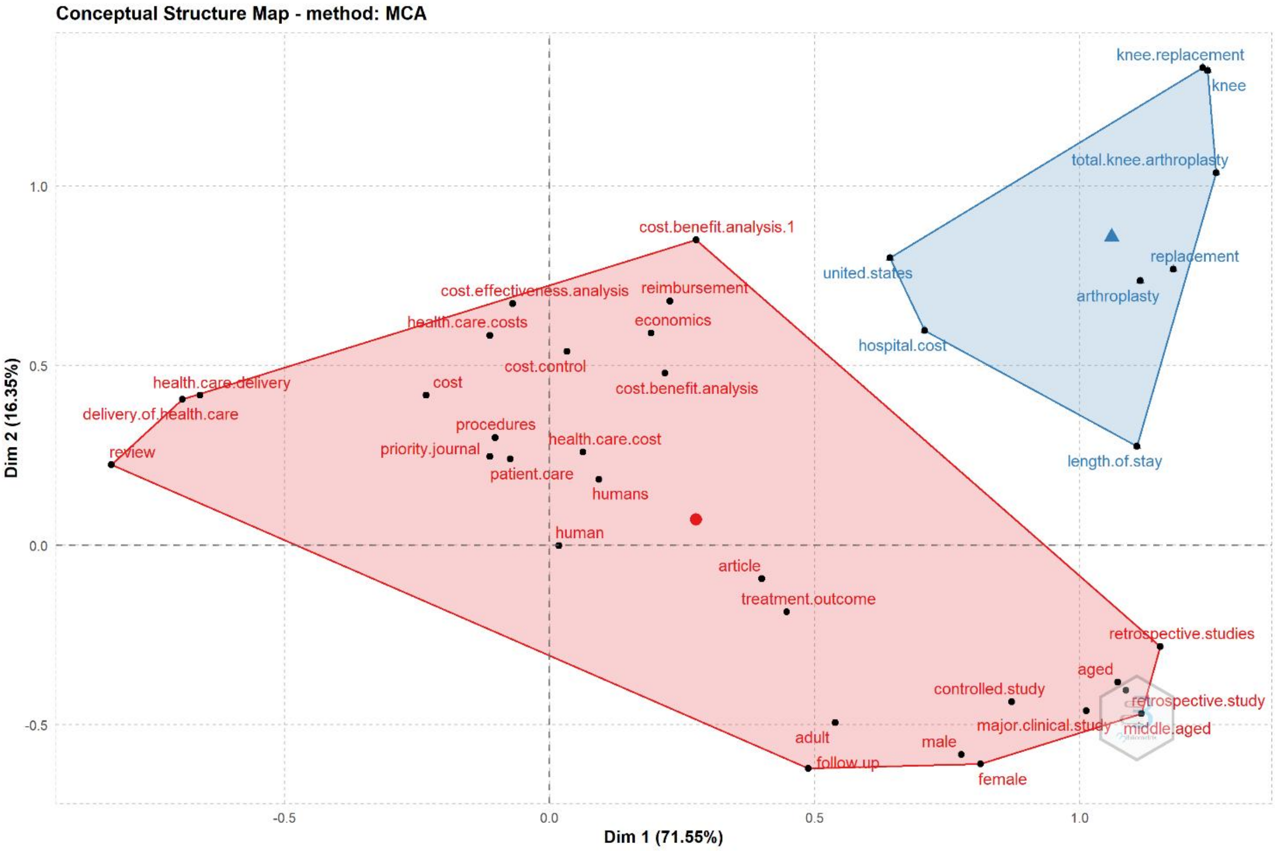
The cooccurrence-source analysis reveals three major clusters: epidemiology (blue), healthcare management (red), and field of application (green) (**Figure 9a**). The co-occurrece analysis of the authors, on the other hand, indicated two groups of authors red and blue realistically referring to the different topics the authors dealt with (**Figure 9b**).

Figure 9: Co-occurence analysis of sources (9a) identifies areas of interest with 3 different colors, while the authors' analysis of co-occurrences (9b) groups them into two different sets



Finally, factorial analysis - another keyword-based study - was conducted to identify subfields within the topic under examination [15]. As illustrated in **Figure 10**, factorial analysis identifies two distinct clusters, one specifically related to orthopaedics and the other to healthcare performance management.

Figure 10: Factorial analysis. Method: multiple correspondence analysis (MCA); field: author's keywords; number of terms:50



Qualitative analysis

The latest analysis performed is based on the 40 most cited articles extrapolated from the bibliometrics (**Table 3**). Nine are review articles. The areas of interest are multiple, encompassing various fields of orthopaedics: the studies deal with rehabilitation, telemedicine, blood transfusions, different costing models and intersect other disciplines close to orthopaedics. Nine out of 40 articles (22.5%) study the application of TDABC in the field of joint replacement.

Table 3: The 40 most cited papers. The columns represent the total of annual and normalized citations and the reference field of the study. The articles in bold are those subject to a more in-depth qualitative analysis because they belong to the main topic.

	Paper	Total Citations	Citations per Year	Normalized TC	Scope
1.	CHILDERS CP, 2018 JAMA SURG	345	69	14,0909	operating room
2.	NAVATHE AS, 2017 JAMA INTERN MED	199	33,167	6,8621	Joint replacement - bundled models
3.	KEEL G, 2017 HEALTH POLICY	169	28,167	5,8276	Joint replacement -Review
4.	KAPLAN RS, 2014 J HEALTHC MANAGE	132	14,667	2,9118	Pilot application of TDABC in several fields

5. AKHAVAN S, 2016 **CLIN ORTHOP RELAT RES**	**128**	**18,286**	**7,1508**	**Joint replacement - TDABC**
6. HAQUE A, 2020 NATURE	72	24	7,5789	Ambient intelligence - review
7. MCLAUGHLIN N, 2014 NEUROSURG FOCUS	64	7,111	1,4118	Neurosurgery and Urology
8. TROCCAZ J, 2019 ANNU REV BIOMED ENG	56	14	7,6	Review on robotics
9. PALSIS JA, 2018 **J BONE JT SURG AM VOL**	**56**	**11,2**	**2,2872**	**Joint replacement - TDABC**
10. MIDDLETON A, 2020 PHYS THER	52	17,333	5,4737	Telehealth rehabilitation
11. MENGER RP, 2018 NEUROSPINE	47	9,4	1,9196	Robotic spine surgery
12. ROTHSTEIN DH, 2018 SEMIN PEDIATR SURG	46	9,2	1,8788	Pediatric surgery - review
13. MIHALJ M, 2020 BEST PRACT RES CLIN ANAESTHESIOL	44	14,667	4,6316	Telehealth evaluation
14. HAAS DA, 2017 **ARTHROPLAST TODAY**	**40**	**6,667**	**1,3793**	**Joint replacement - TDABC**
15. ANDREASEN SE, 2017 **J ARTHROPLASTY**	**39**	**6,5**	**1,3448**	**Joint replacement - TDABC**
16. CHEN A, 2015 **KNEE**	**39**	**4,875**	**1,9943**	**Joint replacement - TDABC**
17. DIGIOIA AM, 2016 J ARTHROPLASTY	38	5,429	2,1229	Joint replacement – several price-based models
18. MUOZ M, 2014 BLOOD TRANSFUSION	37	4,111	0,8162	Iron therapy
19. MENENDEZ ME, 2018 **J BONE JT SURG AM VOL**	**36**	**7,2**	**1,4704**	**Joint replacement - TDABC**
20. HUSTED H, 2018 **ACTA ORTHOP**	**34**	**6**	**1,388**	**Joint replacement - TDABC**
21. ANZAI Y, 2017 ACAD RADIOL	34	5,667	1,1724	Radiology
22. WEI DH, 2015 J BONE JT SURG AM VOL	34	4,25	1,7386	Value-Based Health - review
23. NARVY SJ, 2016 AM J ORTHOP	33	4,714	1,8436	Cuff repair - TDABC
24. LEE DJ, 2019 CURR UROL REP	29	7,25	3,9357	Operating room - review
25. MUOZ M, 2013 BLOOD TRANSFUSION	29	2,9	0,8056	Iron therapy
26. MENENDEZ ME, 2020 J SHOULDER ELBOW SURG	28	9,333	2,9474	Innovation post COVID19
27. CARDUCCI MP, 2020 **J BONE JT SURG AM VOL**	**28**	**9,333**	**2,9474**	**Joint replacement- TDABC**
28. MENENDEZ ME, 2018 J SHOULDER ELBOW SURG	27	5,4	1,1028	Pain therapy
29. JACOBS JC, 2017 PHARMACOECONOMICS	27	4,5	0,931	Healthcare cost methods - review
30. GOVAERT JA, 2015 WORLD J SURG	27	3,375	1,3807	Surgical auditing - review
31. HAMID KS, 2014 FOOT ANKLE INT	27	3	0,5956	Foot and Ankle cost methods
32. CARDUCCI MP, 2019 J SHOULDER ELBOW SURG	26	6,5	3,5286	Shoulder surgery outcome
33. SCHWARTZ AJ, 2019 J AM ACAD ORTHOP SURG	26	6,5	3,5286	Joint replacement cost methods - review
34. KOEHLER DM, 2019 J HAND SURG (USA)	26	6,5	3,5286	Carpal Tunnel Release
35. ARONSON S, 2020 ANESTH ANALG	25	8,333	2,6316	Preoperative care
36. ANDERSON GH, 2017 BMJ OPEN	25	4,167	0,8621	non-operative trauma micro cost
37. ETGES APBDS, 2020 VALUE HEALTH	24	8	2,5263	TDABC in several fields - review
38. HAMID KS, 2017 **FOOT ANKLE INT**	**24**	**4**	**0,8276**	**Joint replacement- TDABC**
39. COOPER L, 2020 J AM GERIATR SOC	23	7,667	2,4211	Geriatric surgery
40. LUTHER G, 2016 J PEDIATR ORTHOP	22	3,143	1,2291	Pediatric trauma

DISCUSSION

Recently, great interest in Value-Based Health Care has turned to the development of a standard costing method to enable healthcare providers to understand the cost of providing care for conditions and control. The main finding of this study is that TDABC is a cost calculation methodology that is gaining scientific attention in the orthopaedic world, particularly in the prosthetic context. Probably, the reason why the annual scientific growth rate exceeds 49% with publication peaks in the last five years (2017-2022), is because the TDABC is an innovative tool based on only two cornerstones: the capacity cost rate and the time required to perform activities in service delivery - hence the name "time-driven" ABC [8]. Visually examining Figure 2 and Figure 3, a drop in production and citations in the two-year period 2020-21 immediately catches the eye, probably linked to the main concentration on the COVID19 pandemic in that period. The recovery of scientific attention on this focus is clearly visible in 2022.

