The Effect of a PACS on Patient Radiation Doses and Operating Costs in a Radiology Department: A Practical Study

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Abstract

This study was conducted to investigate how the implementation of a picture archiving and communication system (PACS) affects patient radiation doses and operating costs of the radiology department. Doses were compared based on measurements of radiation loads before and after PACS operations. Obtained results showed that the use of PACS was significant in causing differences in the total radiation doses and in operating costs of radiology department.

Keywords: Hospital information system; Radiology information system; operational costs; radiation dose.
1. Introduction

Principles of PACS were first time internationally discussed by radiologists in 1982. Radiologist Duerinckx reported in 1982 [1] that he had first used the term PACS in 1981. However, Dwyer in 2000 [2] designated Judith M. Prewitt for introducing the term. PACS, in generally, can be characterized as a computerized means of replacing the roles of conventional radiological film: images are acquired, stored, transmitted, and displayed digitally [3]. The system is based on personal computers and is integrated with the existing hospital information system (HIS). The integration is important, since communication of PACS with RIS (Radiology Information System) insures effective conditions for radiologist [4]. Picture archiving and communication system has 4 main functions [5]: it enables physicians to review images on their workstations either at work or at home; it allows short term and long term archiving of crucial radiology information (magnetic or optic media); it shares image information thanks to local or communal communication networks; it insures integration of all sorts of different radiology modalities with other clinical information systems.

Deeper history of PACS is connected with the teleradiology. First attempt of distance teleradiology using the Finland national television broadcasting network was tested in 1969 [6]. Hospital information systems based on Local Area Network have been introduced in 1970s [7]. Wireless network connections for teleradiology include satellite transmission, microwave transmission and mobile phones connections. Satellite connections are used directly or as part of WAN (Wide Area Network) connections. These high-capacity networks are mostly used for image traffic between PACS archives and also for regional teleradiology and image transfer networks [8].

The purpose of this study is to explore the tendency of radiation dose to patients and changes in operating costs in a Radiology Department after implementing a Picture Archiving and Communication System. The paper is structured as follows. The next section provides a short review about development/introduction of PACS and set of summaries of selected related works. Then methodical approaches leading to data collection are described. Subsequently, obtained results are in a table form presented and discussed. Finally, major findings and their implications are presented.

2. Related works

Practical implementation of the first PACS systems happened in the early 80s in USA – University of Pennsylvania, University of California - Los Angeles and University of Kansas. In Europe similar implementation took place in Denmark, Belgium, France, Austria, Italy, Great Britain, Germany and in Scandinavian countries. Most of these systems focused on image sharing within one department, mainly radiology and nuclear medicine. Physician Harold Glass, working in London, was one of the pioneers of PACS implementation into practice. At the beginning of the 90s he managed to get financial means from the government of Great Britain and thus was able to start a project which transformed Hammersmith Hospital in London into the first film-free hospital in Great Britain [9].

Principally, there are two basic systems for digitalization of the image in scigraphic examinations: 1. Computed radiography (CR) that is a form of x-ray imaging, where digital X-ray sensors are used instead of traditional photographic film. Advantages include time efficiency through bypassing chemical processing and the ability to digitally transfer and enhance images; 2. Direct radiography (DR) is based on the same sensors and moreover it is a cassette-less based digital radiography technology. DR's advantage with comparison to CR is that it is much faster and also easier for staff to work with. Direct Radiography is however more expensive than CR [10]. Digital radiography has many advantages: higher image quality, dose reduction, image post-processing, digital archiving, telemedicine options, various printing options, etc. [11], [12]. For documentation of digital images we can use the following printing methods: laser camera, video printer,
classic PC printer and so forth. These options can be applied to all digital modalities in radiology department [13].

There has been considerable interest in the development of PACS since the 1980s. Apart from optimists, others emphasized the possible negative aspects of PACS effectiveness, particularly the sceptical view was dedicated to the issue of whether PACS are ready for routine use [14], [15]. Nowadays, it is beyond question that PACS are ready for routine use for consultations between clinicians and radiologists [16], [17].

In generally, three basic PACS implementation approaches can be identified [18]. In the first approach, through a systems integrator, a multidisciplinary team with technical know-how is assembling selected PACS components from various vendors. The team develops system interfaces and writes the PACS software according to the clinical requirements of the hospital. The second approach is based on requirements specification and contracting. A team of experts, from both outside and inside the hospital, is assembled to write detailed specifications for the PACS for a specific clinical environment. Subsequently, a supplier is contracted to implement the system. In the third approach a turnkey program is applied. The manufacturer develops a turnkey PACS and installs it in a department for clinical use. Each of these approaches has advantages and disadvantages as it is described in details by Hayt and Alexander [19].

