J Med Syst (2012) 36:2697–2704
DOI 10.1007/s10916-011-9744-8

ORIGINAL PAPER

Managing Repeat Digital Radiography Images—A Systematic Approach and Improvement

Wen-Sheng Tzeng · Kuang-Ming Kuo · Chung-Feng Liu · Huan-Chung Yao · Chin-Yu Chen · Huang-Wei Lin

Received: 1 April 2011 / Accepted: 23 May 2011 / Published online: 31 May 2011

Abstract Repeat analysis is an important issue for improving image quality in the field of radiology. However, the required data for repeat analysis is not easy to collect, and the accuracy of the analysis results remains controversial. The main purpose of this study is to introduce a systematic approach and, with the assistance of information technology, to improve the accuracy of data collection methods and repeat analysis in a fully digital environment. Another purpose of the study was to reduce the human resources required to maintain image quality on a daily basis. The main participant in this study is the radiology department of a medical center in Taiwan. The hospital had previously implemented a Picture Archiving and Communication Systems (PACS), which was seamlessly integrated with Radiology Information Systems (RIS) and Hospital Information Systems (HIS). A comprehensive mechanism was built for repeat analysis. The analysis was primarily achieved through comparing the difference between the amount of accumulated digital radiography (DR) images and uploaded PACS images with data mining tools. Initially, the radiologic technologists seemed to be resistant to the new quality assurance mechanism, which introduce inaccuracy into the collected data. However, after introducing the improved standard operating procedures with the proposed approach for radiologic technologists, the number of DR images generated became optimal for comparison with the number of PACS images, which made this mechanism feasible. Furthermore, information was collected regarding the reasons for repeat images and was used for improving image quality. The results revealed that the new mechanism was both effective and accurate in the analysis of repeat images.

Keywords PACS · Quality assurance · Digital radiography · Data mining · Repeat analysis

W.-S. Tzeng · H.-C. Yao · C.-Y. Chen · H.-W. Lin (✉)
Department of Radiology,
Chi Mei Foundation Medical Center,
Yung Kang District,
Tainan City, Taiwan
e-mail: 850934@mail.chimei.org.tw

W.-S. Tzeng
e-mail: tzengg@ms31.hinet.net

H.-C. Yao
e-mail: gary737195@yahoo.com.tw

C.-Y. Chen
e-mail: chency@seed.net.tw

K.-M. Kuo
Institute of Information Management,
National Chung Cheng University,
Min-Hsiung,
Chia-Yi, Taiwan
e-mail: kuangmingkuo@gmail.com

C.-F. Liu
Department of Information Management,
Chia-Nan University of Pharmacy and Science,
Jen-Te District,
Tainan City, Taiwan
e-mail: fredliu@mail.chna.edu.tw

Background

The main purposes of "quality assurance" include cost control, reducing radiation exposure, and improving radiology image quality [1]. "Reject analysis" or "repeat analysis" is a crucial way of ensuring quality assurance [2–5]. In the past, a film that was deemed useless was considered a reject and was discarded. A repeat is a radiograph that is retaken to provide further diagnostic information, and that is sent with the original for analysis

[4]. Numerous indices exist with respect to radiographic image quality that cannot be calculated in concrete terms; however, repeat analysis can be used to determine factors that influence image quality [1]. Factors that negatively influence image quality should be determined and addressed to reduce the number of retakes [3]. The repeat rate is frequently used as the indicator for repeat analysis. The repeat rate is calculated as the ratio of the number of repeated images to the total number of images taken [6]. The practitioners performing the examinations usually decide which images to repeat [6]. Repeat analysis involves the calculation of the number of repeat images and can only be conducted after the number of repeat images is confirmed.

Obtaining radiographs involves exposing patients to radiation, and potential hazards are increased with increased exposure. Thus, in the field of radiology "ALARA (As Low As Reasonably Achievable)" is closely adhered to [7, 8]. Digital images are currently primarily obtained through Computed Radiography (CR) or Digital Radiography (DR). However, the price of CR/DR image plates is high, and every additional image increases hospital costs, as well as increasing wear on the CR/DR equipment. Thus, it is obvious that repeat images affect the health of patients by increasing their radiation exposure as well as causing a financial burden to hospitals. Thus, the radiology department should reduce the amount of repeat images as much as possible, and identify the reasons for repeat images through repeat analysis or reject analysis to improve image quality.

