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SYSTEMS-LEVEL QUALITY IMPROVEMENT

Challenges of Implementing Picture Archiving and Communication System in Multiple Hospitals: Perspectives of Involved Staff and Users

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Abstract

Today, despite the advantages of the PACS system, its implementation in some healthcare organizations faces many challenges. One of the important factors in the successful implementation of a PACS system is identifying and prioritizing the challenges from the perspectives of involved staff and user of this system. Therefore, the aim of this study was to determine and compare the challenges of implementing PACS from perspectives these users in educational hospitals. This study was conducted on all IT and medical equipment staff, and radiology residents ($n = 140$) in Kerman University of Medical Sciences (KUMS) and Shiraz University of Medical Sciences (SUMS) in 2016. The data were collected through two researcher-made questionnaires. Their validity was approved by radiologists, IT staff, and medical informatics specialists and their reliability through calculation of Cronbach's Alpha (0.969 and 0.795). We used Multivariate Analysis of Variance (MANOVA) to compare the scores given by three groups of participants in the challenges and Univariate Analysis of Variance (ANOVA) to compare the scores in two universities. The participants believed that technical challenges were more important than other challenges ($\bar{x}$=3.74, SD = 0.7). IT experts ($\bar{x}$=3.87, SD = 1) and radiology residents ($\bar{x}$=3.95, SD = 0.9) gave the higher scores to the "shortage of high quality monitors" factor and medical equipment experts ($\bar{x}$=4.26, SD = 0.87) to the "low speed of communication networks" factor among all technical challenges. The mean scores given to technical ($\bar{x}$=76.1, SD = 13.5) and managerial ($\bar{x}$=16, SD = 5.9) challenges in SUMS were more than the scores of the same challenges in KUMS ($\bar{x}$=69.9, SD = 15.7) and ($\bar{x}$=11.9, SD = 6.4) ($p < 0.05$). The technical challenges are the most common challenges to PACS implementation, and different universities experience different levels of technical challenges. Eliminating implementation challenges can reduce the risk of failure in the utilization process. Based on the results of this study, providing necessary infrastructures such as appropriate monitors and upgraded IT equipment can prevent many of the PACS implementation challenges.

Keywords Health information systems · Radiology · Hospital information systems · Picture archiving and communication system · Radiology information systems

This article is part of the Topical Collection on *Systems-Level Quality Improvement*

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Introduction

A huge number of images including MRI (Magnetic Resonance Imaging), CT scan and radiography images are annually produced in hospitals. Storage, archiving, and retrieval of these images are time-consuming [1] and impose high costs on hospitals [2]. The fast pace of technological advancement in digital imaging has facilitated the management of patients documents, images and data for healthcare organizations around the world [3]. These images are an essential element in clinical diagnosis and treatment plan. The review and interpretation of the increasing number of images in hospitals impose a high pressure on radiologists and result in poor diagnoses and overlooking patient's problems [4]. Besides, shortage of radiologists has persuaded imaging centers to use more efficient methods for managing images [5]. Picture Archiving and Communication System (PACS) is a computerized system which is used for collecting, archiving, processing, communicating and presenting medical images and reports [6–9]. PACS provides simultaneous and ubiquitous access to medical images for physicians and other healthcare specialists [2, 8, 10], and enables them to process images and to make 3D presentations [11–13]. Improving the quality of the images by PACS [2, 14] reduces the need for repeated imaging and improves the efficiency and effectiveness of the medical diagnoses [15, 16]. This system reduces the expenses associated with traditional radiology films [12, 17] and the space required for archiving radiology films [18], and provides the possibility of teleradiology [5]. It also reduces the risk of image deterioration or loss [19], prevents environment pollution caused by radiology film disposals [2] and improves access to images [11]. Morgan [20] in a study showed that integrated PACS systems can improve radiologists' diagnosis and decision making. Although this system is apparently designed for physicians and other healthcare specialists, its benefits are eventually realized by patients [21–23].

The transition from analog to digital imaging and implementation of a PACS face many challenges [24]. Some challenges include requiting substantial budget and investment to purchase, install and maintain a PACS [3], inflexibility of this system [16], difficulty of networking and integration of PACS with other information systems such as Hospital Information System (HIS) and Radiology Information (RIS) [25, 26], and the need for continuous training of PACS users and technical team [26–29]. Therefore, the decision to implement a PACS does not guarantee its success, but in order to implement a PACS successfully, it is necessary to devise an active strategy that considers all technical, financial, organizational and human challenges [26].