The current analysis covers the entire time span from the first publication on the topic (2011) to December 2022. The orthopaedic-related field remains highly fragmented. The 346 collected articles are distributed among 186 sources and, according to Lotka's law, most writers contribute to the topic through two articles (Figure 5). Concerning the most cited articles (Figure 3, Table 3), the one that received the most citations was published in 2018 [18] and aimed to show the average cost of the operating room (OR) using financial data from California in the fiscal year 2014. In terms of geographic distribution of author's affiliations (Figure 7), the United States has the most productive researchers with a total of 659 published papers (46%), followed by Canada (4%), the United Kingdom (3%), and Brazil and Italy tied at 2.5%. Followed by other European countries and Australia and India.

Science mapping is a tool that can return the connections across topics, authors, and countries. According to the co-occurence authors, two distinct groups of researchers were detected: those in the medical area and those in business management and accounting (Figure 9b), and this result is consistent with an examination of the twenty most productive authors (Figure 4), twelve of whom (Jawa A, Courtney PM, Menendez ME, Mattingly DA, Smith EL, Yayac M, Fang CJ, Goh GS, Shaker JM, Krueger CA, Lonner JH, Tsai MH) are in the medical area (orthopaedists, radiologists, anesthesiologists, epidemiologists) and eight in business management and accounting (Bozic KJ, Cunningham BP, Parikh HR, Shah AS, Feeley TW, Kaplan RS, Urman RD, Polanczyk CA).

The keywords co-occurrence in this context identify three clusters: general epidemiology area (blu nodes), healthcare management (red nodes), and specific orthopaedic field of application (green nodes) (**Figure 9a**). Because of the connections between these nodes, the most closely matched nodes - relating to the economic evaluation - demonstrate the importance of interdisciplinarity between the economic and medical fields. This finding is consistent with economic studies related to organizational management, which therefore involve all dimensions, including the clinical/medical ones and then employ these sources. This finding is corroborated by a word cloud of the most commonly occurring words, which i.g. lists *value, cost, arthroplasty*, and *patient reporting outcomes* as keywords with a high frequency of occurrence (**Figure 8**). It is crucial to note that building a process benchmark in the clinical area and conducting cost-effectiveness assessments are cornerstones of the value-based agenda [19, 20], which recognizes these methodologies as particularly proper for cost and value analysis [3-5]. Furthermore, Kaplan and Porter highlighted the TDABC as a strategy to ″solve the cost crisis″ in healthcare organizations in the first of TDABC study [2]. Unfortunately, this utopian result has not yet been achieved.

The factorial analysis verifies the sample′s separation into two subfields, one focused on orthopaedic procedures and the other on healthcare performance management (**Figure 10**). Properly, there is a particular focus on joint replacement which support the most relevant sources: due to the structure of the sample, it is not surprising that the most active journals are OR-based (**Figure 6**) and that the most relevant topic is arthroplasty (**Table 3**). Indeed, being the TDABC developed on the analysis of the time taken to perform an action, it is more suitable to be applied when this action is methodologically repeated [21, 22]. As a result, the scientific maturity of activity-based costing as applied to non-standardized or non-surgical healthcare is quite low. On the contrary, according to the most cited papers, the TDABC approach is the most used in the field of surgery (**Table 3**). Based on this evidence, it has been reported that one third of these (13 out of 40) come from joint replacement, which is a specific and frequently performed surgery.

Excluding the review articles, the qualitative analysis was carried out on the 9 most cited articles which reported the results of the use of the TDABC in the prosthetic field. Five of these were set in academic hospitals, where most surgeries were performed by trainee/fellow orthopaedic surgeons (**Table 4**).

Table 4: A qualitative overview of joint replacement TDABC-related articles

	Design of study	Study period	Administration	Sample and surgeons	Process map	Lenght of stay	Main findings
Akhavan S [21]	Retrospective TA vs TDABC Monocentric	2012 - 2013	tertiary care medical center	677 patients 700 THA and TKA 3 surgeons	TJAs operating day	NA	The cost categories with the greatest variability between TA and TDABC were operating room services and room and board.
Palsis JA [23]	Retrospective TA vs TDABC Monocentric	2014	Academic medical center	124 THA 148 TKA 4 attending orthopaedic surgeons	from the day surgery was scheduled to 90 days post-discharge	THA: 3 days TKA: 2 days	Costs calculated using TDABC were 59% (THA) and 58% (TKA) of costs calculated using the TA. Costs of equipment and consumables were equivalent between the 2 methods, but in percentage terms represent: TDABC/TA 55%/32% (THA) and 65%/37% (TKA)
Haas DA [24]	Retroscpective TDABC multicentric	2014	9 Academic centers 20 community hospitals	At least 200 TKA per Hospital	NA	NA	The primary drivers of surgical operation costs were the duration of the operation, including time spent prepping and cleaning the room. purchase prices of implants and cement and personnel vary enormously between hospitals, with no difference in clinical outcomes
Andreasen SE [25]	Retroscpective Fast-track TDABC double center	2014-2015	2 departments with different logistical set-ups	Hospital 1: 229 THA and 196 TKA Hospital 2: 20 THA and 20 TKA	from the preoperative visit to inpatient stay to follow-up	2 days (100% discharged home)	The most costly aspects of the carecycles are surgery and inpatient stay (51.1% and 31.2% respectively at Hospital 1 and 59.3% and 24.5% respectively at Hospital 2). Implant cost not included.
Chen A [26]	Prospective TDABC monocentric	NA	Teaching hospital	20 TKA	from the decision to admit the patient to discharge from the ward	5 days (4-7)	The largest cost drivers were operating room consumables and implant (34.35%), company overheads (30.46%) and ward costs (16.79%)

Menendez ME [27]	Prospective TDABC monocentric	2016-2017	Teaching hospital	415 TSA 1 shoulder fellow	preoperative, intraoperative and postoperative	2.2 days	Implant purchase price was the main driver (57%) of total inpatient costs, followed by personnel cost from patient check-in through the time in the operating room (20%).
Husted H [28]	Prospective Outpatient TDABC Double center	NA	Hospital ward and Ambulatory surgery department	6 patients 1 TKA 1 uncemented THA 1 cemented THA (in each institute)	from the first visit to 90 days post-discharge	11h (ward) 7h (ambulatory)	Compared to the cost associated with fast-track, outpatient procedures are approximately two-thirds cheaper. Implant and indirect cost not included.
Carducci MP [29]	Prospective TDABC monocentric	2015-2018	orthopaedic specialty hospital	22215 patients 10979 TKA 10067 THA 688 RSA 392 TSA 75 TAA 14 TEA 53 surgeons	mentioned, but NA	3.14 TKA 2.29 THA 2.27 RSA 1.92 TSA 1.87 TAA 2.35 TEA	The cost of the implant represented 53.8% and is related to the higher total costs for a cycle of hospital treatment. Length of stay was correlated with the increase in personnel costs, without significant effect on total cost
Hamid KS [30]	Prospective TDABC Monocentric comparing two techniques	2014-2015	Academic medical center	87 TAA Single surgeon	mentioned, but NA	NA	Shorter OR time for patient-specific instrumentation results in cost-savings threshold over standard referencing.

The total number of patients examined undergoing joint replacement exceeds 20000 for THA and TKA (only one author [24] did not report the exact number); 1495 shoulders, 162 ankles and 14 elbows arthroplasty. The use of the TDABC provides for the rigorous consequential introduction of the seven steps defined in the literature [2] for the use of this tool. (1) The first step is to select the medical condition, defined as an "interrelated set of patient circumstances that are best addressed in a coordinated way and should be broadly defined to include common complications and comorbidities" [2]. No article adhered to the definition of a medical condition because they did not include comorbidities or complications related to the medical condition, which could lead to a loss of granularity in the cost analysis. Only two articles [29, 30] mentioned the inclusion of complications, but this was not evident in the subsequent cost analysis. The reason may be that studying highly standardized care is easier to compare than studying patients with many comorbidities who need individualized treatments. (2) The second step is to define the care delivery value chain, which is to track the activities that occur and their locations throughout the entire care cycle. This step is directly related to the following ones, consisting of (3) developing process maps for each activity in patient care delivery and (4) obtaining time estimates for each process. Six studies published process maps or more simply chronologically listed the phases of the process from preoperative, intraoperative and to discharge and follow-up [23, 25-28, 30]. In one case [21] the process map concerns only the day of the intervention, while in 3 works it is not available [24, 29]. (5) The fifth step is to estimate the cost of providing patient care resources, replaced by the cost of all primary resources (direct care costs) [31], and then estimate the cost of the resources needed to deliver them (indirect care costs), e.g., overhead and support center costs. (6) At this point, the capacity cost rate (CCR), which is the cost of the capacity providing the resources divided by the practical capacity of those resources, is calculated. In each article, the CCR was calculated by comparing the average monthly salary of each type of staff with the time spent providing the health service. This method was used for all the operators present considering the different salaries. However, deriving from different health systems, it is not possible to compare if an operator is rightly paid more. Finally, all the calculated costs were added up, thus defining the total cost of patient care in the structure examined (7). In this way, through the TDABC it is possible to find out which items cost more, ignoring the patients' reporting outcomes. The most expensive items of care cycles were found to be those related to the operating room (including surgical time, personnel, consumables, and implant) [21, 24-27, 29, 30] followed by length of stay [21, 25, 26, 28, 29]. In articles comparing TDABC to traditional costing methodologies (TA), equipment and consumable costs were equivalent between the 2 methods, but in percentage terms there was large variability in favor of TDABC [21, 23]. The purchase price of the implant was not included in the sum of costs by 3 authors: Andreasen et al. compared the fast track in two hospitals [25], Husted et al. compared the costs of fast-track VS outpatient surgery [28], and Hamid et al. compared the same procedure using a navigation system VS a traditional operation [30]. Only for Chen et al. high administration overheads (30.46%) are among the major costs incurred during hospitalization [26].

In conclusion, TDABC appears as a decision-making tool that can be used by all actors in a healthcare institution in order to illuminate the shady informations regarding investments and waste in orthopaedic surgery, and more precisely in the field of prosthetics. Anyhow, there is a relative lack of scientific maturity on this topic. The findings help in the identification of future study directions. While the applicability of TDABC to healthcare services appears to be best established in terms of empirical medical evidence, research on how this technique affects the management of organizations and their actors seem to be in an immature and more theoretical stage. Little research has been conducted on how healthcare organizations should change or adapt to implement the TDABC in the design, monitoring, delivery, and evaluation of a healthcare delivery process in order to improve it and assist managers and clinicians in meet all the necessary decisions on the steps taken by the patients.

