



# A Comparison of the Efficiency and Effectiveness of Radiology Departments in Hospitals before and after Digital System Implementation

Parvin Ebrahimi<sup>1</sup>, Shahram Heydari<sup>1</sup>, Aidin Aryankhesal<sup>1</sup>, Kimia Zargari<sup>2</sup>, Mohanna Rajabi<sup>1\*</sup>

<sup>1</sup>Department of Health Services Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran.

<sup>2</sup>Department of Health Information Technology, School of Allied Medical Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

## Abstract

**Background and Objectives:** Considering the importance of the radiology department, which devours most of the financial resources, efficiency and effectiveness in this department is one of the main concern of policymakers in most health care systems. The aim of this study was to investigate the efficiency and effectiveness of a radiology department before and after the implementation of the digital system.

**Methods:** This was a descriptive analytical study. The research population included the staff and radiology departments of the eight hospitals affiliated with Social Security Organization in Tehran, Iran. In this study 80 staffs were surveyed and the census sampling was used. Data, from 6 months ago (July-December) and the same 6 months after the implementation of the digital radiology system in 2014-2015, were collected using 2 tools including a data collection form to evaluate the efficiency and a researcher-made questionnaire to investigate effectiveness. The collected data were analyzed using descriptive statistics, Wilcoxon nonparametric test, and single sample t test, using SPSS software version 20.

**Results:** There was no significant difference between the ratio of patients to personnel, the ratio of patients to radiology apparatus, the ratio of images to personnel, and the ratio of images to radiology apparatus before and after the digital system implementation ( $P>0.05$ ). The analysis of the data collected through the questionnaire showed an increase in the effectiveness of radiology department after the implementation of the digital system in this hospitals ( $P<0.05$ ).

**Conclusion:** The implementation of the digital system can help relevant authorities to make the right decisions and optimal allocation of resources in order to increase the satisfaction of the staff and patients, save costs and time, strengthen knowledge sharing and provide remote services in radiology departments.

**Keywords:** Efficiency, Effectiveness, Digital system, Social Security Organization, Radiology Department

## Background and Objectives

Health promotion in the community requires the availability of the facilities and the correct use of them.<sup>1</sup> Health sector managers in each country are working to provide the community with the best qualified care through the use of available resources.<sup>2</sup> As evidenced by the large body of studies conducted in this area, achieving effectiveness and efficiency, i.e., achieving goals and maximize results with the lowest available resources and facilities, is one of the main concerns of policymakers and managers in most health and medical systems.<sup>3-7</sup> WHO estimates squandered costs because of deficiency in the health

sector to be between 20% and 40%.<sup>8</sup>

On the other hand, the advancement of medical science as well as the needs of community and therapy staff has led to the development of hospitals and the expansion of diagnostic and therapeutic services, and in line with this, a high volume of referrals to benefit from these services.<sup>9</sup> According to available statistics, more than 80% of those who come to general hospitals need medical imaging.<sup>1</sup> The radiology department, due to the use of advanced diagnostic equipment and apparatus, adequate human resources and the physical space required for various radiology apparatus, will make a significant contribution to the costs involved and, if used appropriately, increase revenues and optimize the efficiency of the hospital.<sup>10-13</sup>

In recent years, technological advances in data processing, raising the level of specialized hospital staff, increasing patient expectations, and the need

\*Corresponding Author: Mohanna Rajabi, Department of Health Services Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran, Tel: +989103465523, Email: rajabi.m@tak.iuums.ac.ir

for cost and time savings have created a huge change in healthcare, especially the dynamic development of radiology diagnostic methods.<sup>14-16</sup> Transmission of images and digital radiology is one of these developments, which was first introduced and implemented in the early 1980s.<sup>17</sup> The rapid advancement of computer technology and subsequent issues such as electronic patient records, telemedicine and medical information led to the introduction of digital radiology replacing the old analog system more quickly.<sup>18,19</sup> During the past 25 years, the gradual shift from analog film radiograph to digital radiology has not been limited to the way images have been made, but archival images and, above all, their evaluation have undergone fundamental changes.<sup>19,20</sup>

Unlike analogue films, digital radiology images are easily accessible to patients and doctors.<sup>22</sup> In fact, it can be said that the use of storage, compression and recovery systems in medical applications is vital because of the use of them in medical records database management, computer-assisted diagnostics, research, teaching and medical education.<sup>15</sup> While the use of digital radiology has many benefits, including maintaining images quality when sending to other medical centers, eliminating contamination caused by the use of chemicals in analog technology, requiring less radiation in digital receivers, reducing the time from requesting images to receiving reports, improving efficiency and productivity of radiology experts and the reduction of non-acceptance, deletion, or recapture in the digital sector, compared to the film-based sections,<sup>23-27</sup> however, we cannot make this hypothesis that digital radiology will generally address all the problems in this section.<sup>28-31</sup>

