Evaluation of the impact of a system for real-time visualisation of occupational radiation dose rate during fluoroscopically guided procedures

To cite this article: V Sandblom et al 2013 J. Radiol. Prot. 33 693

View the article online for updates and enhancements.

Related content
- On the feasibility of utilizing active personal dosimeters worn on the chest to estimate occupational eye lens dose in x-ray angiography
  Artur Omar, Maria Marteinsdottir, Nils Kadesjö et al.
- Staff lens doses in interventional urology. A comparison with interventional radiology, cardiology and vascular surgery values
  E Varo, J M Fernandez, L E Resel et al.
- Optimisation of occupational radiological protection in image-guided interventions, potential impact of dose rate measurements
  Å Almén, V Sandblom, M Båth et al.

Recent citations
- Defining the Key Competencies in Radiation Protection for Endovascular Procedures: A Multispecialty Delphi Consensus Study
  Bart Doyen et al.
- Assessment of the occupational eye lens dose for clinical staff in interventional radiology, cardiology and neuroradiology
  Artur Omar et al.
- Combined Use of a Patient Dose Monitoring System and a Real-Time Occupational Dose Monitoring System for Fluoroscopically Guided Interventions
  Christina Heilmaier et al.
Evaluation of the impact of a system for real-time visualisation of occupational radiation dose rate during fluoroscopically guided procedures

V Sandblom\textsuperscript{1,2}, T Mai\textsuperscript{2}, A Almén\textsuperscript{1}, H Rystedt\textsuperscript{3}, Å Cederblad\textsuperscript{1}, M Båth\textsuperscript{1,2} and C Lundh\textsuperscript{1}

\textsuperscript{1} Department of Medical Physics and Biomedical Engineering, Sahlgrenska University Hospital, SE-413 45 Gothenburg, Sweden
\textsuperscript{2} Department of Radiation Physics, University of Gothenburg, SE-413 45 Gothenburg, Sweden
\textsuperscript{3} Department of Education, Communication and Learning, University of Gothenburg, SE-405 30 Gothenburg, Sweden

E-mail: viktor.sandblom@vgregion.se

Received 21 February 2013, in final form 30 May 2013, accepted for publication 6 June 2013
Published 4 July 2013
Online at stacks.iop.org/JRP/33/693

Abstract

Optimisation of radiological protection for operators working with fluoroscopically guided procedures has to be performed during the procedure, under varying and difficult conditions. The aim of the present study was to evaluate the impact of a system for real-time visualisation of radiation dose rate on optimisation of occupational radiological protection in fluoroscopically guided procedures. Individual radiation dose measurements, using a system for real-time visualisation, were performed in a cardiology laboratory for three cardiologists and ten assisting nurses. Radiation doses collected when the radiation dose rates were not displayed to the staff were compared to radiation doses collected when the radiation dose rates were displayed. When the radiation dose rates were displayed to the staff, one cardiologist and the assisting nurses (as a group) significantly reduced their personal radiation doses. The median radiation dose ($H_p(10)$) per procedure decreased from 68 to 28 $\mu$Sv ($p = 0.003$) for this cardiologist and from 4.3 to 2.5 $\mu$Sv ($p = 0.001$) for the assisting nurses. The results of the present study indicate that a system for real-time visualisation of radiation dose rate may have a positive impact on optimisation of occupational radiological protection. In particular, this may affect the behaviour of staff members practising inadequate personal radiological protection.

(Some figures may appear in colour only in the online journal)
1. Introduction

In health care, many categories of medical staff use technologies involving ionising radiation for diagnostic and/or therapeutic purposes. Cardiologists and interventional radiologists, who operate the x-ray unit during fluoroscopically guided procedures, are two examples of such categories. During most of a fluoroscopically guided procedure the operator is required to be present in the room and close to the patient. Operators working with these procedures have one of the highest exposures to ionising radiation among all medical staff [1–4] and the lens of the eye, for instance, can receive high radiation doses [5–12]. As a consequence, an elevated prevalence of lens opacities and cataracts among cardiologists and interventional radiologists has been seen [13–15], indicating the relevance of optimisation of radiological protection in fluoroscopically guided procedures [16]. In addition, the International Commission on Radiological Protection (ICRP) recently lowered their recommended equivalent dose limit for the lens of the eye from 150 to 20 mSv year$^{-1}$ [17].

