# Radiology workload analysis – role and relevance in radiation protection in diagnostic radiology

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*Abstract*— **It has been demonstrated that data entered by radiographers into Radiology Information Systems (RIS) can be used as dose audit data, removing the necessity for radiographer to separately collect data for patient dose audit purposes. Access to RIS data also provides the potential for much more analysis. The data entry process itself can be audited, and is now routinely performed at a small number of hospital sites in the North-West region of the UK. An analysis of the number of examinations performed by a single tube is possible together with the generation of dose audit data. This information is useful for departmental managers to investigate why certain rooms are being used more than others or for certain types of examinations. The work a tube does can be compared with life expectancy enabling better planning within the tube life cycle. In addition, the RIS contains extra information concerning the operator. Once again, the departmental manager can use this analysis to look at operator work patterns and scheduling. This will assist any investigations in the case of accidental exposure of staff.**

**This paper begins by introducing the term 'tubeload' and then gives examples of analyses that have been performed using data from a large hospital over a three-month period. Results are shown detailing the initial types of analyses that have been performed on single rooms, single operators and the site overall. The results are then discussed with emphasis on what further analyses could be performed and how this information could be used as a basis for decision making in radiation protection.**

*Keywords*— **Tubeload, RIS, dose audit, radiology workload**

## I. INTRODUCTION

It is known and accepted that a quality assurance (QA) program and dose audits are an essential part of both radiation protection and equipment performance [1-3]. Between 1992 and 2002 an application has been designed and built for the purposes of entering not only patient dose data, but also QA data [4-7]. It is called the Quality Assurance Dose Data System (QADDS) and was built using visual basic and a Microsoft Access 2 database. However, Access 2 became dated and unsupported so it was decided to re-engineer the application as a web based application on a Java platform.

Around the same time, RIS was being introduced to hospital departments. These systems would link the patient's details through referral to the exposure and allow the operator to record details of the exposure. The advent of digital radiography meant that images could also be stored along with details from the rest of the imaging chain [8-10].

With a RIS in place, however, radiographers were now being asked to record exposure details separately to that which is already been entered on to the RIS when performing a patient dose audit. With the upgraded structure and design of the application, investigations were made into whether the information entered into RIS could be imported directly into it, reducing the need for radiographers to record the same data twice and also enabling continuous patient dose audit. This proved successful [11-14] and is the current system in place for a number of hospitals [15] in order to help them fulfill their dose audit requirements [1, 16-17].

The report sent to hospitals also includes an audit of quality of the data that has been entered into the RIS on site. It was noted that there were omissions of data or wrong data types entered into fields of the RIS, which would cause errors if placed in a data type specific field within a database. However, a hospital departmental manager requested this information for audit purposes [18], which lead to the discussion of what other information and analyses could be taken from this data. There is much more information held within the RIS other than the kV and mAs for each examination, and, with this information in a large multi-site database, much more powerful analyses can be performed. It is possible to describe each room in terms of the number of examinations performed, and also the tubeload, which is defined as the kV multiplied by the mAs, given in Joules [19]. In addition, the operators who perform each examination are recorded in RIS. It is possible to show the number of examinations performed and which rooms each operator uses. Each operator can be analyzed by workload, which could be used as indication of occupational risk.

## II. METHODOLOGY

### *A. Current process of dose audit*

Full details of the process for uploading the data into QADDS are being also submitted for publication, however a brief summary is reproduced here.

- The RIS manager will run a query which will return data on all examinations performed, within specified parameters, such as timescale, & rooms, as a comma separated variable (CSV) file, a standard Microsoft Excel (XLS) file or an extensible markup language file (XML)
- The file is sent to a central repository by an automated file transfer protocol (FTP)
- The file is checked for errors in the data (blank fields, extremes of data)
- The error free data is placed in the database and a report is produced showing a breakdown of how much data was auditable (*see definitions*)
- The database is interrogated using an off-the-shelf statistical package to produce two reports. The first being a patient dose audit report and the second detailing tubeload per room (*see definitions*) and operator workload

All of the above steps can be automated.

