Heart Surgery Forum 2025; 28(1): E001-E009
doi: 10.59958/hsf.8229

Article

Time-Driven Activity-Based Costing Analysis of Coronary Flow Velocity Reserve Assessment with Regadenoson Stress Echocardiography

Heming Zheng[1,†], Lijuan Zhang[2,†], Ran Cao[3], Xiaozhi Zheng[4,*]

[1]Wenzhou-Kean University, 325060 Wenzhou, Zhejiang, China
[2]Department of Ultrasound, The Fourth Affiliated Hospital of Nanjing Medical University, 210031 Nanjing, Jiangsu, China
[3]Department of Ultrasound, Fuding Hospital Fujian Province/Fuding Hospital Affiliated to Fujian University of Traditional Chinese Medicine, 355200 Fuding, Fujian, China
[4]Department of Ultrasound, Yangpu Hospital, School of Medicine, Tongji University, 200090 Shanghai, China
*Correspondence: zxzfxxc@126.com (Xiaozhi Zheng)
†These authors contributed equally.

Submitted: 18 November 2024 Revised: 10 December 2024 Accepted: 18 December 2024 Published: 13 January 2025

Abstract

Objective: Accurate measurement of healthcare costs is required to assess and improve the value of Regadenoson stress echocardiography (RSE). The purpose of this study was to determine the costs associated with Regadenoson stress echocardiography. **Methods**: Time-Driven Activity-Based Costing (TDABC) was used to calculate the non-directly traceable cost of RSE. Data were collected between January 2021 and December 2023. TDABC steps involved (1) constructing process maps for the RSE pathway; (2) determining capacity cost rates for staff, medical equipment, space, water and electricity; (3) measuring the time required for each process through direct observation and participation and (4) calculating the total non-directly traceable cost of RSE. Finally, the total costs of RSE were obtained by summing up the direct retroactive cost and non-directly traceable cost. **Results**: Total costs of RSE were 1306.18 Chinese Yuan ($181.60), of which Regadenoson, human resources and equipment accounted for 61.09%, 19.96% and 13.17%, respectively. **Conclusion**: Regadenoson expense was the greatest contributor to the costs of RSE, followed by labor cost. Understanding the actual costs and cost drivers of RSE may better inform resource utilization to lower the cost and improve the quality of RSE.

Keywords

cost; Regadenoson; stress echocardiography; Time-Driven Activity-Based Costing

Introduction

Coronary flow velocity reserve (CFVR), defined as the ratio between maximal (stimulated) coronary blood flow, induced by using a coronary vasodilator, and baseline (resting) blood flow [1–4], has been used as a diagnostic and prognostic tool in various clinical situations, such as the diagnosis of functionally significant coronary stenosis, evaluation of patients with intermediate coronary stenosis, follow-up after percutaneous coronary intervention, evaluation of coronary microcirculation in the setting of hypertension, diabetes and other conditions, risk stratification in patients with dilated cardiomyopathy, after heart transplantation and other diseases and assessment of the effectiveness of certain therapeutic intervention. It reflects global coronary atherosclerotic burden, endothelial function and state of the microvasculature [1]. CFVR measured by vasodilator stress echocardiography has been validated against myocardial blood flow reserve measured by positron emission tomography and invasively using a Doppler wire and has shown excellent reproducibility and reliability [2–4].

Regadenoson, a kind of vasodilator, selectively activates A2a receptors, which can be given as a single bolus, weight-unadjusted dose, unlike the weight-adjusted infusion dose of Adenosine and Dipyridamole [5–8]. Moreover, it has less undesirable side effects including atrioventricular block and bronchospasm than Adenosine. This ease of administration and the reproducible, comparable efficacy to Adenosine with fewer side effects made Regadenoson the most widely used pharmacological agent for stress testing in the United States since its approval by the Food and Drug Administration (FDA) in 2008 [9]. However, Regadenoson stress echocardiography (RSE) has not been widely used in China and its cost has not been studied.

Time-Driven Activity-Based Costing (TDABC), an approach proposed by Porter and Kaplan [10–12], is a cost-sharing method using time as a cost generator, which has been commonly used in the healthcare field in recent years [13–21]. It has been found that this cost system improves resource allocation and provides more accurate cost information in complex environments with resources focusing on skills and implicit knowledge such as health care services [22,23]. Therefore, some authors believe that TDABC is the most practical approach for measuring value in this field [24].

In the present study, we sought to estimate resource consumption and the total costs of the RSE service for a patient from a hospital perspective in China using the TDABC calculation method.

Methods

Our study was reviewed and granted exempt status by the institutional review board (Ethics Committee of Yangpu Hospital, School of Medicine, Tongji University). The total costs of RSE were divided into direct retroactive costs apportioned according to the number of cases, and non-directly traceable costs based on time. We used TDABC to calculate the non-directly traceable costs of RSE. The steps were as follows.

