Review

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Evaluation of reporting in time-driven activity-based costing studies on cardiovascular diseases: a scoping review

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Aim: This scoping review evaluates the application of the time-driven activity-based costing (TDABC) methodology in cardiovascular disease (CVD) studies. **Materials & methods:** The evaluation was conducted using the 32-item TDABC Healthcare Consortium Consensus Statement Checklist. A systematic search was performed in Medline, Embase and Scopus in September 2023, including only full-text, peer-reviewed studies reporting the application of TDABC in CVD research. **Results:** Twenty studies were included in the review. The positive response rate for individual studies ranged from 31 to 81%. The most frequently addressed checklist item was the clear definition of study objectives, while presenting costs per patient included in the analysis was the least reported item. Although 70% of the studies achieved a positive response rate above 50%, adherence to the TDABC checklist remains inconsistent. **Conclusion:** There is significant room for improvement in the reporting of TDABC methodology in CVD studies. Providing a more comprehensive and standardized description of the methodology would enhance the utility, reproducibility and accuracy of the information generated, supporting the development of evidence-based health policies and improving accountability in healthcare cost assessments.

Shareable abstract: This scoping review explores the reporting of cost assessment studies in cardiovascular disease using the time-driven activity-based costing Healthcare Consortium Consensus Statement Checklist.

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Healthcare expenditure and affordability are critical concerns for health systems worldwide [1–3]. In the USA, the sector spending is expected to increase two to fourfold by 2050 [4,5]. Demographic and epidemiologic shifts characterized by aging populations, have made noncommunicable diseases led by cardiovascular diseases (CVD) – the leading cause of mortality and a major driver of disability and costs globally [4,6,7]. CVD accounts for 51% of the noncommunicable diseases costs and approximately 4% of the gross domestic product in low- and middle-income countries, with comparable budgetary impacts projected for high-income countries [4,8–10].

In this context, accurately measuring costs for health technologies during the incorporation process and throughout the care cycle is crucial [1,2,11,12]. Time-driven activity-based costing (TDABC) is a microcosting assessment method that enhances data accuracy by accounting for direct and indirect costs based on patient-specific resource use throughout the care pathway. The TDABC framework evaluates the length of time and the volume of each resource required to perform a specific activity along the care pathway, and estimates the cost per activity and resource consumed. By achieving this level of cost information granularity, TDABC methodology enhances the accuracy of

cost information and enables managers to quantify costs, assess resource utilization and identify opportunities to reduce waste and increase value in healthcare [13,14].

To support the development and reporting of studies using TDABC, while maximizing the utility of the methodology and ensuring transparency, the TDABC in Healthcare Consortium proposed a standardized framework in 2020. This framework was presented as a checklist comprising 32 questions, addressing how researchers measure time variables, account for resources in the care pathway and calculate cost estimates. TDABC in Healthcare Consortium Consensus Statement Checklist was developed based on prior literature regarding microcosting studies, a focus group process to create the preliminary checklist, and validation with researchers from multiple countries with expertise in costing studies and TDABC. The checklist elements are categorized as 'Mandatory' and 'Strongly suggested, but not mandatory', with guidance on the appropriate paper sections for including each element [15].

As the body of literature on TDABC has grown in recent years, including studies focused on CVD [16], a critical assessment of these studies is necessary to examine variations in the implementation and reporting of TDABC methodologies and to identify common limitations. This scoping review aimed to systematically identify CVD studies utilizing TDABC to evaluate healthcare costs and assess the credibility of its application by using the TDABC Checklist.

Materials & methods

The scoping review was conducted following the Joanna Briggs Institute methodology [17]. The reporting of the methodology was structured in compliance with The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews (Supplementary Table 1). The research question was: "*How are studies on CVD using the TDABC methodology for cost analysis being reported?*". A previous protocol of this scoping review was not registered.

Eligibility criteria

Only full-text peer-reviewed studies reporting the application of TDABC on CVD (considering any intervention and process of care related to CVD) were considered eligible. Conference abstracts, reviews, opinions and letters were excluded. There was no limit regarding the date when the study was published nor restriction regarding the language for study selection.