During fluoroscopically guided procedures, optimisation of radiological protection can be very different from optimisation in other activities involving ionising radiation. In activities where the exposure situation for personnel is predictable, most of the optimisation can be performed in advance. One challenge during fluoroscopically guided procedures is that they often include unstable patients who require individual care; their medical status can rapidly change during a procedure and the exposure situation for personnel can thus evolve very differently. In these situations, optimisation of radiological protection has to be performed during the procedure, under varying and sometimes difficult conditions.

One prerequisite for optimisation of radiological protection during fluoroscopically guided procedures is knowledge of radiation dose levels and of how different types of behaviour affect these levels. This knowledge could be improved by providing the staff with instant feedback of their personal exposure throughout a procedure. A system for real-time visualisation of occupational radiation dose rate, intended for monitoring the personal exposure of medical staff working with fluoroscopically guided procedures, recently became commercially available. The system (the DoseAware Personal Dose Meter system, Philips Healthcare, Best, The Netherlands) consists of individual dosimeters that detect the radiation dose rate with a 1 s interval [18]. The dosimeters of the system are calibrated to measure the personal dose equivalent in soft tissue at a depth of 10 mm, $H_p(10)$, and are normally worn at chest height outside a lead apron. The radiation dose rate is displayed on a monitor as a colour-coded bar diagram on a logarithmic scale (figure 1). The bar is green if the radiation dose rate is between 0 and 0.2 mSv h$^{-1}$, yellow if between 0.2 and 2 mSv h$^{-1}$ and red if above 2 mSv h$^{-1}$. The radiation dose data are also stored to enable retrospective analysis. The technical performance of the dosimeter has been evaluated [19, 20], and in a recent study this system was used for clinical measurements of staff radiation doses [21]. However, the impact of the system on such radiation doses was not evaluated. Nevertheless, it is conceivable that a system for real-time visualisation of radiation dose rate may influence the behaviour of the staff, alerting them to high radiation dose rates and providing instant feedback of the effect of dose-reducing actions. The aim of the present study was therefore to evaluate the impact of a system for real-time visualisation of radiation dose rate on optimisation of occupational radiological protection in fluoroscopically guided procedures.

2. Material and methods

To evaluate the impact of a system for real-time visualisation of the radiation dose rate in clinical environments, measurements were carried out at a cardiology laboratory, using
Figure 1. Colour-coded bar diagrams showing the personal radiation dose rate. These bars are displayed on a monitor visible to staff during the procedure.

Figure 2. The cardiology laboratory where clinical measurements were carried out using a DoseAware system. The position of the DoseAware monitor is marked with a solid line circle. The position of the reference dosimeter is marked with a dashed line circle.

a DoseAware system (figure 2). Two main procedures were performed in this laboratory: coronary angiography (CA) and percutaneous coronary intervention (PCI). A PCI is almost always preceded by a CA—in the present study, such a combined procedure was treated as only one procedure: a PCI.

The medical staff working in the cardiology laboratory consisted of three cardiologists and ten nurses, and all staff members participated in the study. During each procedure, radiation dose data were collected for the cardiologist, i.e. the staff member operating the x-ray unit, and for the nurse assisting the cardiologist. For the cardiologists, the radiation dose data were analysed both individually and collectively. For the nurses, the radiation dose data were only analysed collectively, due to the limited number of procedures per nurse. This means that, for the nurses, the radiation dose data were associated with the working role of the assisting nurse, while the data for the cardiologists were also associated with individual cardiologists (cardiologists 1–3). In addition to the personal dosimeters worn by the staff, one dosimeter was placed on the x-ray unit as a reference to give a general measure of the amount of scattered radiation produced during each procedure (figure 2). The radiation dose data registered by this dosimeter were associated with the different cardiologists and are referred to as reference 1–3.
Table 1. Number of procedures, median radiation dose per procedure and p-value from the Mann–Whitney U-test. The personal dose reduction was statistically significant for cardiologist 1 and the assisting nurses.