Construction of Process Map for RSE

The process map for RSE was constructed through direct observation and participation in the clinical setting. RSE mainly had three job centers, which were reception, examination and report production. They were divided into 8 sub-jobs: triage, pre-examination prepa-

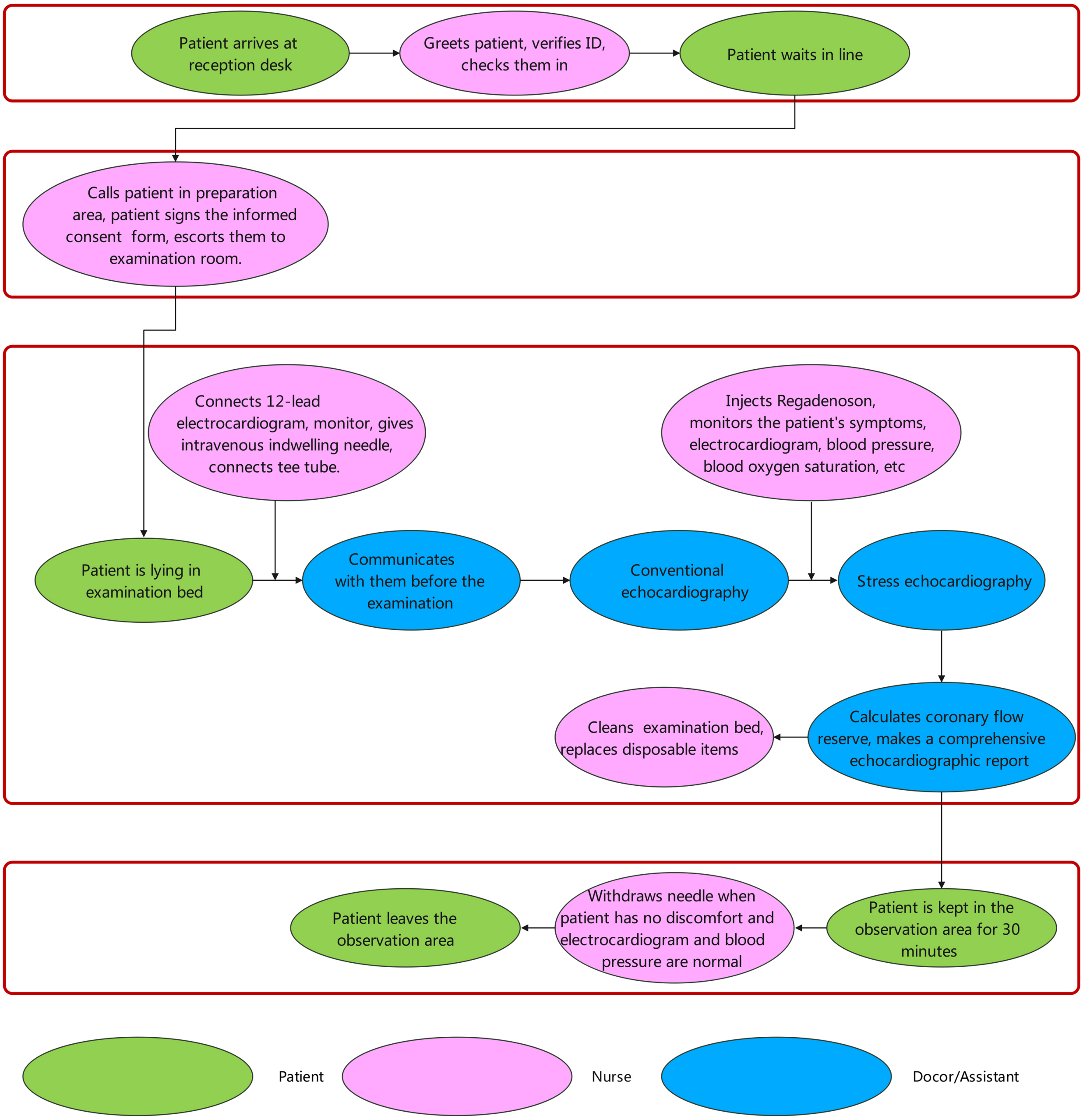

Fig. 1. The process map of Regadenoson stress echocardiography.

ration, conventional echocardiography, Regadenoson injection, stress echocardiography, report production, post-examination monitoring and examination room reset, which were interspersed with the connection links in which the patients were waiting alone. The process map of RSE was seen in Fig. 1. There was a slight difference in different hospitals. The operators included doctors, assistants and nurses. Conventional echocardiography included measurement of cardiac size, function, and hemodynamics, observation of segmental wall motion abnormalities, scanning of coronary arteries, and storage of blood flow spectrum at the distal end of the left anterior descending coronary artery. Stress echocardiography included the storage of the blood flow spectrum at the distal end of the left anterior descending coronary artery within 0–2 minutes, 2–4 minutes and 4–6 minutes after Regadenoson injection, respectively (Fig. 2), and observation of the 17 wall motion segments of the left ventricle.