### *B. Definitions*

Previous work has defined data supplied for dose audit purposes as either 'auditable' or 'un-auditable' [11, 15]. Patient entrance surface dose (ESD) is calculated using exposure factors [23]. If any of the data required for this calculation is missing, and no assumptions can be made regarding the missing data, it is assumed to be un-auditable.

Preliminary analyses showed that simply stating how many examinations had been performed by an individual tube was not indicative of how much work had been performed by the tube. For example, a tube that performs 50 low exposure examinations, such as extremity, may do less work than, say, 10 high exposure examinations, such as lumbar spine. To be able to prove this, an indication of how much work the tube does is required. The term '*tubeload*' is used by manufacturers [19, 20], and tubeload per examination is also used here.

### *C. The data*

The data for this study was received from a large hospital and consists of 58815 records from the period 1st May 2008 to 31st July 2008. 10 rooms (6 main and 4 A&E) were chosen for the purposes of this study (35857 records). 12 operators were also chosen at random from a total of 129 for the further analysis.

## III. RESULTS

The results can be split into a number of sections:

A summary table with the number of examinations distinguished by room is shown in table 1 and a summary graph showing the distribution of tubeload is shown in Fig. 1. Extra information about how much of the data is auditable/un-auditable, broken down by month can also be included on request of the departmental manager

Each room is then analyzed individually in terms of number of examinations by type (Fig. 2), tubeload by examination type and operators that have performed examinations in each room

Each operator is then analyzed in terms of the distribution of the rooms they have worked in and examinations performed, again by frequency and tubeload.

The RIS data can be analyzed further in a number of different ways, but space precludes its inclusion here.

Table 1 Summary Table

| Room Name | Number of Records | % Auditable |
|---|---|---|
| Room 1 | 16825 | 92.1 |
| Room 2 | 4630 | 94.5 |
| Room 3 | 2773 | 87.6 |
| Room 4 | 2497 | 88.1 |
| Room 5 | 264 | 1.5 |
| Room 6 | 582 | 40.4 |
| Room 7 | 375 | 16.5 |
| Room 8 | 3919 | 94.6 |
| Room 9 | 2639 | 96.9 |
| Room 10 | 1353 | 95.9 |

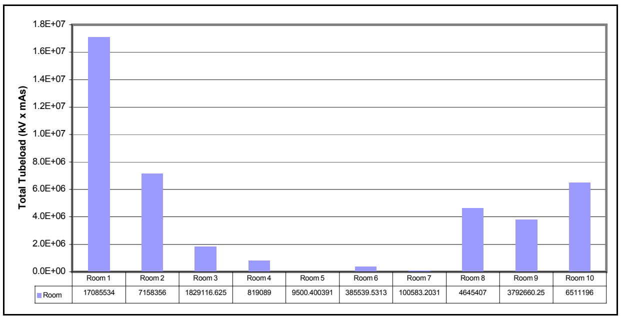


Fig. 1 Graph of tubeload for selected rooms

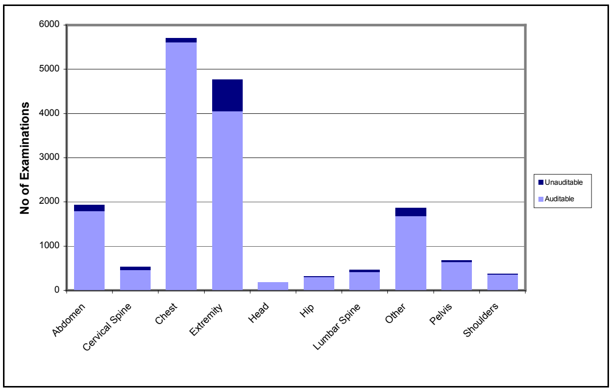


Fig. 2 Number of examinations by type performed in Room 2

Table 2 Tubeload per examination for each room

| Room Name | Tubeload per examination (J) |
|---|---|
| Room 1 | 1015.485 |
| Room 2 | 1546.481 |
| Room 3 | 659.616 |
| Room 4 | 328.029 |
| Room 5 | 35.986 |
| Room 6 | 662.439 |
| Room 7 | 268.222 |
| Room 8 | 1185.335 |
| Room 9 | 1437.358 |
| Room 10 | 4812.414 |

