

Unit Cost Calculation of CT Scan Services based on Step-Down Method: A Case Study of Iran

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Abstract

Background: CT-scan is one of the radiology units in which various services are carried out by injection and without injection to describe the patient's anatomy better. Given the increasing costs of the CT due to diagnostic equipment, it is necessary to calculate the exact costs of services provided to determine optimal pricing and logical tariff of these services.

Methods: The present study is an applied and cross-sectional research performed by step-down costing method using the data of 2018 at the CT-scan unit of the radiology department of Imam Reza Hospital in Urmia. In this study, standard forms related to direct and indirect costs of CT units and other activity centers have been used to collect the data. Appropriate sharing bases were used to determine the share of the costs of other departments in the services of this unit.

Results: The cost of a brain scan without injection was calculated 66.7\$PPP, the brain with injection 143.9\$, the chest without injection 84.4\$PPP, the chest with injection 163.5\$PPP, upper and lower limbs without injection 150.1\$PPP, spine (cervical, thoracic, lumbar) 135.6\$PPP, abdomen and pelvis without injection 149.2\$PPP, abdomen and pelvis with injection 243.9\$PPP, sinus 94.1\$PPP, carotid CT angiography (extracranial) 287.5\$PPP, and thoracic aortic CT angiography 277.8\$PPP.

Conclusion: The study results showed a significant difference between the actual price of CT scan services and tariffs. Also, the shorter the service time and the more services in the CT scan department, the lower the unit cost. Comparing the cost of selected CT services in this study, we found that some time-consuming services, which were mainly related to injection services, imposed higher costs on the centers.

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Introduction

The radiology department is one of the paraclinical departments of hospitals, where various services are performed, including Computed tomography (CT), radiography, Magnetic Resonance Imaging (MRI), and sonography.¹ CT is one of the radiology units where

multiple services are performed with and without injection to better describe the patient's anatomy.² In addition, advanced diagnostic equipment is used in the radiology department, and more than 80% of hospital clients require radiology services.³ Consequently, it would be the costly hospital unit which accounts for a large share of hospital costs.⁴

Increased hospital costs made managers and health policymakers in all countries find new ways to control the costs to use services more efficiently while maintaining the quality of services with fewer resources and, therefore, lower costs.^{5,6} Cost analysis is a management tool that can help managers access the data needed to make more informed investment decisions about actions and infrastructures.⁷ Cost analysis can help ward managers, heads, and hospitals authorities and policymakers determine whether costs are higher than the total revenue and subsidies available. They provide operational performance information centered on cost issues. Comparing this information with the expected budgeted function can help identify the problems that need immediate attention, intervention, and corrective actions.^{8,9}

At present, to use financial resources more efficiently and effectively, cost management systems are increasingly used.^{10,11} One of the new methods with growing applications in day-to-day service activities is the step-down method. In this method, a network is designed for hospital units, which are considered as a network. First, the overhead units, central units (diagnostic), and final units (patient care) are listed. General and overhead service units and intermediate service units are indirect services, and the last service units are direct service units. This system uses appropriate methods to estimate the effects of changes in activities, complexity, diversity, and specific characteristics of each activity in calculating its costs.¹² This method relates costs to actions based on the number of resources used and then allocates them to cost purposes based on the number of activities.¹³⁻¹⁶

In a study conducted to calculate the cost of radiology services in educational and medical hospitals in Ahvaz, the costs attributed to radiology services were estimated at \$1727627.1, with the largest share (3.43%) of costs related to workforce costs. The present study showed that accurate methods of calculating costs, such as activity-based costing, should be used for pricing services.¹⁴ Another study conducted in Shafa Hospital of Kerman based on the activity-based costing method showed that personnel costs with \$231837.8 PPP account for 7.55% of the total cost, which has the highest share in the costs of the ward. In addition, 68.97% of the department total expenses are related to direct costs, and \$9662.5 (32.2%) are associated with indirect costs.¹⁵ Therefore, due to the increasing costs of the radiology department, including the CT unit due to the use of advanced diagnostic equipment and devices, the cost of services provided are calculated and accurately determined by a step-by-step method to estimate the actual cost to help budget the hospital. It is necessary to prevent waste of resources and control costs, and shift services to the private sector. Given the

importance of the issue for the health policymakers and managers of the Social Security Organization and the economic problems and high costs of CT services, it seemed necessary to calculate the cost precisely. This study used a step-by-step reduction method to analyze and estimate the unit cost of CT services at Imam Reza hospital in Urmia, aiming to determine optimal pricing and rational tariffs for the services.