In the past, calculation of the number of repeat images was primarily performed manually [3, 9–12]. The efficiency of such process is low, and the continued implementation of quality assurance creates a large burden to the limited human resources of a radiology department. Although automated methods [5, 9, 13] have been developed for the collection and analysis of repeat images, this type of analysis is influenced by several factors including radiologic technologists' performance and radiographic capabilities. Furthermore, radiologic technologists may be compelled to collect the information involuntarily, which negatively influences the accuracy of information [9]. Past studies have also revealed that the implementation of such data collection methods for quality assurance is not easy, even in a digitized environment [5, 14]. Additionally, the number of medical apparatus and Picture Archiving and Communication Systems (PACS) vendors that can provide software with the required functionality is still limited [5, 9]. Even if quality assurance activities are provided, the mechanism requires integrating with Hospital Information Systems (HIS), and cannot be accurately calculated or analyzed in the time being. Conducting quality assurance analysis in a PACS environment is very difficult, and automatic evaluation is even more challenging [5].

Based on the above-mentioned criteria, this study proposes an innovative approach utilizing DR, PACS, a repeat image management system, data mining, and On-Line Analytical Processing (OLAP) tools, along with established repeat image administration procedures (coercive registration of repeat images by radiologic technologists when repeat images occurred and daily auditing of repeat images), to improve the accuracy of repeat image calculation. The purpose of this study was threefold: first to introduce a method to improve the accuracy of the calculation of repeat images without increasing the burden on the human resources of the radiology department. This was accomplished with the help of information technologies in a digital environment. The second purpose of the study was to assure quality by automating part of the quality assurance procedure. The final purpose was to analyze the reasons causing repeat images and to formulate coping strategies. The proposed repeat image calculating approach is not only laborsaving but also more accurate than manual operations. In addition, the proposed repeat image auditing mechanism lowered the rate of repeat images in the hospital in the study. Finally, improvements on reducing repeat images are proposed, which can be referenced by other healthcare organizations for improving image quality. A flowchart of the study is shown in Fig. 1.

Material & methods

Hospital of the study

The hospital in this report is a medical center with more than 1,300 beds. It is one of the primary medical institutions in southern Taiwan. The hospital conducts 249,215 general radiography examinations annually and produces an average of 384,194 images with an equivalent image size of 3.12 terabytes per year. The HIS of the hospital was developed quite early, primarily in-house. Before the introduction of the PACS, the hospital already had Radiology Information Systems (RIS) in place to assist the radiology department. The PACS was introduced in 2005. The PACS software was StarPACS 5.090 by Infinitt, Korea. The hospital has 12 DRs, (Canon CXDI-40G/50G, Japan) 5 of which are mobile (Canon CXDI-50G, Japan). Both patient demographic data and orders are input into RIS and PACS through the HIS using ODBC (Open Database Connectivity). They provide a standard DICOM (Digital Imaging and Communications in Medicine) modality worklist.

Most DRs can record the number of X-ray images taken in different time periods. If no retakes were made during the image radiography session, the number of images generated by DR (A) should be equal to the number of images uploaded

