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Observational Study

Fluoroscopy Procedure and Equipment Changes to Reduce Staff Radiation Exposure in the Interventional Spine Suite

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Background: Fluoroscopic guided percutaneous interventional spine procedures are increasingly performed in recent years as they have been shown to be target specific and enhance patient safety. However, ionizing radiation has been associated with stochastic effects such as cancer and genetic defects as well as deterministic effects such as cataracts, erythema, epilation, and even death. These are dose related, and hence, measures should be taken to minimize radiation exposure to patients and health care personnel to reduce these adverse effects.

Objective: A risk reduction project was completed with the goal of reducing effective doses to the staff and patients in a university-based spinal interventional practice. Effective dose reduction to the staff and patients was hypothesized to occur with technique and equipment changes in the procedure suite. The goal of this study was to quantify effective dose rates to staff before and after interventions.

Study Design: Retrospective study comparing descriptive data of effective dose to the health care staff before and after implementation of a combination of technique and equipment changes.

Methods: Technique changes from pre to post intervention period included continuous needle advancement under continuous fluoroscopic controlled by the interventional physician to intermittent needle advancement under pulsed fluoroscopic controlled by the radiology technician. Equipment changes included circumferential lead drape skirt around the procedure table and use of mobile transparent lead barriers on both sides of the procedure table.

Effective dose exposure measured in Millirem (mrem) from the radiation dosimetry badges for pre-intervention (February 2009 through June 2009) and post-intervention (November 2009 through March 2010) periods were examined through monthly radiation dosimetry reports for the fluoroscopy suite staff.

Results: A total of 685 interventional procedures were performed in the pre-intervention period and 385 in the post-intervention period. The median cumulative mrem (interquartile range) for all staff combined in the pre-intervention period was 71 (28,75) and post-intervention period was 1 (0,3). The median mrem per procedure was significantly higher in the pre-intervention group 0.46 (0.36, 0.54) compared to post-intervention 0.01 (0.0.03); $P < 0.01$. The percentage reduction in overall effective dose per procedure to all staff was 97.3%.

Limitations: Observational study, multiple radiation reduction interventions confound the individual effects of each intervention's effective dose

Conclusions: Spinal injection technique and equipment changes in the procedure suite significantly reduced the rate of effective dose to the clinical staff.

Key words: Fluoroscopy, effective radiation dose, spine

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Fluoroscopic guided interventional procedures are performed in large numbers in the United States and Europe. The number of procedures performed has increased annually over the past 20 years (1). The growing use and increasing complexity of these procedures have been accompanied by public health concerns resulting from the increasing radiation exposure to both patients and health care personnel (2). Exposure to ionizing radiation is an established environmental risk factor for malignancy (3,4). Maximizing patient benefits by using these less invasive percutaneous interventional procedures is important but so is developing strategies to reduce fluoroscopic induced radiation risks to health care personnel involved in these procedures (5). Most of the risks of radiation dose to the physicians and staff in the interventional suite are due to scatter, which is the dose of radiation that bounces off the patient (6). Traditional protective measures, such as wearing lead aprons and skirt for physicians, have been shown to reduce exposure to the upper body but not the lower body (7). The radiation dose depends on several factors such as the type of procedure, size of the patient, and technique used. Even a relatively simple procedure has the potential to become a high dose procedure if poor techniques are used. It is important to understand what actions the fluoroscopist can take to reduce the radiation output that can decrease the skin dose to the patient as well as staff members in the procedure room. It has now been established that use of continuous radiation in fluoroscopy is associated with increased radiation dose. The risks can be minimized by using pulsed fluoroscopy that acquires images at 15 frames/second rather than the usual 30 frames/second (2,8) along with adopting proper techniques and adequate training.

Modern day C-arms are usually equipped with advanced image intensifiers and image processing software. This, along with the use of pulsed fluoroscopy, allows for decreased exposure to ionizing radiation during interventional procedures. As described by Fishman et al in 2002 (6), the risks can be minimized by a healthy respect for electromagnetic radiation, proper safety education, and adopting some commonsense practices, keeping exposure as low as reasonably achievable (ALARA). However, no amount of radiation can be considered safe to the patient, physician, or other personnel. According to the national council on radiation protection and measurements (NCRP), the maximum annual exposure limit for physicians is 5 REM (9). Previous studies on fluoroscopic guided procedures have reported low exposure rates that are well below the maximum permissible dose (10,11). However, it should not give a false sense of security as the risks due to chronic low dose cumulative exposure are still unclear (12).