## IV. DISCUSSION

### *A. Room Use*

It has been noted that for Rooms 1-7, the tubeload relates closely to the number of examinations. On inspection of Rooms 8-10, it is noted that Room 10 performed 1353 examinations when compared with Room 8, which did almost three times more with 3919 (table 1). However the tubeload for Room 10 is about 30% higher than Room 8 (fig. 1). Even taking the number of examinations into account (table 2), Room 10 has a higher tubeload per examination by almost 2.5 than the nearest. Room 10 is generally used for higher dose examinations such as abdomen. The expected lifetime of all of these tubes is given as 7 years, however, this information could provide reasoning for more frequent QA given the harder working tubes such as Room 10 or Room 1 for sheer numbers may be more likely to require replacement sooner. This is being investigated by correlation with tube replacement frequencies from the department to give a more accurate indication that a high tubeload or tubeload per examination has been the cause of a replacement. In addition, tubeload per examination can be compared with the manufacturers recommendations for maximum tubeload. If the tube is working at a high percentage of the maximum, investigations can begin into how to lower the tubeload.

This information also provides evidence for better risk prevention. Any incident of staff exposure in Room 10 will have more of a consequence than a staff exposure in Room 8.

### *B. Examination Types performed*

Approximately every five years, the National Radiation Protection Board (NRPB), now merged with the Health Protection Agency (HPA) [21] release a document detailing the doses for a selected number of examinations [17]. The aim of their report is to set national reference doses for the most commonly used examinations to ensure compliance with the IR(ME)R recommendation of using diagnostic reference levels (DRLs). The latest review [22] states that 23,000 ESD records, collected with thermoluminescent devices (TLDs), and 57,000 dose area product (DAP) data records were collected for common plain film examinations from 316 hospitals in the UK over 5 years. In the present study over 58,000 records were collected on a single hospital site over a three-month period with minimum time and effort. In addition, approximately 20% of data supplied to the HPA was rejected due to missing information. Less than 15% of this study was classified as unauditable, however, this 15% contributes information that is of use to the hospital. The methodology proposed in this paper would seem to be eminently suited to large-scale dose audits with minimum time and effort

### *C. Operator work patterns*

The first finding of the study was to show where data was missing from the RIS system. It was noticed that one particular operator was consistently leaving fields blank in the RIS. In order to ensure adherence to the standards for clinical audit [1, 18, 21], staff should be following procedures created by the hospital radiation protection committee (RPC). This process requires audit, which this study has shown can be provided.

This study also shows which operators have been working in high tubeload rooms more often than others. It is noted that one operator (operator 2) performed 266 examinations in Room 10 whereas the next most frequent user of this room did 138. This raises the question of whether the high tubeload is because one operator uses higher exposure factors than necessary. There is also the increased risk of a significant staff exposure to this particular operator. The departmental manager may wish to train other staff to perform the procedures that are predominately performed in Room 10, whilst at the same time, operator 2 may be rescheduled to work in rooms with lower tubeload.

To show this information to a departmental manager can be achieved for a sample of 10 operators, however this study comprised of 129 operators. Future studies will establish a method for simplifying the presentation of this information for all operators with departmental managers being given opportunity to select staff for more detailed analyses.