Limits

This study has some limitations that must be addressed. Firstly, although the bibliometric analysis is based on a statistic procedure, that is objective and replicable, the chosen keywords, as well as the use of a single database, could be insufficient. Second, the objective of the qualitative review was to explore in which orthopaedic settings TDABC was most widely used, and the analysis includes only 9 studies of the 40 most cited. However, the scientific quality of the studies was not assessed, and it is possible that articles with methodological deficiencies or misreported results were included. In addition, the literature presents some clear limitations of TDABC that need to acknowledge. TDABC is still a new technique in the field of healthcare and one of the major barriers shown is the lack of understanding or appreciation of its possible impact. The methodology applied, such as the timing of how much time each patient spends with staff in a hospital, does not show standardized ways of conducting TDABC studies, making it more difficult to compare results. Indeed, many of the conclusions are likely limited to their respective fields and institutions. In addition, the process maps required for TDABC can become very difficult to construct and involve a significant amount of time and resources to develop. Finally, a major limitation of TDABC in orthopaedic surgery is that there is little field experience with this cost-effective approach. The topics analysed, while involving heterogeneous contexts, all concern well-standardized procedures without including more demanding conditions in determining the real value of a procedure, which can also have complications.

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Article 2

What Is The Inpatient Cost Of Hip Replacement?
A Time-Driven Activity Based Costing Pilot Study In An Italian Public Hospital

INTRODUCTION

Osteoarthritis (OA) is one of the most common chronic degenerative diseases affecting a wide range of the population, as well as one of the most frequent causes of disability in the elderly. Symptomatic osteoarthritis is estimated to affect, in Italy alone, at least 4 million people, with a public annual cost of approximately EUR 6.5 billion [1,2]. Total hip arthroplasty (THA) is considered the best solution for the treatment of patients with severe hip osteoarthritis [3].
In 2019, 118.673 hip replacement surgeries were performed in Italy, this number is increasing at a rate of approximately 2.7% per year: in 2017 and 2018, the surgeries were 112.375 and 115.308 respectively [4,5]. This pattern is in line with the Organization for Economic Co-operation and Development (OECD) data, which reveals a significant rise in THAs for the majority of OECD nations [6]. In that pre-COVID period, the reimbursement by the Italian National Health System related to arthroplasty surgery was about EUR 1.625.853.413 [7]. Due to its significant effect on healthcare system costs and the high frequency and demand for this surgical procedure, in particular many authors have defined THA complications as a real health emergency [8,9]. This is also the reason for an increasing interest in understanding the real cost related to this procedure.
In fact, using resources for acquiring important information for the entire activity of healthcare organizations is crucial in the era of value-based healthcare. Tools for management accounting might be regarded helpful for information gathering in the context of healthcare, in order to accomplish this purpose. The costs of medical treatments calculated using Activity Based Costing (ABC) tend to have more accuracy in the computation of resource consumption than standard cost accounting systems, among other techniques of cost calculation or reimbursement, like Diagnosis-Related Groups (DRG) [10]. Furthermore, the capacity to precisely identify expenses at the level of the treatment process and manage the complexities associated to accounting in the healthcare sector make the Time-Driven Activity-Based Costing (TDABC) [11,12], the most effective and straightforward instrument, even when compared to the traditional ABC. TDABC is an innovative approach to measure costs more accurately by estimating the amount of time and cost per unit of time each provider uses during a care episode. For example, if a staff member spends 30 minutes with a patient and that staff member's time cost is EUR 100 per hour, the cost of interacting with that patient is EUR 50.
In addition, the use of the TDABC method estimates the practical capacity (i.e., actual production time) of each element providing capacity (operator and equipment) and the average time required for each element to carry out the action, on the basis of observation, data collection, questionnaires. The improved process consistency makes TDABC particularly appropriate for the surgical area [13].
This "bottom-up" accounting method makes it possible to identify transparent analyzes of the entire care cycle by adding up the individual costs of all the resources used by a single patient [13].

Furthermore, this model allows to redesign the process in order to reduce costs, incorporate new activities in the care cycle, make changes and above all, it allows to compare the best pathway and offer to the patient the best available solution, identifying areas for improvement in terms of time, goods consumed, and activities carried out.
Clinical management, including medical professionals and support employees, would greatly benefit from this development in healthcare since it would make it easier for them to quickly assess a treatment's efficacy and resources usage. TDABC's process mapping might reveal which processes offer the most value, if waste can be reduced, and whether resources are being underutilized from the standpoint of redesigning the delivered healthcare process to create high value for the patient. According to numerous authors [13–16], its use in orthopaedic surgery is very suited. The ability of activity-based methodology to not only supply more information but also to provide better detail and higher timeliness of the same, so constituting a legitimate support to the decision-making process, is another point on which all of these authors agree. Furthermore, the use of this technique lowers the percentage of unspecified allocated overhead costs, and process mapping makes it easier to oversee every step of the process efficiently, taking corrective action as needed [17]. The resources used and the actions performed are precisely specified, ensuring that the cost analysis is accurate and complete [18].
A recent systematic review concluded that TDABC can help overcome a key challenge associated with current cost accounting methods and should be gradually incorporated into functional systems [12].
Additionally, the information gathered, and the methods used to identify expenses improve the transparency in the business management that enable, as shown by the research by Demeere N. et al. [19], an internal examination aimed at establishing a reference benchmark and creating value.
The goal of this pilot study is to understand the true cost of a total hip replacement using the TDABC in an Italian public hospital and to comprehend how the adoption of this method might enhance the process of providing healthcare from an organizational and financial standpoint.

METHODS

Study Design

During 2019 a prospective experimental case study [20,21] was conducted in a public hospital in central Italy. The orthopaedic department under observation is made up of 26 hospital beds, 7 orthopaedic and trauma surgeons, and 4 residents; it is part of a regional HUB and performs about 1600 orthopaedic surgeries per year.
Using the TDABC, details regarding all the activities, consumables, and participating healthcare professionals were gathered. Seven steps have been methodologically introduced, as it is mandatory for the use of this tool [12], and they are identified by the increasing number in brackets of the following paragraphs.

Study Participants

(1) Inclusion criteria: patients 60–80 years old, suffering from primary hip arthritis undergoing THA. Patients with concomitant femoral neck fractures, cemented prostheses, intraoperative fractures, or systemic complications (such as cardiopulmonary diseases, which would have increased standard surgical times) were excluded.

Measurement

To understand how patients move through the care cycle and quantify the usage of human resources by activity, a process map for primary hip replacement was created from the entrance in the operating room to the exit (2).

Direct observation, interviews, and multidisciplinary care plan validation sessions with frontline personnel were used to build process maps with time estimates for each stage. The necessary resources for each process step (such as staff and consumables like implants) were noted (3).

We calculated the overall expenses over a patient's cycle of care after estimating the cost of providing each service based on the time needed for each resource type (4).

The questions performed to the healthcare staff are listed in the Appendix A (**Table A1**).

Costs Analysis of Hip Arthroplasty

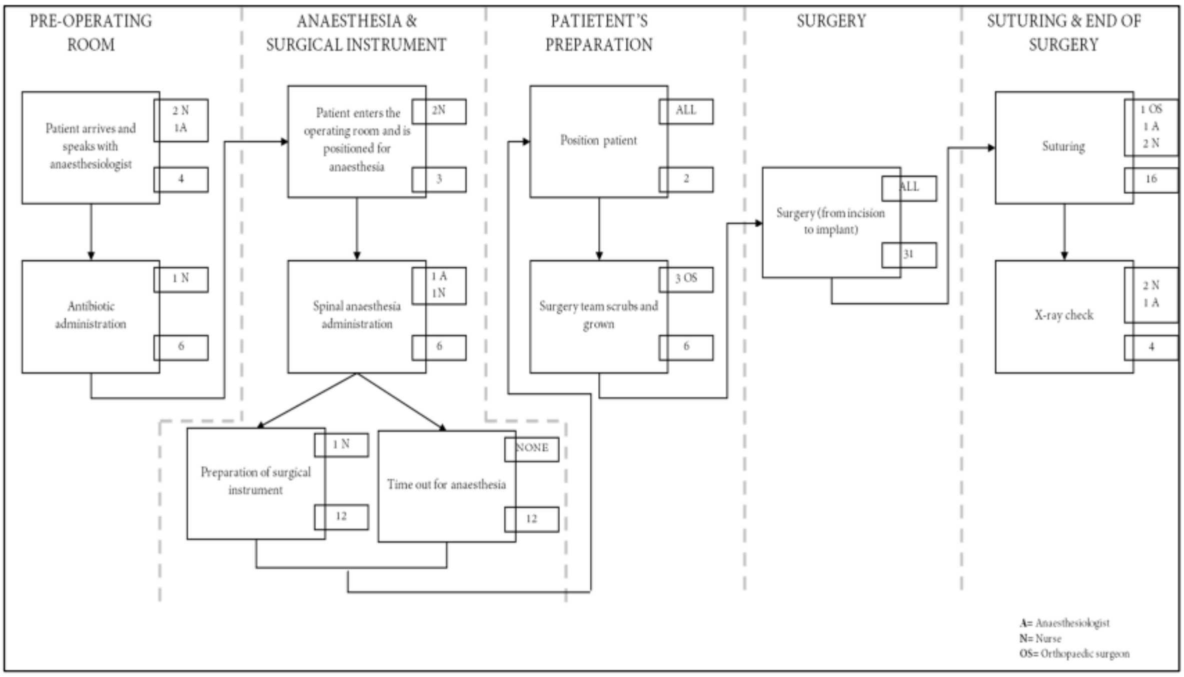
(5) The average price stated by the regional fee schedules as compensation for services rendered in pre-hospitalization was used as a reference point to determine the cost of prehospitalization exams [22]. The cost of most consumer goods used throughout the entire therapeutic process was provided by the Director of hospital's pharmacy by filling out a pre-set table based on the information needs derived from the process maps; the cost of the prosthetic device was obtained by extracting the price from the purchase of regional tender. The hourly cost of an active operating room used for major hip surgery, net of material, and labour costs, was derived from the literature [23], as well as the average cost of a day of hospitalization [24]. (6) Comparing the average monthly pay of the operators with the actual amount of time spent delivering the health service, the capacity cost rate [11], defined as practical capacity of each active operator, was determined. This method was used for all the operators present, considering the different remuneration (7). It is important to point out that in the Italian system, the salary for clinical staff in a public hospital is regulated nationally. There is no difference pay based on the procedures carried out; rather, it is dependent on the total number of hours worked each month and the operators' seniority.

Finally, to define the total cost of hip arthroplasty, from the admission to the patient's discharge, all the calculated expenses (pre-operative tests + hospitalization + theatre + general consumer goods + prosthesis + staff employed) were added up.

RESULTS

Fifteen patients who met our inclusion criteria were included in this study. The cementless prosthetic implant was the same for each patient and the surgical team was the same for all operations. The average of actions and time spent on these patients made up the process map shown in **Figure 1**: this diagram outlines the arthroplasty operating day including anaesthesia preparation, surgical preparation, and surgery. From the moment the patient enters the pre-operative room until the last radiographic control following the surgery, the estimated time for the intervention is, on average, 90 min.