We hypothesized that a combination of measures involving technique changes and equipment changes mainly to reduce scatter will further reduce the effective dose to the staff. To this end, we implemented some technique changes from use of continuous needle advancement using continuous fluoroscopy controlled by the physician to intermittent needle placement using pulsed fluoroscopy controlled by the radiology technician and equipment modifications such as introduction of a lead drape skirt around the table and placement of mobile plastic lead barriers on both sides of the table with a goal to reduce the effective dose exposure. Our objective was to retrospectively measure the effective dose to the interventional suite staff members in the procedure room before and after implementation of procedural and equipment changes to determine the dose exposure and risk reduction to radiation exposure.

Methods

All procedures were performed in an academic setting at the Penn Spine Center at the hospital of the University of Pennsylvania. The procedures both before risk reduction intervention and after risk reduction intervention included outpatient percutaneous spinal procedures including interlaminar epidural injections, transforaminal epidural injections, zygaphophysial joint injections, medial branch blocks, sacroiliac joint injections, and large peripheral joint injections. Luxel+® dosimetery badges (Laundaur, Glenwood, IL, USA) were placed on the outside of lead vests in the upper chest and neck areas of all monitored nursing, radiologic technologist, and physician staff. A Siemens Siremobil Compact L fluoroscopy C-arm (Siemens, Malvern, PA, USA) was used in both pre-intervention and post-intervention assessment periods (Figs. 1 and 2).

Effective doses (mrem) measured from the radiation dosimetry badges were collected for 5 months before and 5 months after implementation of radiation reduction techniques. The pre-intervention period was defined as February 2009 through June 2009 and the post-intervention period was defined as November 2009 to March of 2010.

Technique and equipment used pre-intervention included continuous needle advancement using continuous fluoroscopy controlled by the physician using

Fig. 1. *Pre-intervention: Continuous needle advancement using continuous fluoroscopy controlled by physician using "foot pedal."*

Fig. 2. *Post-intervention: Use of pulsed fluoroscopy controlled by hand held device by radiology technician, use of lead skirts around the procedure table and mobile transparent lead barriers.*

Fig. 3. *Mobile opaque lead barrier with small window used in pre-intervention period.*

a foot pedal (Fig. 1) and use of an opaque lead barrier with small windows (Fig. 3). The implementation period of the radiation reducing practice primary changes occurred during a 4 month period from July 1, 2009, to October 31, 2009 (Fig. 4). Radiation reduction interventions using the injection technique and equipment changes were implemented as follows:

Installation of lead lined table skirt on both sides of the table (Fig. 2)

Translucent lead-lined plastic mobile barriers (Fluke Biomedical Radiation Management Services, Cleveland, OH, USA) (Fig. 2)

The needle was guided using the pulsed fluoroscopic technique (Fig. 2).

Control of the x-ray beam was delegated to the radiologic technologist, who used intermittent spot fluoroscopy controlled by a hand-held device.

Statistical Analysis

Effective dose (mrem) values for each staff were obtained from their dosimetry badges and recorded from February 2009 to March 2010 in Microsoft Excel 2007 (Richmond, WA). The pre and post intervention data was analyzed using comparative analysis software JMP (SAS Campus Drive, Cary, NC). Data analysis included