Methods

This is an applied descriptive-analytical study using descending reduction costing and the data of 2018 in the CT unit of the radiology department of Imam Reza Hospital in Urmia. Researchers' standard forms through national and international studies have been used to collect the data in the present study. Data collection checklists in this study have been used in various domestic and foreign studies. Experts have confirmed its validity in this field, and the double-check method was used to check its reliability. The obtained data were analyzed using a step-down method and economic and accounting techniques of cost calculation in the following steps.

Step 1: Activity Centers Definition

Activity centers cause direct costs in the center of activity and attract indirect costs from other activity centers. Observation and interview techniques were used to identify the hospital centers of activity. CT-scan centers, radiology, facilities, administrative and financial, pantry, etc., were recognized and identified in this stage.

Step 2: Separation of Activity Centers According to Operations

Activity centers were divided into three general categories according to the procedures they perform:

1. **Operational Activity centers:** These are the wards that are directly involved in the process of providing services to patients. According to the purpose of this study, the radiology department was selected as the center of operational activity.

2. **Output-Based Activity Centers:** These activity centers operate to provide diagnostic and additional services to operating departments and patients and can also be considered independent cost units. In this study, units such as pharmacies were selected as the center of output-oriented activity.

3. **General Support Activity Centers:** These centers provide public service and support activities for operational and diagnostic activity centers and are not directly involved in providing the patients with services. In this study, units such as accounting, warehousing and logistics, security, butler's pantry, facilities, office and finance, telephone house,

self-service and kitchen, cleaning and housekeeping, and urban facilities were selected as support activities centers.

Step 3: Determining the Output of Each Activity Center

After identifying the activity centers, we determined the outputs for each activity center. That is, the type of output of each activity center was determined at this stage. The activity centers defined outputs in the “number of scans taken” in diagnostic processes. Due to the nature of their tasks and performance, these units do not have a specific output; rather, all activities of these units are in line with providing services to operational and diagnostic departments.

Step 4: Costing Operations Based on Each Activity Center

Costs in each activity center are divided into two general groups: direct and indirect costs. The direct costs of the radiology department include:

Cost of Workforce

The cost of the workforce in this center of activity includes the costs of salaries, overtime, productivity, and all the benefits that the hospital pays to the radiology department staff. Besides, all auxiliary costs such as insurance, taxes, etc., imposed on the hospital are part of the workforce cost.

Cost of Materials and Consumables

In this stage, material and consumables costs are divided into two general categories: direct and indirect material costs. Direct material costs are those used to provide services in this center of activity. Indirect costs, such as the cost of film used for radiology operations, include the costs unrelated to the provided services to each patient. Still, they are more commonly used for the general activities in the center, such as office supplies or costs related to the nutrition of the staff working in the hospital radiology department.

Depreciation Costs

Depreciation costs replace the existing property and equipment, calculated according to their use and shelf life. The direct depreciation method will determine the annual depreciation cost each asset according to the current equipment price and their shelf life. To determine the annual depreciation cost of the building, considering the base price per square meter and valuable life (which is considered a maximum of 50 years), we finally calculated the share of CT unit from the radiology department based on the space occupied by each activity center.

Step 5: Attributing the Costs of Each Activity Center to the Final Cost Centers

At this stage, the costs of different centers are allocated to the radiology activity center. In this study, the criterion or basis for sharing general expenses and support for the intermediate and final wards is the number of staff working in the wards, number of consumables and the area of the unit; the criterion for allocating the cost of the middle wards to the radiology department is the number of photographs.

Step 6: Calculating the Cost in Terms of Each Output

For calculating the cost of each production (including CT and MRI services), the total costs allocated to the radiology department were divided by the number of defined outcomes of this department. Thus, the cost of CT and MRI services were obtained separately.

