Radiation Exposure of the Hand and Chest during C-arm Fluoroscopy-Guided Procedures

Cheol Hee Jung, MD, Jae Sung Ryu, MD, Seung Woo Baek, MD, Ji Hye Oh, MD*, Nam Sik Woo, MD, Hae Kyoung Kim, MD, and Jae Hun Kim, MD

Background:
The C-arm fluoroscope is an essential tool for the intervention of pain. The aim of this study was to investigate the radiation exposure experienced by the hand and chest of pain physicians during C-arm fluoroscopy-guided procedures.

Methods:
This is a prospective study about radiation exposure to physicians during transforaminal epidural steroid injection (TFESI) and medial branch block (MBB). Four pain physicians were involved in this study. Data about effective dose (ED) at each physician's right hand and left side of the chest, exposure time, radiation absorbed dose (RAD), and the distance from the center of the X-ray field to the physician during X-ray scanning were collected.

Results:
Three hundred and fifteen cases were included for this study. Demographic data showed no significant differences among the physicians in the TFESIs and MBBs. In the TFESI group, there was a significant difference between the ED at the hand and chest in all the physicians. In physician A, B and C, the ED at the chest was more than the ED at the hand. The distance from the center of the X-ray field to physician A was more than that of the other physicians, and for the exposure time, the ED and RAD in physician A was less than that of the other physicians. In the MBB group, there was no difference in the ED at the hand and chest, except for physician D. The distance from the center of the X-ray field to physician A was more than that of the other physicians and the exposure time in physician A was less than that of the other physicians.

Conclusions:
In conclusion, the distance from the radiation source, position of the hand, experience and technique can correlate with the radiation dose. (Korean J Pain 2013; 26: 51-56)

Key Words:
distance, exposure time, radiation dose, radiation protection.
INTRODUCTION

Nowadays, the C-arm fluoroscope is an invaluable tool for the intervention of pain. However, the danger of radiation exposure is well acknowledged. Ionizing radiation can cause both somatic and genetic damage. Examples are seen in squamous cell carcinomas of the hands, leukemia, thyroid cancers, stomach cancers, and birth defects [1]. It is common practice to wear lead aprons during fluoroscopy-guided procedures, and many pain physicians use thyroid shields routinely. Lead gloves, however, are not routinely used by pain physicians [2]. During fluoroscopy-guided procedures, pain physicians may be at risk from ionizing radiation both directly from the primary beam and indirectly via scattered radiation. The occupational dose limits, recommended by the International Commission on Radiology Protection, have been adopted by most countries in the world, including the European Union and the United States [3]. The limit for radiation dose is 20 mSv per year, averaged over a defined period of 5 years [4].

The aim of this study was to assess the radiation exposure doses in the hand and chest of pain physicians during C-arm fluoroscopy-guided procedures.

MATERIALS AND METHODS

This study was conducted from May to August of 2012. This is a prospective study about radiation exposure experienced by pain physicians during transforaminal epidural steroid injection (TFESI) and medial branch block (MBB). The pain physicians consisted of four doctors (one professor, and three fellows). The physician represented as the professor has more than 40 months of experience and the three fellows have 3 to 6 months of experience.

Two dosimeters were used to record the radiation exposure. One (PDM-127, Aloka, Tokyo, Japan) was worn on the palmar aspect of the right hand (Fig. 1A). The other (PDM-227, Aloka, Tokyo, Japan) was worn on the left side of the chest over the lead apron (Fig. 1B). The effective doses (ED) at each physician’s hand and chest were measured from direct reading dosimeters. Exposure times and the radiation absorbed doses (RAD) were collected from the C-arm fluoroscope (OEC 9800 Plus, GE healthcare, Salt Lake City, Utah). Immediately after X-ray scanning by C-arm fluoroscopy, the distance from the center of the X-ray field to the physician during X-ray scanning was also investigated. When we checked real-time fluoroscopy, we administrated contrast media through a 75-cm-long extension tube. We reviewed patients’ medical records to collect their age, height, and weight.

All statistical analyses were performed on SPSS version 17. Interphysician comparisons of the demographic data, such as age, weight, height, and sex of the patients, along with distance from the X-ray field, time, ED, and RAD were analyzed by ANOVA and Turkey’s multiple comparisons test. The ratio of male/female for each group was compared using a chi-square test. Statistical significance was defined as $P < 0.05$.