Figure 1: Process map of THA. The large boxes represent activities with arrows indicating sequence. The personnel ID is in the upper smaller boxes (see legend) while the numbers in the smaller boxes correspond to minutes used per activity.



The healthcare delivery process of THA in the hospital analysed involved seven healthcare professions, in particular:

- three orthopaedic surgeons (one of them involved for 55 min and two involved for 39 min)
- one anaesthesiologist (involved all the time)
- one nurse dedicated to the anaesthesiologist (involved all the time)
- one surgical nurse (involved 85 min)
- one general nurse (involved 85 min)

The pre-operative tests, including blood tests, chest x-ray, pelvic x-ray, ecg, and anaesthesia evaluation reached a total cost of EUR 90,29 per patient, according to the regional fee.
The total cost related to the personnel involved in the THA implantation procedure is EUR 201.34 and it is shown in detail in **Table 1**. Considering the average of the wages specified in the Italian National Labour Contract for operators with that level of experience, 36 h per week were calculated for nurses, and 38 h per week for doctors.

Table 1: The cost refers to the total minutes spent by each health worker during the procedure.

Helthcare Professional	Monthly Pay	Total Time Spent	Total Cost
Orthopaedic Surgeons (x 2)	EUR 5330	39 min for each surgeon	EUR 45.59
Orthopaedic surgeon (x 1)	EUR 5330	55 min	EUR 32.14
Anaesthesiologist	EUR 6000	90 min	EUR 59.21
Nurses (x 2)	EUR 2052	85 min for each nurse	EUR 40.80
Nurse (x 1)	EUR 2052	90 min	EUR 21.60
TOTAL COST			EUR 201.74

The cost of the consumables charged for each operation performed by healthcare professionals was grouped by stage, and it represents an expense of EUR 97.02 (**Table 2**).

Table 2: The grouped-by-stage cost of consumables charged for each operation performed by healthcare professionals.

Stage	Cost of Consumables
Pre-operating room	EUR 8.44
Anesthesia and surgical field	EUR 42.25
Position of patient	EUR 18.16
Surgery (prosthetic implant excluded)	EUR 13.01
Suture and dressing	EUR 15.16
TOTAL COST	EUR 97.02

The cost of each consumable item is listed in the Appendix A (**Table A2**).
The final cost of the implanted prosthetic device was EUR 3029.208 according to the regional tender, and it is analysed in **Table 3**.

Table 3: The total cost of prosthesis refers to the specific components used

Purchase Prices of Prostheses		
1.	Cup	EUR 786.60
2.	Insert	EUR 425.60
3.	Head	EUR 280.25
4.	Stem	EUR 1420.25
	Total without VAT	EUR 2912.70
	VAT	EUR 4%
	TOTAL COST	EUR 3029.21

The cost of an active operating room used for major hip surgeries, minus material, and labour expenses, was calculated by Cinquini et al. [23], who estimated an hourly cost of EUR 90 for the theatre. By multiplying the hourly cost by the amount of time spent in the operating room for the procedure (90 min), a cost of EUR 135 was obtained.
The average inpatient stay was 3.7 days. On 2007, the Italian Ministry of Economy and Finance estimated the average cost of hospitalization to be EUR 674 per day [24]. The final cost of hospitalization was calculated by multiplying the average daily cost of a day by the number of days spent in the hospital by the patient, resulting in EUR 2493.80.
The total cost of THA from pre-operative tests to discharge is EUR 6002.06. It is presented in detail in **Table 4.**

Table 4. The sum of all cost items calculated by the TDABC approach.

Inpatient Total Cost of Tha	
1. Pre-operative tests	EUR 90.29
2. Hospitalization	EUR 2493.80
3. Operating room	EUR 135.00
4. Consumables	EUR 97.02
5. Prosthesis	EUR 3029.21
6. Personnel	EUR 201.74
FINAL COST	EUR 6002.06

DISCUSSION

The world health system is facing an unprecedented period of change and crisis. The ongoing war in Eastern Europe and the post-COVID crisis have also caused an increase in national healthcare spending, predictably far greater than inflation. This unsustainable health care expenditure has increased the demand for providing high quality care while reducing the costs of delivering these outcomes. The main finding of this pilot study is that the TDABC methodology can also be applied in an Italian public hospital and provides a complete and detailed description of the patient's path, of the staff involved, and an accurate understanding of the operation costs.

The value of health care, defined by health outcomes achieved for every dollar spent [25], can be improved if costs and outcomes are measured in sufficient detail to assess the impact of changes in care systems and processes [26,27]. It is not just economic argument, since knowing organizational and clinical details can allow healthcare professionals to redesign care processes with a patient-centred view, thus providing the best possible care using resources efficiently.

An accurate understanding of costs is important for the effective implementation of cost saving strategies. Elective orthopaedic surgeries are often standardized and to increase the efficiency of such surgical procedures it is essential to develop process maps for each step of care in the total joint replacement. In this way, we will be able to identify redundancies and welfare inefficiencies, whose financial impact was not previously detectable due to the lack of detailed analysis of the processes obtained with traditional accounting methods. On the other hand, the times and consumables used are certainly different, depending on the surgeon's background, on the adhesion of the operating team to the most recent evidence-based scientific literature, or to guidelines. It is crucial to point out that regardless of the structure or volume of surgeons, standardization is associated with better processes and outcomes for patients undergoing THA and thus process mapping can also help improve procedures, increase productivity, and raise the number of hip replacement surgeries performed. The mapping of the clinical path, in fact, allows us to understand the connections between the activities, operators, roles, and responsibilities of the care delivery cycle. In addition, this allows service providers to have a better awareness of the costs related to certain services and allows them to evaluate the effects of changes to support systems and procedures.

The TDABC has been described by a number of authors as a managerial tool that promotes collaboration between medical professionals and support staff by outlining every step of the value-creation process [17–19]. In our experience, the total composition of the cost of a hospitalized patient to undergo THA has two major economic items: the component that has the greatest impact on this value is the cost of the prosthetic device, which alone represents 50.4% (about EUR 3000) of the total cost, followed by costs relating to hospitalization, which constitute 41.5% (about EUR 2500).

Our results agree with the literature showing that the largest and most common direct cost is the purchase price of the implant [28]. This is a common finding both in the literature on hip and knee arthroplasty [29], and in shoulder prostheses [30]. Robinson et al. showed that the average cost of the implant per case can range from USD 2392 to USD 12,651 for total hip replacement procedures [31].

Haas et al. [32] recently noted that hospitals using a joint committee of hospital administrators and surgeons to negotiate prices with vendors paid 17% less for implants than institutions without a joint purchasing committee. Therefore, with a view to improving the efficiency or comparing costs with other institutes and methodologies, these data highlight the importance of rationalizing purchases and, where possible, reducing hospital stays.

While directly decreasing medication and personnel costs may not be feasible, indirectly lowering costs by reducing length of stay must be an area for improvement. It is proven that the common reasons why patients need to stay an extra day in hospital after joint replacement are outdated customs, unscientific fears and, at best, problems related to pain and social support, all potentially responsive to initiatives of quality improvement [33]. Strategies to reduce length of stay after THA have to start the first moment surgery is considered, ensuring adequate postoperative social support and setting realistic expectations about pain management [30].

Finally, to achieve higher-value care for patients undergoing THA, TDABC costs must be linked to patient experience, quality of life, and functional outcomes, which is the object of our future research. Nevertheless, this study is an important step toward introducing clarity into the cost conundrum of THA and will hopefully stimulate further research into this increasingly important topic.

Having the mechanism by which to identify true costs locally and throughout the lifecycle of care and having a mechanism to reduce costs without negatively impacting outcomes and experiences, are necessary steps to reduce health care costs and improve value (by protecting or enhancing outcomes and the experience of care) globally.

Limits

This study has limitations. First, as a pilot experiment it is a small scale preliminary observational study undertaken to decide how and whether to start a large-scale project, which could aim at collecting data from multiple institutes to integrate and compare the results obtained in a public hospital with those obtainable in a private or university hospital. Secondly, it is important to underline that TDABC does not contain all expenses calculations usually included in a DRG-based reimbursement: it is a method to determine the cost of the process. The object cost is the healthcare delivery process of total hip replacement in the hospital. From this perspective, it may appear that the TDABC process does not fully account for all indirect and THA-related costs (such as administrative, research, or sterile treatment), nor time spent caring for the patient outside the hospital, such as medication, rehabilitation, and social support, but it does account for facilities, equipment, information technology, and most other traditional “overhead” costs [34]. In addition, our exclusion criteria reflect the assumption that surgery and postoperative recovery are without complications, which obviously would add costs to both staff and medications, blood transfusions, any new surgeries, and, in any case, a longer length of stay, which would certainly amplify the costs.

APPENDIX A

Table A1: Questions submitted to the clinical staff

1. How many operators are engaged during the surgery? 2. How long is the procedure? 3. What is the patient's path through the operating unit? 4. What is the timing of each stage of surgery? 5. Are all operators present at each stage? 6. What are the tasks of each individual operator in each phase? 7. What consumables are needed?

Table A2: Unit costs consumables. Due to the low cost of the single element, cents were kept in

	Unit cost	**Cost by Quantity**
Pre operating room:		
Cannula	0,3416 EUR	0,3416 EUR
Betadine	0,99 EUR	0,99 EUR
Patch (9mt roll)	0,28 EUR	0,005612 EUR
Saline solution 0,5 lt	0,37 EUR	1,122 EUR
Antibiotic:		
- Cefamezin	0,87 EUR	0,869 EUR
- Amicasil	0,55 EUR	0,55 EUR
Anti-allergic prophylaxis:		
- Flebocortid 1g	3,25 EUR	3,245 EUR
- Trimeton	0,99 EUR	0,99 EUR
Needle	0,01 EUR	0,03 EUR
ECG Electrodes	0,10 EUR	0,2928 EUR
Washing:		
- Sponges	0,38 EUR	1,891 EUR
- Caps	0,02 EUR	0,1952 EUR
- Face mask	0,05 EUR	0,3416 EUR

Anesthesiologist:		
Sterile dressing (3 pack)	0,46 EUR	0,9272 EUR
Latex gloves	0,20 EUR	1,7568 EUR
Spinal needle	0,85 EUR	0,854 EUR
Syringe	0,02 EUR	0,0488 EUR
Chirocaine	8,80 EUR	8,8 EUR
Dressing	0,28 EUR	0,2806 EUR
Surgeons/Nurse:		
Nurse Scrub	5,25 EUR	5,246 EUR
Surgeons scrubs	5,25 EUR	15,738 EUR
Hip prosthesis disposable kit	24,34 EUR	24,339 EUR
Aspirator/Hoses	0,76 EUR	0,7564 EUR
Electrosurgery equipment	3,12 EUR	3,1232 EUR
Scalpel blade	0,06 EUR	0,122 EUR
Disinfection pads (pack of 10)	0,05 EUR	0,0976 EUR
Oprafol	8,91 EUR	8,906 EUR
Drainage	4,39 EUR	4,392 EUR
Silkam 0	1,10 EUR	2,196 EUR
Safil1	2,81 EUR	5,612 EUR
Vicryl 2	1,10 EUR	2,196 EUR
Absorbent dressing	0,73 EUR	0,732 EUR
Specific patch (10mt roll)	1,71 EUR	0,03416 EUR

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Article 3

The Pathway Of Hip And Knee Replacements: Finfindgs From Public, Private, And University Hospitals.