Search strategy

Searches were performed on the following electronic databases: Medline (via PubMed), Embase and Scopus, for registers available until 4 September 2023. The search strategy included terms for TDABC and the cardiology field, using controlled vocabulary and free terms, adapted for each database. The full search strategy is available at Supplementary Table 2.

Study selection & data extraction

All registers identified in the searches were pooled in a reference manager software (EndNote 20) and duplicate records were removed [18]. The remaining records were exported and included on Rayyan, a web-based software for systematic reviews management, where the selection of titles and abstracts was performed [19]. Full-text records of potentially eligible and uncertain studies identified in this stage were retrieved for the final assessment. All the selection process was performed by two reviewers and doubts about the eligibility of studies were discussed with a third reviewer.

For the included studies, a data extraction formulary was applied by one reviewer to retrieve information about the characterization of each study, the intervention/process being assessed, and the patients included.

Assessment of reporting & analysis

We evaluated the alignment of each study with the 32 questions from the TDABC in Healthcare Consortium Consensus Statement Checklist [15]. This evaluation was conducted by one researcher and independently verified by a second reviewer. Each question was categorized as 'Yes', 'No', 'Not applicable (NA)', or 'Not informed (NI)' (Supplementary Table 3). In cases of disagreement, a third reviewer was consulted to reach a consensus.

The positive response rate was calculated for each study (the number of questions marked as 'Yes' divided by the total number of questions) and for each question (the number of studies with a 'Yes' response divided by the total

number of included studies). Additionally, the median positive response rate and interquartile range (IQR) were estimated for both metrics.

Results

A total of 129 studies were identified through electronic searches. After removing duplicates, 81 studies were screened, and 47 were retrieved for full-text assessment. Following the selection process, 20 studies described across 21 publications were included in this review [20–40]. The detailed selection process is illustrated in Figure 1.

The characteristics of the included studies and their positive response rates are summarized in Table 1. The studies were published between 2014 and 2023 and were conducted across eight countries: the USA, India, Brazil, Germany, Uganda, Italy, France and Sweden. Most studies (n = 12) were conducted entirely or partially in the USA. Sample sizes ranged from 1 to 5526 patients, with four studies not reporting sample sizes. The conditions assessed included examinations, pharmacological treatments, telehealth services and surgical interventions for various cardiovascular conditions. The TDABC methodology was most frequently applied in hospital settings (75% of the studies) to evaluate the costs of clinical management (n = 9), surgery (n = 4) or interventional procedures (n = 4).

The positive response rate for each study ranged from 31 to 81%, with a median rate of 63% (IQR: 40–70%). Most studies (70%) have a positive rate greater than 50%. The positive rates for both mandatory and nonmandatory questions were similar across all manuscripts (Table 1). The median positive response rate per question was 65% (IQR: 34–80%) (Table 2), with the detailed response rate of each question presented in Table 2. Among the mandatory questions, the positive response rate among the included studies ranged from 5% (question 7.2) to 95% (question 3.2). For the nonmandatory questions, the positive response rate varied from 15% (question 7.6) to 100% (question 1.1).

The three most addressed items (answered 'Yes') in the analyzed articles were the definition of study objectives (question 1.1), justification for using the TDABC methodology (question 1.4) and the definition of included resources (question 3.2). Conversely, the three least addressed items (answered 'No') were presenting costs per patient included (question 7.2), presenting mean costs per activity at a micro level (question 7.4) and accounting for capacity idleness (question 7.6).

Questions with the highest rates of missing information (answered 'NI') were related to using a multidisciplinary team to apply TDABC (question 2.2) and interviewing professionals to better identify resources used in each activity (question 3.4). Regarding how authors collected time variables, 20% of studies did not explain their methods for collecting time data (question 6.1), 25% explicitly reported using interviews with professionals or medical record reviews to assess time data (question 6.2) and only 15% described how the sample size was determined for observing time directly (question 6.3). In terms of cost reporting, 30% of studies did not present or calculate costs at the individual or per-technology level (question 7.1), and 80% did not calculate or report costs at a micro level (question 7.4).