Many studies have been conducted on PACS implementation [25, 27, 30–38]. In these studies, the PACS implementation challenges were generally investigated, and prioritizing the challenges of implementing this system was not evaluated. On the other hand, in these studies, the views of involved staff and users in the implementation of the PACS system have not been determined. Also in these studies, the data were collected from the individuals who did not have a significant role in implementing PACS (physicians, nurses, and executive technicians and managers). Involved user's views and their acceptance are an important factor in identifying and prioritizing the challenges of implementing HISs [39]. Esmaeilzadeh et al. [40] defined users' acceptance as their willingness to use Information Technology (IT), which is designed to support tasks. Moreover, user acceptance can be defined as demonstrable willingness within a user group to employ IT for the tasks it is designed to support [39]. It is important to consider the viewpoints of all key user groups, because resistance by any of these groups could delay the overall adoption rate. HIS and communication technologies must be designed to meet the purposes of user groups through an understanding of human behavior and values [39].

Additionally, discovering what motivates people to use new systems and understanding the source of resistance toward using new systems is important to hospital managers, system designers, and developers as it can help to increase the success of projects [40]. The success of Health Information Technology (HIT) depends a great deal on the individual-level responses of clinician end users; these responses include acceptance/rejection of IT and how (or even whether) clinicians use IT [41–44]. As a result, users' perception is the key factor to manage the implementation of PACS optimally, and this fact should be considered by healthcare managers and policy makers [45]. Also, the key parameters that determine their optimal utilization are systematic planning, a well-qualified and experienced PACS administrator/IT department, periodic radiologist training, regular maintenance, and the readiness to upgrade and, if necessary, to switch to a more appropriate technology at the importunate time [46]. Also according to the findings of Zahiri Esfahani et al. [47], the structure of PACS committee and the viewpoints of various groups of stakeholders play an important role in the decision making process. Their study showed that information technologists, radiologists, and medical equipment experts have different views about the effective factors in the selection of PACS.

In Iran, usually IT administrators, medical equipment experts, and radiologists have the key roles in PACS implementation. Recently, two large universities in

Iran, namely Kerman University of Medical Sciences (KUMS) and Shiraz University of Medical Sciences (SUMS), have implemented this system. The aim of this study was to identify and compare the challenges that the hospitals affiliated with these two universities faced when implementing and adopting their PACS systems. The findings of this study can be used by other hospitals to overcome the challenges of implementing, and successfully implement PACS systems.

Methods

This descriptive-analytic study was conducted to identifying implementing challenges of PACS from the perspective of key individuals in the implementation of PACS across seven educational hospitals affiliated with two large universities (KUMS and SUMS) in two geographic regions (Kerman and Fars provinces) in 2016. Kerman is the first and Fars the fourth largest provinces among 31 provinces in Iran. We included hospitals with different specializations. For example, the following four general hospitals are mainly known for one of their specialties: Bahonar and Rajaei hospitals are known because of their trauma department, Shafa because of its cardiovascular department, and Afzalipour because of its internal medicine department. The individuals were included if they had actively participated in the process of PACS implementation and had at least 1 yr of experience with a PACS. All 140 IT administrators, medical equipment experts and radiology residents working in teaching hospitals affiliated with KUMS (Afzalipur, Shafa and Bahonar) in Kerman and with SUMS (Faghihi, Namazi, Chamran and Rajaei) in Shiraz meet the criteria and were invited to participate in this study. At the time of the study, all hospitals had already implemented PACS. All four hospitals in Shiraz and Afzalipour in Kerman implemented Infinitt, which is a PACS from a Corean vendor. Bahonar in Kerman implemented a PACS called Medal, which was developed by an Iranian vendor. Shafa in Kerman implemented a PACS called Marco, which was developed by an Iranian vendor. All the teaching hospitals affiliated with KUMS were included except Beheshti hospital which was a psychiatric hospital and had no radiology resident. Since the number of beds and the type of specialties in hospitals may affect the variables of the study, hospitals with a similar number of beds and specialties were selected from SUMS. The network bandwidth used for PACS in these hospitals was 50 Mbps. In these hospitals, between 7 and 64 active accounts were defined for using PACS. Also in these hospitals, the number of diagnostic monitors used for PACS were between 12 and 86.

Data were collected using two questionnaires that were designed based on the review of the literature [29, 30, 35], desk research and consultation with medical informatics and IT specialists. The first questionnaire was designed for IT administrators and medical equipment experts (Appendix A) and the second for radiology residents (Appendix B). Each questionnaire had two sections; the first sections contained seven questions concerning demographic information of the participants, and the second sections contained six groups of questions concerning technical, human, organizational, financial, managerial and standardization challenges related to the implementation of PACS. The first section in both questionnaires was equal, but in the second section, the first questionnaire contained 65 questions and the second questionnaire contained 35 questions. In both questionnaires, the last question was an open-ended question asking other challenges not mentioned in the earlier closed questions (Appendix A, B).