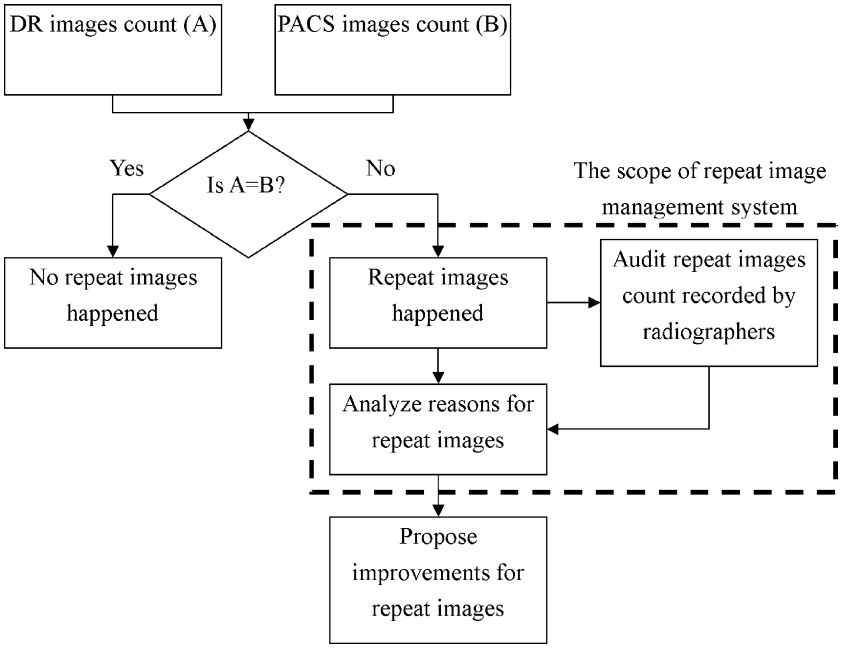

Fig. 1 Flowchart of this study and the scope of repeat image management system (in *dotted-rectangle*)

to the PACS (*B*) (i.e., in a specific time period, the total number of images generated by DR = number of images uploaded to the PACS). If the number is not equal, it means that there are repeat images (*C*), i.e., ($A–B = C$). The previous equation is true under the assumption that radiologic technologists will not upload repeat images intentionally or accidentally.

Although the hospital was using PACS, the above equation was not satisfied. In addition, the calculation of repeat images was done manually, and the results of repeat analysis and reject analysis were not optimal. Because of the size of the hospital and the sophistication of its IT applications, the hospital was selected as the subject of this study, which aimed at formulating an improved standard operating procedure for the radiology department to solve the problem of effort-consuming repeat analysis.

Image count generated through DR

DR systems almost universally include QC (Quality Control) stations that have the capability of modifying images before being sent to the PACS, as well as deleting unacceptable images. However, the DR system in the hospital did not track whether images were uploaded to the PACS or not. Other important information (e.g., exposure times), which can be used to calculate the number of images generated is usually stored on a file in QC stations of DR systems, which may be deleted by radiologic technologists intentionally or accidentally. At the hospital, the radiology department implemented rigorous administrative procedures to prevent this from occurring. Most of the information, such as DICOM headers and reasons of repeat images, were transferred to a data warehouse automatically from the PACS database. However, information regarding the number of daily DR images was not automatically transferred to the data warehouse; instead, the information was manually input into the RIS database by radiologic technologists because the DR system is not interoperable with RIS.

Uploaded PACS image count

Most PACSs in Taiwan are developed through outsourcing. Therefore, PACS vendors do not allow hospitals direct access to PACS databases. Hospitals can only access a PACS database through the worklist to exchange information between the HIS/RIS and the PACS. With an agreement between the hospital and the PACS vendor, the hospital was allowed to access the PACS database through a “read-only” format without disrupting PACS operation. With respect to the number of uploaded images, the hospital used the daily automatic exporting function of the database to transfer PACS information to the data warehouse.

Reasons for repeat images

Images that did not conform to diagnosis requirements were classified according to the reasons for the repeat images, and the collected reasons were then analyzed to improve the situation. To classify further the reasons for repeat images, the radiology department requested

the information technology department to develop a repeat image management system. The image management system is mainly based on client/server architecture. The development tool for the client is Visual Basic 6.0 (Microsoft) while the server database is Informix 9.4 (IBM). The primary function of the image management system is to record data required for repeat analysis. This includes patient information, radiologic technologist information, accession number, and the reason for the repeat images. Radiologic technologists were asked to complete the required fields of the repeat image management system whenever repeat images occurred during their shift. This had not been previously required. The reasons for repeat images, and definitions of reasons for repeat images were established through review of the literature [2, 5] and clinical experiences. Reasons were classified into equipment factors and other factors (Table 1).

Collection and analysis of repeat images

In order to reduce the cost of the collection and analysis of repeat images, all of the information was collected in the central database before conducting the analysis. Data warehouse (IBM, Informix RedBrick 6.3) and OLAP tools (Oracle, Hyperion 8.3) were utilized to conduct analyses on the gathered information. Data cubes, which can be used to organize and search information from multiple perspectives, were generated from the data warehouse. A data cube is an abstract representation of data structures of RDBMS (Relational Database Management Systems) that allows for fast and multi-perspective analysis. An appointed radiologic technologist preset the data cubes for rapid analysis of the repeat images from the data warehouse. Thus, the analysis of repeat images can be accomplished faster and more efficiently.