RESULTS

Three hundred and fifteen cases were included for this study. The number of cases in the TFESI and MBB analysis were 200 and 115, respectively. The ratios between males and females were compared using a chi-square test. Statistical significance was defined as $P < 0.05$. The professor has more than 40 months of experience and the three fellows have 3 to 6 months of experience.

Two dosimeters were used to record the radiation exposure. One (PDM-127, Aloka, Tokyo, Japan) was worn on the palm aspect of the right hand. The other was worn on the chest over the lead apron. Circle: detector of dosimeter.
Table 1. Demographic and Radiation Related Data in Transforaminal Epidural Steroid Injection

| Physician | A (n = 38) | B (n = 55) | C (n = 65) | D (n = 42) | P value |
|-----------|------------|------------|------------|------------|---------|
| Age (yr)  | 55.8 ± 14.8| 60.6 ± 15.0| 62.7 ± 16.2| 59.0 ± 13.8| 0.153   |
| Height (cm)| 165.2 ± 6.8| 162.1 ± 9.2| 162.6 ± 7.9| 165.1 ± 8.3| 0.139   |
| Weight (kg)| 65.8 ± 10.0| 64.4 ± 12.5| 63.5 ± 10.2| 68.1 ± 8.8 | 0.146   |
| Distance (cm)| 74.1 ± 13.4| 40.7 ± 9.5 | 43.9 ± 3.7 | 46.9 ± 1.4 | 0.000*  |
| Time/level (sec)| 17.5 ± 7.4 | 27.0 ± 15.9 | 28.2 ± 17.3 | 37.8 ± 15.3 | 0.000*  |
| Hand/level (μSv)| 3.4 ± 3.8 | 13.1 ± 9.3 | 12.7 ± 9.1 | 37.8 ± 35.3 | 0.000*  |
| Chest/level (μSv)| 6.4 ± 8.8 | 20.1 ± 16.0 | 26.9 ± 19.6 | 26.5 ± 36.5 | 0.000*  |
| RAD/level (rad/cm²)| 103.5 ± 87.5| 229.0 ± 145.8| 120.5 ± 85.4| 236.2 ± 148.5| 0.000*  |

Distance: the distance from center of X-ray field to physician, Time/level: exposure time per one level, RAD/level: radiation absorbed dose per one level, Hand/level, Chest/level: radiation dose at hand and chest per one level. Values are expressed as mean ± SD. N: number of the patients. *P < 0.05. Small letter: the same letters indicate non-significant difference between groups based on Turkey’s multiple comparison test.

Table 2. Demographic and Radiation Related Data in Medial Branch Block

| Physician | A (n = 15) | B (n = 4) | C (n = 33) | D (n = 49) | P value |
|-----------|------------|------------|------------|------------|---------|
| Age (yr)  | 56.7 ± 19.7| 49.5 ± 2.9 | 60.1 ± 16.8| 56.4 ± 15.0| 0.553   |
| Height (cm)| 162.5 ± 6.8| 168.4 ± 11.2| 160.8 ± 6.1| 163.0 ± 6.0| 0.089   |
| Weight (kg)| 66.7 ± 11.3| 62.8 ± 11.9| 60.1 ± 8.5 | 60.2 ± 6.7 | 0.061   |
| Distance (cm)| 69.0 ± 3.1 | 43.3 ± 2.8 | 44.0 ± 4.4 | 39.4 ± 3.6 | 0.000*  |
| Time/level (sec)| 2.1 ± 0.9 | 8.5 ± 3.4 | 5.5 ± 3.0 | 4.9 ± 2.1 | 0.000*  |
| Hand/level (μSv)| 0.6 ± 0.7 | 2.6 ± 2.0 | 1.7 ± 5.8 | 0.9 ± 0.8 | 0.519   |
| Chest/level (μSv)| 0.4 ± 0.5 | 1.6 ± 1.9 | 1.2 ± 2.3 | 0.5 ± 0.4 | 0.062   |
| RAD/level (rad/cm²)| 12.3 ± 8.3| 229.0 ± 145.8| 236.2 ± 148.5| 304.6 ± 250.0| 0.174   |

Distance: the distance from center of X-ray field to physician, Time/level: exposure time per one level, RAD/level: radiation absorbed dose per one level, Hand/level, Chest/level: radiation dose at hand and chest per one level. Values are expressed as mean ± SD. N: number of the patients. *P < 0.05. Small letter: the same letters indicate non-significant difference between groups based on Turkey’s multiple comparison test.