Determination of Practical Capacity Cost Rates

Between January 2021 and December 2023, cost information was collected from the Cost Accounting Office of three tertiary hospitals in East China with more experience using RSE. The cost information of adverse event management and equipment were also collected from the Doctor-Patient Communication Office and Equipment Section. The categories and numbers of participants in each step of the examination, as well as the working time were recorded in detail. From the provider's perspective, we took into account the actual costs incurred during RSE according to the requirements of full-cost accounting of medical institutions. They could be divided into direct retroactive cost apportioned according to the number of cases, such as vasodilator (Regadenoson), sanitary materials, and non-directly traceable cost based on time, such as equipment depreciation, equipment maintenance, labor cost, and sanitary materials cost. Administrative costs were not taken into consideration as their proportions were small and were not easy to collect. In addition, due to the great differences between regions, only house construction costs were included in the calculation of house depreciation costs, while land purchase costs were ignored.

RSE was completed by the cooperation of doctors, nurses and assistants. Assistants are usually standardized training residents, whose salaries are comparable to that of junior doctors. The total cost for a person was equal to the sum of salaries, benefits costs, and overhead costs. Equipment cost was calculated by summing equipment depreciation and annual maintenance costs. Equipment depreciation cost for the current year was calculated by the straight-line depreciation method (assuming the depreciation life was 30 years). Space costs were based on type and size of rooms and were defined by the institution. House depreciation cost for the current year was calculated by the straight-line depreciation method (assuming the depreciation life was 30 years). Water and electricity costs were allocated by the institution. The cost of Regadenoson, sanitary materials, other consumables and adverse event management were directly obtained from the Cost Accounting Office in each institution.

For personnel capacity, the number of days a person was available in a year was calculated along with the number of available minutes/day. Vacation, weekends, holidays, and time away was typically deducted from the total number of days in a year to give the number of days a person was available to work. The number of minutes a person was available to work in a day was calculated by subtracting

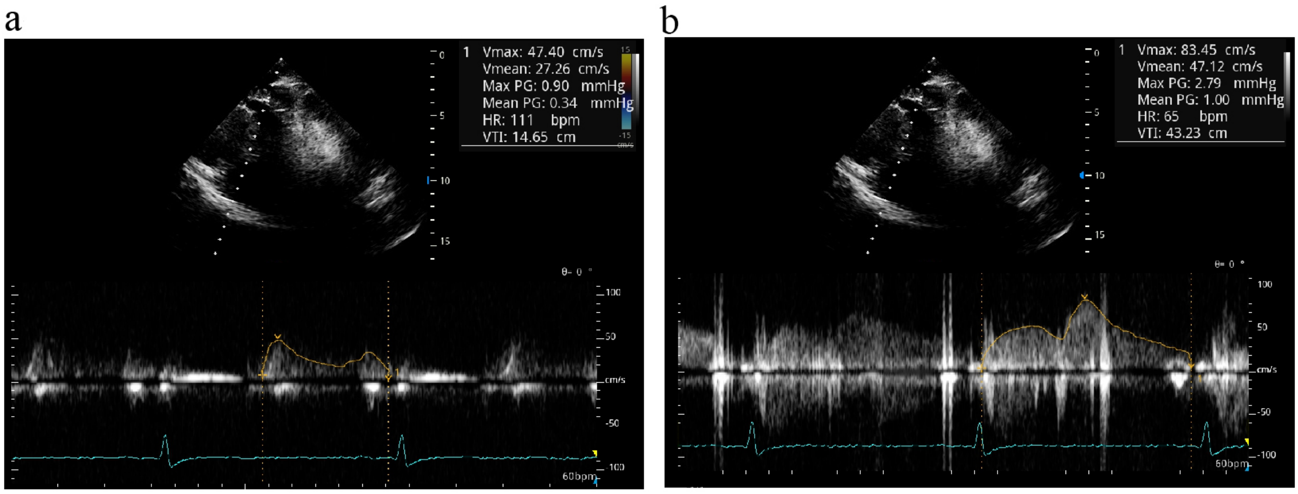

Fig. 2. Deceased CFVR was observed in a patient with angiographically proved coronary heart disease. (a) In the resting state; (b) Regadenoson loading state (3 minutes after intravenous injection of 0.4 mg Regadenoson). Based on the maximum or mean flow velocity at the distal end of the left anterior descending coronary artery, CFVR is calculated as follows: CFVR = 83.45/47.40 = 1.76, or CFVR = 47.12/27.26 = 1.73. CFVR, coronary flow velocity reserve.

lunch hour, lecture time, and meeting times from the number of hours that person was at work per day. The number of minutes available per day was then multiplied by the number of days a person was available to work to get the total number of minutes a person can work per year. The capacity cost rate (cost/minute) was then calculated by dividing the total cost for a person by the previously calculated total number of minutes a person was available to work in a year. Similar to personnel; equipment, space and water and electricity capacity rate (cost/minute) were calculated by dividing their cost by the total number of minutes they were available in a year.

