Potential applications of dose-tracking and active dosimetry systems to encourage X-ray image optimization and minimise staff dose

H.B.Wilkins[a], K.M.Knapp[b]

[a]Medical Physics Department,
Royal Devon and Exeter NHS Foundation Trust,
Exeter, United Kingdom

[b]Medical Imaging Department,
University of Exeter, United Kingdom

Abstract. UNSCEAR and other authorities have documented worldwide variability in doses to patients undergoing X-ray imaging procedures and the need for optimization of diagnostic exposures. We outline results of a multi-centre study of chest radiography DAP values which provides additional evidence and note related concerns about patient and staff doses in invasive cardiac X-ray procedures, interventional radiology and CT. The transition to digital radiology has broken the link between over-exposure of patients and image degradation, encouraging dose creep. Current widespread manual recording of patient dose indicators is time-consuming and prone to transcription errors. DICOM and IHE standards for radiation dose structured reports and radiation exposure monitoring are catalysts in the emergence of dose-tracking informatics tools. These automate collection of patient dose data, enable detailed analysis and have considerable education and training potential to inform and drive dose-reduction programs. They can facilitate audit, assist development of reference level benchmarks, help to identify sub-optimal practice and encourage optimization through provision of relevant dose information to staff at all levels. Recent developments in active dosimetry systems indicate dose-rates to operators at time of exposure, raising awareness and potentially encouraging reduction of staff doses in interventional procedures, with eye doses in particular a topical issue.

1. Introduction

This paper discusses potential applications of recent technological developments to develop radiation protection practices in X-ray medical imaging. The main focus is on the emerging use of dose-tracking informatics tools to collect, analyse and apply dosimetry data to increase understanding of doses incurred by patients undergoing X-ray imaging procedures, with a view to encouraging optimization. It also refers to other technological developments which can assist attempts to reduce doses to staff undertaking diagnostic exposures.

Underlying this approach is a belief that the provision of accurate, timely, easy-to-collect data is essential, not only to understand existing doses received by patients and staff but also to inform and drive dose-reduction programmes. Digital radiology developments in recent years, notably the development of dose structured reports [1] and radiation exposure monitoring [2], are laying the platform for automated collection and analysis of patient dose indices via data-mining techniques. Such data, which can be sorted by a variety of parameters including procedure, patient characteristics and operator, is a potentially powerful tool which can increase awareness of ALARA possibilities and perhaps ‘nudge’ operators towards optimization of exposure factors.

There is thus a definite ‘education and training’ component to these developments. Variability in doses to patients from X-ray imaging is well-documented [3] and there is recent evidence that staff occupationally exposed, particularly those involved in X-ray interventional procedures, are at greater risk of cataract formation than hitherto supposed [4, 5]. By providing better dose data to staff undertaking medical exposures it is envisaged that they will be more empowered, and indeed motivated, to apply their skills to achieving fit for purpose diagnostic imaging with minimal dose to patients and themselves. It will hopefully address the phenomenon of dose creep [6], facilitate diagnostic reference level benchmarking and help to identify and remediate sub-optimal practice where it occurs.

2. Methods

DICOM (Digital Imaging and Communications in Medicine) is an evolving standard promoting communication of digital image information and facilitating interoperability of medical imaging equipment regardless of device manufacturer [7]. Its radiation dose structured reports (RDSR) encapsulate patient dose information associated with X-ray images in a standardized format [8]. Linked to this the Integrated Health Enterprise (IHE) Radiation Exposure Monitoring (REM) profile provides a standard format for imaging modalities to export radiation exposure details [2]. Contemporary PACS (Picture Archiving and Communication Systems), RIS (Radiology Information Systems) and imaging systems are generally expected to be compatible with these formats [9, 10].

This standardization of image transfer formats and protocols lends itself to computerized data-mining techniques to collect and analyse patient dose information [11]. Traditionally patient dose data has been read from imaging / dose devices and manually entered by radiographers and technicians into PACS/RIS systems, which is time-consuming and subject to transcription errors. It is readily foreseeable that automation of these steps will have become commonplace for many if not most X-ray imaging procedures during the next decade. Another recent approach is via automated collection and analysis of dose data directly from the imaging system modalities. Either way makes available valuable data which can either be used to assist management of individual patients considered to be at risk or applied to patient populations. In the latter case the resultant data sets can generate patient dose indicators at various levels.

Such data can be compiled and collated in national registries, facilitating production of detailed national diagnostic reference levels and international comparisons. At hospital or institution level the data can be used to derive local diagnostic reference levels, which can be targeted more precisely to individual X-ray rooms and operators. This could be a powerful tool to discourage dose creep and encourage optimization.

