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Critical Success factors for implementing PACS Technology in Iran's Hospitals

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Abstract—**This study clarified the critical success factors (CSFs) that effect on adopting and implementing PACS and its applications in Iranian hospitals. We identified CSFs by literature review and interview by experts. Then examined its importance by T-test with 110 respondents. Kaiser-Meyer test and Varimax rotation are used for validity of data. Factor analysis is used for clustering. And the results are examined in 11hospitals who have implemented PACS. 20 of 23 CSFs, are distinguished important by T-test and clustered in 6 groups by Factor analysis. (1st) Ability to choose and purchase the appropriate PACS; (2nd) Being patient-centered and paying attention to patient satisfaction; were the most important CSFs. 77% questionnaires were completed by less than 2% miss data. The results are approved in 11 hospitals in Iran. This paper fulfils an identified need to study how PACS can be adopted in Iran's hospital by determining 6 CSFs. They can be applicable for policy makers and managers of other hospitals of Iran and some developing countries such as Iran to use of PACS as integrated IT technology.**

Keywords- PACS, Cloud computing, Futures trends, CSF, decision makers

I. INTRODUCTION

Using digital radiology technology or PACS(picture archiving and communication system) has numerous advantages compared with traditional printing systems. Currently, a percentage of medical images are repeated due to improper or incorrect settings on imaging instruments and hence not only patients are repeatedly exposed to harmful rays, but films are printed repetitively too. This is a waste of

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medical resources, while this repeat is much less frequent in digital radiology [1, 2]. On the other hand, many general practitioners (GPs) and specialists request various medical images such as radiology or MRI images for their diagnosis. Generally, in Iran, if the patient is fine and healthy, these images are discarded after consideration by the physician. And if the patient has problems, then these images are maintained in the hospital records or by the patients themselves, which can easily be lost or misplaced. PACS can solve these problems. In digital radiology systems, the image and its recorded date are stored in the main servers, and retrieved easily later at any time [1]. Therefore, using PACS, solves problems such as loss of patients information or inaccessibility at any time.

So far, a comprehensive study has not been conducted to find the problems and obstacles that are on the way for digital radiology systems or PACS being developed in Iran's hospitals. Thus, the main question of this study is determining the critical success factors for implementing PACS in Iranian hospitals. This study tries to investigate and evaluate these problems and obstacles for helping policy makers to take a step towards health promotion programs in the field of IT. In the first section, the current status of the PACS and its applications in Iran are investigated. Then, the trends of this technology are presented along the importance of PACS implementation. Then the methodology is presented. And in the last section the findings and results are explained.

A. Introduction of PACS and its applications in the world

PACS was first introduced in 1980 but its commercial recognition was not until 1990 [3, 4]. Americans were the first PACS providers. During 1995 to 2002, more PACS companies focused on storage, processing power, network and bandwidth but from this time, focus moved to technological development, speed, quality and improvement of reliability. Today there are between 1200 and 1500 PACS installer companies in the United States less than two years old. By the end of 2000, only 342 hospitals used PACS in the United States [5, 6]. But at the end of 2008 this number had reached 3928 hospitals, while the number of vendors selling PACS from 39 vendors in 2003 reached 67 vendors in 2008 [7]. Now PACS is like the heart of an imaging center and is responsible for safe storing of images [8].

Among Asian countries, China, Japan and Korea were the first users and developers of PACS. The Chinese are a little more successful than the Japanese, because the Chinese developed their PACS based on DICOM standard from the beginning But the Japanese tried to work with their own standards but did not succeed and went back to using the DICOM standard [4, 9].

In Iran, some medical centers have attempted to install this system in the past few years, but it has not been used properly. This can be overcome by using the experiences of other frontier countries in this regard.

PACS is included the imaging tools, a safe and secure network for the transfer of data and patient information, workstations for interpreting and reviewing images and archival storage and retrieval of images and reports [10]. Using PACS will cause medical staff development [11] and on the other hand, it provides better desired services to patients [12]. Other advantages of using PACS are: reducing the number of lost images [2], providing quick access to images anytime, anywhere [13, 14], saving costs [14, 15], better management of patients [12], remote access to multimedia information of patients [16], security in archiving and transmission of images [17] and better quality of images [18]. Given the above advantages, many developed countries in America [6], Europe [7] and Asia [9] have turned to the use of these systems.