In fact, the main purpose of using digital systems in radiology department is to improve the efficiency along with advancement in the diagnostic capabilities of doctors.<sup>32</sup> In this regard, many studies have been carried out to measure the efficiency of radiology department at various hospitals.<sup>33-38</sup> For example, the results of Srinivasan's study showed that digital radiology system saved money and reduced financial costs.<sup>33</sup> Based on the results of this study, by eliminating printing and distribution of x-ray film, the digital radiology system saves UCDHS more than \$2 million annually.<sup>33</sup> Siegel and Reiner in their study that surveyed transition from conventional film based to filmless operation at Baltimore VA Medical Center, concluded that it is absolutely essential to integrate the PACS into the patient's electronic medical record in order to maximize efficiency and clinical effectiveness of the system.<sup>39</sup>

Considering the foregoing cases and the lack of resources in providing health care and the importance of radiology department that accounts for the vast majority

of hospital resources,<sup>40</sup> it is necessary to pay attention to the efficiency and effectiveness of service provision in this unit of the hospital. Since the Radiology department of the hospitals affiliated with Social Security Organization in Tehran city in Iran have been equipped with digital systems from the beginning of 2015, no research had ever been done on the efficiency and effectiveness of the radiology department in these hospitals. Therefore, the present study compared the efficiency and effectiveness of radiology department in these hospitals before and after the implementation of the digital system. Obviously, the results of this study can help policy makers, managers and relevant authorities to make the right decisions and future plans for employing personnel, use of new equipment and technologies, and optimal allocation of resources, as well as improving radiology services and patient satisfaction.

## Methods

This was descriptive analytical study that conducted in summer 2016. The research population included the staff (experts/radiologists, clerks and radiology specialists) and radiology departments of the eight hospitals affiliated with Social Security Organization in Tehran, Iran, equipped with the digital system since 2015. Considering the fact that the number of personnel employed in radiology departments of related hospitals was 80 persons, in this study, the census sampling was used and the whole population surveyed.

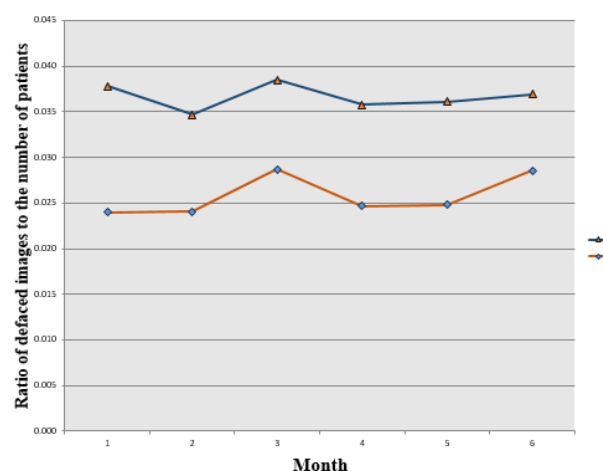
To evaluate the efficiency and effectiveness of radiology department, 2 tools were used separately. To comparison of the efficiency in the hospitals studied, data from 6 months ago (July-December) and the same 6 months after the implementation of the digital radiology system in 2014-2015, were collected using data collection form that consisted the number of radiology inpatients and outpatients, the number of graphs done for inpatients and outpatients, the number of radiology department staff as physician, clinical staff, administrative staff and number of devices separately. To prepare an efficiency measurement form, at first, items that are considered as input and output of the hospital radiology department were selected. Then, the indicators that were considered proper by the researcher to evaluate the radiology department's efficiency were finalized after consult with experts. This form was completed by referring the researcher to the hospitals and the data were collected from the radiology department offices and hospital information system.

A researcher-made questionnaire was used to investigate the effectiveness of radiology department in the hospitals studied before and after implementation of the digital system, that was prepared based on the review

of the texts.<sup>4,5,29,34,41</sup> This questionnaire consisted of 2 parts of general and specific questions. General questions included demographic characteristics of the radiology department staff, including age, gender, organizational position, current position in radiology department, and education. Specific questions based on research objectives, compares dimensions of image clarity (6 question), incorrect diagnostic status (5 question), level of satisfaction (5 question), and usefulness of the digital system (5 question). We utilized a 5-point Likert scale from strongly disagree (1) to strongly agree (5) to collect and analyze the data. So, if the mean score of each dimension was higher than 3, the situation would be improved.