INTRODUCTION

Healthcare professionals are under increased financial pressure after decades of a fee-for-service mechanism. In a system that is continually marked by significant waste of already limited resources [1], it would be desirable to apply a costing system that can provide more accurate patient-level costs per medical condition. Besides, evolving global healthcare reforms are set to shift the industry away from fee-for-service reimbursement to bundled or pay-for-performance models, with the goal of finding innovative ways to re-engineer healthcare delivery changing from quantity-based to value-based efficiency [2, 3]. The value-based healthcare model (VBHC) is an innovative alternative to fee-for-service that has emerged as a promising framework for encouraging continuous improvement in the quality of care provided to patients and for better control of healthcare costs [4]. In fact, many healthcare organizations are unprepared for bundled-payment reimbursement due to a fundamental lack of knowledge of patient care expenses.

Activity-Based Costing is a "top-down" cost calculation method that aggregates overhead and indirect costs (such as non-clinical wages) to specific activities (such as revenue cycle billing) based on personnel interviews [5]. Such traditional strategy allows a practical evaluation of hospital costs in general, but the model is difficult to use on a large scale because it requires an update every time occurs a change in costs for a given service. Furthermore, Activity-Based Costing also introduces potential biases by relying on the subjective opinions of individuals with the natural inclination to always demonstrate 100% productivity. In reality, productivity levels are probably closer to 80-85%, taking into account factors such as presenteeism (non-productive time at work).

To address the limitations of established cost accounting methods and successfully implement VBHC, Time Driven Activity Based Costing (TDABC) is defined as a managerial tool that promotes cooperation between physicians and administrative staff [6]. It evaluates real healthcare costs by mapping the entire value-creation process and using a microcosting approach that allows to evaluate the resources consumed in the healthcare system by each patient [7]. According to Moffitt and Vasarhelyi [8], accounting models should evolve and adapt to focus more on data quality, atomicity and data linkages; as a result, intelligence gathering should move from periodic data collection to real-time flow. Furthermore, due to the increased standardization of the process, TDABC is particularly suitable for the surgical field [9], providing more and better knowledge on timing, procedures, and costs. This is especially true in orthopaedics, where there has been a steady year-over-year increase in the number of hip and knee replacements [10] and their treatment costs, adjusted for inflation, are estimated to have increased by 66% between 2000 and 2010 [11].

Previous studies have analyzed the variance in costs between hip and knee arthroplasties [12-15]. However, there is a paucity of data directly comparing cost between different healthcare organizations and clinical outcomes. The present study brought together 3 different Italian institutions with different administrations: public, private, and academic hospital. To date, there is no published research that describes TDABC for total hip (THA) and knee (TKA) arthroplasty in

Italy. The aims of the present study were (1) to identify whether variation exists in total cost among different setups, and, if so, (2) to determine which cost parameters drive this variation. Finally, (3) if different procedures equal better clinical outcomes for patients.

METHODS

A prospective, multicenter, experimental [16] study was conducted from 2019 in 3 different hospitals providing total hip and knee replacements. Different scenarios of orthopaedic surgery in Italy were analysed. In particular, the following were considered:

- A public hospital
- A public university hospital
- A private hospital

The hospitals are located in central Italy, in two different regions (Abruzzi and Latium) and perform at least 200 total joint arthroplasties (TJA) per year. For each hospital, patients were observed consecutively until a minimum of 30 THA and 30 TKA were enrolled.

Patients included in this study were a cohort of surgically and medically “noncomplex” patients undergoing primary THA and TKA. Exclusion criteria: bilateral or additional procedures, patients with concomitant fractures, intraoperative fractures, systemic complications (such as cardiopulmonary disease, diabetes, and rheumatoid arthritis) or treatment complications (such as infections and thrombosis or unrelated acute medical diseases), which would have increased standard surgical and inpatient times.

Demographic

Sample characteristics such as age, gender, body mass index (BMI), and American Society of Anesthesiologists (ASA) were recorded. To carry out a subjective assessment (patient-reporting outcomes - PROMs) of the health status of patients with primary arthritis of the hip and knee, the 12-item Short Form Health Survey (SF-12) was used [17]. This questionnaire represents a reduced version of the SF-36: it allows an estimation of physical and mental health perceived by the patient. Pain symptoms were assessed using a visual analogue scale (VAS) graphically represented by a graduated scale ranging from 0 (the worst possible state of health) to 100 (the best possible state of health) on which the interviewee indicates his or her perceived level of systemic pain. Patients undergoing THA were assessed with the Harris Hip Score (HHS) which is a 0-100 points objective and reproducible evaluation method, based on the examination of pain and functional capacity of the hip. The lower the overall score, the worse the patient-reported outcomes [18]. Patients undergoing TKA were assessed with the Oxford Knee Score (OKS), which is a validated and widely accepted 12-item patient-reported outcome measure specifically designed and developed to assess function and pain after total knee replacement. By adding the individual scores, an overall score is obtained which varies from "0" (worst result) to "48" (best result). The lower the overall score, the worse the patient-reported outcomes [19].

In the university hospital and in the private hospital, patients underwent THA using a posterolateral approach, while in the public hospital a lateral approach was preferred. In the public hospital, a navigation system for TKA was used, while in the academic and private hospital, patients were operated on with standard technique.

Physiotherapy was started as soon as possible after surgery. Clinical and radiographic parameters were recorded pre-operatively and at 30 and 90 post-operative days and then annually.

Time-Driven Activity-Based Costing

By reproducing the seven steps methodology of the pilot study previously carried out, a process map of the full carecycle provided in a THA and TKA (from the initial clinical visit to the final outpatient follow-up) was obtained. The main activities and the time dedicated to them during delivery process, as well as the subjects involved, were identified through questionnaires collected through interviews and submitted to health professionals. Process maps have been created including all activities performed and all consumables needed at each stage of the care process, including the implant device. The staff time dedicated to specific procedures was calculated and the capacity cost rate was determined by comparing the average monthly salary of each type of employee with the time actually spent providing the health service. Time spent on each activity was described by sample statistics.

The cost of the patient's own medication was not included as it is the policy of observed institutions that patients are asked during pre-assessment to bring in their normal medication for use during the inpatient stay. Peri-operative antibiotic use, 10 days of thromboprophylaxis with heparin, anaesthetic drugs and analgesia were included, with the hospital's pharmacy purchase prices used to cost these.

In either analysis the costs of postacute purchase services (for examples, health physical rehabilitation therapy or skilled nursing facility service) were not included as these are not financially integrated with observed institutions.

To obtain the final cost of the hip and knee prosthesis surgery, all the calculated expenses (pre-admission screening + hospitalization + theater + generic consumables + prostheses + personnel employed) were summed.

Indirect fixed costs such as buildings, operating room equipment and premises, sterilization process, heating, lighting, and administration will not be taken into consideration. Finally, the costs of the outpatient clinical and radiological evaluation are not taken into consideration as they are often carried out privately.

Statistics

The distribution of the variables was tested applying *Shapiro-Wilk test*. The statistical tests performed to evaluate the initial demografic differences between THA groups and between TKA groups were: the *t-test* for normally distributed variables (age, gender), the *Wilcoxon rank sum test* for non-normally distributed variables (BMI, ASA).

The clinical differences between groups at baseline and at the last follow-up were assesses by *unpaired T-test* (HHS, SF12) and *Wilcoxon rank sum test* for nonparametric data (OKS, VAS). For the analyzes, a statistical confidence level of 95% was selected. A p value < 0.05 determined significance.

Descriptive statistics are used, reporting the minutes spent on processes and activities and the cost in EUR.

RESULTS

PROMs

A total of 180 patients were enrolled. Ninety underwent THA and ninety underwent TKA. No differences were found between the demographics data of the three THA groups and the three TKA groups, that appeared homogeneous for age (p=0.10), gender (p=0.44), BMI (p=0.63) and ASA (p=0.27). Demographic characteristics are reported in **Table 1.**

Table 1: Demographic characteristics of the observed sample

	THA (n= 30 per hospital)				TKA (n= 30 per hospital)			
	AGE	GENDER	BMI	ASA	AGE	GENDER	BMI	ASA
Private	64.4 ±6.5	18 w 12 m	29.1 ±7.5	9 ASA 1 21 ASA 2	64.3 ±8.3	16 w 14 m	27.1 ±6.5	10 ASA 1 20 ASA 2
Public	71.4 ±6.9	16 w 14 m	27,1 ±8.6	7 ASA 1 23 ASA 2	68.6 ±3.9	17 w 13 m	28.3 ±4.8	8 ASA 1 22 ASA 2
Academic	68.7 ±4.8	14 w 16 m	29.9 ±6.8	6 ASA 1 24 ASA 2	71.3 ±7.4	19 w 11 m	26.9 ±8.6	9 ASA 1 21 ASA 2

In all groups there was a marked improvement in all the parameters compared to the preoperative conditions without any statistically difference. **Table 2** summarizes the mean values of HHS (p = 0.94) and OKS (p = 0.816) collected before surgery and at the last clinical follow-up at least 2 years after surgery. Pain was significantly reduced: the mean VAS for THA decreased from 51.3 to 5.4 (no difference between the three groups - p = 0.099), while the mean VAS for TKA decreased from 49.8 to 9.2 with no significant difference between the three groups at last follow-up (p < 0.001). The SF-12 rate increased in the THA groups from 32.1 to 44.9 and from 32.3 to 40.8 in the TKA groups (respectively p <0.001 and p = 0.16)

Table 2: Mean results of clinical rating scores of patients undergoing total hip and knee arthroplasty

	Harris Hip Score (HHS)		Oxford Knee Score (OKS)	
	Pre-op	Final F-Up	Pre-op	Final F-Up
Private	68.4	90.3	19	41
Public	65.9	89.9	20	38
Academic	61.5	90.4	23	42

Process maps and consumables

Pre-admission assessments and patient screenings are the same for all 3 hospitals. The process map is illustrated in the **Figure 1** and shows the patient's path up to the day of admission.