In order to assess the participants' agreement with each item a 5-point Likert scale ranging from strongly disagree to strongly agree was used. The reliabilities of two questionnaires were confirmed by Cronbach's Alpha of 0.969 and 0.795 respectively. The content validity of the questionnaires was confirmed by experts who had practical experience with implementing a PACS including three IT administrators, two radiologists, and two medical informatics specialists.

In order to collect the data, one of the researchers distributed the questionnaires among the study population and assured the confidentiality of the data. The data were analyzed using descriptive and inferential statistics in SPSS v.19. Responses to each item were scored from 1 (strongly disagree) to 5 (strongly agree). We first used the matching coefficient to adjust the effects of the number of questions, and according to the number of questions, we assigned a coefficient to each category. To analyze the data, the total score given by each participant to each group of challenges was calculated. The mean scores were calculated through dividing the total score of each category by the number of questions in that category. The Kolmogorov–Smirnov test was used to determine the normality of the data distribution ($p > 0.05$). First, we used Multivariate analysis of variance (MANOVA) to compare three groups of participants in terms of 6 categories of PACS implementation barriers. Wherever the difference was significant, we used Tukey Test to perform paired comparisons between each two group. Univariate Analysis of Variance (ANOVA) was used to compare the scores given by participants in the challenges of PACS implementing in two universities. This study was confirmed by Ethics Committee of KUMS (IR.KMU.REC.1396.1343).

Table 1 Demographic characteristics of participants in the study

Demographic Information	n	(%)
Gender		
Male	49	53.3
Female	43	46.7
Age		
< 30	49	53.3
30–39	35	38
40–49	8	8.7
> 50	0	0
Educational degree		
Associate's	5	5.4
Bachelor's	28	30.4
Masters's	14	15.2
Doctoral degree and higher	45	48.9
Employment status		
Permanent	12	13.2
Contractual	3	3.3
Arbitrary	25	27.5
Temporary	6	6.6
Resident	45	49.5
Work experience		
> 16	6	6.6
11–15	10	11
5–10	20	22
< 5	55	60.4
Job		
Information Technology	28	30.4
Medical Equipment	19	20.7
Radiology Resident	45	48.9
Workplace		
Afzalipour Hospital	11	12
Shafa Hospital	12	13
Bahonar Hospital	11	12
Namazi Hospital	20	21.7
Faghihi Hospital	18	19.6
Chamran Hospital	10	10.9
Rajai Hospital	10	10.9
University		
Kerman	34	37
Shiraz	58	63

Results

Ninety-two out of 140 participants (66%) answered the questionnaire (IT response rate: 71%, Medical Equipment response rate: %61, Radiology Resident response rate: %64), of which approximately 53.3% were men. Most participants aged less than 30 years (53.3%), and had Ph.D. or higher degrees (49%), and were radiology residents (49%). Also, the majority of them had low work experience so that 60.4% of them had less than 5 years of work experience (Table 1).

Figure 1 shows the average score assigned by the participants in the challenges of PACS implementing.

According to the findings, IT experts ($\bar{x}$=3.87, SD = 1) and radiology residents ($\bar{x}$=3.95, SD = 0.9) gave the higher scores to the "shortage of high quality monitors" factor and medical equipment experts ($\bar{x}$=4.26, SD = 0.87) to the "low speed of communication networks" factor among all technical challenges.

The results of Multivariate Analysis of Variance (MANOVA) in Table 2 shows that there is a significant difference ($p < 0.0001$) between the scores given by three groups of participants to six groups of PACS implementation challenges.

Based on MANOVA, there was a significant difference between the scores given by three groups of participants to six groups of PACS implementation challenges ($p < 0.0001$). The results of analyzing the difference between the scores given by each group of participants and the scores given by other groups using post-hoc Tukey test are shown in Table 3.

Figure 2 shows the mean and standard deviation of the scores given to the challenges of PACS implementing in the hospitals of KUMS and SUMS. The maximum difference of the mean scores in two universities was related to technical and managerial challenges.

The results of Univariate Analysis of Variance (ANOVA) showed that there was a significant difference between the score assigned by the participants of two universities to the technical ($p = 0.047$) and managerial challenges ($p = 0.001$). Concerning other challenges, there was no significant difference between the scores assigned by the participants in two universities ($p > 0.05$). The participants in KUMS encountered more technical and managerial challenges regarding the implementation of PACS than the participants in SUMS.