To provide the appropriate services to customers using PACS, it is not just enough to buy the system, PACS must be transferred to the country. As is known, technology transfer has four dimensions: human-ware, knowledge-ware, hardware and software. It is obvious that investment should be made in each of these four dimensions. Investment in this area requires paying attention to both initial system purchase and receiving aftersales services. Therefore, these costs can be divided into two types: direct and indirect costs. Direct costs of PACS include [19]: The cost of hardware equipment purchase, software and maintenance. Indirect costs of PACS include:

- The cost of setting up and maintaining server rooms
- The amortized cost of equipment
- The cost of staff training
- The cost of archive maintenance

B. Trends of PACS technologies and necessity of its implementation in developing countries

In developed countries, healthcare services are among their first five priorities in their strategic planning, while healthcare in Iran is of much lower priority. It is essential that we put the health at first five priorities in our country programs.

The more the share of healthcare from the GNP of a country, the better it is at taking steps towards development. In some European countries, this share is up to 16 percent, however in many developing countries this share is less than five percent. The World Health Organization (WHO) defined health in terms of wellness, that is physical, mental, and social well-being, not merely the absence of disease. Therefore, increase in the health share of GNP indicates that governments are trying to keep their citizens healthy and to avoid treatment. Paying attention to information technology issues in healthcare, such as hospital information systems, decision support systems, PACS and other similar systems can fulfill the above and lead to an increase in GNP and hence increase in patient satisfaction [20].

Increasing volume of medical images is one of the serious challenges facing the health authorities for maintenance, management, sharing and access to data. On the other hand, the increase of medical images is directly proportional to the technology, for example, volume of new medical images such as three-dimensional imaging, or MRI has increased. So

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hospitals are looking for ways to reduce their maintenance and management cost of their medical images. Many treatment centers do not have IT resources or enough storage devices to manage this large volume of growing data. Therefore, organizations seek to share their resources via cloud services to reduce their costs. Cloud services provide the ability of storing, preparing images archive, sharing and access to images for health organizations in an efficient and cheap way [21, 22].

Since many centers do not have the financial ability to setup a traditional PACS, alternative cloud computing can help to meet this need. Many believe that new approaches instead of focusing on the large supercomputers should use small clusters for information management [23]. Thus the main objective of the next generation is facilitating the implementation of applications which are distributable, scalable, and widely accessible through the Web. The ultimate goal of these services is facilitating the use for any one and minimum use of software, hardware and network [24]. According to Gartner, Cloud computing will be among the top ten technologies in the next years [25]. The study of future trends suggests that information management will move towards networking to reduce costs and availability of data [26]. Based on what is mentioned above, PACS will be offered on cloud in the future and will reduce the costs and responsibilities for the end users.

The benefits of cloud computing include [21, 22]:

- Data Portability
- Increased and Flexible Storage Capacity
- Data Migration

Based on those mentioned above, the trend is towards cloud computing in the IT world [27, 28]. Therefore, if the country hospitals decide to implement PACS costs can be reduced by using this new technology.

PACS will have a growing trend in the next decade. In addition to cloud computing, the following trends in cloud computing technology in the next ten years is predicted as follows [29]:

- Replacing PACS workstations with iPads and tablets.
- Replacing DICOM protocol with MINT Which is web-based
- Replacing email with cell phone for sending reports
- Replacing CDs with images sharing media

II. Methodology

In this study the current situation of PACS and its future trends in the world as well as in developing countries is investigated. Also, the need for PACS implementation and factors affecting its successful implementation were explored. After identifying success factors in the implementation of this system from the literature [11, 30, 31], these factors were prepared and customized in the form of a questionnaire, to five experts in the field to rectify issues that were neglected in the questionnaire. These experts had more than 5 years of experience in this field and were familiar with PACS and its problems. Academically, they had Masters and PhD degrees in information technology management or related engineering fields. The validity of the final questionnaire with 23 questions was confirmed by the experts. Furthermore, the validity of the questionnaire was assessed by an experimental study with a random sample (n = 25) and its reliability was confirmed by Cronbach's alpha ($0.7 < \alpha$).