The key to Figure 1 and general roles for designing process maps:

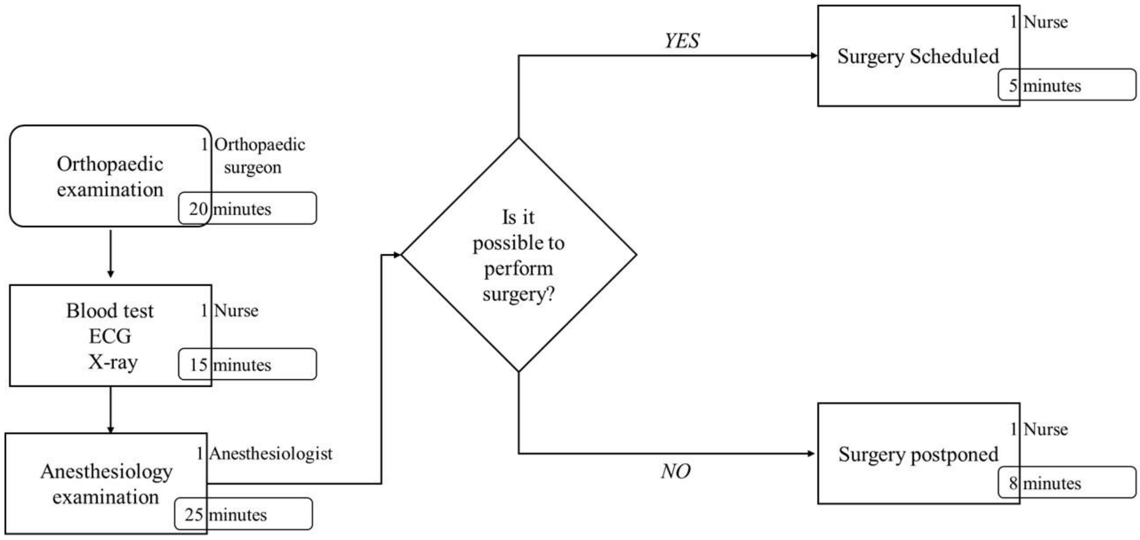
- Rounded rectangles represent the start or the end of the process;

- Rectangles represent the activity performed;

- Arrows show the order of the activities within the process;

- The rhombus is the symbol for “decision turning-points”. It represents where a decision is needed

Figure 1: Pre-admission screening for patient undergoing elective surgery, from the first clinical evaluation to surgery scheduled



The sequential process map related to THA is shown in **Figure 2** and the one related to TKA is shown in **Figure 3**. They represent patient care from hospitalization to post-surgery.

Figure 2: Process map of total hip arthroplasty

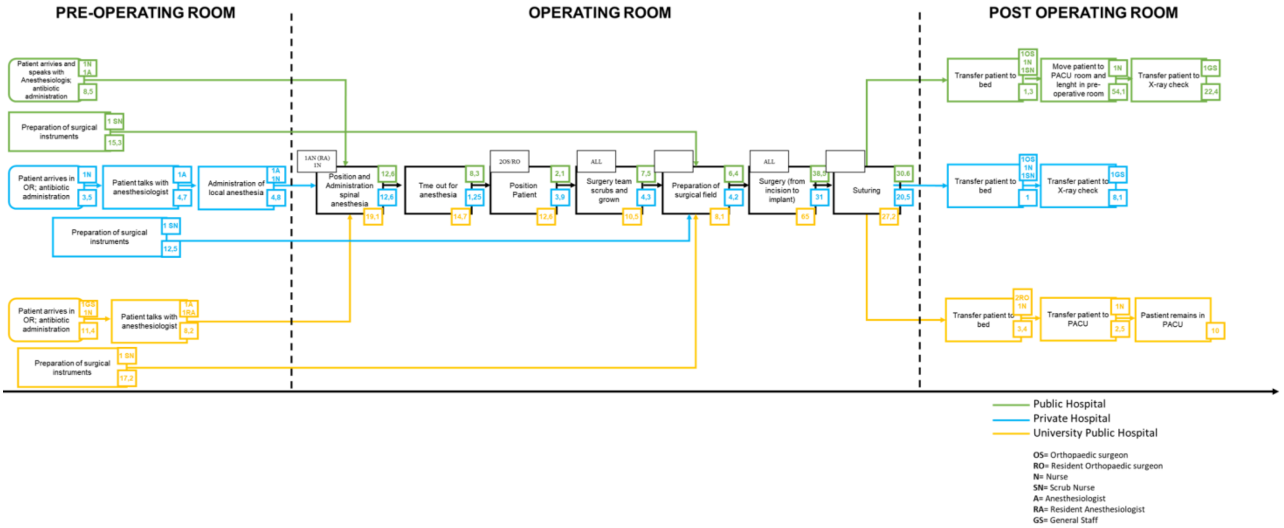
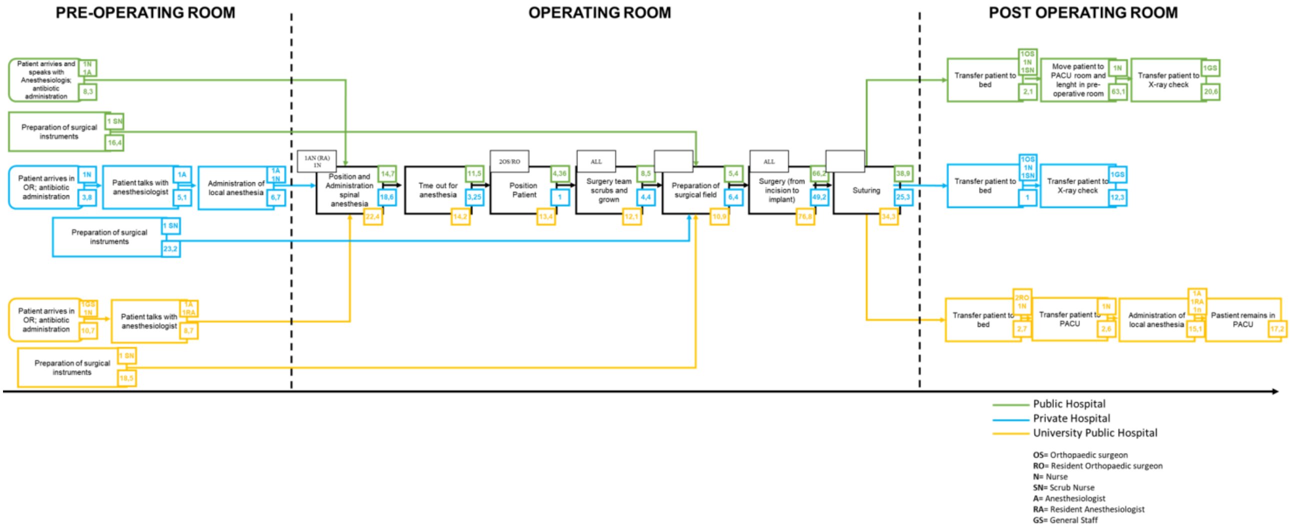


Figure 3: Process map of total knee arthroplasty



The diagrams show the process maps outline of the arthroplasty operating day including anaesthesia preparation, surgical preparation, and surgery. The large boxes represent activities with arrows indicating sequence. The colours correspond to different hospitals (see legend) with personnel ID in the upper smaller boxes (see legend). The numbers in the smaller boxes correspond to minutes used per activity.
OR = operating room; PACU = post-anesthesia care unit.

Except for the academic hospital, every organization analyzed shows the same patient pathway for THA and TKA. Except for the academic hospital, where local anesthesia in PACU is administered only to patients undergoing TKA, the main flows for the two surgical procedures observed are the same. For both procedures, in fact, the activities concerning the operating room are the same in all the hospitals analysed. They differ only due to the need for time and personnel involved.

Table 3 lists all the activities and the time required to carry them out in each facility.

Table 3: Mean time (minutes) required for all the activities
**not included in estimation; μ=mean, σ=standard deviation, NP= not performed.*

Activity	**Public Hospital**		**Private Hospital**		**Public University Hospital**	
	THA	TKA	THA	TKA	THA	TKA
Patient arrives in room *Administer antibiotic*	μ=8,5 σ=3,9	μ=8,3 σ=3,8	μ=3,5 σ=0,7	μ=3,8 σ=0,8	μ=11,4 σ= 2,7	μ=10,7 σ=2,4
Patient speaks with anaesthesiologist			μ=4,7 σ=0,9	μ=5,1 σ=1,0	μ= 8,2 σ= 1,6	μ=8,7 σ=1,1
Administer local anaesthesia	NP	NP	μ=4,8 σ=0,8	μ=6,7 σ=1,1	NP	μ=15,1 σ=1,4
*Preparation of surgical instruments**	μ=15,3 σ=5,3	μ=16,4 σ=5,7	μ=12,5 σ=1,8	μ=23,2 σ=3,3	μ=17,2 σ=1,3	μ=18,5 σ=1,2
Position for spinal or general anaesthesia and administer anaesthesia	μ=12,6 σ= 6,8	μ=14,7 σ=8,0	μ=12,6 σ=2,9	μ=18,6 σ=4,3	μ=19,1 σ=3,3	μ=22,4 σ=3,05
Time out for anaesthesia	μ=8,3 σ=3,4	μ=11,5 σ=4,8	μ=1,25 σ=0,5	μ=3,25 σ=1,3	μ=14,7 σ= 0,4	μ=14,2 σ=0,9
Position patient	μ=2,1 σ=1,3	μ=4,36 σ=2,9	μ=3,9 σ= 0,6	μ=1 σ=0,1	μ=12,6 σ=2,8	μ=13,4 σ=1,4
Surgery team scrubs and gowns	μ=7,5 σ=1,7	μ=8,5 σ=2,0	μ=4,3 σ= 0,7	μ=4,4 σ=0,7	μ=10,5 σ=1,3	μ=12,1 σ=1,2
Preparation of surgical field	μ=6,4 σ=1,4	μ=5,4 σ=1,2	μ= 4,2 σ=1,0	μ=6,4 σ=1,5	μ=8,1 σ=0,8	μ=10,9 σ=1,2
Surgery (from incision to implant)	μ=38,5 σ=12,6	μ=66,2 σ=20,0	μ=31,0 σ=3,83	μ=49,2 σ=6,0	μ=65 σ=6,4	μ=76,8 σ=5,6
Suturing	μ=30,6 σ=7,6	μ=38,9 σ=9,4	μ=20,5 σ=3,88	μ=25,3 σ=6,6	μ=27,2 σ=4,1	μ=34,3 σ=3,9
Transfer patient to bed	μ=1,3 σ=1,27	μ=2,1 σ=0,7	μ= 1 σ= /	μ=1 σ=/	μ=3,4 σ=1,1	μ=2,7 σ=0,9
TOTAL of TIME	**131,1**	**176,36**	**104,25**	**147,95**	**197,4**	**239,8**
Move patient to PACU	μ=3,3 σ=1,2	μ=2,2 σ=1,0	NP	NP	μ=2,5 σ=0,9	μ=2,6 σ=0,8
Patient stays in PACU	μ=50,8 σ=28,8	μ=60,9 σ=40,2	NP	NP	μ= 10 σ= 1,2	μ=17,2 σ=2,1
X-ray check	μ=22,4 σ=2,09	μ=20,6 σ=2,3	μ= 8,1 σ= 1,6	μ=12,3 σ=2,4	NP	NP
Transfer patient to ward	μ= 6,2 σ= 2,1	μ=2,9 σ=1,3	μ= 5,1 σ= 1,8	μ=5,5 σ=1,6	μ= 7,1 σ= 1,4	μ= 6,9 σ=1,2
TOTAL PROCESS TIME	**213,8**	**262,96**	**117,45**	**165,75**	**217**	**266,5**

As can be seen from Table 3, the main time differences between the three hospitals, both in THA and in TKA, are related to both pre- and post-operative activities. These differences mainly concern the following key points of surgical services:

• the steps performed by the patient;
• use of the device; and
• the asset involved.