Some of the respondents stated one of the following challenges in response to the open-ended question concerning other challenges to PACS implementation; exotic and confusing PACS tools and functionalities, lack of security protocols for establishing secure connections, lack of a national PACS system, lack of space for archiving current images and a scheduled deadline for archival, incompatibility of the PACS interface with users' needs and limitations, problem of defining access level to authorized individuals and confidentiality of patients information.

Discussion

The results of this study showed that among six categories of PACS implementation challenges (technical, human,

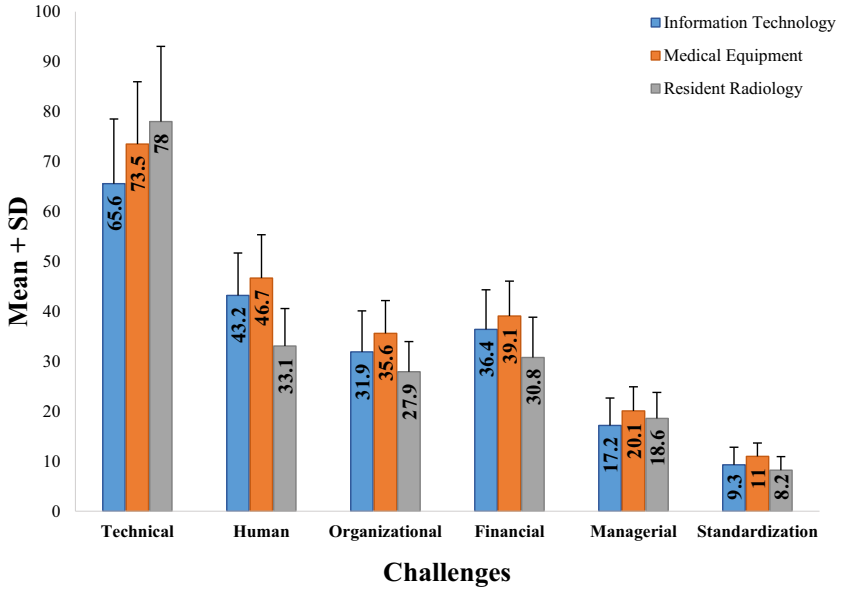

Fig. 1 Mean and standard deviation of scores given by three groups of participants to PACS implementation challenges

organizational, financial, managerial and standardization), the issues included within the technical challenges category were perceived as being the most challenging by the participants. More precisely, the findings of this study showed that the respondents gave higher scores to the issues within the technical challenges category. Issues within human, financial, and organizational categories received the next scores, respectively. Also from the perspective of participants in this study, lack of senior management support in the implementation of PACS and lack of a comprehensive standard for interconnection are not major challenges.

Consistent with these findings the results of a PACS evaluation in three hospitals in Riyadh, Saudi Arabia [28] showed that the frequent errors, tedious failure of system and difficulty in finding images, as technical challenges and insufficient users training as human challenges were among the most important challenges of PACS implementation. Also, Odhiambo-Otieno [48] showed that technical factors is one of the most important criteria for implementing healthcare information systems. In this study, the factors of "shortage of high-quality monitors" and "low-speed communication networks" were the most important technical challenges in PACS implementation.

Table 2 Comparing the scores assigned by three groups of participants to six groups of PACS implementation challenges

Challenges	Group	Mean	SD	F	*p* value
Technical	Information Technology	65.67	12.91	7.874	0.001
	Medical Equipment	73.52	12.48		
	Radiology Resident	78.08	15.06		
Human	Information Technology	43.21	8.49	25.163	$p < 0.0001$
	Medical Equipment	46.73	8.64		
	Radiology Resident	33.17	7.48		
Organizational	Information Technology	31.92	8.20	7.939	0.001
	Medical Equipment	35.63	6.59		
	Radiology Resident	27.91	6.07		
Financial	Information Technology	36.42	7.95	9.160	$p < 0.0001$
	Medical Equipment	39.1	6.98		
	Radiology Resident	30.8	8.03		
Managerial	Information Technology	17.28	5.48	45.408	$p < 0.0001$
	Medical Equipment	20.15	4.82		
	Radiology Resident	18.6	5.21		
Standardization	Information Technology	9.35	3.52	78.050	$p < 0.0001$
	Medical Equipment	11	2.66		
	Radiology Resident	8.26	2.74		

Table 3 The pairwise analysis of the scores given by different groups of participants to six groups of PACS implementation challenges