To evaluate the validity, the questionnaire was reviewed by 3 faculty members from school of health management and information sciences and 4 experts in health services management. After completing the corrections according to the experts, the final version of the questionnaire was prepared and randomly distributed among 10 staff members. The instrument reliability was confirmed by calculating the Cronbach alpha ( $\alpha=0.886$ ). Finally, the questionnaires were distributed among around 80 employees of radiology department of the hospitals affiliated with Social Security Organization in Tehran city through the presence of researcher in these departments. After obtaining informed consent from staffs and ensure confidentiality of the names of the participants in the study, during 5 weeks 80 questionnaires were completed and returned to the researcher.

Descriptive statistical analysis included frequency, percent, mean, and standard deviation. For inferential statistical analysis, we used non-parametric Wilcoxon test and single sample t test ( $P<0.05$ ). The data were analyzed using the SPSS software version 20.



**Figure 1.** Ratio of Defaced Graphs to Total Patients in the 6 Months Before and After Implementation of Digital System Compared With Analog System.

## Results

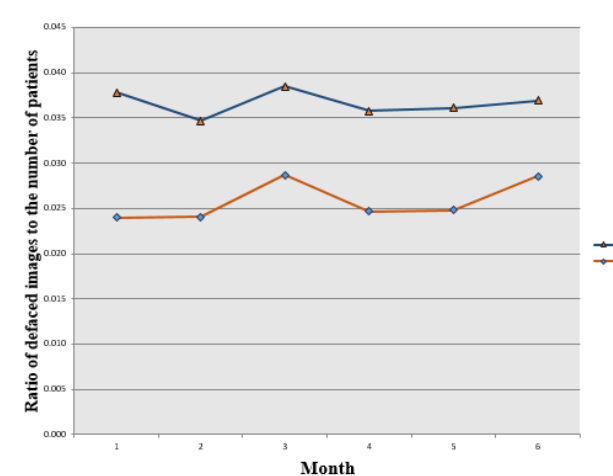
Findings of this study included the evaluation of the efficiency status and the effectiveness of radiology department in the hospitals affiliated with Social Security Organization in Tehran.

Results showed that half of staff were male and the other half were female; the average age of the staff in the studied departments was  $39.68 \pm 5.99$ ; most of the staff were between 36 and 41 years old; more than half (53%) of those worked in these departments as radiologist; 29.6% of the staff had a job history between 11 to 15 years; 77% of the staff had more than 10 years of work experience, and the official recruitment was 84.1% which is the highest recruitment of those who participated in this study.

Table 1 showed descriptive results of indicators that used to comparing the efficiency before and after the implementation of the digital system in eight social security hospitals.

Based on the results of this research, there was no significant difference between the ratio of patients to radiology department personnel, the ratio of images to radiology department personnel, the ratio of patients to radiology apparatus, and the ratio of images to radiology apparatus before and after the digital system implementation ( $P>0.05$ ). While, there was a significant statistical relationship between the number of defaced graphs, as well as, between the ratio of defaced graphs to the number of patients ( $P=0.012$ ) and the ratio of defaced graphs to the number of radiological images ( $P=0.012$ ) before and after the implementation of the digital system (Table 2). That means, based on decreasing in the ratio of defaced graphs after the implementation of this system, efficiency has increased.

As Figure 1 shows, the ratio of defaced graphs to total



**Figure 2.** Time Series of Ratio Reduction of Defaced Graphs to Total Images in the 6 Months Before and After Implementation of Digital System Compared With Analog System.

**Table 1.** Ratio/Number of Efficiency Indicators in Radiology Department Before and After Digital System Implementation

Hospital	Situation	Total Patients to Total Personnel	Total Radiological Images to Total Personnel	Total Patients To Radiology Apparatus	Total Radiological Images To Radiology Apparatus	Number of Raw Defaced Graphs	Ratio of Defaced Graphs to Total Patients	Ratio of Defaced Graphs to Total Radiological Images
Hospital 1	Before	2020.65	2283.44	17555.67	19789.67	797	.015	.013
	After	2162.77	2489.23	28116	32360	374	.007	.006
Hospital 2	Before	1331.43	1529.29	4660	5352.5	314	.033	.029
	After	1481.14	1687.43	5184	5906	301	.015	.013
Hospital 3	Before	1044.77	1246.92	2716.4	3242	204	.018	.015
	After	1090.85	1240.85	2836.2	3226.2	107	.008	.007
Hospital 4	Before	720.33	895.67	10805	13435	202	.019	.015
	After	767.34	914.93	10487	12504	114	.011	.009
Hospital 5	Before	769.36	906.21	2692.75	3171.75	245	.023	.019
	After	747.79	885.43	2617.25	3099	81	.008	.007
Hospital 6	Before	1305.56	1664.13	2984.14	3803.71	818	.039	.031
	After	1393.56	1796.19	3185.29	4105.57	245	.011	.009
Hospital 7	Before	1124.14	1436.57	7869	10056	553	.035	.027
	After	1059.36	1434.50	7415.5	10041.50	280	.019	.014
Hospital 8	Before	305.22	338.48	2808	3114	409	.058	.052
	After	311.6	413.75	2477.33	2758.23	197	.027	.024