Table 3. Radiation Dose at the Hand and Chest in TFESI

| Physician | Hand/level (μSv) | Chest/level (μSv) | P value |
|-----------|------------------|-------------------|---------|
| A (n = 38) | 3.4 ± 3.8        | 6.4 ± 8.8         | 0.003*  |
| B (n = 55) | 13.1 ± 9.3       | 20.1 ± 16.0       | 0.000*  |
| C (n = 65) | 13.2 ± 9.0       | 26.5 ± 19.2       | 0.000*  |
| D (n = 42) | 37.8 ± 35.3      | 26.5 ± 36.5       | 0.010*  |

TFESI: Transforaminal Epidural Steroid Injection, Hand/level, Chest/level: radiation dose at hand and chest per one level. Values are expressed as mean ± SD. N: number of the patients. *P < 0.05.

There were no significant differences in the patient’s sex, age, height, and weight among each of the physicians (Table 1, 2). In the TFESI group, there were statistically significant differences in the distance from the X-ray exposure time, and ED at the hand and chest, as well as RAD between the physicians (Table 1). The distance from the center of the X-ray field to physician A was more than that of the other physicians, and the exposure time, ED, and RAD in physician A were less than that of the other physicians, ED at the hand of physician D was more than that of the other physicians. There were significant differences between ED of the hand and ED of chest in all the physicians (Table 1). In physician A, B, and C, the ED at the chest was more than the ED at the hand. In physician A, the lowest dose was received at the hand and chest, while the distance from the X-ray field was the furthest among the physicians (Table 1).

In the MBB group, there were no differences between the ED at the hand and chest, except for physician D (Table 4). There were statistically significant differences in the dis-
| Physician | Hand/level (μSv) | Chest/level (μSv) | P value |
|-----------|-----------------|-------------------|---------|
| A (n = 15) | 0.6 ± 0.7       | 0.4 ± 0.5         | 0.057   |
| B (n = 4)  | 2.6 ± 2.0       | 1.6 ± 1.9         | 0.155   |
| C (n = 33) | 1.7 ± 5.8       | 1.2 ± 2.3         | 0.654   |
| D (n = 49) | 0.9 ± 0.8       | 0.5 ± 0.4         | 0.000*  |

MBB: medial branch block, Hand/level, Chest/level: radiation dose at hand and chest per one level. Values are expressed as mean ± SD. N: number of the patients. *P < 0.05.

**Fig. 2.** Various position of hands during X-ray scanning. (A) Physician A’s position, (B) Physician B and C’s position, (C) Physician D’s position.

**Fig. 3.** The positions of each physician’s hand which was looked down. (A) Physician A’s position, (B) Physician B and C’s position, (C) Physician D’s position.

**DISCUSSION**

Radiation has the potential to cause harm, as well as provide benefits during medical use. Thus, limiting the potential risks from radiation exposure in these procedures is essential, while physicians must remember that there is no dose below which there is zero risk [5]. The adverse effects of ionizing radiation on the human body include skin...
diseases, thyroid cancers, brain tumors, and cataracts [6]. The degree of the risks to health from radiation is primarily dependent on intraoperative exposure time, cumulative career exposure, and the effectiveness of the utilized protective measures [7,8]. The ED of the hand depends on the position of the physician’s hands, Fig. 2 and 3 show various positions of the hands and the distance from the field during X-ray scanning. The hand dosimeter was worn only on the palmar aspect of the right hand. Therefore, the ED was not measured at the dorsum of the hand, but at the palm of the hand. If the physician’s palm faced the opposite side of the radiation source, ED at the hand for this study would be decreased. Although the hand was closer than the chest in physician A during TFESI, the radiation detector faced the opposite side from the radiation source during X-ray scanning, which could be related to a less effective dose than that of the chest. The mean ED at the hand of physician D was the highest during TFESI. The physician’s palm faced the radiation source for a longer duration than the others during the procedures (Fig. 2). Moreover, the hand of physician D was higher than the ED of the chest. The causes of these results are thought to be due to MBB being a simple procedure, with the differences of ED and RAD being very small among the physicians, along with their experience, did not influence radiation exposure. However, in the TFESI groups, it was shown that the hand and chest positions, distance from the radiation source, and the physician’s experience influenced radiation exposure.