In this questionnaire (Table I in appendix), the participants were asked to comment on any of the questions raised as a problem or obstacle to PACS implementation and development, using the Likert standard. Response range was considered from "extremely important" with a score of 9 to "very low importance" with a score of 1.

The target audience of this study were the staff at hospitals of Tehran (Iran), such as a doctor, nurse, technician or executive manager familiar with PACS. 110 of these people were identified and the questionnaires were distributed among them.

The data has been presented by descriptive and analytical statistics. Kolmogorov Smirnov normality test was used for data analysis and then according to the results, parametric or non-parametric tests were used for data analysis. To determine the major factors and clustering of factors, factor analysis was used. With this model, the critical success factors were extracted. Then 11 hospitals in Tehran (Iran), which PACS was implemented in, were studied with these models and the results were presented using descriptive statistics.

III. Results

The average age of the respondents to the questionnaire was 32 and the average work experience of them was 5.5 years. Generally, 63% of respondents had experience of practical work with PACS. The rest of respondents did not have practical experience with PACS but were completely familiar with the system.

From 110 distributed questionnaires, 100 were received. 15 questionnaires had more than 50% miss data and excluded of research. 85 questionnaires had less than 3% miss data and included in research. So, the overall response rate was 77%, which is pretty high. Stability of data was measured by Cronbach's alpha reliability which was 0.725. The value is greater than 0.7 so questionnaires have an appropriate stability.

To ensure the convergence of comments on the questions, Kolmogrov Smirnov test for normality of the data was used. In this case, P-value for every question was less than 0.05, so T-student test can be used for analyzing the data.

The results showed, the minimum and maximum averages were 6.45 and 8.29 for the fourth and ninth question respectively. The lowest standard deviation (SD) was 1.10, which corresponds to the ninth question. The maximum SD was 2.10, which corresponds to questions 4, 10 and 14. The questions were about the quality of service, patient satisfaction, training of PACS before implementing it and purchasing it considering its cost. Respondents in these three cases had different

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answers, but they reached consensus. Following T-test results prove this claim. The remarkable thing is that the ninth question has both highest average and lowest SD which shows good consensus. Therefore, the issues raised by this question which are hospital managers' interests in investment on PACS implementation, are one of the main factors in its implementation. On the other hand, the fourth question, which has the lowest mean, has the highest SD too which shows high dispersion. This question relates to increase in quality of service and patient satisfaction. There are no good views of PACS in Iran because of its poor implementation. T-test was used to determine the respondents' opinion consensus. The results showed, the low and high levels of 95% confidence factor were positive, the first hypothesis was rejected and the assumption that these factors are considered as an influential factor in PACS implementation is proved. Also the minimum consensus on the answers to questions 2, 4, 10 and 14, was approved by the descriptive analysis. Meanwhile, the maximum consensus was on answers to the ninth question.

For data validity of the factors, classification using factor analysis and Kaiser-Meyer test was used to obtain the coefficient of KMO. Since all coefficients were greater than 0.6, then this test was valid. We used the factor analysis test and Varimax rotation for Classification. The results showed that three of the data should be deleted. Because they did not belong to any category. By removing questions 7 and 12 and 19 data were properly classified. The Cronbach's alpha was upgraded to 0.747. Results of Extraction Sums of Squared Loadings in SPSS showed that the cumulative variance covers 79.224% of the data. The results of factor analysis show that, as shown in Table I, six distinct critical success factors (CSF) have been identified and named.

Table I. Naming and classification of critical success factors (CSF) in PACS implementation in hospitals based on the results of the factor analysis with a Varimax rotation.