Measurement of the Time Required for Each Process Step

The time required for each process step, i.e., consumption time, was the time needed to perform each activity of a RSE cycle, which was defined as the number of minutes a doctor, nurse or assistant spent in each step to perform a RSE pathway. In our study, consumption time was measured both manually through clinic observation and using data from the real-time location system. The doctor participated in the examination of the patient throughout the process, and the assistant followed the doctor all the way, taking the same time as the doctor. In addition to triage, nurses were also involved in preparation before examination, Regadenoson injection and post-examination monitoring. The consumption time of the equipment was the sum of steps from the beginning of the preparation before the examination by the doctor to the end of the production of the report. The consumption time of house depreciation cost and water and electricity sharing cost was the total time of a RSE cycle.

Calculatation of Untraceable Unit Cost of RSE

Untraceable unit cost of RSE were the product of practical capacity cost rate (cost/minute) of personnel, equipment, space and water and electricity in a RSE cycle and their respective number of minutes the patient spends in each step according to the TDABC cost calculation method.

Calculatation of Total Costs of RSE

The total costs of RSE were obtained by summing up the cost of various resources, including direct retroactive cost and non-direct traceable costs.

Results

Cost and its Composition

The average costs and its composition related to RSE between January 2021 and December 2023 were listed in Table 1.

Practical Capacity Cost Rate

Between January 2021 and December 2023, the number of theoretical working days for a person per year was 249.67 days, and 8 hours per day. It is generally believed that the practical working hours were 85% of the theoretical working hours. The theoretical working days for a piece of equipment were 268.92 days and 8.50 hours per day, and the practical working hours were 90% of the theoretical working hours. The capacity cost rate of personnel, equipment, space and water and electricity are shown in Table 2.

Table 1. Cost and its composition related to RSE.

Resource category	Cost
Direct retroactive cost	
Regadenoson	798.00 CNY per agent
	344,736 CNY per year
Sanitary materials	26,460 CNY per year
Other consumables	1378 CNY per year
Adverse event management	90.72 CNY per year
Non-directly traceable cost	
Total human resources	4,665,264 CNY per year
Doctor (senior title)	363,712 CNY/person/year
Doctor (intermediate title)	256,327 CNY/person/year
Assistant/Doctor (junior title)	192,852 CNY/person/year
Nurse	169,680 CNY/person/year
Equipment depreciation	391,667 CNY per equipment per year
Equipment maintenance	105,869 CNY per equipment per year
House depreciation	7965 CNY per room per year
Water and electricity allocation	9258 CNY per year

CNY, Chinese Yuan; RSE, Regadenoson stress echocardiography. The exchange rate: 1 US dollars = 7.32768 CNY.

Table 2. Practical capacity cost rate of personnel, equipment, space and water and electricity.

Category	Annual theoretical/ actual working hours (h)	Annual practical working hours (h)	Practical capacity cost rate (CNY/min)
Doctor (senior title)	1997.36	1697.76	3.57
Doctor (intermediate title)	1997.36	1697.76	2.52
Assistant/Doctor (junior title)	1997.36	1697.76	1.89
Nurse	1997.36	1697.76	1.67
Equipment	2285.82	2057.24	4.03
House	2285.82	2285.82	0.06
Water and electricity	2285.82	2285.82	0.07

CNY, Chinese Yuan; RSE, Regadenoson stress echocardiography. The exchange rate: 1 US dollars = 7.32768 CNY.

Table 3. Unit job consumption of RSE.

Job center	Number of doctors	Consumption time (min)	Number of nurses	Consumption time (min)	Number of assistants	Consumption time (min)	Unit operating time (min)
Clinical reception and triage			1	2.97			2.97
Preparation before examination	1	3.39	1	9.28	1	3.39	16.06
Conventional echocardiography	1	20.23			1	20.23	40.46
Regadenoson Injection			1	1.24			1.24
Stress echocardiography	1	10.54	1	10.54	1	10.54	31.62
Report production	1	6.31			1	6.31	12.62
Examination room reset	1	2.23	1	2.23	1	2.23	6.69
Post-examination monitoring			1	3.54			3.54
The sum of consumption time		42.70		29.80		42.70	115.20

RSE, Regadenoson stress echocardiography.