The different phases performed by the patients were shown by Figures 2 and 3. The differences in the use of resources and devices are shown in **Table 4**; in particular, private and university hospitals use the ultrasound for the administration of local anesthesia, specifically the first in the pre-operative room and the second in the post-operative room, while the public hospital requires catheterization of the patient, which the other two structures no.

Table 4: Device and asset used in the three different structures

	Device	Asset	Public	Private	Academic
Catheter	Yes	No	No	No	Yes
Echograph	No	Yes	No	Yes	Yes
Intraoperative X-Ray check	No	Yes	No	No	Yes
Post Anaesthesia care unit	No	Yes	Yes	No	Yes

The mean length of stay in the public hospital was 8.5 days for THA and 9.5 days for TKA, while in the university hospital hospitalization lasted an average of 7.75 days for THA and 6.4 days for TKA. In no case patients were discharged to their own home: 100% of the patients continued the rehabilitation treatment in dedicated facilities.

In contrast, a difference in the type of discharge was noted in the private hospital. In particular, 88.5% of THA were discharged home (average hospitalization 5.4 days) while 11.5% were transferred to a rehabilitation clinic (after 6.4 days). Patients undergoing TKA remained hospitalized for an average of 5.8 days if discharged home (33.4%) and 7 days if discharged to the rehabilitation clinic (63.6%).

Since discharge, patients in each case received outpatient nursing care at 2 weeks (20 min), ambulatory radiography (7 min), and orthopedic examination (20 min) at 30 and 90 days after surgery.

Cost analysis

The pre-operative tests, including blood tests, chest X-ray, pelvic/knee X-ray, ECG, and anaesthesia evaluation reached a total cost of EUR 90.29 per patient, according to the regional fee. The cost of the first orthopaedic evaluation is not included because very often this is performed privately also for the public and academic hospital, as well as for the private one as foreseeable.

The cost of the implant varied greatly based on the brand chosen and the preferences of the surgeon. In particular, in the university hospital a short bone-saving stem (notoriously more expensive) was preferred for hip prostheses, while in the public hospital the navigation system for the knee has an additional cost of EUR 105 per implant.

The total price of the single pieces of a prosthesis was as follows: THA public hospital EUR 2201.36, private hospital EUR 2906.88, academic hospital EUR 3968.72; TKA public hospital EUR 2758.65, private hospital EUR 1456.00, academic hospital EUR 2392.00 (cement included).

The total cost of personnel involved in THA and TKA differs according to the commitment of the health care worker in different hospitals. Below, two tables summarize the total time spent by each operator and the cost for the actions performed based on the monthly salary for THA (**Table 5**) and TKA (**Table 6**).

Table 5: The cost refers to the total minutes spent by each health worker during THA. CCR = capacity cost rate

	Public		Private		Academic	
	Time spent	CCR	Time spent	CCR	Time spent	CCR
Nurse	145	31.7 EUR	77	16.6 EUR	136	29.8 EUR
Anaesthesiologist	90	59.8 EUR	74	150 EUR	118	78.6 EUR
Scrub nurse	92	20.1 EUR	68	14.6 EUR	117	25.6 EUR
Social health worker	104	18.2 EUR	8	1.4 EUR	103	18.2 EUR
Ortho surgeon	85 (x 2)	112.8 EUR	63 (x2)	1178 EUR	-	-
Orthopaedic boss	46	34.7 EUR	35		75	56.9 EUR
Anaest resident	-	-	-	-	119	21.7 EUR
Ortho resident	-	-	-	-	126 (x3)	69.1 EUR
TOTAL COST		278.3 EUR		1360.6 EUR		299.9 EUR

Table 6: The cost refers to the total minutes spent by each health worker during TKA. CCR = capacity cost rate

	Public		Private		Academic	
	Time spent	CCR	Time spent	CCR	Time spent	CCR
Nurse	193	42.1 EUR	105	22.6 EUR	160	34.9 EUR
Anaesthesiologist	128	84.9 EUR	104	150 EUR	157	104.3 EUR
Scrub nurse	129	28.1 EUR	105	22.5 EUR	140	30.6 EUR
Social health worker	140	24.7 EUR	86	15.1 EUR	121	21.4 EUR
Ortho surgeon	125 (x2)	166.1 EUR	86 (x2)	1181 EUR	-	-
Orthopaedic boss	74	35.2 EUR	53		89	67.1 EUR
Anaest resident	-	-	-	-	157	28.6 EUR
Ortho resident	-	-	-	-	150 (x2)	54.6 EUR
TOTAL COST		381.1 EUR		1391.2 EUR		341.5 EUR

As surgical procedures largely standardized, intraoperative consumables are pre-packaged in customized packaging. The cost varies slightly depending on the operation and hospital. In particular, general consumer goods during THA cost: public hospital EUR 60,3 private hospital EUR 85.7, academic hospital 73.0; the consumer goods during TKA cost: public hospital EUR 92,9 private hospital EUR 96.5, academic hospital 81.0

As shown by the process maps, the operating room usage time, including cleaning and set change, was: THA public hospital 106 min, private hospital 77 min, academic hospital 157 min; TKA public hospital 156 min, private hospital 108 min, academic hospital 184 min. The cost of an active operating room used for major replacement surgeries, minus material, and labour expenses, was calculated by Cinquini et al. [20], who estimated an hourly cost of EUR 90 for the theatre. By multiplying the hourly cost by the time spent in the operating room in the different hospitals, different amounts were obtained: THA public hospital EUR 159, private hospital EUR 115.5, academic hospital EUR 235.5; TKA public hospital EUR 234, private hospital EUR 162, academic hospital EUR 276.

On 2007, the Italian Ministry of Economy and Finance estimated the average cost of hospitalization to be EUR 674 per day [21]. The final cost of hospitalization was calculated by multiplying the average daily cost of a day by the number of days spent in the hospital by the patient. For the private hospital, a weighted average was used based on the different length of stay due to discharge type. The results are: THA public hospital EUR 5729, private hospital EUR 3707, academic hospital EUR 5223; TKA public hospital EUR 6403, private hospital EUR 4448, academic hospital EUR 4313.

The final cost of full care cycle of THA and TKA is presented in detail in **Table 7** and **Table 8**. Being large digits, decimal numbers have been removed from the calculation.

Table 7: The sum of all cost items of a THA calculated by the TDABC approach

	Public	Private	Academic
Preoperative tests	90 EUR	90 EUR	90 EUR
Hospitalization	5729 EUR	3707 EUR	5223 EUR
Operating room	159 EUR	115 EUR	235 EUR
Consumables	60 EUR	85 EUR	73 EUR
Prosthesis	2201 EUR	2906 EUR	3968 EUR
Personnel	278 EUR	1360 EUR	299 EUR
FINAL COST	8517 EUR	8263 EUR	9822 EUR

Table 8: The sum of all cost items of a TKA calculated by the TDABC approach

	Public	Private	Academic
Preoperative tests	90 EUR	90 EUR	90 EUR
Hospitalization	6403 EUR	4448 EUR	4313 EUR
Operating room	234 EUR	162 EUR	276 EUR
Consumables	92 EUR	96.5 EUR	81 EUR
Prosthesis	2758 EUR	1456 EUR	2392 EUR
Personnel	381 EUR	1391 EUR	341 EUR
FINAL COST	9958 EUR	7643 EUR	7493 EUR

DISCUSSION

The main findings of this study are that the items involving the greatest expenditure are consumables and length of stay and that the item that differs the most between the various structures is the purchase of the implant. These cost differences do not seem to be supported by better clinical outcomes for higher costs, nor by better optimization of the internal organization.

With a view to reorganizing the healthcare delivery process to achieve high patient value, clinical pathway mapping allows to understand the connections between activities, actors, roles, and responsibilities of the service delivery process and to generate information on which steps add the most value and whether waste can be reduced, or resources are under-utilised [22]. Furthermore, the application of the Time-Driven Activity-Based Costing method in orthopaedic surgery is particularly appropriate, as demonstrated by several authors [9, 23, 24]. Indeed, even if quality measures may not be completely comprehensive, the small variation between them indicates large opportunities to reduce the variation in joint arthroplasty costs without negatively impacting outcomes. Conversely, because THA and TKA are commonly performed procedures, inefficiencies in performing these practices can cause significant waste in overall healthcare expenditure.

It is crucial to underline that, as described by Laberge et al., elective hip and knee surgeries are highly standardized procedures with substantially overlapping clinical pathways [25]. While these surgeries require different materials and patient preparation, the processes are the same. This is confirmed by the results of this study; therefore, both processes can be discussed as a whole. The process map analysis reveals three main differences between the TKA and THA delivery processes between the three hospitals, namely: (1) time required, (2) activity performed in pre and post operating room, and (3) assets and devices involved.

The time required for the healthcare delivery process is higher for both procedures in academic hospitals. This could mainly be attributed to the context of the 'educational' hospital, which requires the participation of the residents in the whole procedure; within this type of hospital, it should also be noted that there are varying levels of expertise in various fields, such as student nurses, radiologist technicians, and residents of various medical fields (e.g., anesthesiology, orthopedics). Therefore, the involvement of residents at different stages of the health care value chain is generally associated with increased and longer surgical times in total joint replacements [26]. The other explanation for the higher time required by university hospitals is the use of a device (catheter) and assets (radiographic control in the operating theatre) not present in other structures.

The difference in activities carried out in the pre- and post-operative room could be related to the different organization of the three structures. According to Bhattacharjee and Ray, patient flow is influenced by seasonal and local variables as well as the location of hospitals and the types of services provided [27]. Furthermore, within the Italian National Health Service, both public and private hospitals are structured in Operating Units or wards, grouped by specialization (e.g., Orthopaedics). The department Head is responsible for providing organizational resources to departmental staff and for establishing a certain organizational climate, which includes unique policies (guidelines), processes and practices that may differ depending on the manager [28]. In addition, clinical decisions regarding surgical strategies may be guided by the background of the clinical staff (e.g., current practices or specialist school legacy) and/or by the adherence of the operating team to the scientific literature (e.g., evidence-based medicine or medical guidelines). This may explain why there is a different approach to using devices (e.g., catheter), resources (e.g., X-Ray in the OR), and activities performed before and after the surgery.