## V. CONCLUSIONS

It can be shown that analysis of RIS data in terms of radiology workload can be useful for x-ray departments in a number of areas. The data management techniques will also be employed in routine QA programs as required by IR(ME)R 2000 in the UK. Whilst this is being rolled out to hospitals in the north west of the UK, further analyses are also being undertaken to improve this fledgling service

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## REFERENCES

1. The Ionizing Radiation (Medical Exposure) Regulations 2000, SI 2000 No 1059. London: HMSO 2000.
2. The Ionizing Radiation Regulations 1999, SI1999 No 3232. London: HMSO 1999
3. Recommended Standards for the Routine Performance Testing of Diagnostic X-Ray Imaging Systems, 2005: IPEM Report 91
4. Cole PR et al, Computer applications in radiation protection. Radiat. Protect. Dosim., 1995: 57(1-4): 203-206
5. Ward M et al, Central dose data management and analysis in IT driven radiation protection strategies. Radiat. Protect. Dosim., 2005: 114(1-3): 135-142
6. Garrard R. Design and development of a quality assurance management system in mammography. M.Sc. Thesis in PC interfacing and software application, University of Central Lancashire, UK (1993)
7. Kerom G. Development of a database application for use in mammography quality control. M.Sc. Thesis in PC interfacing and software application, University of Central Lancashire, UK (1994)
8. The Royal College of Radiologists, Radiology Information Systems. London: The Royal College of Radiologists. Available from http://www.rcr.ac.uk [Accessed 11/02/2009]
9. Pilling J. Installing PACS in a large acute hospital. Br. J. Healthc. Comput. Inform. Manag., 2002: 19(7): 35-37
10. Charnock P. Effects of monitor specification on soft-copy reporting in mammography. M.Sc. Thesis in Medical Physics, University of Manchester, UK (2007)
11. Wilde R et al. (2008) Automating patient dose audit and clinical audit using RIS data. IPEM Proceedings or the 14th Annual Scientific Meeting, Bath, UK, pp63-64
12. Ward et al, Medical physics expert led audit and research opportunities presented by hospital information systems. IPEM Proceedings of the 13th Annual Scientific Meeting, Cardiff, UK, pp61-62
13. Valentin J, Managing Patient Dose in Digital Radiology (ICRP Pub. 93). Annals of the ICRP, 2004: 34 (1): 1-73
14. Warren-Forward H et al, An assessment of exposure indices in computed radiography for the posterior-anterior chest and the lumbar lateral spine. Br. J. Radiol., 2007: 80: 26-31
15. Fazakerley J et al. The development of a 'gold standard' patient dose audit data set. IPEM Proceedings of the 14th Annual Scientific Meeting, Bath, UK, pp61
16. Guidance on the Establishment and Use of Diagnostic Reference Levels for Medical X-Ray Examinations, 2004: IPEM Report 88
17. Hart D, Hillier MC and Wall BF. Dose to Patients from Radiographic and Fluoroscopic X-ray Imaging Procedures in the UK – 2005 Review. Health Protection Agency, HPA-RPD-0292005, 2007. ISBN 9780859516006
18. Department of Health. A strategy for NHS information quality assurance. 2004, Available from: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4125508 [Accessed 11/02/2009]
19. Farr RF, Allisy-Roberts PJ, Physics for Medical Imaging, Elsevier Health Sciences, 1996 ISBN: 9780702017704
20. McClelland IR. X-Ray Equipment Maintenance and Repairs Workbook for Radiographers and Radiological Technologists. World Health Organization, 2004, ISBN 9241591633
21. Department of Health. Guidance on the establishment and use of diagnostic reference levels (DRLs). 2007, Available from http://www.dh.gov.uk/en/publicationsandstatistics/publications/publicationspolicyandguidance/DH_4007957 [Accessed 11/02/2009]
22. Hart D et al. National reference doses for common radiographic, fluoroscopic and dental x-ray examinations in the UK. Br. J. Radiol., 2009: 82: 1-12
23. George J et al. Patient Dose Optimization in Plain Radiography Based on Standard Exposure Factors. Br. J. Radiol., 2004: 77: 858-863

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