Table 4. Untraceable Unit costs of RSE.

Category	Capacity cost rate (CNY/min)	Capacity consumption (min)	Unit cost (CNY/case)
Doctor (intermediate title or above)	3.05	42.70	130.24
Assistant	1.89	42.70	80.70
Nurse	1.67	29.80	49.77
Equipment	4.03	42.70	172.08
House	0.06	82.72	4.96
Water and electricity	0.07	82.72	5.79

CNY, Chinese Yuan; RSE, Regadenoson stress echocardiography. The exchange rate: 1 US dollars = 7.32768 CNY.

Consumption Time Each Process Step

In our study, the complete process of RSE took about 40–50 minutes. The consumption time of each sub-job is shown in Table 3. It took 42.70 minutes for doctors, 29.80 minutes for nurses and 42.70 minutes for assistants.

Untraceable Unit Cost of RSE

The untraceable unit costs of RSE are listed in Table 4, of which equipment was the highest, followed by doctors.

Total Costs of RSE

The total costs of RSE were 1306.18 CNY ($181.60) (Regadenoson, 798.00 CNY; sanitary materials, 61.25 CNY, other consumables, 3.19 CNY; adverse event management, 0.21 CNY; total human resources, 260.70 CNY; equipment, 172.08 CNY; house, water and electricity, 10.75 CNY), of which Regadenoson, human resources and equipment represented 61.09%, 19.96% and 13.17%, respectively (Fig. 3).

Discussion

To the best of our knowledge, this is the first analysis of coronary flow velocity reserve assessment with RSE using the TDABC method.

Adenosine and Regadenoson are two common pharmacologic stress agents used to induce cardiac hyperemia in patients unable to achieve the target workload by physical exercise alone, each with different pharmacological properties, clinical applications and financial impact. Adenosine is a nucleoside that is composed of adenine and d-

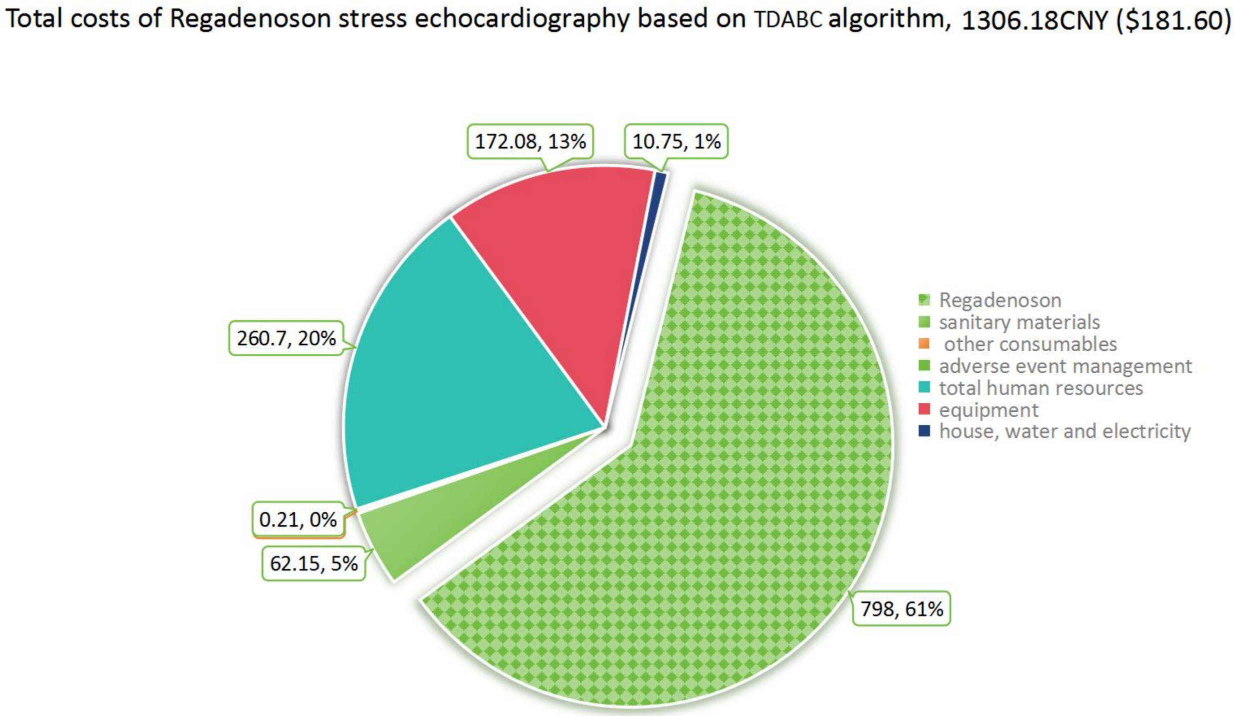

Fig. 3. Pie chart of total cost of Regadenoson stress echocardiography.