<table>
<thead>
<tr>
<th>Dosimeter(s)</th>
<th>Number of procedures</th>
<th>Median dose/procedure</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period 1</td>
<td>Period 2</td>
<td>Period 1</td>
</tr>
<tr>
<td>Cardiologists, pooled</td>
<td>80</td>
<td>81</td>
<td>9.9</td>
</tr>
<tr>
<td>Assisting nurses, pooled</td>
<td>69</td>
<td>73</td>
<td>4.3</td>
</tr>
<tr>
<td>Reference, pooled</td>
<td>70</td>
<td>81</td>
<td>59</td>
</tr>
<tr>
<td>Cardiologist 1</td>
<td>22</td>
<td>20</td>
<td>68</td>
</tr>
<tr>
<td>Cardiologist 2</td>
<td>30</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>Cardiologist 3</td>
<td>28</td>
<td>38</td>
<td>1.3</td>
</tr>
<tr>
<td>Reference 1</td>
<td>18</td>
<td>20</td>
<td>61</td>
</tr>
<tr>
<td>Reference 2</td>
<td>24</td>
<td>23</td>
<td>52</td>
</tr>
<tr>
<td>Reference 3</td>
<td>28</td>
<td>38</td>
<td>61</td>
</tr>
</tbody>
</table>

but were also analysed without association to specific cardiologists. The collected radiation dose data were used to determine the accumulated radiation dose per procedure.

The measurement period was divided into two data collection periods of 1 month each. During the first period the personal dosimeters and the reference dosimeter registered the radiation dose but the dose rate information was not displayed, only stored for analysis. During the second period the system was used to its full extent and the radiation dose rate information was displayed. The staff received education about the DoseAware system, containing information about the design of the dosimeter and about how to interpret the colour-coded bar diagrams shown on the monitor, and underwent a 1 h repeat training session in basic radiological protection and safety before each period. The staff were not informed about any personal radiation exposures registered during the first period until after both data collection periods were completed. The first period consisted of 80 procedures and the second period consisted of 81 procedures. Due to various technical problems with the dosimeters, radiation dose data were missing for 11 and 8 procedures from the first and second periods, respectively, for the assisting nurses and for 10 procedures from the first period for the reference dosimeter (table 1).

The patient size distributions for the two data collection periods were similar. The mean body mass index (BMI) of the patients was calculated both for all patients pooled and separately for the three cardiologists. A Student’s t-test of equality of means generated p-values larger than 0.6 for all cardiologists, indicating that the difference in patient size was not a factor influencing the results and patient size was thus not further considered in the study.

The accumulated radiation doses per procedure did not follow a normal distribution and thus, the non-parametric Mann–Whitney U-test (MW test) was used to evaluate the potential difference in radiation dose during the two periods. A p-value smaller than 0.05 was considered statistically significant. The MW test was performed using the software IBM SPSS Statistics 20 (Statistical Product and Service Solutions, International Business Machines Corporation, Armonk, NY, USA).

3. Results

Cardiologist 1 showed a statistically significant personal dose reduction (from a median dose of 68 to 28 µSv/procedure, p = 0.003) when the radiation dose rates were displayed in period 2 (figure 3, table 1). For this cardiologist, the median value of the amount of scattered radiation
produced (reference 1) was reduced from 61 to 45 µSv/Procedure (p = 0.108) (table 1). No statistically significant dose reduction was found for cardiologists 2 and 3 or collectively for the cardiologists, neither for their personal dosimeters nor for the reference dosimeter. The personal radiation doses recorded for the assisting nurses showed a statistically significant dose reduction (from a median dose of 4.3 to 2.5 µSv/Procedure, p = 0.001) between the two data collection periods (figure 4, table 1).