Implementation of the system

Past study [16] indicated that in the initial adoption stages of information systems, users may react negatively, and thus influence the acceptance of the system. In the preliminary stages of adoption, most radiologic technologists did not support the repeat image logging process. They objected to recording the necessary information into the image management system when repeat images occurred. They considered the process an additional work burden which negatively influenced their personal performance. The results were that the difference between DR statistics and PACS statistics were largely different from those logged in by radiologic technologists. Thus, in the early stages of system adoption, radiologic technologists doubted the accuracy of the resulting data. In order to prove the accuracy of the figures generated by the system, the radiology department decided to implement the system first in the emergency radiology department. The main considerations were the relatively simple shift system of radiologic technologists (three shifts only), and a compact and independent satellite working space which was separate from the main radiology department. These factors made it more convenient to conduct a pilot trial of repeat image monitoring and recording. The hospital's emergency radiology department was equipped with 1 DR and 3 image plates, which have the ability to process all of the radiographic position requirements.

The system was piloted in late 2007, and officially went online in January 2008. In the beginning stages of the adoption process, the radiologic technologists were encouraged, but not forced to use the system. The repeat image fulfillment rate (the repeat image count/actual repeat image count) reached a mere 60–70% (Table 2).The system was subsequently strictly enforced in June 2008, and the radiology department instructed that the execution rate of the system be included

Table 1 Code chart of the reasons for repeat images

Error Type	Code	Description
Equipment factors	MI	Image plate problems
	MC	DR or computer problems
	MX	X-ray problems
	MO	Other equipment problems
Other factors	P	Position error
	A	Artifacts
	PM	Patient movement
	PI	Image plate setting error
	PO	Problems with DR protocol
	PE	Image parameter error
	WS	Incorrect patient order (e.g., incorrect body part)
	WN	Incorrect MWL information (e.g., incorrect accession #)
	T	Test image without orders
	O	Other human-related errors

Table 2 Repeat analysis in Emergency Department for year 2008

Month	DX image count (A)	PACS image count (B)	Actual repeat image count (C=A–B)	Image repeat rate (C/A)	Repeat image count (D)	Repeat image fulfillment ratio (D/C)
Jan	12,014	11,373	641	5.34%	449	70.05%
Feb	11,915	11,180	735	6.17%	460	62.59%
Mar	12,641	11,905	736	5.82%	494	67.12%
Apr	12,063	11,429	634	5.26%	426	67.19%
May	12,139	11,452	687	5.66%	434	63.17%
Jun	11,769	11,180	589	5.00%	575	97.62%
Jul	11,129	10,725	404	3.63%	390	96.53%
Aug	11,001	10,591	410	3.73%	415	101.22%
Sep	11,159	10,765	394	3.53%	393	99.75%
Oct	12,415	12,023	392	3.16%	387	98.72%
Nov	11,759	11,288	471	4.01%	475	100.85%
Dec	12,455	11,978	477	3.83%	472	98.95%
Total	142,459	135,889	6,570	4.61%	5,370	81.74%

1. "Actual repeat image count (C)" refers to the difference between images count generated from Digital Radiography and uploaded to PACS.

2. "Repeat image count (D)" refers to the figure of repeat images reported by radiologic technologists, which is input into the image management system developed in this study.

3. The reason why the repeat image fulfillment ratio (D/C) went over 100 was due to the multiple entries by radiographers. The figures have not been altered to preserve the original figures.

in the annual assessment of radiologic technologists' performance. The subsequent usage rate reached almost 100% by the end of June 2008.

Results

Results of the analysis of 2008 data (Table 2) revealed that the occurrence of repeat images decreased from 5% to 3%, and that the fulfillment rate of repeat images increased from an average of 60% to 70% to nearly 100%. The results indicate that the implementation of the mechanism accurately revealed the number of repeat images, and thus could provide an accurate repeat images rate. The difference between the accumulated image count of DR and the number of images uploaded to the PACS by the hospital's emergency radiography system was very close to, or the same as, the numbers registered in the repeat image management system, proving that the mechanism of repeat images calculation was working properly (i.e., $A–B = C$).

In this study, the repeat images were analyzed with respect to the reasons for the repeat images and body parts. The most common reasons for repeat images between January and December 2008 were position errors, artifacts, and patient movement, which accounted for 79.93% of the repeat images (Table 3). Position errors accounted for the highest percentage of repeat images (35.59%). With respect to body parts where repeat images occurred, the thoracic spine (lateral view) and the pelvis were the most common accounting for 5.29% and 5.06%, respectively (Table 4). Positioning errors were the most common reasons for repeat images in different body parts, and accounted for 33.04% and 50.25% of the repeat images in the thoracic spine and pelvis, respectively (Table 5).