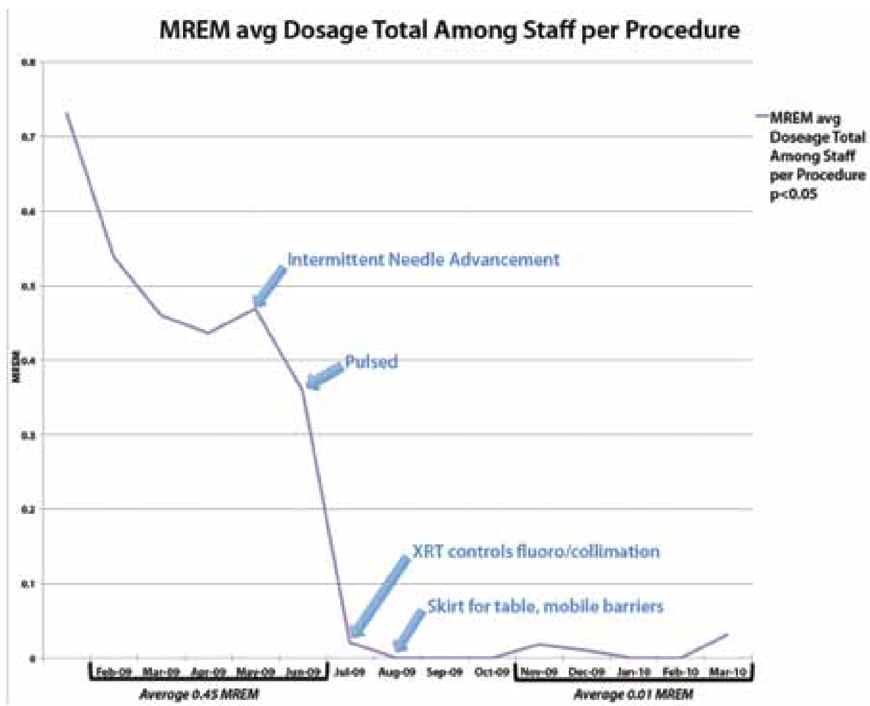

Fig. 4. *Cumulative Effective Dose (mrem) for all staff per procedure.*

data collected 5 months before (February – June 2009) and 5 months after (November 2009 – March 2010) the implementation period. The dosimetry badge reading for each of the staff (nurse, radiation technologist, and physicians) were recorded monthly. These data were summed to calculate the total dose received by all staff members collectively. The total number of injection procedures was also recorded for each of these months. To account for variation of the number of procedures per month, an mrem per injection procedure per month was calculated for use for further analysis. See Table 1. Paired sample t-test was used to compare the means of the mrem per procedure between the pre- and post-intervention period. The percentage risk reduction was also calculated.

Results

The total number of injections performed in the pre-intervention period was 685 and post-intervention period was 385. Although twice as many procedures were performed in the pre-intervention time period compared to the post-intervention, the total dose exposure after our intervention is only one hundredth of the pre-intervention period (315 versus 3 mrem). A statistically significant difference in the effective dose per procedure for staff was found between the pre-intervention [0.45 (0.36, 0.54)]; median (interquartile range) and post-intervention period [0.01 (0, 0.03); $P < 0.01$]. See Table 1. The actual numbers of various percutaneous procedures performed in the 2 time periods are shown in Table 2. There was a 97.3% overall risk reduction in effective dose post-intervention.

Discussion

The results of this study on effective dose measurements on fluoroscopy staff in the interventional spine suite showed that the risk of radiation exposure can be greatly reduced by adopting some procedural and equipment changes along with taking standard precautions such as wearing lead aprons, skirts, and thyroid and eye shields. The procedure changes included intermittent needle advancement with the use of pulsed fluoroscopy that was controlled by the radiology technician using a hand-held device. Equipment changes included installation of a lead skirt around the procedure table on both sides and use of mobile transparent plastic lead barriers.

Traditionally, it has been more comfortable to perform fluoroscopy while standing next to the patient. Reducing effective dose can be enhanced by practically implementing the inverse square law, and by standing behind a barrier shield (5). This can be easily done by removing the foot pedal. Removal of the foot pedal and delegating control of the fluoroscope to the radiologic technologist by adding a hand spot controller helps to limit the effective dose and keeps staff exposures ALARA. This technique may also reduce inadvertent use of the fluoroscope, which can occur by unknowingly stepping on the foot pedal. Furthermore, some clinicians tap the pedal more than once during spot fluoroscopy, or even tap the wrong pedal (i.e., the continuous or boost fluoroscopy). In our study, we used continuous fluoroscopy controlled by the physician using the foot pedal in the pre-intervention period and pulsed mode controlled by the radiologic technologist using a hand-held device in the post-intervention period as recommended (8,13). Our study further adds to the literature evidence that pulsed mode is associated with reduced effective dose exposure. In addition, we introduced some technique changes to needle insertion from continuous needle advancement to intermittent needle advancement as recommended by the International Spine Interventional Society (ISIS) and North American Spine Society (NASS) (8,14). This is likely to have contributed to our decreased effective dose.

Physicians and staff should be mindful of the scattered radiation which is 2 to 3 times the patient's absorbed skin dose (11,15). In addition to each staff using a lead apron and lead skirt, we introduced some equipment changes such as using mobile transparent lead barriers in the post-intervention period as opposed to large opaque lead barriers that were used in the pre-intervention period. These mobile barriers are not only lightweight, but also provide adequate lead equivalence and more importantly reduce scatter and do not have to be adjusted each time. We also introduced lead skirts all around the procedure table. Our goal was to reduce the effective dose by implementing a combination of technique and equipment changes. Our results showed that, with the introduction of all these changes, we were able to demonstrate an exposure risk reduction of 97.3%.