Challenges	Group	Group	Mean Difference	p value
Technical	Information Technology	Medical Equipment	9.42	0.056
		Radiology Resident	−4.22	0.47
	Medical Equipment	Radiology Resident	−13.64	$p < 0.0001$
Human	Information Technology	Medical Equipment	3.92	0.21
		Radiology Resident	13.54	$p < 0.0001$
	Medical Equipment	Radiology Resident	−9.62	$p < 0.0001$
Organizational	Information Technology	Medical Equipment	2.44	0.45
		Radiology Resident	6.81	$p < 0.0001$
	Medical Equipment	Radiology Resident	4.36	0.036*
Financial	Information Technology	Medical Equipment	2.62	0.48
		Radiology Resident	8.10	$p < 0.0001$
	Medical Equipment	Radiology Resident	5.48	0.016*
Managerial	Information Technology	Medical Equipment	1.24	0.59
		Radiology Resident	−7.91	$p < 0.0001$
	Medical Equipment	Radiology Resident	−9.16	$p < 0.0001$
Standardization	Information Technology	Medical Equipment	4.03	0.003*
		Radiology Resident	12.32	$p < 0.0001$
	Medical Equipment	Radiology Resident	8.29	$p < 0.0001$

*Significant at $p < 0.05$

Also, in a study by Ahmadian et al. [49] the "lack of appropriate hardware and powerful data networks", had the highest priority among the challenge of implementing hospital information systems. Our findings are in line with Jabbari's [34] findings concerning upgrading hardware and software facilities of hospitals based on PACS requirements. Tan [29] also showed that over half of the personnel believed that lack of high quality monitors was among major challenges of PACS implementation in their hospitals. It seems that high-quality monitors can affect the accuracy and timeliness of radiologists' diagnoses. Kapoor [3] in a review study has suggested equipping imaging centers with high-quality motors in order to prevent errors.

Based on the results technical challenges in SUMS were more than technical challenges in KUMS. In a study to investigate the IT infrastructure of SUMS, Nematolahi [50] reported that none of the teleradiology consultants and other image-based diagnosis centers in SUMS use quality monitors with high-resolution displays.

According to Nematolahi, [50] internet speed and bandwidth are critical for communication of images. Our results showed that the low speed of communication network was one of the main challenges in the implementation of PACS. Consistent with this result, Hiss [51] also pointed out that slow communication of images in PACS is a critical problem that should be resolved. High-speed network enables quick and easy communication of images

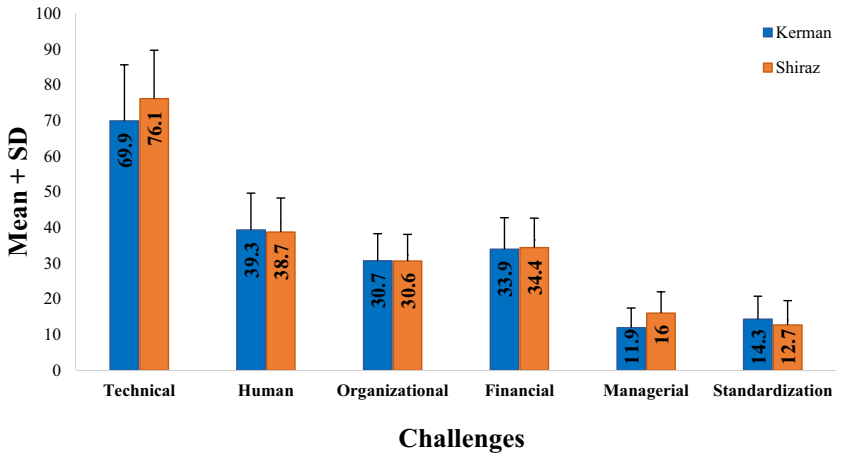

Fig. 2 The mean and standard deviation of the scores assigned to challenges of PACS implementing in KUMS and SUMS

to the physicians and radiologists in other locations. Kifle [52] and Gemmill [53] discussed that the speed of transferring data and network bandwidth are the main components of an IT infrastructures. A wide network bandwidth communicates a high amount of data and high-resolution images in a very short time, therefore, improves the efficiency of PACS. Rohaya [27] also mentioned lack of technical support for IT services as one of the main challenges of implementing PACS in developing countries.