ribose. It acts on A(1), A(2A), A(2B), and A(3) adenosine receptors, and is not receptor-specific. As it is the A(2A) receptor that mediates the desired coronary vasodilation, the A(1), A(2B), and A(3) Adenosine receptors are deemed responsible for most side effects associated with Adenosine [25,26]. These sides effects are hypotension, tachycardia, atrioventricular block, bronchospasm, peripheral vasodilatation, and gastrointestinal symptoms [25,26]. Adenosine can be rapidly taken up by red blood cells, with a short duration of action and a half-life of less than 10 seconds. Therefore, Adenosine may require multiple doses or continuous infusion. Moreover, Adenosine dosing is dependent on patient weight or renal impairment. Regadenoson is the first Food and Drug Administration-approved selective A2A Adenosine receptor agonist used in myocardial perfusion imaging. Compared to Adenosine, Regadenoson dosing is as one injection because of long half-life [25,26]. Patients were more comfortable during the Regadenoson stress procedure than during an Adenosine infusion. As Regadenoson dosing is not dependent on patient weight or renal impairment and can be administered by rapid injection, it has the potential to simplify the stress procedure, reduce costs, and streamline the working day for the staff of the ultrasound department. Although Brink *et al.* [27] reported that Adenosine exhibited a lower medication price than Regadenoson based on the average wholesale price, its multiple administration and complex processes may increase Adenosine and human capital. When choosing which pharmacologic stress agent to use, clinicians and managers should consider the specific condition and cost of the patient. Our study provides help for clinicians and managers in making choices by analyzing the actual cost of RSE using the TDABC method. In the future, a large-scale, multi-center, comparative studies of the cost-effectiveness of Regadenoson and Adenosine are needed.

At present, the reform of the medical and health care system in China has entered the deep water zone. The reform of modern hospital management and medical insurance payment has been continuously promoted, and fine management has become the core of the high-quality development of medical institutions. To quantify the services provided by healthcare, different cost systems for allocation of resources have been developed, such as Diagnosis-Related Group (DRG), diagnosis-intervention packet (DIP), Activity-Based Costing (ABC) and TDABC. These cost systems not only effectively regulate provider behavior, but also improve the rational allocation of the regional healthcare resources. TDABC, in particular, have served to improve the cost identification, control, and efficiency in healthcare.

Through the real-world data, it was found that the costs of RSE was 1306.18 CNY ($181.60) per case, which is lower than other invasive and non-invasive methods in the field of coronary flow velocity reserve assessment, such as intracoronary Doppler flow-pressure wire, intracoronary provocation testing, positron emission tomography and cardiac magnetic resonance imaging. At the same time, RSE may be more economical in the case of similar diagnostic efficiency. In our study, we found that human and equipment resources accounted for 33.13% of the total cost of

RSE, which indicated that RSE took a long time and the overall process needed to be optimized. Regardless of the waiting time of patients, RSE took 46.36 minutes from the time patients entered the preparation area to sign the informed consent form to the completion of the report. There was a lack of coordination between process steps, and there was idle capacity. In the future, it will be necessary to strengthen the fine management consciousness and reduce the resource consumption on the premise of ensuring the quality of the examination. The following two methods can be used as a reference: one is to arrange a fixed team for the RSE clinic to ensure the proficiency of the staff and the continuity of the process; the other is that several clinics share a drug delivery nurse, and doctors will call nurses to enter the examination room when they need to inject Regadenoson, thus reducing the total number of staff and salary expenses. While the overall scale is still limited, the latter may be more economical. Therefore, in the early stage of development, the RSE clinic of the RSE group can be arranged in the adjacent area, with 1–2 drug delivery nurses responsible for arranging for patients to the sign informed consent form, inserting an intravenous indwelling catheter and injecting the Regadenoson, so as to reduce the resource consumption caused by idle personnel. After the technology has matured, adjustsments in the doctor-to-nurse ratio, optimization of the operational steps and strengthening the process management, can further shorten the waiting time. For medical institutions, compared with other invasive and non-invasive methods mentioned above, RSE can usually be examined on the same day or the next day, and the report can be completed within 30 minutes, which greatly speeds up the diagnosis and treatment. Therefore, exploring the scientific process and popularizing the application of RSE can effectively reduce the backlog of patients in the imaging department, quickly detect CFVR and release the hospital capacity.

