Coaching Reduced the Radiation Dose of Pain Physicians by Half during Interventional Procedures

A. S. Slegers, MSc*; I. Gultuna, MD†; J. A. Aukes, MD†; E. J. J. A. van Gorp, MD†; F. M. N. Blommers, BHS‡; S. P. Niehof, PhD§; J. Bosman, MSc, PhD*

*Department of Medical Physics, Albert Schweitzer Hospital, Dordrecht; †Department of Anesthesiology, Albert Schweitzer Hospital, Dordrecht; ‡Department of Radiology, Albert Schweitzer Hospital, Dordrecht; §Department of Medical Physics, Maasstad Hospital, Rotterdam, the Netherlands

Abstract: The increased use of C-arm fluoroscopy in interventional pain management has led to higher radiation exposure for pain physicians. This study investigated whether or not real-time radiation dose feedback with coaching can reduce the scatter dose received by pain physicians. Firstly, phantom measurements were made to create a scatter dose profile, which visualizes the average scatter radiation for different C-arm positions at 3 levels of height. Secondly, in the clinical part, the radiation dose received by pain physicians during pain treatment procedures was measured real-time to evaluate (1) the effect of real-time dose feedback on the received scatter dose, and (2) the effect of knowledge of the scatter dose profile and active coaching, on the scatter dose received by the pain physician. The clinical study included 330 interventional pain procedures. The results showed that real-time feedback of the received dose did not lead to a reduction in scatter radiation. However, visualization of the scatter dose in a scatter dose profile and active coaching on optimal positions did reduce the scatter radiation received by pain physicians during interventional pain procedures by 46.4% (P = 0.05). Knowledge of and real-time coaching with the scatter dose profile reduced the dose of pain physicians by half, caused by their increased awareness for scatter radiation and their insight into strategic positioning.

Key Words: scatter dose, pain interventions, coaching, education, scatter dose profile, fluoroscopy, radiology, C-arm

INTRODUCTION

Scatter radiation, as a side effect of fluoroscopy, increasingly constitutes an occupational hazard for pain physicians. Fluoroscopic guidance is used for accurate needle placement to ensure target specificity and accurate delivery of the injected drug, often combined with pulsed radiofrequency/radiofrequency (PRF/RF) treatments of the nerves and intradiscal procedures. Fluoroscopy involves risks of radiation exposure, not only for the patient, but also for the pain physician and the personnel in the room.1-4

Studies evaluating dose levels received by pain physicians performing fluoroscopically guided interventional procedures show that radiation dose levels to physicians are within regulated acceptable dose limits if
adequate radiation protection measures have been implemented.1,5–10 Still, the as low as reasonably achievable (ALARA) principle has to be taken into account in view of the uncertainties in the cumulative effects of low levels of radiation.5,11,12

A method to optimize radiation protection during fluoroscopy is knowledge of radiation dose levels and of basic strategies to minimize these levels.13 Awareness of dose levels can be provided to specialists using a system that gives real-time information about the received dose.14,15 The Dose Aware system (Philips Healthcare, Best, the Netherlands) contains personal dosimeters for real-time visualization of the received dose on a monitor. A prototype of the Dose Aware system was used in an angiography room in a study of Sanchez et al.14 They concluded that the system can help to optimize staff members’ radiation protection during fluoroscopy. Recently, the Dose Aware system was used by Sandblom et al.15 to evaluate its impact on the dose rate of cardiologists during fluoroscopically guided procedures. They found that real-time visualization of radiation dose rate may have a positive impact on optimization of occupational radiological protection for cardiac interventions.15

The primary source of radiation to pain physicians during interventional procedures is from scatter radiation that is reflected by the patient. Pain physicians performing fluoroscopically guided procedures generally stand close to the patient and the radiation source, which makes it difficult to avoid exposure to radiation scatter.16–19 Furthermore, new possibilities and increased complex pain treatments demand a higher number of fluoroscopic guided procedures.20 As an indication, the pain physicians in our hospital treat about 1,080 patients a year, and receive a dose of 7.1 mSv a year on top of their lead apron. So far, little is known about scatter radiation dose in pain intervention management. Therefore, this study investigated if it was possible to further reduce the scatter radiation dose received by pain physicians.