In this study, human challenges were the second main challenges of PACS implementation after technical challenges. In human challenges, "poor knowledge of managers and users about how to cooperate with PACS implementation team group", "lack of professionals" and "inadequate training of professionals" were the most important factors. As a result, training about how to operate a new system and promoting an interactive organizational culture among users and design teams can contribute to the successful implementation of the PACS system. In study by Berkowitz et al. [38], user training was one of the most important keys to success in a large informatics transition. Moreover, challenges such as lack of educational resources to train users, and inability to recruit appropriate staff and to employ experts who can accomplish the information technology activities, were the most important reasons that led to failure in information system implementation strategies [54].

After technical and human challenges, financial challenges were the most important challenges to PACS implementation. Although in this study financial challenges did not receive a high priority, but participants had emphasized factors like "lack of funds", "insufficient investment" and "expensive hardware of PACS". In this study, participants did not appreciate the financial challenges because they weren't paying for the system. In this regard MacDonald [24] estimated that more than 58% of PACS implementation expenses are related to hardware, and stated that the high expenses of hardware are among the main challenges of PACS implementation.

Organizational challenges had a lower priority after financial challenges. However, the participants believed that "poor education of experts" and "lack of training programs for new skills" were the most important challenges in this category. Tan's [29] study also showed that approximately half of the individuals had not received any training for viewing and working with digital images and they claimed that they did not have access to any training course, while PACS managers stated that all staff had received training twice a year. Tan concluded that before implementation of a PACS all staff should receive sufficient training.

After organizational challenges, managerial challenges had the lowest importance. However, in this category, the factors "lack of support from senior managers", "slow data analysis and report generation" and "mismanaging workload of radiology department" were frequently reported by the participants. Based on Almalki et al. [54], sometimes senior management may fail to understand the purpose of IT initiatives or may not trust the information system strategies capability.

In this study standardization challenges were the least important challenges. Among these challenges, IT experts and medical equipment experts mostly referred to "incomplete standardization" and radiology residents to "lack of comprehensive standards for establishing mutual communications". According to King [55] standardization is one of the most important challenges in the radiology department, so that without standardization, deploying teleradiology and PACS is impossible. Since, before implementation of PACS in KUMS and SUMS hospitals interoperability of PACS with hospital information system and radiology modalities were checked and the selection of the PACS was carried out based on a comparison of existing PACSs, standardization challenges were less than other challenges in this study.

In this study, from perspective of the participants, redundant and confusing PACS tools and functionalities, lack of security protocols for establishing secure connections, lack of a national PACS system, incompatibility of the PACS interface with user's needs and limitations, the need to define access level for authorized individuals and concerns about the confidentiality of patients information were other challenges of PACS implantation. The Importance of security and privacy of information in HISs have been suggested in the literature [56–59]. As a result, maintaining the confidentiality and security of patient information when sharing among different stakeholders is one of the important issues for the successful implementation of HISs.

The difference of the viewpoints of IT administrators, medical equipment experts, and radiology residents concerning challenges to PACS implementation was statistically significant. Congruent with this result, Ahmadian [49] showed the relationship between identification of hardware factors and the organizational position individuals.

In this study, in order to increase the accuracy of the data, we included the individuals who were directly involved and had a key role in the implementation of PACS. Also, in order to expand the scope of the study and collect comprehensive data, two major universities (KUMS and SUMS) were included.

This study had three limitations. First, we conducted the study in two universities out of 47 medical universities across Iran. This may limit the generalizability of the results. However, these two universities are among the largest universities in Iran and since due to the central healthcare system in

Iran, the organizational structures of the hospitals are similar. Therefore, extending the scope of the study to other universities could bring the same results. Second, the following four groups of staff have key roles in the implementation of PACS: information technology staff, medical equipment staff, radiology residents and senior radiologists. In the context of Iranian health care system, both radiology residents and senior radiologists have almost an equal role in the implementation of a PACS. However, because of the senior radiologists are not very responsive to the questionnaires and they did not cooperate in providing the data because of their busy time schedule, they were excluded from the study. Removing them not only have no negative impact on the results of our study, but also prevents the bias of collecting poor quality data. Moreover, because of the low number of the senior radiologists ($n = 15$), we think that excluding them form this study would not have much effect on our results. Thus, to increase the accuracy and validity of the data and to avoid incorrect answerers, only radiology residents were invited. Third, although a questionnaire may not quantify all challenges experienced by individuals involved in a PACS implementation, we used one open-ended question at the end of the questionnaire to let the participants add other challenges not mentioned in the earlier closed questions.