In addition, the RSE pricing of some hospitals in China is not closely related to the actual cost to the hospital. The charge after deducting Regadenoson from RSE pricing is often lower than the actual operating cost of the hospital, which underestimates the resource investment of hospitals and doctors, does not reflect the people's affirmation and encouragement of the value of new technology, and needs to be further improved.

Limitations

Our study has several limitations involving several factors, such as job division, time estimation, and indirect resource allocation. We were unable to quantify the time-consuming changes caused by the professional quality and proficiency of the medical staff, and could not completely describe the advantages of TDABC. We believe that there will be more related studies to make up for these deficiencies and achieve more accurate cost measurements in the future. In addition, we only analyzed the situation in hospitals with small sample sizes. It was difficult to avoid deviations in the statistical results. Research based on a larger sample size will carry more influence.

Conclusion

This study provided a TDABC analysis of coronary flow velocity reserve assessment with RSE based on the hospital perspective and reflected the resource consumption of this technology, which provided a theoretical basis for medical service pricing. We found that the application of TDABC in the medical and health care field could not only describe the operation of service items in hospitals more accurately, but also allocate the various resources more effectively. There were, however still some difficulties in the actual implementation, which are important to the internal and external cost control of public hospitals.

Availability of Data and Materials

All data points generated or analyzed during this study are included in this published article.

Author Contributions

HZ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing–original draft. LZ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing–original draft. RC: Conceptualization, Data curation, Formal analysis, Methodology, Resources. XZ: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–review & editing. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study was was approved by the Ethics Committee of Yangpu Hospital, School of Medicine, Tongji University (LL-2020-SCI-053, 12/19/2020). The study was carried out in accordance with the guidelines of the Declaration of Helsinki. Informed consent was obtained from all participants enrolled in this study.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Simova I. Coronary Flow Velocity Reserve Assessment with Transthoracic Doppler Echocardiography. European Cardiology. 2015; 10: 12–18. https://doi.org/10.15420/ecr.2015.10.01.12.

[2] Saraste M, Koskenvuo J, Knuuti J, Toikka J, Laine H, Niemi P, *et al*. Coronary flow reserve: measurement with transthoracic Doppler echocardiography is reproducible and comparable with positron emission tomography. Clinical Physiology (Oxford, England). 2001; 21: 114–122. https://doi.org/10.1046/j.1365-2281.2001.00296.x.

[3] Caiati C, Montaldo C, Zedda N, Montisci R, Ruscazio M, Lai G, *et al*. Validation of a new noninvasive method (contrast-enhanced transthoracic second harmonic echo Doppler) for the evaluation of coronary flow reserve: comparison with intracoronary Doppler flow wire. Journal of the American College of Cardiology. 1999; 34: 1193–1200. https://doi.org/10.1016/s0735-1097(99)00342-3.

[4] Hildick-Smith DJR, Maryan R, Shapiro LM. Assessment of coronary flow reserve by adenosine transthoracic echocardiography: validation with intracoronary Doppler. Journal of the American Society of Echocardiography: Official Publication of the American Society of Echocardiography. 2002; 15: 984–990. https://doi.org/10.1067/mje.2002.120982.

[5] Al Jaroudi W, Iskandrian AE. Regadenoson: a new myocardial stress agent. Journal of the American College of Cardiology. 2009; 54: 1123–1130. https://doi.org/10.1016/j.jacc.2009.04.089.

[6] Cerqueira MD, Nguyen P, Staehr P, Underwood SR, Iskandrian AE, ADVANCE-MPI Trial Investigators. Effects of age, gender, obesity, and diabetes on the efficacy and safety of the selective A2A agonist regadenoson versus adenosine in myocardial perfusion imaging integrated ADVANCE-MPI trial results. JACC. Cardiovascular Imaging. 2008; 1: 307–316. https://doi.org/10.1016/j.jcmg.2008.02.003.

[7] Iskandrian AE, Bateman TM, Belardinelli L, Blackburn B, Cerqueira MD, Hendel RC, *et al*. Adenosine versus regadenoson comparative evaluation in myocardial perfusion imaging: results of the ADVANCE phase 3 multicenter international trial. Journal of Nuclear Cardiology: Official Publication of the American Society of Nuclear Cardiology. 2007; 14: 645–658. https://doi.org/10.1016/j.nuclcard.2007.06.114.

[8] Palani G, Ananthasubramaniam K. Regadenoson: review of its established role in myocardial perfusion imaging and emerging applications. Cardiology in Review. 2013; 21: 42–48. https://doi.org/10.1097/CRD.0b013e3182613db6.

[9] Drug Approval Package: Lexiscan (Regadenoson) NDA #022161. Available at: https://www.accessdata.fda.gov/drugsatfda_docs/nda/2008/022161s000_LexiscanTOC.cfm (Accessed: 2 June 2008).