The aim of this research was firstly to evaluate the effect of real-time dose feedback on the dose received by pain treatment physicians. Dose registration and real-time visualization of the radiation dose was achieved using the Philips Dose Aware system. Additionally, we evaluated the effect of actively coaching the pain physicians to optimize their dose using scatter dose profiles, a visualization of scatter radiation from the X-ray tube in different directions, in combination with real-time feedback of the received dose.

### METHODS

This study was performed at the Albert Schweitzer hospital, location Sliedrecht, the Netherlands in 2012 to 2013. It consists of both phantom and clinical measurements. The study was granted exempt status by the Institutional Review Board.

Scatter radiation was measured using a Dose Aware system, which used personal dosimeters (PDMs). These PDMs have a solid-state detector with an X-ray dose rate range of 3 nSv/second to 15 μSv/second. This system was used to measure scatter radiation dose in both phantom and clinical stage. The PDM has a solid-state detector equipped with a wireless connection that sends the scatter dose rate and cumulative scatter dose readings to a base station each second when it detects a certain level of radiation.14 If the dosimeter does not detect any significant radiation levels, information is transmitted to the base station each hour.

**Phantom Measurements**

Phantom measurements were made to create a scatter dose profile of the situation on site. This profile visualizes the average scatter radiation for different C-arm (Ziehm, Vision Ortho Plus) positions at 3 levels of height.

The PDMs were used in phantom measurements to visualize the scatter radiation in transverse and longitudinal directions. The obtained phantom measurements were visualized in a scatter dose profile. For the phantom measurements, a PMMA block, size 8 × 30 × 30 cm, was placed at the center of the table to symbolize a scattering surface of a human body. We measured at 3 levels of height, representing three parts of the physicians body: 45 cm from the floor for the knees, 110 cm for the abdomen, and 165 cm for eye level. The scatter radiation was measured in 16 angles from the target for each height, at a radius of 60 cm, 100 cm, 150 cm, and 200 cm from the center of the table, (Figure 1). A profile was estimated for the posterior–anterior (PA) position as well as for the lateral (LAT) position of the C-arm. The settings used for the PA position were an automatic fluoroscopy of 67 kV, 7.8 mAs, 25 pulses/second, and a table position of 83 cm from floor level. The settings for the LAT position were an automatic fluoroscopy of 110 kV, 7.2 mAs, 25 pulses/second, and a table position of 83 cm from floor level. These settings were adjusted to the C-arm at the operation room, as well as to the C-arm at the pain.
The measured radiation doses were processed in Matlab (version 2013b; The Mathworks Inc., Natick, MA, USA).

Clinical Measurements
The clinical study included 596 interventional pain procedures. Dose measurements were performed during nerve blocks (head/neck, thorax, lumbar, pelvis, and sacrum) and other complex treatments (neuromodulation, epiduroscopy, and nucleoplasty). Nerve blocks were performed with fluoroscopy in the operating room as well as in our pain treatment unit.

The received doses of the pain physicians were measured in mSv during a variety of pain procedures. Only adults were considered for pain procedures in our hospital. There was no patient selection; all pain procedures between October 15, 2012 and January 4, 2013 with fluoroscopic guidance were included in this study. Nerve blocks were performed with fluoroscopy in the operation room as well as in a pain treatment unit. Both locations were equipped with the same model mobile C-arm and had the same measurements.

Three clinical measurement stages were distinguished in this study. The time period for each stage was 3 weeks. During these measurement stages, one PDM was placed on top of the pain physicians lead apron at chest level. A second PDM was positioned on the mobile C-arm, 33 cm from the X-ray tube, to obtain a reference scatter dose for each interventional procedure. The patients’ weight was measured to assess whether the patient population between the 3 stages was similar.