None of the ten studies published after the release of the TDABC checklist referenced its use in either the development or reporting of their methodology. However, nearly all studies (13/14) with a positive response rate exceeding 50% were published after 2020.

Discussion

In this scoping review, we identified 20 studies that employed the TDABC methodology to evaluate costs within the cardiovascular field. These studies were published over the last decade, aligning with the growing body of literature on TDABC in healthcare, which began approximately 15 years ago and has gained momentum in recent years [16]. Most of these studies were published in the same year as, or after, the release of the TDABC in Healthcare Consortium Consensus Statement Checklist at the end of 2020 [15]. However, among the 20 studies reviewed, the checklist was not widely utilized to guide the application or reporting of the methodology.

Applying the checklist to evaluate the implementation of TDABC in CVD studies revealed significant variation in how the methodology is described. While researchers emphasized the importance of selecting TDABC as a microcosting technique, nearly half of the checklist items were not addressed in the reviewed publications. Notably, 20% of studies failed to provide clear explanations about how time variables were collected, highlighting a gap in methodological transparency. Our review also demonstrates that the full potential of the TDABC methodology is not being realized. In many cases, costs were not reported at an individual level – whether per patient, activity or resource – thereby limiting the depth of insights that TDABC could provide.

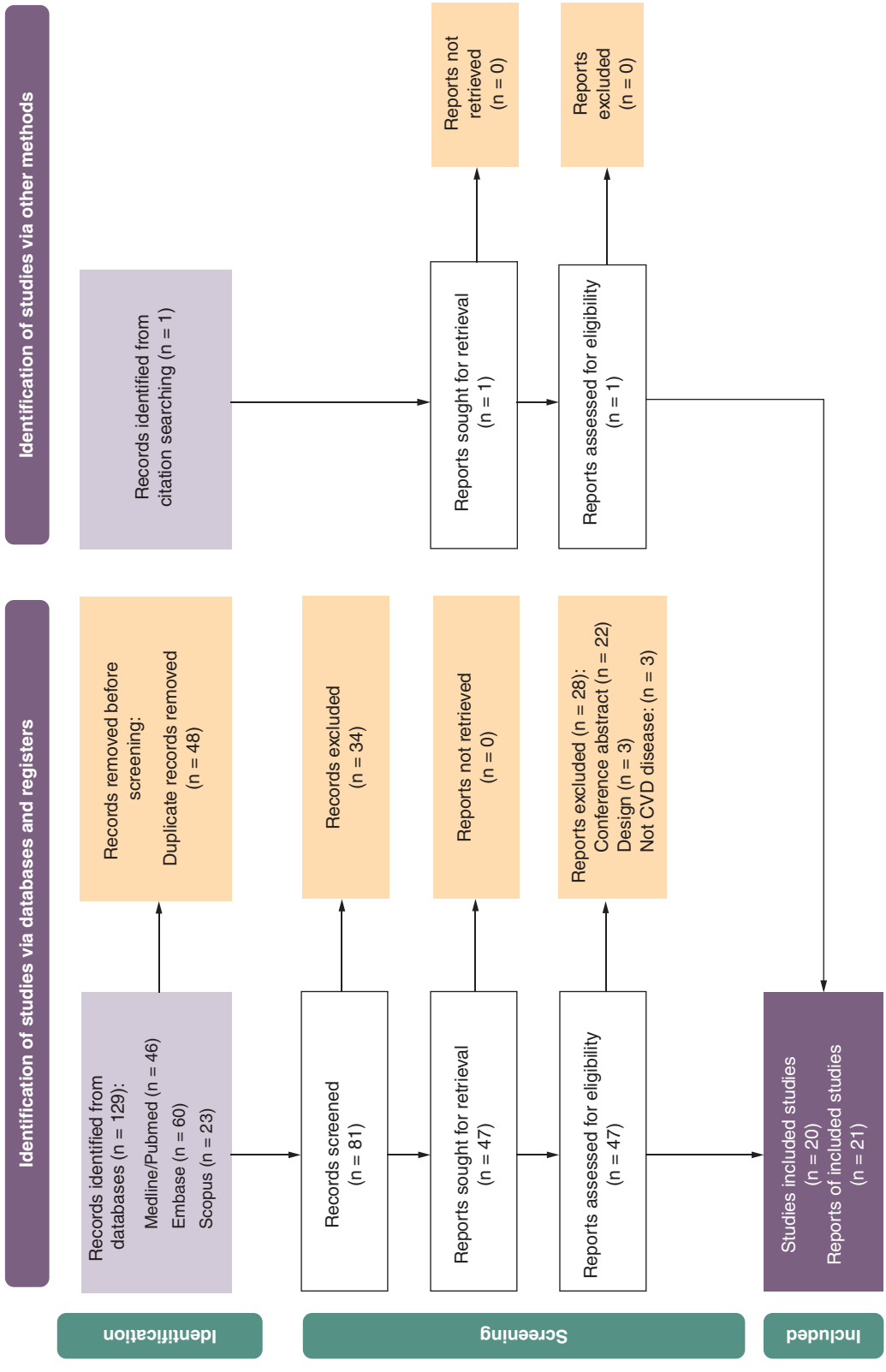

Figure 1. Study selection process.

Table 1. Characteristics of the included studies.

Study	Publication year	Title	Country	Object of assessment	Type of healthcare	Setting	Sample size	Positive response rate All questions (mandatory questions)	Ref.
Donavan *et al.*	2014	How Cleveland clinic used TDABC to improve value	USA	Mitral valve repair, aortic valve replacement	Surgery	Hospital	NI	41% (41%)	[20]
Tabit *et al.*	2017	Cardiology consultation in the Emergency Department reduces re-hospitalizations for low-socioeconomic patients with acute decompensated heart failure	USA	Guideline-directed education and intensive outpatient follow-up and early consultation with cardiologist in the Emergency Department for low-socioeconomic urban patients with acute decompensated heart failure	Clinical management	Ambulatory	784	31% (27%)	[21]†
Chong-Yik *et al.*	2018	Cost-saving opportunities with appropriate utilization of cardiac telemetry	USA	Cardiac telemetry	Diagnosis	Hospital	250	38% (36%)	[22]
