Development of an Online Automatic Computed Radiography Dose Data Mining Program: A Preliminary Study

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Abstract

Recent studies have reported the computed radiography (CR) dose creep problem and therefore the need to have monitoring processes in place in clinical departments. The objective of this study is to provide a better technological solution to implement a regular CR dose monitoring process.

An online automatic CR dose data mining program which can be applied to different systems was developed based on freeware and existing softwares in the Picture Archiving and Communication System (PACS) server. The program was tested with 69 CR images. This preliminary study shows that the program addresses the major weaknesses of some existing studies including involvement of manual procedures in the monitoring process and only applicable to a single manufacturer's CR images. The proposed method provides an efficient and effective solution to implement a CR dose monitoring program regularly in busy clinical departments to regulate the dose creep problem so as to reinforce the 'As Low As Reasonably Achievable' (ALARA) principle.

Keywords

Computed Radiography

Data Mining Program

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1. Introduction

Recent studies have reported the computed radiography (CR) dose creep problem and the need to implement dose monitoring process in place in clinical departments [1-3]. The dose creep problem is the effect of several causes. The wide dynamic range of CR systems enables technologists to produce acceptable or even better quality images in usual overexposure situations. However, underexposure remains undesirable due to quantum mottle (noise). A tendency has occurred to overexpose patients for obtaining acceptable or better images. This problem can propagate because good image quality is always favoured by radiologists but overexposure is difficult to identify when looking at CR images [2,4,5]. This problem can be overcome through quality assurance (QA) programming by evaluating exposure indices of CR images regularly [1,2,6]. Exposure indices are dose feedback indicators provided by CR manufacturers to show relative radiation amounts that reach image plates such as AGFA's logarithm of median exposure (Lgm), Fuji's sensitivity number (S-number) and Kodak's exposure index (EI) [6-9]. This information is stored in the Digital Imaging and Communication in Medicine (DICOM) header of an image but in different tags (AGFA's Lgm in tag 0019,1015 [1]; Fuji's S-number in tag 0018,6000 [2,7] and Kodak's EI in tag 0018,1405 [8]).

In the study conducted by Stewart et al. [2], a dose monitoring program was implemented to monitor Fuji CR dose. A Fuji data mining program running on a Picture Archiving and Communication System (PACS) (Centricity 2.0, GE Healthcare) was executed automatically once per month. This program extracted S-numbers and other relevant information such as accession number, study date, study time, study description and station name from DICOM headers of images archived in the PACS of the previous month. The main weakness of this Fuji program is that it is only able to extract the S-number from the first image of each examination. A manual process was developed to export monthly missing information, i.e. exposure result log from the CR stations to a floppy disk. Then, a visual basic (VB) program was used to integrate this text file with the comma separated values (CSV) file output from the data mining program for generating a dose report using Microsoft Excel manually. In a similar study conducted by Juste et al. [1], an offline executable program (compiled by MathWorks Matlab 7.3) was developed to extract Lgm values from DICOM headers of AGFA CR images exported from archive for dose monitoring purposes. Again, this requires a manual process to accomplish the export task. The objective of this study is to provide a better technological solution to implement a regular dose monitoring process, i.e. to develop an online automatic CR dose data mining program which can be applied to different CR systems including AGFA, Fuji and Kodak with the aim of reinforcing the ‘As Low As Reasonably Achievable’ (ALARA) principle [4,10].

2. Materials and Methods

At our institution, a freeware PACS, ConQuest DICOM server 1.4.13 [11], running the Microsoft SQL Server 2005 database management system (DBMS) was installed in a Dell PowerEdge 2950 machine with a Microsoft Server 2003 Operating System (OS). A web server, Internet Information Services (IIS) 6.0, bundled with the OS was also installed for a web-based PACS service. The primary purposes of this PACS are for archiving DICOM files from two AGFA CR stations and a VIDAR film digitizer in student X-ray laboratories and external sources for research purposes, and demonstrating the PACS operation to medical imaging students.

A model of a CR dose data mining program is proposed by taking into consideration the possibility of providing an online automatic solution for the dose monitoring purpose (Fig. 1). A web client such as a person in charge of dose monitoring can use a web browser to provide different evaluation parameters such as manufacturer, study period, image quality baseline and dose limit to the web server over the network such as internet or intranet (step 1). The image quality baseline is a baseline of EI to obtain acceptable image quality. An EI of an image beyond this value indicates that it has unacceptable quantum noise and been underexposed. The dose limit is another extreme and an EI beyond this point represents overexposure.

Fig. 1 – A model of a CR dose data mining program.

Following are the recommended values of image quality baselines and dose limits for different CR systems: AGFA – 1.76 (baseline) and 2.26 (limit) [6]; Fuji – 75 (limit) and 500 (baseline); and Kodak – 1700 (baseline) and 2200 (limit) [12]. It is noted that dose increasing yields a smaller S-number in Fuji system while dose decreasing produces a larger value. For example, a S-number of 74 indicates overexposure while a value of 501 represents underexposure. This arrangement is different from other manufacturers [6,9,12]. The web server executes appropriate Active Server Pages (ASP) scripts (ASP-VBScript), i.e. the CR dose data mining program to retrieve the file paths of DICOM images matching the search (evaluation) parameters from the PACS database using Structured Query Language (SQL) (step 2). These scripts then retrieve the DICOM files from the image archive system (step 3) and execute a freeware component object model (COM) object, ezDICOMax Library 1.0, ezDICOM [13], to extract header information from the DICOM images (step 4). The extracted headers are further processed by the ASP scripts to mine values of relevant tags including service object pair (SOP) instance unique identifier (UID), series instance UID, study instance UID, accession number, study date, study time, study description, station name, exposure index (Lgm, S-number or EI depending on the selected manufacturer) and manufacturer. The extracted information is exported to a CSV file for providing a possibility for further Microsoft Excel manipulation.

