An Observational Survey of Nail and Skin of Spine Surgeons-Possible Damage by Occupational Ionizing Radiation Exposure

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Abstract:

Introduction: Orthopedic surgeons are exposed to ionizing radiation daily. With the increase in the number of minimally invasive surgery performed under X-ray fluoroscopy, radiation exposure to unprotected fingers will increase. Although the effect of high dose radiation exposure is known, the long-term effect of exposure to low doses is unclear. This study aims to investigate damage to the nail and skin on the thumbs of spine surgeons via occupational ionizing radiation exposure.

Methods: Forty male spine surgeons (group S) and 40 males of the same age group who were not exposed to radiation (controls; group C) were included. Using a scoring system, we evaluated the damage to the fingernail and skin of the bilateral thumb. Scoring was based on fingernail pigmentation (melanonychia), fingernail crack, and periungual dermatitis status. We investigated the number of examinations and operations under radiation exposure in the last 3 months.

Results: Group S had 17.83 (3-28) years of surgeon experience. In group S, the dominant side scored significantly higher than the non-dominant side; however, there was no dominant vs. non-dominant difference in group C. Only the dominant side had a significantly higher score in group S than in group C. In group S, surgeon experience and the score of the dominant side were significantly correlated; however, for the non-dominant side of group S and both thumbs of group C, no correlation was observed. The kappa coefficients for fingernail pigmentation, fingernail crack, and periungual dermatitis status were 0.458, 0.248, and 0.612, respectively. The average number of examinations and operations under radiation exposure was 11.89 ± 9.04 (0-30) and 26.34 ± 14.67 (1-63), respectively.

Conclusions: The dominant side in group S had a significantly higher score than the non-dominant side in group S and the dominant side in group C, suggesting the possibility of radiation damage to the dominant side in group S.

Keywords:

spine surgeon, nail and skin damage, occupational ionizing radiation exposure, minimally invasive surgery

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Introduction

The exposure of healthcare workers to ionizing radiation is gaining increasing attention. Maintaining a certain distance, decreasing exposure time, and using proper shields are essential measures to prevent radiation exposure.

Orthopedic surgeons are often exposed to radiation[1,2], and the lifetime incidence of cancer in orthopedic surgeons is five times that of other radiation workers[3]. Surgeons are at a high risk for routine radiation exposure, and the use of protectors is required during fluoroscopic examinations and surgeries. However, exposure to upper limbs, especially fingers, which are difficult to protect with protectors, can be quite high[4-6]. Additionally, with the increasing popularity of minimally invasive surgeries in recent years, the number of procedures conducted under X-ray fluoroscopy is increasing.

A study that investigated the radiation exposure of one spine surgeon in routine practice showed that the effective dose in the protected chest was below the detection limit. Surprisingly, the equivalent dose for unprotected fingers was 368 mSv (equivalent to 1472 mSv per year). This exceeds the equivalent dose limit of 500 mSv[7].

There are several reports on the risk of skin ulcers and skin cancers caused by acute and high dose ionizing radia-

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Figure 1. A 52-year-old spine surgeon's thumb. Grade 1 nail pigmentation and grade 1 periungual dermatitis on the right thumb. Arrowhead indicates nail pigmentation, and arrow indicates periungual dermatitis.

tion exposure[8-10]. Conversely, it is generally known that long-term low-dose radiation exposure causes finger dermatitis and fingernail pigmentation; however, no study has investigated this condition, and the available evidence is weak. We hypothesized that spine surgeons are more likely to have dermatitis of the fingers due to daily radiation exposure compared with those who are not exposed to radiation. Additionally, we hypothesized that changes in the nail and skin may be strongly observed in the dominant hand. To elucidate these hypotheses, we compared the nail and skin conditions of the thumbs of spine surgeons with those of non-radiation workers.

Materials and Methods

This study was approved by the institutional review board. Forty male spine surgeons who provided their consent to participate in the study were assigned to group S. Of the 48 members of the Spinal Surgery Research Group, 40 were in agreement with this study. Forty men within the same age group (20-50 years) who were not exposed to radiation daily were assigned to the control group (group C). The dominant hand of each subject was the right hand. Those with a history of finger trauma or infection were excluded. Pictures of 160 thumbs from 80 participants were taken (Fig. 1-3). Using an original scoring system blindly and independently, nail and skin damage were evaluated by three spine surgeons (SF, KM, and TS). Differences between the dominant and non-dominant sides in groups S and C were analyzed statistically. The correlations between the score, age, and years of surgeon experience were also analyzed. Inter-examiner reliability was analyzed to assess the reliability of the scoring system. To estimate the annual dose, we investigated the number of examinations and operations under radiation exposure of group S in the last 3 months.