Discussion

According to the results of the repeat analysis, the average occurrence rate of repeat images in the hospital was 4.61%, a figure lower than that reported in the literature [4, 13]. The repeat rate between January and May 2008 may have been underestimated, but the rate since June 2008 has remained under 3%. The most common reasons for repeat images included position errors, artifacts, and patient movement, and position errors accounted for the highest percentage of repeat images (as shown in Table 3). The results are similar to those found in previous studies [4, 5, 10, 11, 14, 15] (Table 6), and indicated that position errors were the most common problem of the radiology department. In June 2008, problems caused by "other human errors" increased greatly, mainly because when the radiology department underwent auditing, they found that radiologic technologists did not use DR properly and deleted images intentionally, causing the number of repeat images to increase to 54 (87.1% of the total number of "other human errors" in 2008). Additionally, the radiologic technologists

Table 3 Analysis of reasons for repeat images in Emergency Department for year 2008

Month	Reasons for repeat images													Subtotal
	P	A	PM	PI	PE	T	MI	MC	MX	PO	WN	WS	O	
Jan	165	132	66	30	31	12	2	6	5	0	0	0	0	449
Feb	178	146	50	50	17	16	1	1	1	0	0	0	0	460
Mar	159	138	91	50	29	14	10	1	1	1	0	0	0	494
Apr	129	112	102	37	15	9	11	5	4	0	0	0	2	426
May	135	114	87	40	17	6	4	19	8	4	0	0	0	434
Jun	232	105	85	43	18	20	7	3	4	3	1	0	54	575
Jul	127	85	66	30	20	17	13	12	13	1	0	3	3	390
Aug	151	103	58	46	16	14	18	9	0	0	0	0	0	415
Sep	149	99	75	27	13	14	7	1	3	3	0	0	2	393
Oct	162	85	78	30	14	11	5	0	0	2	0	0	0	387
Nov	167	134	106	35	11	15	4	1	1	1	0	0	0	475
Dec	157	164	100	25	5	14	4	0	1	0	0	1	1	472
Subtotal	1, 911	1, 417	964	443	206	162	86	58	41	15	1	4	62	5, 370
Repeat images ratio (%)	35.59	26.39	17.95	8.25	3.84	3.02	1.6	1.08	0.76	0.28	0.02	0.07	1.15	

Reasons of repeat images include *P* Position error; *A* Artifacts; *PM* Patient movement; *PI* Image plate setting error; *PE* Image parameter error; *T* Test image without orders; *MI* Image plate problem; *MC* Equipment or computer problems; *MX DR* problems; *PO* Problems with DR protocol; *WN* Incorrect MWL information; *WS* Incorrect patient order; *O* Other human-related error

did not report all of the repeat images between January and May 2008, leading to an underestimation of the actual figures. However, underestimation of the repeat image count had always been difficult to prevent [14].

In this hospital, the occurrence of position errors was relatively high. Because this is related to the radiographic abilities of the radiologic technologists, the radiology department formulated a series of education and training programs to improve the abilities of the radiologic technologists. The collected data indicated that the main cause of artifacts were objects that patients brought with them. The radiology department thus added three additional dressing rooms to address this problem. Furthermore, multimedia presentations were designed and implemented to provide patient education, which including the need to remove objects from their bodies and how to hold their breath during examinations to reduce the occurrence of patient movement. In addition, the hospital began holding weekly sessions to discuss past errors and announce the three radiologic technologists with the highest image repeat

Table 4 Analysis of repeat images in Emergency Department for 2008—based on body parts

Body parts	Total repeat images (A)	Total images count (B)	Repeat rate (A/B)
Thoracic spine	115	2,173	5.29%
Pelvis	197	3,890	5.06%
Abdomen	989	22,247	4.45%
Chest	2,179	51,485	4.23%
Skull	543	12,989	4.18%
Lumbar spine	145	3,554	4.08%
Shoulder	32	845	3.79%
Extremity	226	6,171	3.66%
Cervical spine	303	9,191	3.30%
Elbow	85	2,818	3.02%
Clavicle	27	964	2.80%
Knee	154	6,378	2.41%
Hand	220	10,399	2.12%
Ankle	78	3,816	2.04%
Foot	77	4,339	1.77%
Total repeat images	4,168	96,338	4.33%