The EI is also analysed by the algorithms inside the ASP scripts to provide a series of descriptive statistics such as mean, standard deviation (SD), median, lower quartile (Q1), upper quartile (Q3), interquartile range (IQR), minimum, maximum, range, percentages of under- and over-exposed images. These results are then exported to a CSV file again and sent to the web browser for display (step 5).

3. Results

Using the proposed model shown in Fig. 1, an online automatic CR dose data mining program which can be applied to different CR systems including AGFA, Fuji and Kodak, was developed. There is a login page for authentication to secure the information. Other security measures include timestamp to show the last login time and ‘Logout’ once finished using the system. A user is directed to the dose monitoring system through the login page upon successful authentication (Fig. 2). In Fig. 2, the first rectangle highlights the main menu for the user to input the evaluation parameters. The recommended values for the image quality baseline and dose limit are provided in the textboxes as default. These values change automatically according to the selection of manufacturer. However, the user is free to modify them in different situations. After the user provides the evaluation period and clicks the ‘Submit’ button, the dose report for the selected period is generated automatically as shown in the third rectangle. This dose report lists the descriptive statistics of EI of different regions of interest and the last row of the table displays the figures of all examinations taken in the selected period. Grey is the default colour for the figures.

Fig. 2 – A snapshot of the online automatic CR dose data mining program. Rectangle 1: evaluation parameter input menu; rectangle 2: user name and last login time (timestamp); rectangle 3: dose report; rectangle 4: report and data export buttons; rectangle 5: logout button.

However, figures are highlighted in either red (overexposure) or blue (underexposure) if they are beyond the input limit or baseline respectively. The user can track unacceptable images through accessing the links under the ‘Examination’ column, i.e. clicking the regions of interest. A new window (dose tracking page) is opened to show the extracted DICOM tag values of the images under the selected category and period such as SOP Instance UID (Fig. 3). This enables the user to retrieve, if necessary, the undesirable images from the PACS based on the SOP instance UID for further investigation. Again, individual items are highlighted in red or blue if their EIs exceed the limit or baseline. The user can also use the ‘Filter’ function (first rectangle) to show information of all images or just the under- or over-exposed ones. The second rectangle highlights the ‘Export Data’ button for the user to download the displayed information as a CSV file. The export function is also available in the system main page for the user to download the report and all raw data for further manipulation if necessary (Fig. 4).

Fig. 3 – A snapshot of the dose tracking page. Rectangle 1: filter function; rectangle 2: data export button.

Fig. 4 – A snapshot to show the raw data export function. This snapshot was taken after the ‘Export Data’ button (rectangle 1) was clicked.

This program has been tested with 69 CR images (27 AGFA and 42 Fuji images). The extracted DICOM tag values and descriptive statistics displayed in the dose reports were verified by comparing them with the figures obtained using a manual approach. No discrepancy was found.

4. Discussion

Evidence to date suggests an online automatic CR dose data mining program can be successfully developed. It addresses the major weaknesses of some existing studies, i.e. involvement of manual procedures and being specific to only a single manufacturer’s CR images [1,2]. It seems the limitation of the latter issue is not significant because a clinical department usually has CR systems supplied by one manufacturer. However, involvement of manual procedures limits the potential of the systems to generate real-time dynamic dose reports because it requires an individual to provide latest data to the program when an update report is requested. This may also lead to human errors in the manual process which will affect the report accuracy [14]. Such situations diminish the value of computer programs which aim at increasing the efficiency (fast report generation) and effectiveness (elimination of human errors) of the regular dose monitoring process.

In contrast, the program developed in this study resides at the PACS server machine and can obtain the latest DICOM images archived in the PACS instantly, generating a real-time dynamic dose report on demand which is then displayed in the web browser of the user's workstation. Results can be exported as a CSV file for further manipulation if necessary. Also, the online access provides the ubiquitous availability of the report through a web browser without intervention of any special client software [15]. This program was developed based on freeware and existing softwares in the PACS server, and can be applied to different CR systems. The dose data mining program can promote the approach of monitoring CR doses regularly and efficiently, so as to reinforce the ALARA principle [1,2,4].

The limitation of this study is that the program has not been evaluated extensively (e.g. clinically and with Kodak CR DICOM files) although it has been tested with AGFA and Fuji CR images at our institution. This then is a direction for further studies. Although it may appear that the data mining process may induce a risk to patient privacy, implementation of security measures could safeguard the patient confidentiality and prevent abuse by users. These include extraction of only image-related information from DICOM headers and with user authentication [16]. Further protection can be achieved by restricting the system access such as it being only available via intranet, i.e. within clinical departments or hospitals.

5. Conclusion

An online automatic CR dose data mining program which can be applied to different CR systems was developed and has been tested with AGFA and Fuji images. Our preliminary study shows that the program addresses the major weaknesses of some existing studies, i.e. involvement of manual procedures and being only specific to a single manufacturer's CR images. This provides an efficient and effective solution to the implementation of a regular CR dose monitoring program in busy clinical departments. In this way, the dose creep problem can be regulated, thus the ALARA principle can be reinforced.

Conflict of interest

None declared.

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