The first stage was the ‘blind phase’, the baseline measurement. The pain physician wore the Philips Dose Aware personal dose meter (PDM) during this stage, but the dose was not displayed, nor was the scatter dose profile of the C-arm explained. In the second phase, the ‘open phase’, the pain physician could see his received scattering dose on a display but was not trained on the dose profile of the C-arm. During the last stage, the ‘open coaching phase’, the pain physician was supported by a coach. The coach could observe the dose the physician received and had knowledge from the scatter dose profile and gave the pain physicians instructions to reduce their received scatter dose. Coaching was done real-time in the clinical setting in which the coach focused on optimal position of physicians in relation to the dose profile of the C-arm. When an increased scatter dose was measured and observed, the coach advised the physicians in using a position in which they received less scatter radiation. Coaching did not influence the progress of the pain procedures.

Additional coaching in between procedures explained the basic strategies of radiation dose minimization, such as the effect of positioning, shielding, and minimizing...
the exposure time. The scatter dose profiles were used to explain the differences in dose profile in posterior and anterior positions of the C-arm and helped the physicians in finding strategic positions to stand. A variety of precautions were already taken in our pain treatment center, eg. the obligation to wear a lead apron, and adjustment of protocols to lower the dose.

Statistical Analysis
Data were analyzed using SPSS software (released 2009, PASW Statistics for Windows, Version 18.0, Chicago, IL, USA). The following information was collected for each intervention in the SPSS database: patients’ weight (kg), fluoroscopy time (seconds), type of procedure, attending physician, dose received by the pain physician (mSv), dose of reference badge on C-arm (mSv), location of procedure (operation room or pain treatment unit), and date of the procedure. Logistic and linear regression were used for multivariate analysis to relate the outcome variable (scatter dose received by pain physicians) to causal variables (the reference dose and the measurement stage). We used a multiple linear regression analysis in SPSS (Anova, 95% confidence interval) to analyze if the dose reduction was significant. A P-value lower than 0.05 was considered significant.

RESULTS
Phantom Measurements
Figure 2 shows the scatter dose profiles for the different C-arm positions. For the PA position, the scattering was the highest at knee level, which was caused by the patient

Figure 2. The profiles are measured at three heights in the room: eye, abdomen, and knee level.
and operating table that reflected the X-rays coming from the tube below. For the LAT position, scatter doses were the highest at abdomen level. The table leg stopped some of the radiation as can be observed in south direction in the PA knee figure. Dose received by radiation scatter is higher in the LAT position than for the PA position. For the LAT position, when standing at the detector side of the table less scatter radiation is received than at the X-ray tube side of the table.

**Clinical Measurements**

In total, 596 interventional pain procedures were included in this study (228, 163, and 205 for the three phases, respectively). Three highly experienced pain physicians, accompanied by an experienced diagnostic radiographer performed all procedures.

One PDM used by a pain physician had technical failures, as was confirmed by the manufacturer. Consequently, the data obtained with this PDM were excluded from the data analysis. Also, all 48 complex treatments (neuromodulation, epiduroscopy, and nucleoplasty) were excluded in the analysis, because of the big variations in fluoroscopy time compared to other procedures and because of the small number of procedures. As a result, all 330 nerve block treatments performed by 2 pain physicians were included in our analysis. The included nerve blocks were divided into 5 anatomical regions, head/neck, thorax, lumbar, pelvis, and sacrum. Table 1 presents an overview of the included number of procedures and of the mean weight of the patients.

Figure 3 presents box plots of the dose received by the pain physician per procedure for the 3 different phases. No significant ($P = 0.05$) dose reduction was found between the blind (baseline phase) and open phase. The median dose was similar in the first stages, 2.65 $\mu$Sv/procedure in the blind phase and 2.64 $\mu$Sv/procedure in the open phase. The open coaching phase showed a dose reduction compared to the blind phase, from a median dose of 2.65 to 1.20 $\mu$Sv/procedure. In addition, the degree of dispersion was much smaller in the last phase than in the blind phase, and the dose was more consistent after coaching.