Goldraich *et al.*	2018	Heart transplantation cost composition in Brazil: a patient level microcosting analysis and comparison with international data	Brazil	Adult patients undergoing heart transplantation	Surgery	Hospital	27	38% (45%)	[23]
Martin *et al.*	2018	Using time-driven activity-based costing as a key component of the value platform: a pilot analysis of colonoscopy, aortic valve replacement and carpal tunnel release procedures	USA	Surgical vs. transcatheter approach for aortic valve replacement (anesthesiologist perspective)	Surgery	Hospital	NI	63% (68%)	[24]
Bobade *et al.*	2019	Time-driven activity-based cost analysis for outpatient anticoagulation therapy: direct costs in a primary care setting with optimal performance	USA	Anticoagulation therapy for warfarin compared with novel oral anticoagulants	Clinical management	Ambulatory	5526	34% (27%)	[25]
Collins *et al.*	2020	Subarachnoid hemorrhage 'fast track': a health economics and healthcare redesign approach for early selected hospital discharge	USA	Earlier discharge (i.e., fast track) in selected patients with subarachnoid hemorrhage compared with other patients with subarachnoid hemorrhage	Clinical management	Hospital	200	69% (82%)	[26]
Erhun *et al.*	2020	Are cost advantages from a modern Indian hospital transferable to the USA?	USA/India	First, nonurgent, isolated and multivessel coronary artery bypass graft surgeries	Surgery	Hospital	NI	72% (73%)	[27,28]‡
Ho *et al.*	2020	Cardiovascular 3D printing: value-added assessment using time-driven activity-based costing	USA	Cardiovascular 3D printing workflow	Material		1	66% (68%)	[29]
Keel *et al.*	2020	Time-driven activity-based costing for patients with multiple chronic conditions: a mixed-method study to cost care in a multidisciplinary and integrated care delivery center at a university-affiliated tertiary teaching hospital in Stockholm, Sweden	Sweden	Outpatient clinical care processes for patients with at least three chronic conditions: established diabetes, cardiovascular disease and kidney disease	Clinical management	Ambulatory	314	78% (86%)	[30]
DeWyer *et al.*	2021	Establishment of a cardiac telehealth program to support cardiovascular diagnosis and care in a remote, resource-poor setting in Uganda	Uganda	Cardiac telehealth program	Clinical management	Ambulatory	1324	63% (64%)	[31]

†Study included by cross-evaluation of conference abstract by the same authors.
‡Included the published study protocol to complement assessment.
CT: Computed tomography; NI: Not informed; TDABC: Time-driven activity-based costing.