[10] Porter ME. What is value in health care? The New England Journal of Medicine. 2010; 363: 2477–2481. https://doi.org/10.1056/NEJMp1011024.

[11] Kaplan RS, Porter ME. How to solve the cost crisis in health care. Harvard Business Review. 2011; 89: 46–52, 54, 56–61 passim.

[12] Kaplan RS, Anderson SR. Time-Driven Activity-Based Costing: a simpler and more powerful path to higher profits. Press HBS: Boston, MA. 2007.

[13] Niñerola A, Hernández-Lara AB, Sánchez-Rebull MV. Improving healthcare performance through Activity-Based Costing and Time-Driven Activity-Based Costing. The International Journal of Health Planning and Management. 2021; 36: 2079–2093. https://doi.org/10.1002/hpm.3304.

[14] Go JA, Weng CY. Process Mapping and Activity-Based Costing of the Intravitreal Injection Procedure. Current Eye Research. 2021; 46: 694–703. https://doi.org/10.1080/02713683.2020.1825747.

[15] Latorre V, Messeni Petruzzelli A, Uva AE, Ranaudo C, Semisa D. Unveiling the actual cost of Schizophrenia: An Activity-Based Costing (ABC) approach. The International Journal of Health Planning and Management. 2022; 37: 1366–1380. https://doi.org/10.1002/hpm.3405.

[16] Özyapıcı H, Tanış VN. Comparison of cost determination of both resource consumption accounting and time-driven activity-based costing systems in a healthcare setting. Australian Health Review: a Publication of the Australian Hospital Association. 2017; 41: 201–206. https://doi.org/10.1071/AH15046.

[17] Nabelsi V, Plouffe V. Breast cancer treatment pathway improvement using time-driven activity-based costing. The International Journal of Health Planning and Management. 2019; 34: e1736–e1746. https://doi.org/10.1002/hpm.2887.

[18] Javid M, Hadian M, Ghaderi H, Ghaffari S, Salehi M. Application of the Activity-Based Costing Method for Unit-Cost Calculation in a Hospital. Global Journal of Health Science. 2015; 8: 165–172. https://doi.org/10.5539/gjhs.v8n1p165.

[19] Niñerola A, Hernández-Lara AB, Sánchez-Rebull MV. Is Time-Driven Activity-Based Costing Coming out on Top? A Comparison with Activity-Based Costing in the Health Field. Healthcare (Basel, Switzerland). 2021; 9: 1113. https://doi.org/10.3390/healthcare9091113.

[20] Keel G, Savage C, Rafiq M, Mazzocato P. Time-driven activity-based costing in health care: A systematic review of the literature. Health Policy (Amsterdam, Netherlands). 2017; 121: 755–763. https://doi.org/10.1016/j.healthpol.2017.04.013.

[21] Shankar PR, Hayatghaibi SE, Anzai Y. Time-Driven Activity-Based Costing in Radiology: An Overview. Journal of the American College of Radiology: JACR. 2020; 17: 125–130. https://doi.org/10.1016/j.jacr.2019.07.010.

[22] Alves RJV, Etges APBDS, Neto GB, Polanczyk CA. Activity-Based Costing and Time-Driven Activity-Based Costing for Assessing the Costs of Cancer Prevention, Diagnosis, and Treatment: A Systematic Review of the Literature. Value in Health Regional Issues. 2018; 17: 142–147. https://doi.org/10.1016/j.vhri.2018.06.001.

[23] Lievens Y, van den Bogaert W, Kesteloot K. Activity-based costing: a practical model for cost calculation in radiotherapy. International Journal of Radiation Oncology, Biology, Physics. 2003; 57: 522–535. https://doi.org/10.1016/s0360-3016(03)00579-0.

[24] Ken Lee KH, Matthew Austin J, Pronovost PJ. Developing a Measure of Value in Health Care. Value in Health: the Journal of the International Society for Pharmacoeconomics and Out-

comes Research. 2016; 19: 323–325. https://doi.org/10.1016/j.jval.2014.12.009.
[25] Johnson SG, Peters S. Advances in pharmacologic stress agents: focus on regadenoson. Journal of Nuclear Medicine Technology. 2010; 38: 163–171. https://doi.org/10.2967/jnmt.109.065581.
[26] Alzahrani T, Khiyani N, Zeltser R. Adenosine SPECT Thallium Imaging. 2022 Sep 12. StatPearls. StatPearls Publishing: Treasure Island (FL). 2024.
[27] Brink HL, Dickerson JA, Stephens JA, Pickworth KK. Comparison of the Safety of Adenosine and Regadenoson in Patients Undergoing Outpatient Cardiac Stress Testing. Pharmacotherapy. 2015; 35: 1117–1123. https://doi.org/10.1002/phar.1669.