Scoring system

The original scoring system was based on three items: nail pigmentation (item 1), nail cracks (item 2), and periungual dermatitis (item 3). The scores assigned for each item ranged from 0 to 2. For item 1, the scores were assigned as follows: 0, no discoloration of nails; 1, nail streaks less than 6 mm wide; and 2, nail streaks 6 mm or more in width. If there are two or more streaks less than 6 mm wide, a score of 2 points was assigned. For item 2, the scores were assigned as follows: 0, no cracks in the nail; 1, cracks in the nail less than 6 mm wide; and 2, cracks in the nail 6 mm or more in width. For item 3, the scores were assigned as follows: 0, no abnormality on the skin around the nail; 1, dry dermatitis around the nail; and 2, wet dermatitis around the nail. If dry dermatitis is widespread, a score of 2 was assigned (Table 1).

Statistics

Using the Mann-Whitney U test, the differences in the demographic data between the two groups were compared. The difference in scores was analyzed using the Wilcoxon-signed rank test, and the correlation between score, age, and surgeon experience was analyzed using Pearson's correlation coefficient. Inter-observer reliability of the observations of the three examiners was assessed using intra-class correla-

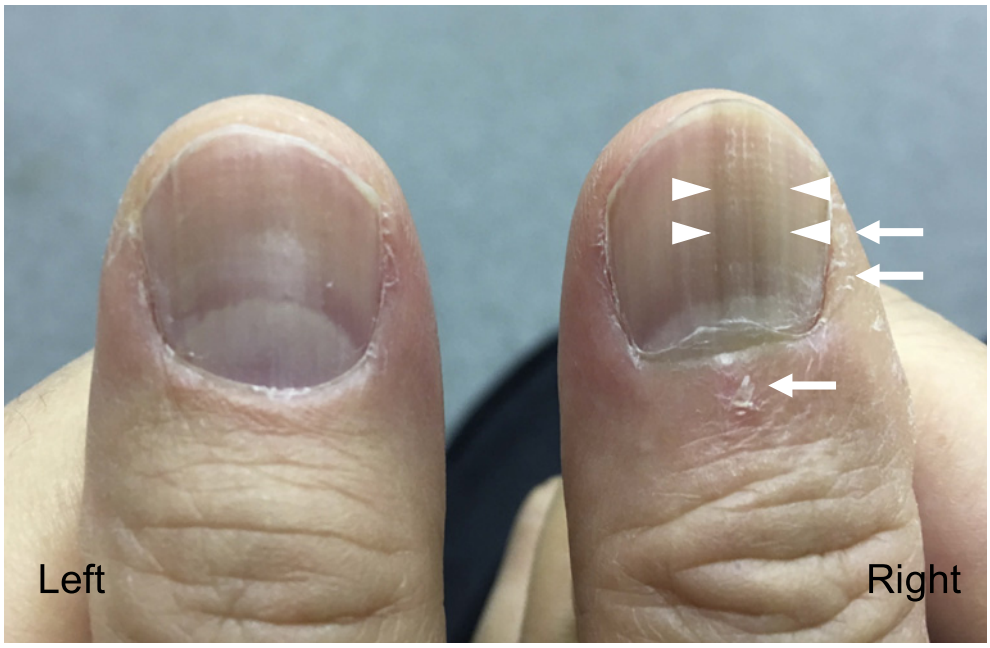

Figure 2. A 46-year-old spine surgeon's thumb. Grade 2 nail pigmentation and grade 1 periungual dermatitis on the right thumb. Arrowhead indicates nail pigmentation, and arrow indicates periungual dermatitis.