The personal radiation doses per procedure showed a large variation between the three cardiologists (figure 3, table 1). During the first data collection period, the median dose per procedure was 68 µSv for cardiologist 1, 13 µSv for cardiologist 2 and 1.3 µSv for cardiologist 3. Although the three cardiologists received substantially different levels of radiation to their personal dosimeters, the reference dosimeter showed that they produced similar levels of scattered radiation (table 1).

4. Discussion

The aim of the present study was to evaluate the impact of a system for real-time visualisation of radiation dose rate on occupational exposure. The results show that such a system may lead to a reduced personal radiation dose for certain cardiologists. Optimisation of radiological protection can to some extent be performed in advance, but during fluoroscopically guided procedures further optimisation actions need to be performed in the examination room during the procedure. The present study addressed the latter. Both personal dosimeters and a reference dosimeter (placed on the x-ray unit) were used in order to enable separation of (1) actions
affecting the amount of scattered radiation produced, generally affecting the personal radiation doses of all staff members present in the room (e.g. x-ray beam collimation or adjustment of fluoroscopic times), and (2) actions only affecting the personal radiation dose of the individual staff member (e.g. use of shielding equipment or adjustment of the position in the room). Using the visualisation system, one cardiologist significantly lowered the personal radiation dose but the amount of scattered radiation produced by the same cardiologist was not significantly lowered. This indicates that this cardiologist mainly performed dose-reducing actions to improve personal radiological protection, such as personal shielding and keeping a distance to the source of scattered radiation.

The personal radiation doses of the three cardiologists showed a large variation. In the first period, the median radiation dose per procedure for cardiologist 1 was about 50 times higher than the personal radiation dose of cardiologist 3 and about 5 times higher than the radiation dose of cardiologist 2. Large individual variations in personal radiation doses are not unique to the present study [3, 4, 6, 9, 11, 12, 22, 23].

During each period, the variation in the radiation dose levels measured by the reference dosimeter for the three cardiologists was small compared to the variation in their personal radiation doses. This indicates that they did use personal radiological protection equipment differently and that there was a smaller difference between their amounts of scattered radiation produced. In addition to their different use of personal protection equipment, this may also have been explained by potential individual differences in the use of imaging angulations during a procedure. Since the position of the reference dosimeter relative to the x-ray source was fixed (figure 2), the radiation dose value measured by the reference dosimeter was relatively independent of the different imaging angulations used during a procedure. The radiation dose
value measured by a cardiologist’s personal dosimeter, on the other hand, was dependent on the angulations used. Lastly, it should be mentioned that cardiologist 3 was positioned in a way that the personal dosimeter was almost always fully shielded by a ceiling-suspended shield, which could explain the relatively low median radiation dose per procedure for this cardiologist. The use of radiation protection equipment was not analysed for cardiologist 1 and 2.

Before the radiation doses were displayed to the staff, cardiologist 1 received the highest radiation doses. This staff member was also the only cardiologist to significantly lower the personal radiation dose using the visualisation system. One explanation to this could be that a cardiologist who practises poor personal radiological protection may improve protection by relatively simple means, e.g. adjustment of the position of an incorrectly positioned lead screen. A cardiologist who already practises proper radiological protection may have little scope for further improvement and may therefore not be as affected by the visualisation system.

Regarding the impact of the visualisation system on the exposure of the assisting nurses, the dose reduction was statistically significant. A reduction in the total amount of scattered radiation produced by the cardiologists between the two periods could have partially explained the statistically significant dose reduction of the assisting nurses. However, no statistically significant reduction of the total amount of scattered radiation produced, i.e. of the radiation doses per procedure registered by the reference dosimeter, was found ($p = 0.274$). Thus, the reduction for assisting nurses was due to personal dose-reducing actions, e.g. better use of shielding equipment or adjustment of the position in the room, and not due to actions by the cardiologist operating the x-ray unit.