3. Data collection

This study is based on a method of comparing the number of repeated X-ray examinations before and after implementation of PACS. X-ray re-examination is needed when image quality is not sufficient for medical diagnostics. It is up to radiographer to make a call to re-examine patient when he clearly sees that the X ray image he made cannot be reported by a radiologist. Certainly radiologist too can make a request for a re-examination when he is not satisfied with the quality of the image he needs to report. Poor image quality can be a result of technical error (exposure problems, film developing problems), radiographer’s error, uncooperative patient etc. Data for this study had been obtained from the reports of repeated X ray examinations from central X-ray examination room that belongs to Radiology clinic, which is a part of University hospital. The above mentioned data were collected during the time when Radiology clinic was undertaking complete digitization. During this time period was this clinic also equipped with state of the art technologies. Digitization was provided by ADC AGFA Company and PACS by renowned IBM. A schematic diagram of a PACS and Radiation Exposure Monitoring (REM) process flow is shown in Figure 1.

![Fig. 1. A schematic diagram of PACS/dose reporting system](image-url)
Data were collected during the time period of 12 weeks (six weeks before and six weeks after the implementation of PACS system). During one 6 week long period, X-ray examination room performed approximately 5200 x-ray examinations. The data collecting duration is in my opinion long enough to suggest an increase or a decrease of repeated examinations.

After the digitization and implementation of PACS, radiology clinic expenses change. It is however important to note that initial costs of such a radical technology improvement are very high. After successful implementation into digitalized workplace, film material expenses vanish. In this study it is shown how much is approximately saved in this radiology clinic on film material and chemical material during a one year period.

4. Results presentation

Final figures of repeated examinations before and after the implementation took place are listed in the following tables. In Table 1 percentage figures are shown. These were calculated from the total number of performed examinations for a certain 6-week period.

Table 1. Comparison of repeated examinations [20]

| Evaluated characteristics       | Before PACS implementation | After PACS Implementation |
|---------------------------------|----------------------------|---------------------------|
| Number of repeated examinations | 141                        | 11                        |
| Percentage of repeated examinations | 2.71 %                  | 0.21 %                    |

Note: Percentages were calculated from 5200 examinations

Department of conventional radiology of University hospital carry out approximately 50500 X-ray examinations per year and approximately 3000 fluoroscopic examinations per year.

Expenditures which consist mostly of film materials and chemicals are for such a number of exams considerable. After the PACS implementation at the Central X-ray unit these expenditures were reduced significantly. Comparison of expenditures before and after PACS implementation is shown in Table 2.

Table 2. Expenditure on films and chemicals per year [20]

| Evaluated characteristic          | Before PACS implementation | After PACS Implementation |
|-----------------------------------|----------------------------|---------------------------|
| Expenditure on films and chemicals per year | 287 585 EURO            | 95915 EURO                |

It is also important to say that, branch workstations of the Radiology clinic were not yet digitalized when this study was conducted (in 2009). After this expected digitization and when the branch workstations will be integrated into PACS, then the expenditure reduction in the long run might be increasingly greater.

5. Discussion and Conclusions

Results of this study show influential reduction of repeated radiology examinations after PACS implementation in real hospital conditions. This fact confirms assumption that PACS has ability to improve the efficiency of the use of medical image information. The reason why patient radiation doses and operating
costs reduction in a radiology department is possible needs some explanation. One of the most typical reasons for repeated X-ray examinations is under-exposition or over-exposition of X-ray films. It causes readability problems for evaluation of X-ray films by radiologists. Images generated through digital radiography are instantly available on the diagnostic monitor with constant high quality. Software tools to zoom in or to add contrast to the digital image are available and enhance ease and accuracy of screening. These post processing tools can improve the quality of an image also in case when exposition wasn’t ideal and this way lower the number of repeated examinations.

Issues of poor readability and deterioration or loss of films are prevented. Moreover, digital radiology systems using PACS can efficiently archive and retrieve large numbers of images. This eliminates the high archiving cost of analogue film based images. Using the universal DICOM (Digital Imaging and Communications in Medicine) format, the PACS is attaching patient information to the right image, eliminating the risk of storing a film in the wrong subject card and enhancing patient safety. DICOM is a format that is most commonly used for system PACS.

It has to be emphasised here that initial investment costs of PACS equipment are quite high. Determining cost-effectiveness is not an easy task to do. Obtained findings regarding the expenditure on films and chemicals before and after PACS implementation show a significant cost saving. In spite of the fact, Arenson [21] a priori does not consider the cost saving to be substantial because of the capital expense of PACS. This fact is a reason for a relatively long pay-back period of such investment. According to Hilsenrath et al.[22] positive cash flow from investing into PACS can be expected after 9 years. However, a reduction in PACS maintenance expenses from 7% to 5% of acquisition cost can reduce the payback period by about 1 year [23].

The main advantages that PACS provides is the ability to provide a timely delivered and efficient access to images, interpretations and related data throughout the hospital. This helps to ease collaboration between radiographers and radiologists. Another feature of PACS is the ability to digitally enhance the images, providing more detailed and sharper images. This improves diagnostic capabilities at radiological examinations. Among further Advantages of PACS rank, for instance: rapid access to critical information to decrease exam-to-diagnosis time; handling and storage costs; images can be easily shared between reading radiologists; radiologists can access digital copy of images instantly after acquisition to expedite diagnosis.

In addition, thanks to PACS and HIS integration, paper documentation is substituted by electronic files and image documentation is replaced by electronic formats and these changes lead to the ability to reach paperless and film less hospital operation.

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