Table 5 Analysis of repeat rate by primary body parts and top three reasons in Emergency Department for year 2008

Body parts	Repeat rate	Primary reason	%	Secondary reason	%	Third reason	%
Thoracic spine	5.29%	Position error	33.04	Patient movement	20.87	Artifacts	20.87
Pelvis	5.06%	Position error	50.25	Artifacts	21.83	Patient movement	11.17
Abdomen	4.45%	Position error	36.30	Artifacts	35.59	Patient movement	13.25
Chest	4.23%	Position error	33.36	Artifacts	30.79	Patient movement	17.67
Skull	4.18%	Patient movement	37.38	Position error	36.10	Artifacts	15.29

rate, thus hoping to motivate radiologic technologists to protect their reputations. Additionally, X-ray quality assuring seminars were implemented every quarter, and the two radiologic technologists with the highest repeat rates had to share their experiences regarding the causes of repeat images and propose methods for improvement. The results showed that radiologic technologists reduced the number of repeat images to avoid having to share their poor performance publicly. Of course, different coping strategies for the causes of repeat images produce different results. Nevertheless, although the approach was implemented in the ER, it is now in an outpatient context. In other words, this new approach is applicable outside of an ER context.

The thoracic spine (lateral view) and pelvis were the body areas where the most repeat images occurred (as shown in Table 5). Generally, examinations of the thoracic spine and pelvis were not performed in the emergency unit. The main reasons were that these procedures are performed infrequently and time was crucial in the emergency unit. In addition, emergency patients were usually supine when the radiographs were taken, and it was not possible to take the images in a way that would yield higher quality images, e.g., through the use of a table Flat Panel Detector (FPD). The most commonly used equipment was a cassette FPD, which was not easy to affix and could result in a higher rate of repeat images. Finally, patients in emergency situations were usually not very cooperative. All these factors led to the high occurrence rate of repeat images in the thoracic spine and pelvic areas.

In past studies, the highest occurrence of repeat images have been reported to occur in the abdomen, chest, and skull, and the rates in these areas were 4.45%, 4.23%, and 4.1%, respectively, in this hospital (as shown in Table 5). Some studies have reported that the most common location of repeat images is in the chest, and this was primarily due to the fact that the chest is the most commonly examined body part [10]. Although in this study the chest was not the body area that generated the highest occurrence of repeat images, the occurrence rate was 4.23%.

The main reason that position errors were most common in the thoracic spine and the pelvis was the abilities of the radiologic technologists. Errors in the thoracic spine were primarily due to patient movement and artifacts (approximately 20.9% in each case). The greatest reason for error in the pelvic region was artifacts (21.83%). Some of the other reasons for the occurrence of repeat images included the fact that most of the patients in the emergency department were treated in an urgent situation due to injury, thus it was difficult to control their movements. Furthermore, due to the urgent nature of the situations, there was frequently not enough time to remove objects carried by patients.

Benefits of the proposed approach

The main purpose of this study was to improve the accuracy of the calculation of repeat images with the assistance of IT. Quality assurance and reducing repeat images were also goals. The results show that the accuracy of the calculation of repeat images is clearly enhanced. Furthermore, the reasons for repeat images are important references for formulating strategies to improve repeat

Table 6 Comparison of study results

Study	Repeat/Retake Rate		
	Position errors	Artifacts	Patient movement
Dunn & Rogers (1998)	85%(Knee)		6%(Thoracic Spine)
Weatherburn et al. (1999)	78.5%		1.4%
Peer et al. (1999)	81%		
Honea et al. (2002)	61.78%	4.38%	
Lau et al. (2004)	55.4%	12.1%	2.3%
Prieto et al. (2009)	65%(Abdomen)		
This Study	50.25%(Pelvis)	35.59%(Abdomen)	37.38%(Pelvis)

images. This can result in a lower repeat rate. Benefits for both administrative control and healthcare quality are attained through this approach.

Managerial/theoretical implication

The approach proposed in this study can be used to guide research on the management of repeat/retake images. The calculation of repeat images can be further investigated to identify a better methodology for improved quality assurance. This study shows that the process of developing and improving the method for managing repeat images requires long-lasting commitment [14], and this goal can only be achieved with the full support of top management. Furthermore, comprehensive and accurate quality assurance requires proper mechanisms which include software and hardware. The future direction for PACS vendors should be the development of automation tools that support the analysis of repeat images.