Information about the DoseAware system and the repeat training in radiological protection and safety was given to the staff before each data collection period to make the starting conditions of both periods as similar as possible. If this information and education had been given only at the beginning of period 2 (i.e. in connection with the introduction of the visualisation of the radiation dose rate), it is possible that a statistically significant dose reduction could have been due to an increased general radiation safety awareness in period 2, rather than due to the visualisation system. For similar reasons, the staff were not informed about any personal radiation exposures registered during the first period until after both data collection periods were completed. If the staff had been provided with information about their personal radiation doses as well as the radiation doses of other staff members it would have been easier for them to compare the radiation doses and thus potentially reduce their personal exposure due to this comparison, rather than due to the visualisation system.

As previously discussed, two main kinds of procedures were performed in the cardiology laboratory: CAs and PCIs. Generally, a PCI results in higher radiation doses than a CA. Consequently, a statistically significant dose reduction could have been due to a larger proportion of PCIs in period 1 than in period 2. Therefore, an additional analysis was performed for the CAs and PCIs. In this analysis, all radiation doses registered by a dosimeter worn by a cardiologist during a PCI were multiplied by the ratio between the median radiation dose registered by the reference dosimeter during a CA and a PCI. MW tests of the recalculated radiation doses per procedure generated similar $p$-values to the analysis of the original radiation dose values presented in table 1. This indicates that the fact that the evaluation of a system for real-time visualisation in the present study included different kinds of procedures did not significantly influence the results.

Since the personal dosimeter was worn outside the lead apron in the present study, it is difficult to estimate the effective doses received by the staff. However, the aim was not to assess personal radiation doses *per se*, but to evaluate the impact of the visualisation system. Nevertheless, it should be mentioned that the radiation doses measured here are similar to those typically reported from measurements outside the lead apron for operators working with
fluoroscopically guided procedures [21, 22, 24–34]. This indicates that the staff participating in the present study, and their way of work, was comparable to and representative of other operators performing fluoroscopically guided procedures.

Visualisation of radiation dose rates in general—not necessarily using the visualisation system evaluated here—should increase awareness of the presence of ionising radiation, reminding the staff to take various dose-reducing actions. The impact of the visualisation system evaluated here could have been influenced by the technical design of the system. Both the length and the colour of the bars (shown in a logarithmic scale) are determined by pre-defined levels, which were not changed, and it is likely that the colour is more prominent than the length of the bar when visualising radiation dose rate. This means that a red bar could be interpreted as something unwanted and a green bar as an approved level, even though optimisation of radiological protection should be applied even if the bar is green. A cardiologist who only sees green bars might not be as concerned about reducing his or her personal radiation dose as a cardiologist who also sees a lot of yellow or red bars. Thus, it is theoretically possible that the visualisation system could even lead to an increased personal radiation dose if only green bars are displayed, due to a false sense of security.

There are several limitations to the present study. First, since the impact of the visualisation system was studied in one cardiology laboratory, the results are based on only three cardiologists. It is therefore difficult to generalise the results to a broad population of operators, especially given the large individual variations associated with occupational radiological protection, as indicated by this study. Nevertheless, the study exemplifies the impact of visualisation of radiation dose rate on optimisation of radiological protection in fluoroscopically guided procedures for a small but relevant sample of operators. Second, the number of procedures per assisting nurse was too low to enable individual analyses for the nurses. Third, the present study included both CAs and PCIs. However, additional analyses indicated that this did not influence the results. Finally, the impact of the system was only analysed using MW tests of recorded radiation dose data and the behaviour of the staff was not further analysed. To be able to correlate visualisation of radiation dose rate to specific dose-reducing actions, a detailed mapping of the actions and reactions of the staff is necessary. The use of video recordings to capture the course of events during a procedure would be beneficial for such work [35].

5. Conclusions

The results of the present study indicate that a system for real-time visualisation of radiation dose rate may have a positive impact on optimisation of occupational radiological protection. In particular, this may affect the behaviour of staff members who practise inadequate personal radiological protection.

Acknowledgments

This work was supported by grants from the Learning and Media Technology Studio (LETStudio) at the University of Gothenburg and the Swedish Federal Government under the LUA/ALF agreement. We would like to thank the staff working in the cardiology laboratory for participating in the present study. None of the authors have any conflict of interest.

References

Impact of a system for real-time visualisation of radiation dose rate