It has been estimated that approximately 19 million interventional procedures are performed each year for management of chronic pain with at least 50% of them being performed under fluoroscopy (1,2). Fluoroscopic guidance allows for precise and accurate needle placement during injections and has become mandatory based on the definition of procedure or requirement of third parties (16,17). Several studies on efficacy of spinal interventional procedures reported incorrect needle placement without fluoroscopic guidance in 25% – 40% of caudal epidural steroid injections (18,19) and 13% – 30% for interlaminar epidural steroid injection (18). In addition, inadvertent intravascular uptake has been reported while performing fluoroscopic guided injections in 8.5% of lumbar procedures with higher percentages for lumbar transforaminal epidural steroid injection(10.8%) (20) and 21% for S1 TFESI (21). The risk is further increased (20% – 32.8% with cervical TFESI (22,23). These studies clearly demonstrate that fluoroscopic guidance is an essential prerequisite to perform these procedures.

Compared to cardiac, vascular, urological, and neurological procedures, fluoroscopic guided interventional spine procedures are considered to be short and safe. However, this should not give a false sense of security because the radiation risks are due to cumulative dose exposure over the years (2,24). According to the results published by the United Nations Scientific Committee on the effects of atomic radiation (25), although interventional spine procedures contribute to only 7% of total radiological procedures in the medical field, the percentage of collective dose arising from these procedures is about 21% of the total medical exposure (1,26). Furthermore, fluoroscopy exposure times have been shown to be significantly higher for commonly performed procedures such as epidural steroid injections, facet joint blocks, sympathetic nerve block, and sacroiliac joint blocks in university teaching hospitals compared to private practice settings (27) due to the increased training times for residents and fellows. With the advent of more non-invasive interventional procedures such as radiofrequency ablation, discography, percutaneous discectomy, etc., fluoroscopy time could increase significantly, resulting in prolonged exposure. Furthermore, using digital subtraction angiography (DSA) in interventional spinal procedures is recommended as it helps to better detect inadvertent intravascular uptake (23). This is likely to contribute to further increases in radiation exposure time (14). This emphasizes the fact that interventional procedures are associated with high cumulative doses to all personnel. Long-term adverse biological consequences of chronic low dose radiation exposure remains unclear, with genetic and malignant change still a possibility (12,28)

As fluoroscopically guided injections continue to increase in prevalence, so too should the commitment to reduce the effective dose to staff and clinicians who perform these procedures. Using dosimeters, the effective dose of radiation to workers can now be monitored. Effective dose is a risk-based measure of radiation dose to the human body. It is a useful measure when considering radiation risk to the body as a whole and is adjusted for the type of radiation and the relative radiosensitivity of the exposed portions of the body. Studies have evaluated the effective doses to orthopedic surgeons using fluoroscopy (29), to interventional cardiologists (30), to urologists during endourologic procedures (31), and to interventional radiologists performing a variety of procedures (32). The measurement for recording the effective dose is the roentgen equivalent man (rem) or mrem, which is measured by using a dosimetry badge. There are many ways to reduce the effective dose to radiation worker staff including increasing the distance from the radiation source; using lead aprons, thyroid shields, and radiation barrier shields; and using collimation and pulsed/low dose modes (8,24). Goodman et al (13) describes the use of collimation, limiting the use of boost, magnification, and digital subtraction to reduce exposure dosage. There is a variation in the available literature with some studies reporting increased fluoroscopy times and radiation exposure with transforaminal and caudal epidural steroid injections (10,11,33). Zhou et al (27) reported that the differences were due to the use of continuous mode in some studies and pulsed mode in other studies.

Previous studies have shown that radiation exposures are less when procedures are performed by more experienced physicians. Radiation exposure is also higher in university teaching hospital settings compared to private practice settings as significant time is added to the fluoroscopy exposure time due to the training of residents and fellows (27). Although experience level of individual physicians appears to be an important contributing factor to increased exposure (7), it is not the only factor. There is a wide variation in fluoroscopy time and radiation dose for attending physicians in different pain clinics in university settings who face the same group of trainee residents and fellows as shown by Zhou et al (27). Our study was conducted in a spine center of a university teaching hospital where there is continuous training of fellows and residents. In spite of this educational environment, we were able to show a decrease in effective dose to all staff including the trainees following implementation of changes. This further emphasizes that the principle of ALARA is achievable even in training settings as long as safe practice procedures are adopted.

Limitations

The multiple simultaneous radiation reduction interventions that took place in this academic setting may confound the individual effects of each intervention on effective dose reduction. However, these changes in technique and equipment were minimal at best, and can be easily adapted to any interventional suite. Although we cannot definitively conclude one change was the key to reducing radiation exposure by 97.3%, we can comfortably say that the changes made have significantly decreased the effective dose to staff. We acknowledge that significantly more procedures were done in the pre-intervention period compared to post-intervention period. To reduce bias, we measured effective dose per procedure in both time periods.

Conclusions

Spinal injection technique and equipment changes in the procedure suite significantly reduced the rate of effective dose to the clinical staff.

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