Critical Success factors (CSF)	Qs	Elements	References	1	2	3	4	5	6
CSF1 Ability to choose and purchase appropriate PACS	Q9	Tendency of manager in investment on PACS	[19,20]	**0.98**					
	Q13	Cooperation of physicians and nurses and radiology staff	[19]	**0.87**					
	Q17	consultation with experts	[8]	**0.98**					
	Q23	Down time of system	[7]	**0.98**					
	Q1	Improvement of medical diagnosis by increasing image quality	[17,18]	**0.53**					
CSF2 Paying attention to patient satisfaction	Q2	Improvement of hospital management	[18]		**0.97**				
	Q4	Increase of quality of service to patients	[17]		**0.99**				
	Q14	Staff training	[26]		**0.99**				
	Q10	Decision to buy PACS despite its cost	The opinions of experts		**0.99**				
CSF3 Tendency to execute the comprehensive national health program	Q11	Existing perspective in the national health program				**0.98**			
	Q15	Senior managers supporting PACS implementation	[13]			**0.984**			
	Q3	Reducing loss of medical records and providing faster access to it	[13,14]			**0.984**			
CSF4 Feasibility study of successful implementation	Q21	Existence of experienced companies for PACS implementation	[21,22]				**0.61**		
	Q20	Existence of imaging equipment consistent with international standards	[20]				**0.69**		
	Q8	Reducing the costs of hospital	[19]				**0.74**		
	Q6	Reducing the waiting time for receiving reports	[2,13,14]				**0.59**		
	Q5	Radiology Physicians and staff satisfaction	[20]				**0.55**		
CSF5 Existence of adequate infrastructure	Q18	Existence of secure network with proper bandwidth	[5, 6]					**0.74**	
	Q22	Integration of an external PACS with existing systems in hospitals	[5,20]					**0.56**	
CSF6 PACS implementation in pilot format	Q16	PACS pilot implementation	[14 , 1]						**0.77**

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A. Analysis of critical success factors considering 11 hospitals as case studies in Tehran

In Tehran, capital of Iran, more than 10 million citizens and immigrants are living. There are about 60 hospitals and 500 clinics in this city. Among these centers, there were only 10 hospitals and one medical center which had tried to implement PACS. Therefore, these centers were chosen as our case studies.

In this section, we first identify six CSF for implementing PACS based on the following 20 factors and then we study the validity of these factors in Tehran hospitals.

For this purpose, a questionnaire consisting of 20 elements and 6 CSFs was given to managers to answer, according to the current status of the hospital based on 5-point Likert scales: "1=very poor condition", "3= poor condition", "5=normal condition", "7= good condition" and "9=very good condition".

There were 11 hospitals in Tehran in which PACS was implemented. Evaluation of these hospitals indicate that they have common characteristics.

They are all older than 25 years and almost cover all areas of medical specialization and have at least 500 beds. One of them is a private hospital and the rest are state hospitals.

All these hospitals have implemented PACS at least six months ago. Questionnaires were given to PACS managers. In Fig. 1, PACS utilization time in four different time intervals is presented.

As shown in this figure, distribution of PACS utilization time in different hospitals is as follows: 3 hospitals between 6 months to a year, three hospitals between 1 to 2 years, three hospitals between 2 to 4 years and 2 hospitals more than 4 years.

According to Fig 1, responses received from hospitals were sorted into four groups in ascending order based on the operation time of PACS.

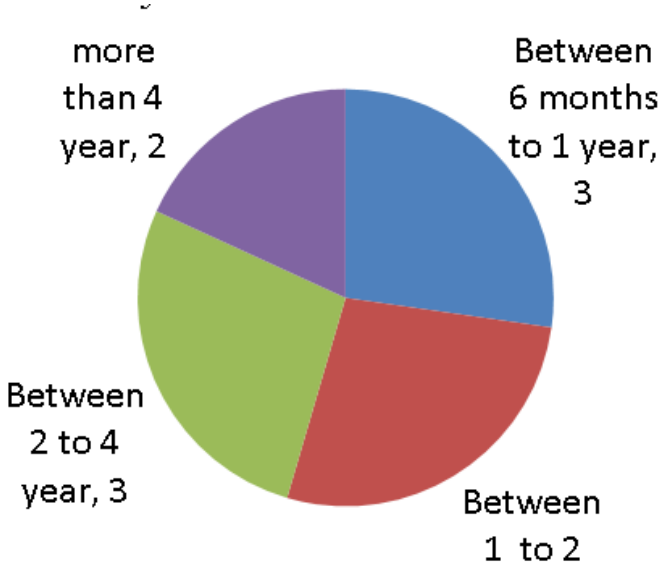

Figure 1. Distribution of PACS utilization times in case studies.