In conclusion, the physician’s distance from the radiation source, position of the hand, experience and technique...
can correlate with the radiation dose in complicated procedures such as TFESI. Therefore, for radiation safety, we have to make efforts to keep our hands and body at a distance from the radiation field, while attempting to master the skills for interventional pain procedures.

REFERENCES

1. Andreassi MG. The biological effects of diagnostic cardiac imaging on chronically exposed physicians: the importance of being non-ionizing. Cardiovasc Ultrasound 2004; 2: 25.
2. Park PE, Park JM, Kang JE, Cho JH, Cho SJ, Kim JH, et al. Radiation safety and education in the applicants of the final test for the expert of pain medicine. Korean J Pain 2012; 25: 16-21.
3. Pradhan AS. Evolution of dosimetric quantities of International Commission on Radiological Protection (ICRP): Impact of the forthcoming recommendations. J Med Phys 2007; 32: 89-91.
4. Miller DL, Vaño E, Bartal G, Balter S, Dixon R, Padovani R, et al. Occupational radiation protection in interventional radiology: a joint guideline of the Cardiovascular and Interventional Radiology Society of Europe and the Society of Interventional Radiology. J Vasc Interv Radiol 2010; 21: 607-15.
5. Harding LK, Thomson WH. International commission on radiation protection. Nucl Med Commun 1990; 11: 585-7.
6. Cousins C, Sharp C. Medical interventional procedures—reducing the radiation risks. Clin Radiol 2004; 59: 468-73.
7. Mroz TE, Yamashita T, Davros WJ, Lieberman IH. Radiation exposure to the surgeon and the patient during kyphoplasty. J Spinal Disord Tech 2008; 21: 96-100.
8. Theocharopoulos N, Perisinskis K, Damalakis J, Papadokostakis G, Hadjipavlou A, Gourzoyiannis N. Occupational exposure from common fluoroscopic projections used in orthopaedic surgery. J Bone Joint Surg Am 2003: 85: 1698-703.
9. Blattert TR, Fill UA, Kunz E, Panzer W, Weckbach A, Regulla DF. Skill dependence of radiation exposure for the orthopaedic surgeon during interlocking nailing of long-bone shaft fractures: a clinical study. Arch Orthop Trauma Surg 2004; 124: 659-64.
10. Bahari S, Morris S, Broe D, Taylor C, Lenahan B, McElwain J. Radiation exposure of the hands and thyroid gland during percutaneous wiring of wrist and hand procedures. Acta Orthop Belg 2006; 72: 194-8.
11. Arnstein PM, Richards AM, Punney R. The risk from radiation exposure during operative X-ray screening in hand surgery. J Hand Surg Br 1994: 19: 393-6.
12. Siegel JA, Marcus CS, Sparks RB. Calculating the absorbed dose from radioactive patients: the line-source versus point-source model. J Nucl Med 2002; 43: 1241-4.
13. Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. The essential physics of medical imaging, 3rd ed. Philadelphia, Lippincott Williams & Wilkins, 2011, pp 837-902.
14. Singer G. Occupational radiation exposure to the surgeon. J Am Acad Orthop Surg 2005: 13: 69-76.
15. Cho JH, Kim JY, Kang JE, Park PE, Kim JH, Lim JA, et al. A study to compare the radiation absorbed dose of the C-arm fluoroscopic modes. Korean J Pain 2011; 24: 199-204.
16. Kallmes DF, O E, Roy SS, Piccolo RG, Marx WF, Lee JK, et al. Radiation dose to the operator during vertebroplasty: prospective comparison of the use of 1-cc syringes versus an injection device. AJNR Am J Neuroradiol 2003: 24: 1257-60.
17. Kruger R, Faciszewski T. Radiation dose reduction to medical staff during vertebroplasty: a review of techniques and methods to mitigate occupational dose. Spine 2003: 28: 1608-13.