Data Analysis Method

The present study is an applied and cross-sectional study. The data were collected through observation, interviews, and completing the forms designed. To determine the indirect costs, we identified the sub-activity centers that provide services to the CT unit of the radiology department. By estimating the share of the costs of other units in the provision of the services of the CT unit, appropriate sharing bases were determined, and indirect costs were calculated using these bases. To calculate the exact cost of each service, we estimated the average time required to perform a service. By summing up the direct and indirect costs shared by other departments, the cost of the selected CT unit services was determined using step-down method and Excel software. The cost price was estimated. In addition, all the costs were calculated based on Purchasing Power Parity (PPP) 2018, adjusted by an **equivalent of ????**

Results

In the CT unit of Imam Reza Hospital in Urmia, the share of general costs (water, electricity, gas, telephone) was \$209.6. The overhead costs (support) were \$339027.9, and the personnel costs were \$882671.6. The cost of annual maintenance and repairs of equipment was \$43852.2. In addition, the cost of consumables was calculated \$7975.3 (Table 1). The depreciation cost of CT equipment was \$36977, and that of building was \$23410.2.

Table 1: Cost share of the computed tomography unit separately (percent)

Share of maintenance and repair costs	3.39
Share of consumables costs	0.62
Share of general costs	1.62
Share of overhead costs	26.19
Share of personnel costs	68.19

The total costs of the CT unit disregarding the depreciation of equipment were \$1294489.2, and the total costs in this unit without considering the depreciation of equipment were \$1664261.4. Also, the total costs of the CT unit with and without taking into account the depreciation cost of the building were \$1664261.4 and \$1687671.6, respectively.

CT-SCAN Service Timing

The time of performing each of the selected services had to be examined to determine the cost of services. For this purpose, performing CT services with and without injection was calculated to check the mean and some selected services such as CT of the brain, spine, limbs, etc. The calculated time was estimated to include routine services at the beginning of each shift and patient admission, training the patient to prepare for imaging, placing the patients on the bed, preparing them for imaging, imaging, viewing the images, reconstructing images, and preparing the final report. In addition to the total observed time of activity and the sub-time of activity and overall, by taking into account the allowed rest time for employees, the average time of all CT steps was determined separately. The results of the timing of the selected CT services in minutes are as follows: performing all CTs of the brain without injection was 8.3, chest without injection 10.5, upper or lower extremity without injection 14.67, neck or chest or back without injection 9.87, pelvis without injection 10.56, and without injection 10.7. In addition, the time of all stages of chest scan with injection was 20.34, Carotid (extracranial) CT angiography 18.76, thoracic aortic angiography 24.56, abdomen, and pelvis CT by injection 21.34 minutes (Table 2).

The Weighting of Selected Services of CT Unit

After obtaining the timing results, we weighted the selected services to calculate the cost of the chosen services by using the number of cases of performing the selected services and the time of performing the service. Among the CT services, CT of the brain without injection, CT of the abdomen and pelvis with injection, CT of the abdomen without injection, CT of

the chest without injection, and CT of the limb without injection per year obtained more weights due to the number of cases per year.

Cost of Selected CT Scan Services Disregarding the Cost of Depreciation of the Building

Cost per service without calculation of building depreciation cost for CT of the brain without injection was \$76.1, brain with injection 164 \$, chest without injection \$96.2, chest with injection \$186.4, upper and lower limbs without injection \$134.4, spine without injection \$90.4, abdomen and pelvis without injection \$96.8, abdomen and pelvis with injection \$195.5, sinus \$98, carotid angiography (extracranial) \$171.9, and aortic angiography \$225. The tariffs of selected CT scan services are shown in Table 3.

The total cost of the CT was \$1687671.6, of which CT scan of the brain without injection \$322297.2 (19.10%), abdomen and pelvis with injection \$180642 (10.70%), upper and lower limbs without injection \$134131.6 (7.95%), sinus \$146451.1 (8.68%), abdomen and pelvis without injection \$58284.9 (3.45%), and spine \$53467.7 (3.17%) account for the largest share of total CT costs, respectively (Table 4).