"Lack of high-quality monitors" and "low-speed communication networks" were the main factors that resulted in giving a higher priority to technical challenges. This finding reflects the lack of a comprehensive plan for the provision of hardware devices, lack of updated hardware and poor organizational structure leading to insufficient planning for implementation of new information systems in hospitals. Therefore, national health policymakers, the ministry of health officials, hospitals managers and budgeting authorities of hospitals should provide sufficient internet bandwidth in hospitals and to upgrade the IT equipment to increase the speed of communication networks for successful implementation of PACS in hospitals. Also, it is recommended to provide appropriate hardware such as high-quality monitors in order to meet the requirements of implementing PACS in hospitals. Failure to fix technical challenges could negatively effect the performance of radiology residents and also the patients' health. Hence, it is recommended to conduct a needs assessment study of radiologists before implementation of PACS. Identifying implementation challenges should be the first step of a plan for deploying information systems in hospitals.

Today, all hospitals across Iran have a plan for implementation of PACS. Therefore, this study provides useful information to health care policy makers and hospital managers concerning the identification and overcoming of PACS implementation challenges. This information is especially helpful in hospitals that are planning to implement a PACS. The findings of this study can also provide information for the maintening and upgrading such systems and their hardware and software components in hospitals.

Conclusion

The findings of this study showed that technical challenges are the most important challenges of PACS implementation from the perspectives of involved staff and users. Among technical challenges, low bandwidth allocated to PACS, and lack of sufficient diagnostic monitors specifically challenge the implementation of the PACS system. These challenges can affect other dimensions and capacities of health care organizations. In addition to technical challenges, human, financial, organizational, managerial and standardization challenges are other challenges of implementing a PACS system. In present study, investigation of key user's views led to the prioritization and comparison of a wide range of PACS implementation challenges in two groups of hospitals affiliated with two different large universities in Iran. Two universities at the same level may face different challenges. As a result, the implementation of health information systems in different healthcare settings may pose both similar and different challenges. However, eliminating implementing challenges can reduce the risk of failure in the utilization process. The results of this study provide useful information to managers and authorities for predicting and overcoming potential challenges of PACS implementation and also to the hospitals that are planning to either implement or update PACS system.

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Compliance with Ethical Standards

Conflict of Interest The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Research Involving Human Participants - Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The study was approved by the Research Ethics Committee of Kerman University of Medical Sciences (Code of Ethics: IR.KMU.REC.1396.1343).

Informed Consent Informed consent was obtained from all individual participants included in the study.

Appendix A

Dear participant,

Thank you for agreeing to take part in this study investigating challenges of implementing Picture Archiving and Communication System in hospitals. To complete this questionnaire, it does not need to mention your name. All provided data will be kept in confidential. Please read each question carefully and answer each items. We greatly appreciate your valuable time and efforts that you will spend in filling out this questionnaire.

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Part A: Demographic information

Gender: Female ◯ Male ◯

Age:

<30 ◯ 30-39 ◯ 40-49 ◯ >50 ◯

Education Degree:

Associate's ◯ Bachelor's ◯ Master's ◯ Doctoral degree and higher ◯

Employment status:

Permanent ◯ Contractual ◯ Arbitrary ◯ Temporary ◯ Resident ◯

Work Experience:

<5 ◯ 5-10 ◯ 11-15 ◯ >16 ◯

Job:

Information Technology administrator ◯ Medical Equipment administrator ◯

Workplace: ……...

Part B: Questions

Please, specify to what extent you agree that the following issues challenge the implementation and adoption of the PACS system?

Number	Questions	Strongly disagree	disagree	Neither agree nor disagree	agree	Strongly agree
1	Low-speed network					
2	Lack of required programs and software					
3	Lack of required hardware					
4	Lack of high quality monitors					
5	Lack of access to comparable PACS information of different vendor for PACS selection such as features, price and maintenance					
6	Failure to integrate the PACS					

	System with HIS/RIS					
7	Impossibility of connecting to multiple workstations					
8	Failure to receive images from different modalities					
9	Being none web-based					
10	Impossibility of connecting to different viewers					
11	Impossibility of attaching audio file to PACS reports					
12	Problem of attaching textual file to PACS report					
13	Lack of experienced PACS vendors in the country					
14	Lack of medical imaging equipment compatible with the DICOM standard					
15	Lack of secure network with enough bandwidth					
16	Incompatibility of imported PACS systems with existing hospital systems					
17	Low speed of communication lines in the country					
18	Low capacity servers					
19	Loss of information when converting data from analog to digital					
20	Locking the worklists on modalities (e.g., MRI)					
21	PACS software bugs					
22	Lack of proper and specialized training for users					
23	Lack of ease of use					
24	Unfamiliarity of designers with the work environment					
25	Users resistance to change					
26	Anxiety for using the system					
27	Concern about losing the job					
28	Low expertize of the PACS administrators					
29	Lack of specialized human resources					
30	Increasing the workload of health care providers by this system					
31	Lack of Manager's awareness of the benefits of PACS					
32	Wasting the health care provider’s time					
33	Lack of research team in selecting and developing a PACS system					