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Table 1. Characteristics of the included studies (cont.).

Study	Publication year	Title	Country	Object of assessment	Type of healthcare	Setting	Sample size	Positive response rate All questions (mandatory questions)	Ref.
Etges *et al.*	2021	Time-driven activity-based costing as a strategy to increase efficiency: an analyses of interventional coronary procedures	Brazil	Elective interventional coronary procedures	Interventional procedure	Hospital	90	66% (73%)	[32]
Masthoff *et al.*	2021	Value improvement by assessing IR care via time-driven activity-based costing	Germany	Interventional radiology for image-guided vascular malformation treatment	Interventional procedure	Hospital	78	63% (77%)	[33]
Zimmerman *et al.*	2021	The direct costs of coronary CT angiography relative to contrast-enhanced thoracic CT: time-driven activity-based costing	USA	Coronary CT angiography and contrast-enhanced thoracic CT as a diagnostic test for assessing coronary artery disease.	Diagnosis	Ambulatory	54	56% (64%)	[34]
Kumar *et al.*	2022	Cost analysis of treating cardiovascular diseases in a superspecialty hospital	India	Cardiovascular diseases such as coronary artery disease, rheumatic heart disease, cardiomyopathy, congenital heart diseases and cardiac arrhythmias, etc.	Clinical management	Hospital	100	31% (32%)	[35]
Etges *et al.*	2022	Moving the Brazilian ischemic stroke pathway to a value-based care: introduction of a risk-adjusted cost estimate model for stroke treatment	Brazil	Ischemic stroke	Clinical management	Hospital	822	75% (77%)	[36]
Morrow *et al.*	2023	Determining the marginal cost differences of a telehealth versus an in-person occupational therapy evaluation session for stroke survivors Using time-driven activity-based costing	USA	Stroke rehabilitation	Clinical management	Hospital	19	72% (73%)	[37]
Nurok *et al.*	2022	It is Not just the prices: time-driven activity-based costing for initiation of veno-venous extracorporeal membrane oxygenation at Three international sites—a case review	USA/France/Australia	Veno-venous extracorporeal membrane oxygenation	Interventional procedure	Hospital	NI	56% (55%)	[38]
Wei *et al.*	2022	Cost of cardiac stereotactic body radioablation therapy vs catheter ablation for treatment of ventricular tachycardia	USA	Ventricular tachycardia	Interventional procedure	Hospital	69	81% (82%)	[39]
Rognoni *et al.*	2023	Time-driven activity-based costing for capturing the complexity of healthcare processes: the case of deep vein thrombosis and leg ulcers	Italy	Venous ulcer management	Clinical management	Hospital	88	63% (64%)	[40]

†Study included by cross-evaluation of conference abstract by the same authors.
‡Included the published study protocol to complement assessment.
CT: Computed tomography; NI: Not informed; TDABC: Time-driven activity-based costing.

Table 2. Proportion of items of the time-driven activity-based costing checklist in the 20 studies included.

