An evaluation of the impact of digital imaging on radiographic practice and patient doses

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Abstract. Direct digital imaging technology was implemented in all areas in general and mobile radiology at Barts and the Royal London Hospitals in 2012. Evidence from recent radiation incident investigations indicates optimum exposure factors are not consistently selected, with the greater dynamic range of the digital detectors allowing sub-optimal practice. To investigate further patient dose data were extracted from the Radiology Information System for adult chest X-ray examinations in 2014, covering over 50,000 studies in the Trust. Chest X-ray examinations were selected as they are low dose but frequent examinations. The patient dose data were evaluated taking into account X-ray system type and detector performance measurements, and individual cases studies were used to highlight where practice can be improved.

1. Introduction

The use of electronic X-ray examination records contained in Radiology Information Systems (RIS) to audit patients doses and set Diagnostic Reference Levels (DRLs) has the advantage of allowing large numbers of examinations to be audited, but is prone to manual data entry error [1, 2]. The Royal London Hospital moved to a fully digital radiography imaging service in 2012 when a new building was opened. It was noted during 2012 that the number of internally reported radiation incidents attributed to either equipment or operator error increased, such as loss of images during transfer due to network problems and operators ignoring system warning messages. Reviewing these incidents highlighted the need for further operator training. More recently staff reporting or reviewing radiographs noted high exposure factors on a number of chest radiographs. A review of the doses and protocols was undertaken.
2 Materials and Methods

2.1 Imaging equipment and radiography protocols

The general X-ray equipment in use at the Royal London Hospital is listed in Table 1. There are 20 Carestream DRX-1 wireless detectors, which can be moved between the different Carestream systems. The eight Carestream rooms are located in Accident and Emergency (A&E) X-ray, Inpatient X-ray and Outpatient X-ray. The two Xograph systems are mounted on a ceiling track and serve the Resuscitation Room in A&E. The mobile systems are allocated to different floors in the hospital.

Table 1. General X-ray equipment at the Royal London Hospital

| System                  | Number | Detector     | Converter | Pixel pitch \((\mu m)\) |
|-------------------------|--------|--------------|-----------|-------------------------|
| Carestream Evolution Dual Bucky | 8      | Carestream DRX-1 | Gd\textsubscript{2}O\textsubscript{2}S | 139                     |
| Carestream DRX Evolution mobile | 5      | Carestream DRX-1 | Gd\textsubscript{2}O\textsubscript{2}S | 139                     |
| Xograph Arco            | 2      | Canon CXDI-70C | CsI       | 125                     |
| Shimadzu Dart mobile    | 3      | Canon CXDI-50C | CsI       | 160                     |

Typical modulation transfer function (MTF) and detective quantum efficiency (DQE) measurements for the three detector types measured during routine quality assurance (QA) testing are shown in Figures 1 and 2. The images required for the analysis were obtained at 70 kV, filtered with 1 mm Cu, with a detector entrance air kerma of approximately 10 \(\mu\)Gy for the MTF measurement, and 2.5 \(\mu\)Gy for the noise power spectrum measurement.

All the systems have programmed exposure factors and exposure charts for manual exposures.

![Figure 1](image1.png)  ![Figure 2](image2.png)

Figure 1. Typical MTF measurements for the 3 system types.  Figure 2. Typical DQE measurements for the 3 system types.

2.2 Dose Recording and Audit

Sectra PACS and RadCentre Radiology Information System (RIS) was used at the Royal London Hospital in 2014. Information on the X-ray examinations is entered into the RIS by the radiographer following the exposures and therefore is prone to data entry error. Examination type and room / mobile unit used are selected from drop down menus. Dose information such as Dose Area Product (DAP), kV and mAs is entered manually. The data extracted from the RIS system included the examination date, examination type, patient hospital ID, patient date of birth, X-ray room or system, kV, mAs, and DAP. Paediatric data was excluded from the data set. No information on patient weight or height was provided.
There were 37,352 adult chest X-ray examinations recorded on the RIS system at The Royal London Hospital in 2014. Of these 30,813 (82.5 %) had a DAP recorded. The room DAP calibration factor was then applied and all DAPs converted to Gycm². The first thing to consider was the accuracy of the data by applying cleansing to the RIS-based data, which was carried out by inspecting the DICOM headers of outliers. Multiple manual data entry errors were found including numbers of examinations entered under one examination code, data entered into incorrect fields, and incorrect DAP unit entered.

Due to the large number of manual data entry errors two approaches were used to review the data. Data was extracted from the DICOM headers via visual inspection of the headers for high dose examinations (DAP > 0.2 Gycm², 650 examinations) and from a sample of 100 consecutive examinations in June 2014. For the second approach, patients who had multiple X-ray examinations during 2014 were reviewed.

3 Results and Discussion

3.1 Data sampled from June 2014

The mean DAP values for each X-ray system, including those in rooms and mobile units, were compared against the Local DRLs (LDRLs) and National DRLs (NDRLs) as shown in Figure 3. All rooms were below both the LDRLs and NDRLs, except for room RLH AEX5 (Resus). This room, which has an Xograph system, had only 4 examinations during the sampling period. All other rooms shown in the figure below are Carestream systems.

![Figure 3. Mean DAP values per X-ray room/mobile unit for a sample of 100 patients.](image)

3.2 High DAP data

Figures 4 and 5 show the DAP values > 0.2 Gycm² plotted against delivered mAs, and the distribution of delivered mAs respectively. Further patient records such as CT scans were inspected for the four outlying data point, and these were found to be bariatric patients. In Figure 4 the distribution of the delivered mAs is illustrated with one third of the examinations were exposed at 8 mAs, which is the backup setting for medium adults on the AEC.
3.3 Example patient case study

A 68 year old female patient had 18 chest X-ray examinations in a two month period, of which 17 were examinations performed in a ward using a mobile X-ray system and therefore exposure parameters would have been selected manually. The selected kV, mAs and field sizes resulted in the DAP varying by an order of magnitude across these examinations. Table 2 summarises the exposure factors and DAP values.

| Table 2. Exposure factors and DAP values for 18 examinations of one patient. |
|-------------------|------------------|-------------------|
|                   | Mean value       | Minimum           | Maximum           |
| kV                | 86.8             | 85                | 90                |
| mAs               | 2.6              | 1.6               | 4                 |
| DAP (Gycm²)       | 0.10             | 0.03              | 0.22              |

4. Conclusions

The data presented demonstrate that there is a wide variation in the radiographic technique. The wide dynamic range of the detectors allows practices that could resulted in overexposure based radiography. These practices are not always identified and corrected.

The large number of examinations apparently terminated by the back-up timer were found not to be due to patient size or poor exposure factor selection, but due to the system defaulting to this setting under certain conditions, and this not being recognised prior to taking the exposure.

Radiographer training and audit is being undertaken to address this. The Trust is also in the process of implementing the Sectra DoseTrack management system on selected modalities, which will enable more effective management of these issues.

References

[1] Charnock, P., Moores, B. M. and Wilde, R. 2013. Establishing local and regional DRLs by means of electronic radiographical X-ray examination records. *Radiat. Prot. Dosim.* 157(1), pp 62-72.

[2] Wilde, R., Charnock, P., Moores, B. M. and McDonald, S. 2011. Qualifying the use of RIS data for patient dose by comparison with DICOM header data. *Radiat. Prot. Dosim.* 147(1-2), pp 329-332.