34	Lack of collaboration between managers and users, and the design team					
35	Lack of customization based on organization requirements					
36	Incompatibility of existing traditional systems with the new system					
37	Failure to analyze existing systems and patterns before designing the new system					
38	Improper training of specialists about system					
39	Insufficient evaluation and control of employees activities					
40	Poor adaptation to use the PACS system					
41	Complexity of healthcare delivery processes					
42	Requiring major organizational changes					
43	Requiring major changes in healthcare delivery processes					
44	Lack of support by senior managers					
45	High cost of PACS hardware					
46	High cost of digitization of images					
47	High cost of purchasing a PACS					
48	Low cost-effectiveness of the PACS system					
49	High cost of designing the PACS					
50	High cost of PACS implementation					
51	High cost of PACS maintenance					
52	Intangibility of the PACS benefits for senior managers					
53	Lack of strategic IT planning					
54	Lack of budget					
55	Insufficient investment					
56	Lack of workload management in radiology department					
57	Lack of senior management support in the implementation of the PACS					
58	Poor management in hospitals					
59	Reluctance of hospital managers to invest on PACS					
60	Manager's fears of increasing complexity of management					
61	Generating high amount of data by PACS and information redundancy for managers					

62	Incompatibility of information systems leading to poor interoperability					
63	Lack of a comprehensive interoperability standard					
64	Problems in DICOM and PACS standardization					

Please add other challenges of PACS implementation that are not listed in the previous table.

Appendix B

Dear participant,

Thank you for agreeing to take part in this study investigating challenges of implementing Picture Archiving and Communication System in hospitals. To complete this questionnaire, it does not need to mention your name. All provided data will be kept in confidential. Please read each question carefully and answer each items. We greatly appreciate your valuable time and efforts that you will spend in filling out this questionnaire.

Maryam Eslami Jahromi

Master of Health Information Technology

Kerman University of Medical Sciences

Part A: Demographic information

Gender: Female ◯ Male ◯

Age:

<30 ◯ 30-39 ◯ 40-49 ◯ >50 ◯

Education Degree:

Associate's ◯ Bachelor's ◯ Master's ◯ Doctoral degree and higher ◯

Employment status:

Permanent ◯ Contractual ◯ Arbitrary ◯ Temporary ◯ Resident ◯

Work Experience:

<5 ◯ 5-10 ◯ 11-15 ◯ >16 ◯

Workplace: ……...

Part B: Questions

Please, specify to what extent you agree that the following issues challenge the implementation and adoption of the PACS system?

Number	Questions	Strongly disagree	disagree	Neither agree nor disagree	agree	Strongly agree
1	Lack of evidence about positive effect of the system on physicians workflow					
2	Lack of required hardware					
3	Lack of high quality monitors					
4	PACS software bugs					
5	Low experience of some radiologist to use computers for diagnosis and reporting					
6	Lack of proper and specialized training for physicians					
7	Low involvement of physicians in PACS implementation					
8	Complexity of using the PACS					

	system					
9	Poor user-friendliness of the PACS system					
10	Users resistance to change					
11	Anxiety for using the system					
12	Increasing the workload of health care providers by this system					
13	Wasting the health care provider's time					
14	Difficulty of using electronic images on screen compared to using traditional radiographs for medical specialists					
15	Lack of customization based on organization requirements					
16	Lack of proper conditions (e.g., organizational problems) for involvement					
17	Improper training of specialists about system					
18	Inadequate documentation with the PACS system					
19	Complexity of healthcare delivery processes					
20	Requiring major changes in healthcare delivery processes					
21	Poor adaptation to use the PACS system					
22	Lack of training courses about using PACS					
23	Low cost-effectiveness of the PACS system					
24	Simultaneous printing of radiographs which is costly					
25	Lack of budget					
26	Insufficient investment					
27	No real time provision of reports for physicians					
28	Generating high amount of data by PACS and information redundancy for physicians					
29	Lack of collaboration between physicians, and the design team					
30	Inappropriate perception of Physicians about software systems and PACS					
31	Incompatibility of information systems leading to poor interoperability					
32	Lack of a comprehensive interoperability standard					
33	Uselessness of the PACS system					

34	Obsoleteness of imaging devices and impossibility of communication with the PACS system					

Please add other challenges of PACS implementation that are not listed in the previous table.

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