Cost of Selected Services of CT Unit Considering the Cost of Building Depreciation

The costs for each service by calculating the depreciation cost of the building based on the Rials

Table 2: The final calculated time of the computed tomography services

Type of Services	Time (Minutes)
Brain without contrast	8.3
Brain with contrast	17.9
Chest without contrast	10.5
Chest with contrast	20.34
Upper& Lower Limb	14.67
Spine (cervical or thoracic or lumbar)	9.87
Carotid CT angiography (extra cranial)	18.76
Thoracic aortic CT angiography	24.56
Abdomen and pelvis without contrast	10.56
Abdomen and pelvis with contrast	21.34
Sinus	10.7

Table 3: Cost per service with and without calculating the cost of the computed tomography building depreciation and their tariffs

Type of service	Cost with considering building depreciation (\$)	Cost without considering building depreciation (\$)	Tariffs (\$)
Brain without contrast	76.1	77.1	41
Brain with contrast	164	166.3	48
Chest without contrast	96.2	97.6	45.8
Chest with contrast	186.4	189	53
Upper& Lower Limb	134.4	136.3	110.8
Spine (cervical or thoracic or lumbar)	90.4	91.7	46.8
Carotid CT angiography (extracranial)	171.9	174.3	112.1
Thoracic aortic CT angiography	225	228.2	108
Abdomen and pelvis without contrast	96.8	98.1	55
Abdomen and pelvis with contrast	195.5	198.3	59.8
Sinus	98	99.4	41

Table 4: Cost-share of service from the final costs of the computed tomography services

Services	Cost (\$)	Percent
Brain without contrast	322297.2	19.1
Brain with contrast	14803	0.88
Chest without contrast	75222.8	4.46
Chest with contrast	76355.2	4.52
Upper& Lower Limb	134131.6	7.95
Spine (cervical or thoracic or lumbar)	53467.7	3.17
Carotid CT angiography (extra cranial)	10459	0.62
Thoracic aortic CT angiography	27385.2	1.62
Abdomen and pelvis without contrast	58284.9	3.45
Abdomen and pelvis with contrast	180642	10.7
Sinus	146451.1	8.68

are as follows: CT of the brain without injection \$77.1, brain with injection \$166.3, chest without injection \$97.6, chest with injection \$189 PPP, upper and lower extremities \$136.3, spine \$91.7, abdomen and pelvis without injection \$98.1, abdomen and pelvis with injection \$198.3, sinus \$99.4, CT of the carotid (extracranial) angiography \$174.3, and aortic CT angiography \$228.2 (Table 3).

Discussion

The present study results showed that the share of general and overhead costs and personnel costs of the CT unit of the radiology department was calculated \$1242661.7. A similar study conducted at Amir Alam Hospital in Tehran in 2007 with a step-down method showed that the share of general, overhead, and personnel costs of the Radiology Department was \$805595.3, of which 63.4% of the public and personnel costs of the Radiology Department was allocated to the CT unit.¹⁶ In addition, the total costs of the CT unit estimated by considering the equipment depreciation were \$166426.1. In contrast, in the same research in Amir Alam Hospital, the total cost was calculated \$632739.5.¹⁶ These results show that CT unit costs increase over time due to increased parts prices, repairs, overhead, and personnel costs. The average cost of each CT service with and without considering the building depreciation cost was calculated at 122.1 and \$120.5, respectively, which is close to the other results due to the low depreciation cost of the CT building. The equipment cost in the above results was 314830 Rials per CT service. Another study in Imam Khomeini Hospital in Tehran in 2010 showed that the cost of performing each CT was \$213.9, of which 51% was the determined share of personnel costs and 49% were non-personnel expenses.⁶ Also, the share of some selected services, such as CT of the brain without injection \$ 66.7, brain with injection \$143.9, chest without injection \$84.4, chest with injection \$163.5, upper and lower limbs without injection \$150.1, spine (neck, chest, back) \$135.6, abdominal and pelvis without injection 149.2, abdominal and pelvis with injection 243.9, sinus \$94.1, carotid (extracranial) CT angiography \$324.6, thoracic aortic CT angiography \$277.8, showed the effect

of time. Consequently, the decreased services increased the total cost of some services like abdominal and pelvic CT with injection, CT of the limb, and CT angiography.

In addition, the study of Nisenbaum et al. showed that brain CT with contrast (70450 patients), chest CT with distinction (7120 patients), and abdominal CT with contrast (74,160 patients), which included 71.2% of the total CT scans, were 189.19, 273.53 and 343.20 \$, respectively. According to the results, the technical costs were higher than expected in the study time period.