Limitations and future research

The results of this study indicated that the proposed system was feasible for the collection and calculation of repeat images at the hospital studied. The concept of comparing the difference in the number of images between CR/DR and the PACS to assist in managing repeat images is quite straightforward; however, there are two points regarding the generalizability of this study that deserve attention. First, generalizability is influenced by many factors such as the types of exams performed and the skill level of the radiologic technologists. Secondly, the mechanism used in this study would not be possible to implement on all PACS/RIS systems and CR/DR units.

Although repeat images might be uploaded to PACS by radiologic technologists intentionally or accidentally, these images will be discovered when radiologists interpret the study. However, this problem might limit the accuracy of repeat image counts. In addition, future studies can focus on repeat images produced by radiologic technologist trainees. The findings of such studies could serve as a valuable reference for later training/teaching programs.

Conclusions

This study has proposed a systematic approach to improve the accuracy of repeat image calculation with the assistance of information technology. By comparing the difference between the amount of accumulated DR images and uploaded PACS images, the number of repeat images can be correctly calculated. The average rate of repeat images improved significantly. Furthermore, the reasons for repeat images were collected and analyzed to formulate coping strategies that would reduce the repeat rate. Owing to the proposed approach, both the accuracy of repeat image calculation and the quality assurance of images significantly improved. Accuracy of repeat image calculation is a perquisite for quality assurance, and this study is only the initial step toward quality assurance. The findings of this study should encourage further research into the management of repeat images. This will be beneficial to academic researchers, practitioners, and patients alike.

References

1. Linton, O. W., Properzio, W. S., and Steele, J. P., Quality assurance: an idea whose time has come. *Am. J. Roentgenol.* 133:989–992, 1979.
2. World Health Organization, *Quality assurance in diagnostic radiology*. World Health Organization, Geneva, 1982.
3. Schandorf, C., and Tetteh, G., Analysis of the status of X-ray diagnosis in Ghana. *Brit. J. Radiol* 71:1040–1048, 1998.
4. Dunn, M. A., and Rogers, A. T., X-ray film reject analysis as a quality indicator. *Radiography* 4:29–31, 1998.
5. Prieto, C., Vano, E., Ten, J., et al., Image retake analysis in digital radiography using DICOM header information. *J. Digit. Imaging* 22:393–399, 2009.
6. Rogers, K. D., Matthews, I. P., and Roberts, C. J., Variation in repeat rates between 18 radiology departments. *Brit. J. Radiol* 60:463–468, 1987.
7. Clark, P. A., and Hogg, P., Reject/repeat analysis and the effect prior film viewing has on a department's reject/repeat rate. *Radiography* 9:127–137, 2003.
8. Farman, A. G., ALARA still applies. *Oral. Surg. Oral Med. Oral. Pathol. Oral. Radiol. Endod.* 100:395–397, 2005.
9. Nol, J., Isouard, G., and Mirecki, J., Digital repeat analysis; setup and operation. *J. Digit. Imaging* 19:159–166, 2006.
10. Weatherburn, G. C., Bryan, S., and West, M., A comparison of image reject rates when using film, hard copy computed radiography and soft copy images on picture archiving and communication systems (PACS) workstations. *Brit. J. Radiol.* 72:653–660, 1999.
11. Peer, S., Peer, R., Walcher, M., et al., Comparative reject analysis in conventional film-screen and digital storage phosphor radiography. *Eur. Radiol.* 9:1693–1696, 1999.
12. Akhtar, W., Aslam, M., Ali, A., et al., Film retakes in digital and conventional radiography. *J. Coll. Physicians Surg. Pak.* 18:151–153, 2008.
13. Foos, D., Sehnert, W., Reiner, B., et al., Digital radiography reject analysis: data collection methodology, results, and recommendations from an in-depth investigation at two hospitals. *J. Digit. Imaging* 22:89–98, 2009.
14. Honea, R., Blado, M. E., and Ma, Y., Is reject analysis necessary after converting to computed radiography? *J. Digit. Imaging* 15:41–52, 2002.
15. Lau, S.-L., Mak, A. S.-H., Lam, W.-T., et al., Reject analysis: a comparison of conventional film-screen radiography and computed radiography with PACS. *Radiography* 10:183–187, 2004.
16. Dowling AF: Do Hospital Staff Interfere with Computer System Implementation? *Health Care Manage* R 5:23-32, 1980.