Turning from patient doses to staff doses, another recent development is the availability of detector systems which display real-time personal dose-rate data, typically for staff working in interventional radiology and cardiology labs [12]. These systems provide instant feedback to operators of the radiation fields in which they are operating and enable subsequent more detailed dose review directly after the operation (in contrast to the delays inherent in TLD and other conventional monitoring). By raising awareness of high dose-rates at the time of exposure such information may prove beneficial in encouraging operators to take immediate steps to reduce doses to themselves and colleagues.

3. Results

Use of these dose-tracking tools is in its infancy but is likely to become widespread during the next few years. Although we are not yet at a stage to provide results, preparations for such work are underway and we anticipate that use of data mining techniques to monitor patient doses will become standard practice within the next decade. Work we have undertaken demonstrates the need for optimization.

Figure 1 summarizes results of a survey carried out in 2010 [13] of Dose Area Product (DAP) values for 469 chest radiographs undertaken in 20 X-ray rooms in 9 UK hospitals using computed radiography, compared with the then recommended national reference dose (NRD) for Chest PA radiographs [14]. Patient size was arbitrarily assigned by radiographers into one of three categories based on visual inspection, this being thought more feasible in busy X-ray departments than measurement of patient weight (plus height if body mass index were to have been used to classify patient size).

As expected the study demonstrates that obese patients tend to receive higher exposures than thin patients. What is striking about these results is the variability in practice implied by these findings

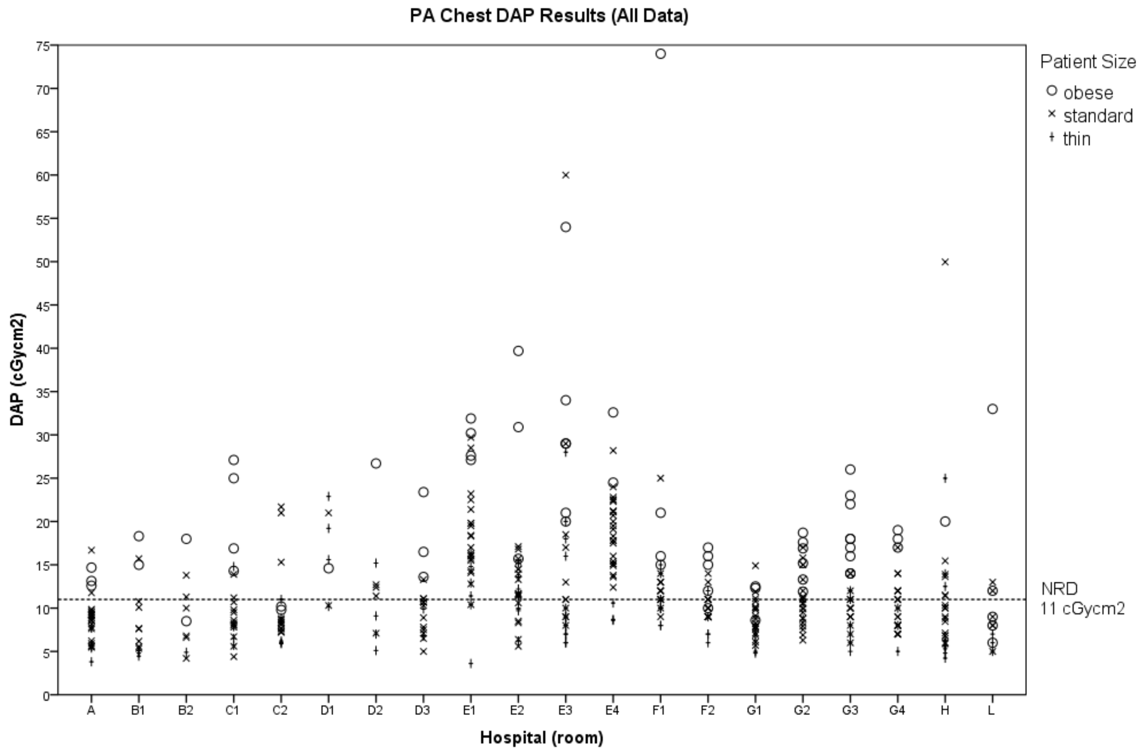

FIG. 1. DAP readings for PA Chest exams for each room in a survey of 20 X-ray rooms.

and the extent to which exposures in some hospitals exceed national reference levels, then largely based on historical film-screen radiography. They reflect differences in the extent to which images had been optimized in different hospitals following the large scale UK transition to digital radiography given impetus by a national PACS programme *circa* 2007. Similar results were found for radiographs of abdomen and lumbar spine [13].

4. Discussion

Conducting this survey was not straightforward because of limited resources. A benefit of dose-tracking informatics tools is that, once set up, they can make dose-related data much more readily available to all concerned, highlighting areas where further work is required to optimize exposures.