Instead, the activities carried out in the operating room are the same in all the structures analyzed due to the general surgical reproducibility of the prosthesis. Even the volume of interventions can lead to a more efficient standardized methodology and therefore to an optimization of working times and a reduction of waste. From a productivity perspective, generally, most of the surgeons who performed at least 300 TJAs per year have access to two operating rooms. It goes without saying that the cost of a surgeon with access to only one operating room is much higher, as the surgeon's time includes the actual operating time plus the time spent waiting for the current case to be finished, for the room to be cleaned and prepared, and for the next patient to be transferred to the room. A conflict can therefore arise between hospitals that want high utilization of their expensive operating rooms and surgeons who want high utilization of their time [29]. Accurate cost accounting helps to resolve this conflict. In fact, the creation of process maps allows us to identify redundancies and assistance inefficiencies, the economic impact of which was previously undetectable due to the lack of a detailed analysis of the processes obtainable with traditional accounting methods.

From the cited findings, it is possible to argue that the main differences between THA and TKA performed by the three analyzed organizations follow some organizational characteristics that act as a "conditioning variable" for specific activities in service processes (**Table 9**).

Table 9: Activities that differ most in terms of time spent between the three structures

Table 9	**Activities**	**Conditioning variables**
Operating Room	Position patient	Different clinical approach
	Surgery	Surgeon's exppertise
	Suturing	
Pre/Post operating room	Lenght of stay in PACU	Organizational structure
	Lenght of stay in ward	
	Discharge	Geographical opportunity

As for the activity performed in the pre- and post-operative room, they can vary according to the organizational structure, and the activity related to surgery can vary according to the experience and background or training of the surgeon. On the other hand, the discharge method can also vary according to the territorial organization, as shown in Table 9.

It is not surprising that the length of hospital stay is strongly correlated with the total cost of hospitalization. While it may be assumed that the prolonged hospitalizations are largely attributable to patient disease or complications, a study of >200,000 general surgery patients showed that much of the variation in length of stay remained unexplained after accounting for such factors and therefore most likely represented for practical style differences [30]. Although this issue requires a formal investigation, one of the main reasons for the extended hospitalization in the current study is due to the lack of rehabilitation clinics geographically close to the public and the academic hospital. It is common practice in central Italy to discharge patients underwent THA and TKA to highly specialized rehabilitation facilities. However, it is not always easy to find a vacant places, and this leads to a prolonged hospital stay. Even if located in a metropolis, the interpretation of the length of stay in the private hospital is impactful: although the duration of hospitalization tends to be shorter, it is not always possible to discharge rapidly to a rehabilitation clinic and this is demonstrated by the fact that patients discharged directly to own home leave on average 1.5 days earlier. Several studies have found no increase in the complication rate when LOS is reduced in an fast-track setting [31, 32]. Fast-track total hip and knee arthroplasty may provide the best available treatment combining evidence-based clinical features with organizational optimization resulting in reduced perioperative morbidity and mortality, shorter convalescence, and earlier achievement of functional milestones [33, 34]. Recently some authors are focusing on the even greater reduction of hospitalizations - maintaining a readmission rate comparable to more conventional stays - using the outpatient setting, understood as discharge appropriate selected patient on the same day as the TJA surgery [13].

Implant cost was highly variable and appears to be the main driver of cost variation. The high variability of implant purchase price suggests ample opportunity for cost savings. Negotiating lower implant prices would result in substantially lowered inpatient costs to the hospital. Previous studies have suggested that large private-practice groups and specialized hospital-physician negotiating committees would increase bargaining power and lower cost [12, 35]. Differences in implant choice or type of surgery were unrelated to different clinical outcomes. In fact, if THA and TKA are confirmed as the best resolution of quality of life in patients with advanced hip and knee arthritis, the clinical results were comparable in all groups. In a recent study that reported a 7.7 percent reduction in adjusted costs from adopting a hospital value-based management program, the authors suggested that a major reason for this positive impact was that the program focused continuously the initiatives on achieving value, not reducing costs, then get more support from frontline doctors [36]. The goal is not to reduce expenses or investments, but to make the process more efficient. The patient-centered approach to care is a strategy to improve the quality of interactions between providers and client institutions by placing consumers (and their families) at the center of decisions that impact their well-being. This methodology involves patient involvement and attraction of patients to a specific hospital. Organizational and market characteristics may also have been favourable, with surgeons able to create efficiencies by moving cases within their hospital. This could also be achieved using devices with a navigation system or robotics, single-use instrumentation or specific devices which would certainly increase intraoperative costs but could prove to be of great appeal with net cost-saving: in a large-scale overview it means offering the most modern technology to the patient while also creating profit for the hospital.

All studies using TDABC to support a VBHC program by exploring opportunities for cost savings and improved outcomes have suggested extending these approaches to other hospital units and clinical procedures [37-40]. The current study had access to real-time location tracking systems to provide actionable insights and more accurate microcosting information to support healthcare decision making. When defining a benchmark of which clinical pathway of THA and TKA may be more suitable, academic hospitals should be excluded from the benchmark. These structures, in fact, carry out educational activities involving the residents in all the supply processes to improve their skills [41], probably lengthening the time required for the procedures [42]. Performing joint replacement surgery necessitates several resources (operating input), which may be divided into two categories: equipment and labour. It is fundamental to monitor and measure: (1) the quantity of resources employed; and (2) the mix of resources employed. Thus, this allows clinical management to manage performance obtained by the operating inputs involved in the clinical pathway. As a consequence, the use of TDABC and the process map analyzes are able to show the weak and strong points of various clinical pathways related to THA and TKA; these points could be compared to create a benchmark for patient satisfaction and cost reduction based on the time and personnel required for each activity.

The strengths of the present study include the large number of cases analyzed and the uniform methodology used to analyze hip and knee replacements. This is the only study to date that has described and analyzed costs with the use of accurate and granular data with a single methodology in private, public, and academic hospitals simultaneously.

Lesson learned

A number of lessons learned in this project will be valuable for others seeking to replicate this TDABC approach.

First, it is important to know that there is a learning curve for understanding how to build the process map for TDABC. Creating the maps and learning where and how to pull costs from various sources takes time. However, perseverance pays off and subsequent efforts go much more quickly once the pilot model is creating [12].

It is important to note, too, that while surgeons typically know the cost of implants, they have not been able to identify implants' percentage contribution to true total cost. It would be helpful to identify a list of clinically equivalent implants (with exceptions allowed for unique anatomical or clinical considerations), determine a lower target implant price, and contract only with manufacturers that meet that price. At this point it could implement an online process whereby manufacturers anonymously bid against each other. The result will be that most manufacturers will agree to lower prices, and therefore healthcare companies will be able to reduce implant costs while maintaining the choice of surgeon, as happened at the Baptist Health System in San Antonio, Texas [43].

Lastly, during the hospital stay, the hospitals also should design their pain management and physical therapy to increase a patient's comfort level with being discharged to own home. While the extra time spent talking with patients and their families and the specialized pain therapy approaches did involve higher costs, these extra costs were calculated to be less than 100 USD per patient [29], a very high savings when compared to discharging patients to specialized rehabilitation facilities.

Limits

The cost estimate in this study is not representative of treatment costs for technically more challenging THA and TKA or for medically frail patients, cause the patient cohort selected from this study represented a ‘noncomplex’ sample based on surgical and medical factors. As a result, generalising the profitability of this procedure based on current study findings would not be appropriate for policy makers. There was no focus on complications, readmissions, or mortality in this study as the objective was to evaluate a course of care for the standard patient. Complications leading to readmissions vary widely between hospitals and countries depending on what is considered a complication, the period studied, and whether treated on an outpatient basis or during a readmission. Additionally, Medicare data [44] indicates that 95%-97% of hospitals were not statistically different from each other on risk-adjusted complication rates and readmission rates for THA and TKA. Therefore, no effort has been made to calculate the cost for potential complications/readmissions, as this is highly variable and depends on a variety of factors: type of complication, time to readmission (weekends can add days), staff available and so on.

This study did not include overhead calculations. To make the carecycle as comparable as possible to other hospitals, overhead was not included. In the Italian health system, it would be impossible to compare overhead between public and private hospitals as there are differences in what an overhead would include that is, the public hospitals do not have the cost of owning buildings but only the maintenance or rebuilding costs. So, including overhead in the calculations would add more complexity to the calculations and make comparisons more difficult.

Finally, the ward costs were not addressed with TDABC, but were calculated using the reimbursement that the Italian Ministry of Health pays for each day of hospitalization. Furthermore, the applied TDABC process was unable to fully account for all indirect and TJA-related costs (such as research or sterile treatment) and other traditional overhead costs. Time spent on patient care outside of patient interaction is difficult to explain, for example in care coordination or inter-provider communication. However, future research adopting these methods in larger, heterogeneous patient populations would be important to compare more accurate rates that account for staff activities during the patient's stay instead of looking at a fixed price of reimbursement regardless of private, public, or academic ownership.

CONCLUSION

This study focused on the topic of TDABC in healthcare organizations in order to represent the latest state of the art in the existing literature and apply the methodology to the orthopaedic field of the Italian National Health Service to increase the cost-effectiveness of the delivery process of health care. The following are the key findings:

- TDABC is increasingly being used in the orthopaedic field, notably in the last five years, and its applications are mostly joint replacement area.
- Applying process maps in a hospital system is difficult to achieve. Maps should be carefully applied to high-volume low-variability service lines to identify areas for improvement.
- Total hip and knee replacements are highly standardized procedures that guarantee excellent clinical results. Comparing three different administrations (public, academic and private hospital) the patient pathway differs only in pre- and post-operative activities.
- TDABC is a useful tool for clinicians and administrators to view transparent cost analyzes and redesign processes to reduce costs and deliver care with similar (or improved) outcomes
- Implant device and hospitalization appear to be the major cost drivers.

These findings seem particularly suitable for practitioners because they allow users to design an efficient surgical procedure. Particularly, the study shows a practical example of a useful process map that formalizes all the activities and resources required in providing surgery. Moreover, process mapping and time detection provide healthcare managers with a comparison between the planned performance and the actual one, according to their own business structure.

Furthermore, the findings show that the main operating differences in THA and TKA processes are not attributable to hospital ownership (private and public hospitals behave in the same way), but to the feature of being a teaching or non-teaching hospital. University hospitals, due to their institutional function, result in higher charges both for time and resource consumption in comparison with general hospitals.

It would be a good management choice for any facility to have a team to optimize patient flow, improve efficiency, and reallocate activities to ensure all team members are working to their peak training. Process mapping can help identify opportunities for cost containment through care redesign.

It is therefore imperative that orthopaedic surgeons also accurately estimate the costs of their services and realize how their care preferences (e.g. choice of implant, ideal length of stay, postoperative routine) affect the overall margin of healthcare expenditure.

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