On average, the cost of each non-contrast, with contrast, and combined scanning head was estimated to be 189.19, 247.7, and 252.83 \$, respectively. CT of the jaw and face without contrast and neck with contrast was calculated at 171.38 and \$273.51, and CT of the chest with a difference and without distinction, 273.53 and 218.86 \$, respectively.⁵ In addition, in this study, the share of personnel costs related to performing each CT was calculated to be \$63/9 PPP. Meanwhile, the study of Imam Khomeini Hospital in Tehran in 2010 showed that the highest cost of the workforce was related to performing each CT with \$109. Also, the most increased non-personnel cost among radiology services was serving each CT with \$105.¹¹ In a study conducted at Amir Alam Hospital, it was found that personnel costs had the largest share among the current costs (66.19%) as well as the total ward costs (62% of total ward costs). In another study in the Dominican Republic, Lewis et al. found that about 84% of a hospital total budget was spent on the workforce.^{18(Ref 17???)} The survey of Ghiasvand et al. showed that the largest share of costs incurred to provide radiology services in all four hospitals studied in 1389 and 1390 was related to direct operating costs to compensate for services delivered by the main sources and the difference between these costs was significant. Since, in the present study, the workforce cost was also classified as direct and operational costs, the workforce (personnel) had a considerable share in costs.¹⁰ Another study conducted by Ahmadi et al. to determine the cost of health services showed that the largest share of costs was related to personnel costs. The unit type varied between 46.5% to 61.5% of total costs.¹⁹

Laurila and colleagues conducted a study using both conventional and activity-based costing methods. Cost data in this study were obtained from information recorded in radiology and the hospital financial and personnel system. The costs allocated to radiology and admission technicians were between 57999 and \$150622, physicians between 52398 to \$83462, equipment between 93799 and \$136608, and the cost of materials and support services ranged from 40381 to \$110592.²⁰

A study by Ibrahim et al. showed that the cost of radiology services was \$8, while the cost calculated based on the activity-based costing method was \$122.2. The results showed that human resources were the main cost of radiology services among the four direct costs. Among the costs associated with human resources (employed personnel) and the services provided, radiology, CT, and sonography had the largest share, respectively. In addition, vascular system tests had the highest cost of consumables and medicines.²¹

The results obtained from Niasti et al.'s study in Shahid Beheshti Hospital of Hamadan showed that the highest cost was related to the workforce (65.2%) and the lowest was to energy consumption (0.4%). In addition, the total cost covered the costs of consumables (8.3%), public services (5.1%), and equipment and repairs (5.4%). The results of this study show a significant difference between the actual price of radiology services and tariffs. According to the results, for controlling the costs and creating a balance between revenues and expenses until the issuance of new tariffs, the reform of financial structures, personnel, repairs, and use of accurate accounting methods should be considered.²² The results of these studies confirm those of the present study. The current study results show that a shorter time of services and delivery of more services in the MRI and CT unit would lower the cost of services. Therefore, the burden of patients referring to imaging centers should be the basis for management decisions to restrict time-consuming services to provide more patients and reduce queue wait times.

It is suggested that the accounting and financial management in hospitals should be reformed. Calculating the cost of services in different parts of the hospital to provide a correct analysis of the costs, revenue, profit, and loss and making the right decision in resource management are recommended in order to provide the best quality services at the lowest price.

One of the limitations of this study was the deficiency of the accounting system of the hospital under study, which did not allow displaying the detailed costs of each activity center.

Conclusion

Comparison of the cost of CT scan services in the

present study showed that some services requiring injection before CT were time-consuming. Therefore, it reduced the number of CT services in this unit and increased the tariff and service costs. Consequently, it is suggested that in cases where the patient's burden is high, prioritization of patients by the management of the radiology department should be considered to receive CT services that need to be injected. This can help adequately manage the resources to respond appropriately to patients and reduce the burden of CT centers by providing services that take a short time to be performed and have more patients.

Authors' Contribution

HY, KH, and BN conceived the study and designed its method. HY performed the computations. KH, AG, and BF wrote the manuscript. All authors contributed to the development and approved the final manuscript.

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This study was approved by the ethics committee of Urmia University of Medical Sciences with the code of IR.UMSU.REC.1398.319. The authors acknowledge the staff of Imam Reza hospital for providing the hospital data.

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