Whilst the chest radiography example above is relatively low dose, separate work which we and others have undertaken demonstrates the need for a focus on optimization of exposure of patients undergoing invasive cardiac X-ray procedures, where there is substantially greater potential for radiation injuries [15, 16, 17]. The significant increase in the numbers of CT examinations in recent years, and increased complexity of interventional radiology, pose similar radiation protection challenges which dose monitoring developments and innovative applications of the data they provide can help address.

With analogue film-screen imaging over-exposure results in a film which is too dark and hence may be rejected. With digital imaging such over-exposure is not readily evident from the image alone because of computer pixel value scaling. Conversely under-exposed X-ray images result in poor image quality with both analogue and digital techniques. The term ‘dose creep’ describes the tendency with digital imaging for operators to increase doses to eliminate under-exposures, without the corresponding risk of blackened films that existed in the era of film-screen radiography. The direct link between over-exposure and image degradation was broken with the transition from film-screen to digital radiography; use of emerging techniques for dose analysis can arguably encourage a return to elements of the art and craft of radiography which may have been lost in this transition.

5. Conclusions

There is well-documented evidence of the need to further optimize doses to patients and better control eye doses to staff undertaking interventional X-ray procedures. Recent technological developments have a significant role to play in making meaningful dose information more readily available to operators undertaking these procedures. We can expect that appropriate exploitation of these innovations will play a significant role in keeping radiation doses as low as reasonably achievable.

REFERENCES

[1] DICOM STANDARDS COMMITTEE WORKING GROUP 6, Digital Imaging and Communications in Medicine (DICOM) Supplement 94: Diagnostic X-Ray Radiation Dose Reporting (Dose SR), Version: Final Text November 02 2005.

[2] INTEGRATING THE HEALTHCARE ENTERPRISE, Radiation Exposure Monitoring (2012), http://wiki.ihe.net/index.php?title=Radiation_Exposure_Monitoring.

[3] UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, UNSCEAR 2008, Report Vol. 1 Sources of Ionizing Radiation, Annex A: Medical Radiation Exposures (2010).

[4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Statement on Tissue Reactions, Approved by the Commission on April 21, 2011, http://www.icrp.org/page.asp?id=123.

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Cataract Study (2012), https://rpop.iaea.org/rpop/rpop/content/news/relid-cataract-study.htm .

[6] UFFMANN, M., SCHAEFER-PROKOP, C., Digital radiography: The balance between image quality and required radiation dose, European Journal of Radiology, **72** 2 (2009) 202-8

[7] DIGITAL IMAGING AND COMMUNICATIONS IN MEDICINE, Strategic Document, Version 2012-13, April 11, 2012. http://medical.nema.org/dicom/geninfo/Strategy.pdf.

[8] SOLOMON, H., DICOM Structured Reporting Overview, http://reportingwiki.rsna.org/images/0/00/RSNA_Reporting_Forum_Solomon.pdf.

[9] CHELL I., Digital analysis and reporting systems for diagnostic radiation doses: Information Paper for Radiology and Medical Physics Staff (2012), http://www.bir.org.uk/media/7260/dose%20data%20stakeholder.doc.

[10] NHS CONNECTING FOR HEALTH, PACS, RIS, Image Archive and Sharing Services Core Statement of Requirements, Version 18/11/11 (2011), http://www.connectingforhealth.nhs.uk-/systemsandservices/pacs/transformation/corereqs.pdf

[11] U.S. FOOD AND DRUG ADMINISTRATION, Tracking Radiation Safety Metrics (2012), http://www.fda.gov/Radiation-EmittingProducts/RadiationSafety/RadiationDoseReduction/ucm299368.htm

[12] VANO, E., FERNANDEZ, J.M., SANCHEZ, R., Occupational dosimetry in real time. Benefits for interventional radiology. Radiation Measurements. **46** 11 (2011) 1262-1265.

[13] WILKINS, H., JEFFERIES, A., WORRALL, M., TRUBSHAW, F., Digital Radiology Optimization - Audit of Radiographic Protocols and Doses for Four Common Examinations, (unpublished).

[14] HART, D., HILLIER, M.C., WALL, B.F., National reference doses for common radiographic, fluoroscopic and dental X-ray examinations in the UK. Br. J. of Radiology **82** (2009) 1-12.

[15] WILKINS, H., Development of IRMER Reference Levels for Cardiac Interventional Procedures, Proceedings of the UK Radiological Congress Manchester 2011.

[16] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Patient and Staff Radiological Protection in Cardiology - Draft Report for Consultation (2011).

[17] DOUGLAS, P., CARR, J., CERQUEIRA, M., CUMMINGS, J., GERBER, T., MUKHERJEE, D., TAYLOR, A., Developing an Action Plan for Patient Radiation Safety in Adult Cardiovascular Medicine. J.Am Coll Cardiol, doi:10.1016/j/jacc.2012.01.005. Published online 22 March 2012.