A log transformation was applied to the reference dose and the dose of the specialist to enroll a more normal distribution. The dose of the specialist was taken as a dependent variable, and the reference dose and phase (blind, open, or open coaching) as explanatory variables. The reference dose corrected for variations in fluoroscopic time.

The weight of the patient had no significant influence on the dose of the specialist. The open coaching phase showed a significant dose reduction of 46.4% ($P = 0.05$). The open phase revealed not a significant reduction.

**DISCUSSION**

The aim of this study was to evaluate the effects of using real-time dose feedback on the scatter dose received by pain physicians. Our findings reflect that real-time dose feedback from the Dose Aware system without coaching had no effect on the scatter dose received by the pain physicians. However, the dose was reduced by half due to active coaching. Active coaching made use of scatter

<table>
<thead>
<tr>
<th>Phases</th>
<th>Blind Phase</th>
<th>Open Phase</th>
<th>Open Coaching Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Procedures*</td>
<td>117</td>
<td>100</td>
<td>113</td>
</tr>
<tr>
<td>Mean Weight (kg)†</td>
<td>80.5</td>
<td>83.0</td>
<td>83.4</td>
</tr>
</tbody>
</table>

*Complex procedures and data from one pain physician is excluded in the data analysis.
†t-test, one-sample.

**Table 1. Overview of Number of Procedures and Mean Weight for the Different Phases**

![Figure 3. Box plot showing the dose of the specialist per procedure for the different phases. The lower and upper limits of the box are the first and third quartile, respectively, and the line inside the box represents the median value. The tails represent the 1.5 interquartile range of the lower quartile, and the 1.5 interquartile of the upper quartile.](image-url)
dose profiles and translated them in optimal positions during pain interventions.

Probably because of the active coaching approach, the findings of our clinical study are not in line with the study of Sandblom et al., who only used real-time visualization of radiation dose rate and stated that this may have a positive impact on optimization of occupational radiological protection. They found a significant dose reduction in 1 of 3 cardiologists when the radiation dose rates were displayed, while we did not find a dose reduction using only real-time dose visualization. Sanchez et al. used in his study a prototype of the Dose Aware system in an angiographic room to optimize the radiation protection of staff members during fluoroscopy. However, they did not verify if there was a significant reduction of dose rate when the Dose Aware system was used. Real-time visualization of dose rate may be less effective in pain management because of the short fluoroscopy times. As a consequence, pain physicians have not enough time to look at the display and correct their position, if necessary.

However, in the last stage the coach helped the pain physicians to instruct and alert them in using a position in which they received less scatter radiation. Dose profiles based on the phantom measurements gave the physicians useful information on strategic positions in which they could receive less radiation. It is more strategic to stand at the caudal or detector side instead of the X-ray tube side where there is a high risk of scatter radiation, especially for a lateral position of the C-arm. Demonstrating dose profiles increased the awareness of the pain physicians as to scatter radiation and provided strategic positions in which to stand. A major advantage of using dose profiles is that the physicians could plan in advance the best location to stand during a procedure.

A limitation of the study was technical failure of one of the Dose Aware badges, however, there was enough data collected from the other badges for the statistical analysis. Another limitation is that this research is performed in 1 hospital, although an interhospital comparison could be valuable.

Our findings reflect that using the Dose Aware system by itself has no effect on the scatter dose in experienced hands. On the other hand, we would have expected a more significant effect in less experienced pain physicians and trainees taking more time to look at the Dose Aware monitor and respond to it. The less experienced physicians and trainees are likely to use higher fluoroscopy times than experienced pain physicians. Therefore, a PDM with real-time dose feedback could alert them and increased their awareness of the scatter dose they received.

CONCLUSIONS

Knowledge of and real-time coaching on scatter dose profiles reduced the dose received by pain physicians by almost 50% for interventional pain procedures. Dose profiles increased the physicians’ awareness for scatter radiation in advance and gave them insight into strategic positioning. Real-time display of the radiation dose did not reduce the dose received by the pain physician, but was helpful during on site coaching to visualize the effects of positioning during interventional procedures.

REFERENCES