TDABC elements	Yes (%)	No (%)	NI (%)	NA (%)
1.1 It is defined if the results are being explored for general health service management or redesign and value or only to assess costs?	100.00%	0.00%	0.00%	0.00%
1.2 Is the clinical pathway, technology or procedure studied justified because of an interest from government, hospital, society or a health technology assessment analysis?	85.00%	15.00%	0.00%	0.00%
1.3 Are study limitations being presented?	85.00%	15.00%	0.00%	0.00%
1.4 Is the TDABC method selection being justified?	90.00%	10.00%	0.00%	0.00%
2.1 Are authors using specific methodologies to design the care pathway?	75.00%	25.00%	0.00%	0.00%
2.2 Are authors using a multidisciplinary team to apply the TDABC? (design the process, correctly consider clinical characteristics, correctly evaluate costs)	80.00%	0.00%	20.00%	0.00%
2.3 Are authors reporting activities in the process map on a macro level?	85.00%	15.00%	0.00%	0.00%
2.4 Are authors reporting activities in the process map on a micro level?	30.00%	0.00%	0.00%	0.00%
2.5 Is the full process map (or a part of) being presented in a picture or graphic display?	80.00%	20.00%	0.00%	0.00%
3.1 Is a table or a map being presented to illustrate the association between activities and resources?	70.00%	30.00%	0.00%	0.00%
3.2 Are the resources that are included in the analysis being defined and justified?	95.00%	5.00%	0.00%	0.00%
3.3 Are authors reporting observation *in situ* approach to better identify resources used in each activity?	55.00%	45.00%	0.00%	0.00%
3.4 Are the authors interviewing the professionals to better identify resources used in each activity?	70.00%	10.00%	20.00%	0.00%
4.1 When using hospital financial database, it is being stated how those data were collected and analyzed?	65.00%	25.00%	0.00%	10.00%
4.2 Are authors defining the currency and applying discount taxes when it is necessary?	60.00%	40.00%	0.00%	0.00%
4.3 When using external financial databases, is there a description of the database and how those data were accessed?	25.00%	15.00%	0.00%	60.00%
4.4 When mixed financial databases are being used (for example, salaries from external reference and structural costs from the hospital) is the origin of each data variable being stated?	40.00%	15.00%	0.00%	45.00%
4.5 Did the authors explaining how the overhead costs are being considered?	70.00%	30.00%	0.00%	0.00%
5.1 Are authors defining if the capacity data used represents the total capacity per resource or it is being considered an expected idleness?	60.00%	40.00%	0.00%	0.00%
5.2 When authors are considering an expected idleness, it is explained how actual performance data were collected and analyzed?	40.00%	15.00%	0.00%	45.00%
6.1 Are authors explaining how time data were collected?	80.00%	20.00%	0.00%	0.00%
6.2 Are authors using interviews with professionals crossed with medical record review to estimate time data?	25.00%	50.00%	0.00%	25.00%
6.3 When using chronanalysis, it is being explained how the sample of data was defined?	15.00%	30.00%	0.00%	55.00%
6.4 Is it being explained if the chronanalysis used a digital technology to collect real time data, such as mobile app, wearable, drone, etc.?	20.00%	20.00%	0.00%	60.00%
7.1 Is the median or average cost per patient (or per technology) being calculated?	70.00%	30.00%	0.00%	0.00%
7.2 Are authors presenting the cost per each patient included in the sample? (chart bar, table, etc.)?	5.00%	95.00%	0.00%	0.00%
7.3 Is the median or average cost per activity on a macro level being presented?	65.00%	35.00%	0.00%	0.00%
7.4 Is the median or average cost per activity on a micro level being presented?	20.00%	80.00%	0.00%	0.00%
7.5 Is the median or average cost per resource being presented?	60.00%	40.00%	0.00%	0.00%
7.6 Are authors performing capacity idleness analysis?	15.00%	85.00%	0.00%	0.00%
7.7 Are authors exploring statistical analyses to better understand costs along the process of care?	35.00%	65.00%	0.00%	0.00%
7.8 If the objective was to use the study to support management and value decisions, are authors reporting how value increasing was achieved or if they are planning to achieve it?	75.00%	0.00%	0.00%	25.00%

Questions marked in bold are considered mandatory.
NA: Not applicable; NI: Not informed; TDABC: Time-driven activity-based costing.