**Table 2.** Difference Between Effective Variables in Radiology Department Efficiency Before and After Digital System Implementation

Ratio/Number	Situation	Mean ± SD	Z	P Value
Total patients to total personnel	Before	1078.31 ± 512.37	-1.820 <sup>b</sup>	.069
	After	1134.30 ± 550.13		
Total radiological images to total personnel	Before	1287.59 ± 587.44	-1.540 <sup>b</sup>	.123
	After	1357.79 ± 644.87		
Total patients to radiology apparatus	Before	6511.37 ± 5356.20	-.280 <sup>b</sup>	.779
	After	7789.82 ± 8685.59		
Total radiological images to radiology apparatus	Before	7745.58 ± 6172.36	.000 <sup>c</sup>	1.000
	After	9250.08 ± 9994.26		
Number of raw defaced graphs	Before	484.50 ± 248.82	-2.521 <sup>d</sup>	.012
	After	212.38 ± 105.49		
Ratio of defaced graphs to total patients	Before	.03 ± .01	-2.524 <sup>d</sup>	.012
	After	.01 ± .01		
Ratio of defaced graphs to total radiological images	Before	.03 ± .01	-2.521 <sup>d</sup>	.012
	After	.01 ± .01		

<sup>a</sup> Wilcoxon signed ranks test; <sup>b</sup> Based on negative ranks; <sup>c</sup> The sum of negative ranks equals the sum of positive ranks; <sup>d</sup> Based on positive ranks.

of patients after implementation of the digital system had decreased significantly compared to the previous 6 month and the analog system. Also, the time series analysis showed a significant decrease in slope of defaced graphs, i.e., after the implementation of the digital system, about 362 defaced graphs were reduced relative to the total radiology images (a decrease of about 13 graphs per thousand cases), which is significant (Figure 2).

Effectiveness assessment showed that, after implementing digital system, the quality of image resolution from the staff's perspective was higher than the middle of the tool score and the use of the digital system improved

decreased significantly compared to the previous 6 month and the analog system. Also, the time series analysis showed a significant decrease in slope of defaced graphs, i.e., after the implementation of the digital system, about 362 defaced graphs were reduced relative to the total radiology images (a decrease of about 13 graphs per thousand cases), which is significant (Figure 2).

Effectiveness assessment showed that, after implementing digital system, the quality of image resolution from the staff's perspective was higher than the middle of the tool score and the use of the digital system improved the situation; the incorrect recognition from the staff's

**Table 3.** Survey of Digital System's Effectiveness From the Employee's Perspective After the Implementation of the Digital System.

Dimensions of effectiveness	Mean±SD	Single Sample T Test	P Value
Image quality	4.64±0.63	t=21.87, df=70	.013
Correct diagnosis	4.52±0.54	t=23.54, df=70	.001
Satisfaction level	4.52±0.46	t=27.63, df=70	.003
Usefulness of digital system	4.55±0.50	t=25.87, df=70	.01
Total	4.56±0.41	t=31.55, df=70	.02

the situation; the incorrect recognition from the staff's view had a better situation by using digital system; the level of employee satisfaction with the digital system was improved; and the utility of the digital system was higher in the employee's perspective than the analog system. According to the collected data, the mean of each dimension is greater than 4.5, that means there was a significant statistical difference between mean of each dimension and middle of the tool score, which indicate an increase in the effectiveness from the employee's perspective after the implementation of the digital system (Table 3). The analysis of the data collected through the questionnaire showed an increase in the effectiveness of radiology department after the implementation of the digital system in this hospitals ( $P<0.05$ ).

## Discussion

Considering the importance of the radiology department, which devours most of the financial resources, efficiency and effectiveness in this department are of the main concerns in most health care systems. Although there have not been studies that reviewed the efficiency and effectiveness of digital system similar to our study, but some researchers have reviewed different aspects of efficiency and effectiveness of digital system, which will be discussed in this section.