The mean and SD of each category of responses were calculated and presented in Table I. The results show that in all hospitals with PACS implementation, the majority of the questions are higher than medium which are equal to or greater than 5.

This shows that conditions are satisfied. From these factors, only three were lower than medium which are as follows:

Q14 of category 3 was 4.33, that is in hospitals with PACS utilization time between 2 and 4 years, the staff training state is lower than average. Q11 of category 2 was 4.33, that is in hospitals with PACS utilization time between 1 and 2 years, "having perspective in the national health program" state is lower than average. Q20 of category 1 was 3.67, that is in hospitals with PACS utilization time lower than one year, having imaging equipment with world standards, is lower than average. Since this happens only for three cases, every case in a different group, it is negligible. The last results show in Table II.

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Table II. Mean and SD of the CSFs of hospitals in four groups according to the duration of the system utilization.

CSFs	Questions	Group 1: Between.05 to 1 years		Group 2: Between 1 to 2 years		Group 3: Between 2 to 4 years		Group 4: More than 4 years	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
CSF 1	Q1	7.67	1.15	8.33	1.15	9.00	0.00	9.00	0.00
	Q9	7.00	2.00	7.00	2.00	8.33	1.15	9.00	0.00
	Q13	7.00	0.00	7.67	1.15	8.33	1.15	9.00	0.00
	Q17	9.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00
	Q23	7.00	0.00	7.67	1.15	7.00	0.00	9.00	0.00
CSF 2	Q2	8.33	1.15	9.00	0.00	9.00	0.00	9.00	0.00
	Q4	7.00	0.00	7.00	2.00	9.00	0.00	9.00	0.00
	Q14	5.67	2.31	5.00	2.00	4.33	1.15	9.00	0.00
	Q10	9.00	0.00	9.00	0.00	8.33	1.15	9.00	0.00
CSF 3	Q11	5.00	0.00	4.33	1.15	5.00	2.00	7.00	0.00
	Q15	8.33	1.15	9.00	0.00	8.33	1.15	9.00	0.00
	Q3	9.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00
CSF 4	Q21	6.33	1.15	7.67	1.15	7.67	1.15	9.00	0.00
	Q20	3.67	1.15	5.67	1.15	5.00	0.00	7.00	0.00
	Q8	7.00	0.00	7.67	1.15	7.67	1.15	9.00	0.00
	Q6	5.67	1.15	7.67	1.15	7.67	2.31	9.00	0.00
	Q5	8.33	1.15	9.00	0.00	8.33	1.15	9.00	0.00
CSF 5	Q18	7.67	1.15	8.33	1.15	8.33	1.15	9.00	0.00
	Q22	7.67	1.15	7.67	1.15	8.33	1.15	9.00	0.00
CSF 6	Q16	9.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00

Figure 2 shows average of the CSFs of hospitals in four groups, according to the duration of system operation. As is seen, replies to most of the questions has been good or very good. Hospitals who have started using PACS earlier, have achieved better efficiency. This can be justified in another way, hospitals which had more financial and scientific ability, equipment and readiness for using this system, have begun using it earlier and have hence benefited from its results. It can be seen that in group four (i.e. hospitals with more than four years' experience of using PACS) the mean of all factors is approximately 9 and standard derivation of answers is 0.

Table III shows the mean and SD of all elements of the CSFs which have been calculated for the 11 hospitals under study. The results shows that the mean of CSFs in all cases is good or very good. SD for the first, fifth and sixth CSF is very low meaning that the distribution of answers to three success factors including: “the ability to choose and purchase the proper PACS " and " existence of adequate infrastructure " and " PACS implementation in pilot format" of the all hospitals is very low and all agree that these factors have led them to success. SD for the second and fourth factors is moderate meaning that the distribution of answers to two success factors including: “paying attention to patient satisfaction" and "feasibility study of successful implementation" of all hospitals is moderate and most agree that these factors have led them to success.

Table III. The mean and standard deviation of all elements of the CSFs for the 11 hospitals in Tehran.