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TDABC offers significant advantages in accurately measuring costs and has the potential to facilitate care redesign and value improvement by detailing costs throughout the care pathway [14,41]. However, several challenges in the microcosting application, particularly in collecting granular data, continue to hinder its full potential in the CVD field. For example, time variables, a critical component of TDABC, can be captured using various methods such as interviews with healthcare professionals, reviewing departmental entry and exit records, or direct observation, often involving digital technology. Despite these options, only a quarter of the reviewed studies reported employing at least one of these methods, while 20% of studies did not disclose how time data were collected. Moreover, most studies were conducted with small, single-center cohorts, likely reflecting both a focus on specific services or health systems and the logistical challenges of collecting time data in multicenter TDABC applications.

This review aligns with previous studies emphasizing the need for consistent application of the TDABC methodology to enable value-based healthcare delivery. However, many studies lack transparency regarding TDABC implementation and their sources for cost estimates [16,42,43]. Standardized tools and guidelines, such as the TDABC checklist, are important for improving the methodological rigor and reporting quality in health economics research [44–46]. The checklist used in this review serves as a valuable tool for enhancing the application, reporting and reproducibility of the TDABC methodology. Widespread adoption of this checklist in TDABC studies could improve clarity and transparency, enhance the accuracy of cost calculations and increase the utility of data for redesigning care and assessing value. A thorough description of the methodology would also facilitate reproducibility, better interpretation and comparison across studies [15].

This study has some limitations. Although the reporting quality assessment was conducted by one reviewer and cross-checked by another, having two independent reviewers would have strengthened the reliability of the evaluation. Furthermore, while the TDABC checklist is a useful instrument for standardizing cost measurement and reporting, other approaches may yield different results. Through this scoping review, we found that most TDABC studies in the CVD field provide limited reporting on methodology and results, as assessed using the TDABC Consortium Checklist. This lack of comprehensiveness in describing TDABC applications reduces the utility of the results generated by the method.

Overall, this review highlights significant gaps in the application and reporting of TDABC in cardiovascular studies. The inconsistent use of the methodology limits data utility, reproducibility and the broader adoption of TDABC as a tool for cost assessment and value improvement in healthcare.

Summary points

- In 2020, the time-driven activity-based costing (TDABC) Consortium introduced a standardized framework to support the development and reporting of studies utilizing TDABC in healthcare.
- This scoping review aimed to identify studies in the cardiovascular field that applied TDABC and evaluate these studies using the TDABC Checklist.
- A total of 20 studies published between 2014 and 2023 were included in this review.
- TDABC methodology was most frequently applied in hospital settings (75% of the studies) to assess the costs of clinical management, surgeries or interventional procedures.
- The positive response rate for individual studies ranged from 31 to 81%, with a median rate of 63% (interquartile range: 40–70%).
- The three most commonly addressed checklist items (answered 'Yes') were: defining study objectives (question 1.1), providing justification for using the TDABC methodology (question 1.4) and defining the included resources (question 3.2).
- The three least frequently addressed items (answered 'No') were: presenting costs per patient included in the analysis (question 7.2), presenting mean costs per activity at a microlevel (question 7.4) and accounting for capacity idleness (question 7.6).
- Through this scoping review, we found that most TDABC studies in the cardiovascular disease field provide limited reporting on methodology and results. This lack of comprehensiveness in describing TDABC applications reduces the utility of the results generated by the method.

Supplementary data

To view the supplementary data that accompany this paper please visit the journal website at: https://bpl-prod.literatumonline.com/doi/10.57264/cer-2024-0013

Author contributions

NB Schneider, EC Roos and MAZ Marcolino were responsible for study conception, data collection, analysis and manuscript writing. F Caldana, FRV do Nascimento and S Decker were responsible for data collection and manuscript writing. APB da Silva Etges and CA Polanczyk were responsible for writing and revision of the manuscript.

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Competing interests disclosure

The authors have no financial and/or nonfinancial competing interests or relevant affiliations with any organization/entity to declare that are relevant to the subject matter or materials discussed in this manuscript. This includes employment, grants or research funding, consultancies, membership on scientific or other advisory boards, honoraria, stock ownership or options, paid expert testimony, patents received or pending, or royalties.

Writing disclosure

No funded writing assistance was utilized in the production of this manuscript. The authors declare that they used ChatGPT (Version 4) in the creation of this manuscript, to improve language and readability. The authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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