Based on the results of our study, there were significant differences between the efficiency of radiology department before and after the implementation of digital system in the hospitals affiliated with Social Security Organization. In these hospitals, after the implementation of digital system the ratio of defaced graphs to the number of patients and the ratio of defaced graphs to the number of radiological images before and after the implementation of the digital system decreased, that means efficiency has increased. The results of study of Srinivasan and et al showed that after PACS implementation, digital system saved money and reduced costs.<sup>33</sup> Siegel and Reiner in their study, reviewed the Baltimore Hospital's nine-year experience from the digital system, and concluded that

PACS maximized efficiency, saving film costs, and saving money.<sup>39</sup> In terms of efficiency measurement, the results of these 2 studies confirm the results of our study, but costs are the criteria for the efficiency of digital radiology system in these 2 studies. Although in our study and other studies to measuring efficiency of digital system, different criteria were used, all studies emphasized that after the implementation of digital system, the efficiency of the radiology department was increased.

In the domain of the effectiveness of the digital system, our results showed that effectiveness of radiology department after digital system implementing had increased, from the employee's perspective. In current study, after digital system implementing, the quality of image resolution from the staff's perspective was better than previous times. In this way, the results of the study by Colin et al showed that the diagnostic accuracy with digital radiology was equivalent to that of conventional radiology, although digital radiology resulted in saving costs, but there was additional cost for maintenance and depreciation. The results also showed that after digital radiology system, working condition including: availability for the patient, safety, and job satisfaction improved.<sup>25</sup> Colin et al reviewed articles that compared digital and analog radiology techniques from publications between 1985–1995.<sup>25</sup> These findings confirmed the results of our study, and it can be said that, similarity of effectiveness measurements (satisfaction and correct diagnosis) in 2 studies had led to similar results.

Based on our results, the level of employee satisfaction after digital system implementation was improved. In this regard, Pathi and Langlois evaluated the effectiveness of digital radiography in emergency department and compared satisfaction between digital and conventional radiography from clinicians' points of view. According to the results of this study, the time for availability of images to requesting clinicians was 70% less for digital radiology compared to conventional radiography. Conventional radiography was equivalent to the analog system in radiology department. The overall satisfaction between digital and conventional radiography was very similar, but most clinicians expressed on opinion that digital radiography offers significant advantages.<sup>35</sup> This finding was not consistent with the results of our study in which after implementation of digital system satisfaction was higher. Pathi and Langlois's studied effectiveness, the time for availability of images and satisfaction using questionnaires distributed to all clinicians of the emergency department and ICU. The results of a study by Hofmann et al, which was a study in line with the improvement of radiology services, it was shown that the rate of image removal in the digital

system is as same and comparable to that of a film-based system.<sup>29</sup> This finding is not consistent with the results of this study because in this study, the overall effectiveness of the radiology department after the implementation of the digital system was higher in the staff's view. In studies that surveyed the effectiveness of the digital system, it can be concluded that the difference in viewpoint of respondents (physician, nurse, radiologist, patient) has led to different results in terms of the effectiveness of digital system.

Considering the above discussion and comparing the results of the current study with the findings of previous studies, it can be concluded that the digital system has a positive impact on efficiency and effectiveness from different perspectives. The implementation of the digital system can help relevant authorities to make the right decisions and optimal allocation of resources in order to increase the satisfaction of the staff and patients, save costs and time, strengthen knowledge sharing and provide remote services in radiology departments.

## Conclusion

According to the results of this study, the efficiency and effectiveness of the radiology department after the implementation of the digital system has increased, therefore establishment of a digital system for all hospitals is suggested. Also, holding workshops and comprehensive digital radiology training courses for staff and doctors to enhance teamwork and applying that knowledge in the radiology department are deemed to be beneficiary.

## Abbreviation

WHO: World Health Organization; UCDHS: The University of California Davis Health System; ICU: Intensive Care Unit; PACS: Picture Archival and Communication System.

## Author's Contributions

PE contributed to the conceptualization and study design, data analysis and interpretation, drafting the article and critically revising several drafts of the article for improvement of its intellectual content. SH contributed to the conceptualization and study design, data collection and interpretation and drafting the article. AK contributed to the conceptualization, study design and critically revising several drafts of the article for improvement of its intellectual content. KZ contributed to the data collection and drafting the article. MR contributed to the data analysis and interpretation and drafting the article. All authors have read and approved the submitted and revised final version of the manuscript and confirm that no part of this paper is copied from other sources.

## Competing Interests

None declared.

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