CSF	average	stdev
CSF 1	8.20	0.61
CSF 2	7.92	1.41
CSF 3	7.67	2.03
CSF 4	7.40	1.28
CSF 5	8.25	0.12
CSF 6	9.00	0.00

SD for the third CSF ranges between medium and high meaning that the distribution of answers to the success factor "tendency to execute the comprehensive national health program" among all hospitals is low. This may be due to the fact that it is only been two years since the enactment of the comprehensive national health program in Iran, hence some hospitals have decided to utilize PACS regardless of this issue.

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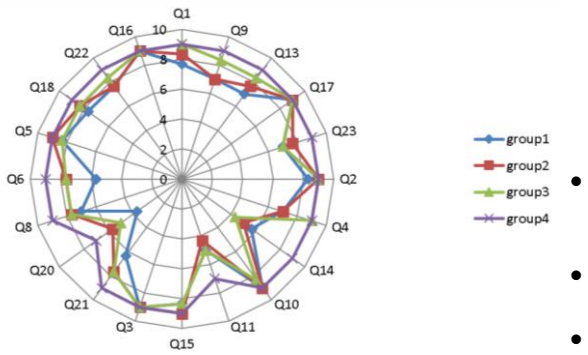

Figure 2. Average radar diagram of the CSFs in four groups of hospitals.

IV. CONCLUSIONS

This study has reviewed PACS technology and showed that digital radiology services are able to produce high quality and low error medical images. The technology can be used in the future world which is to be network-based and will use cloud computing. Results of this study appear that out of the 6 critical success factors for policy makers in the implementation of PACS technology in Iran, three have gained high rating in all case hospitals: 1) Ability to make decision for choosing and purchasing the appropriate PACS: the results suggest that this ability depends on having experienced consultants and interested managers in PACS. Collaborating physicians, nurses and radiology staff is effective in this ability. However, the selection of a high quality system with the least possible downtime is very important. 2) Proper infrastructure in the country and the hospital: access to a secure network with a proper bandwidth for hospitals on the one hand, and the compatibility and integration of PACS with existing hospital information systems on the other, are all part of the necessary infrastructure that encourages hospital managers to implement this system more enthusiastically. 3) PACS pilot implementation: this is also an important factor, in particular when it comes to migrating to a new system while there is not enough trust for complete replacement. In such a case, hospitals tend to undergo a pilot implementation in one department with the old system still in use, until all the bugs of a new system are identified and eliminated, and the users are happy with its operability. It is only then that the full system is developed and implemented in all other departments of the hospital or care center.

If a hospital is patient-centered, it would aim to improve its management and quality of services, and it would spend money on staff training and purchasing appropriate equipment if necessary. Results show that using companies with experience of implementation, having imaging equipment compliant with international standards, reducing costs and waiting time for reports and finally, the satisfaction of radiology department physicians and staff are the main factors that make the feasibility study of a successful implementation possible.

Tendency to execute the comprehensive national health program is the last CSF. If the implementation of PACS are emphasized in the perspective of the national health program, then hospital managers will ensure all efforts are made for its realization. This will result in patients' medical records being accessed faster with less loss. For the successful implementation of PACS in hospitals of Iran, where there is less experience in such fields, it is recommended that the following points be considered:

- 1. Cooperation with domestic companies and using the experiences of successful domestic hospitals can make PACS implementation more effective.
- 2. Paying attention to the medical center needs is very important in the customization of PACS.
- 3. Using high speed Internet and Intranet infrastructure both inside and outside the hospital is very important, which increases the speed of PACS implementation.
- 4. Full-time presence of technical experts of PACS in the hospital is essential. This leads to better service to patients and reduction of system down time.
- 5. Increasing patients' knowledge of imaging without film by providing informative leaflets and brochures. This is because some patients are still used to receiving films with their reports after various medical imaging such as X-Ray and MRI.
- 6. It is useful to have some enforcement laws by the Health Ministry or government for the compulsory implementation of PACS in all hospitals and health centers. This will be of great help when it comes to transferring a patient's medical records and imaging from one center/hospital to another.
- 7. Issues related with the security of PACS in different hospitals is also of great concern that can affect patients' attitude.

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