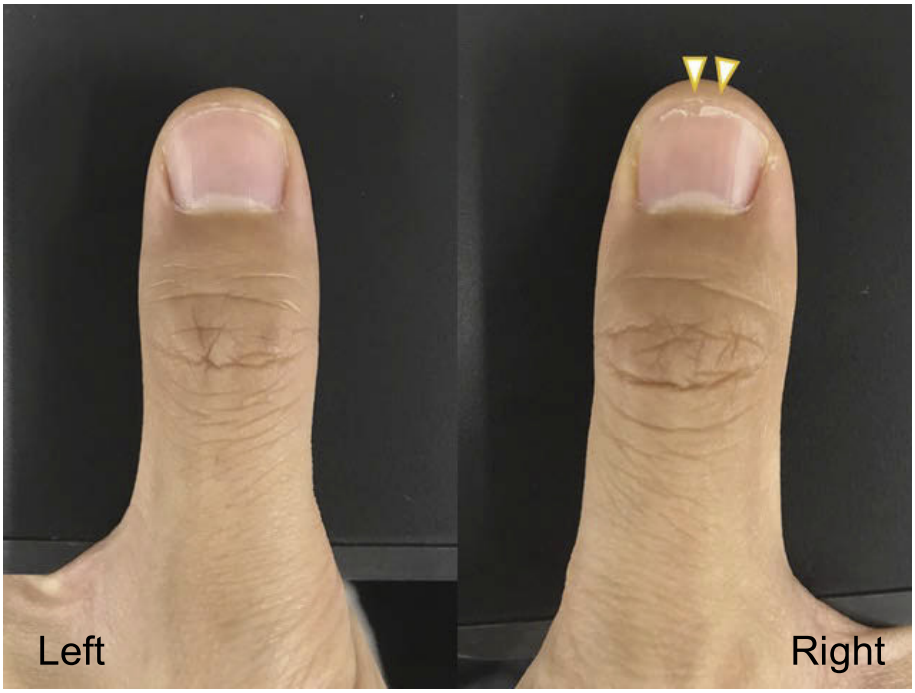

Figure 3. A 35-year-old spine surgeon's thumb. Grade 1 nail crack on the right thumb. Arrowhead indicates nail crack.

Table 1. Scoring System for Nail and Skin Damage of the Thumb.

	Grade 0	Grade 1	Grade 2
Item 1: nail pigmentation	No discoloration	Streaks < 6 mm wide	Streaks ≥ 6 mm wide, ≥ two streaks
Item 2: nail crack	No crack	Cracks < 6 mm wide	Cracks ≥ 6 mm wide
Item 3: periungual dermatitis	No abnormality	Dry dermatitis	Wet dermatitis, widespread dry dermatitis

Table 2. Results of Comparison between Dominant and Non-dominant Sides in Group S and Group C.

		Examiner 1	Examiner 2	Examiner 3
Group S	Dominant	1.75	1.125	1.2
	Non-dominant	0.5	0.35	0.65
		p < 0.001*	p < 0.001*	p = 0.0066*
Group C	Dominant	0.425	0.325	0.275
	Non-dominant	0.275	0.4	0.175
		p = 0.1694	p = 0.8231	p = 0.2902
	Dominant Group S vs Group C	p < 0.001*	p < 0.001*	p < 0.001*

Wilcoxon-signed rank test, *p < 0.05: significant

Table 3. Results of Correlation with Age.

		Examiner 1	Examiner 2	Examiner 3
Group S	Dominant	r = 0.428	r = 0.274	r = 0.239
		p = 0.059	p = 0.086	p = 0.136
	Non-dominant	r = 0.268	r = 0.244	r = 0.140
		p = 0.093	p = 0.129	p = 0.388
Group C	Dominant	r = 0.133	r = 0.060	r = 0.152
		p = 0.412	p = 0.711	p = 0.692
	Non-dominant	r = 0.117	r = 0.173	r = 0.059
		p = 0.468	p = 0.284	p = 0.717

Pearson's correlation coefficient

Table 4. Results of Correlation with Years of Surgeon Experience in Group S.

	Examiner 1	Examiner 2	Examiner 3
Dominant	r = 0.381	r = 0.215	r = 0.178
	p = 0.015*	p = 0.1822	p = 0.271
Non-dominant	r = 0.199	r = 0.169	r = 0.093
	p = 0.217	p = 0.297	p = 0.567

Pearson's correlation coefficient, *p < 0.05: significant

tions (ICCs). The inter-observer reliability was classified as poor (0-0.39), moderate (0.4-0.74), or excellent (0.75-1). Statistical analysis was conducted using SPSS version 22.0 (IBM Japan, Ltd., Tokyo, Japan). A *P* value of < 0.05 was considered significant in all analyses.

Results

The average years of physician experience were 17.83 ± 7.13 years (range: 3-28 years). The average age of participants in group S was 43.27 ± 6.83 years (range: 27-53 years), and that of participants in group C was 40.58 ± 6.65 years (range: 29-51 years) (p = 0.0719). No significant difference was found between the two groups. In group S, the examiners assigned a higher score to the dominant side than to the non-dominant side. Conversely, in group C, there was no dominant vs. non-dominant side difference. In the comparison between groups S and C, the examiners assigned a higher score to the dominant side in group S (Table 2). By contrast, the non-dominant sides were not significantly different between the two groups. No correlation was found between age and score in either group (Table 3). In group S, the years of surgeon experience and the score of the dominant side were significantly correlated in the evaluation of one examiner. However, no correlation was observed in the non-dominant side of group S and both sides of group C (Table 4). The kappa coefficient for item 1 was 0.458 (95% confidence interval: 0.348 < ICC < 0.559), 0.248 (95% confidence interval: 0.151 < ICC < 0.35) for item 2, and 0.612 (95% confidence interval: 0.532 < ICC < 0.686) for item 3. The average number of examinations and operations under radiation exposure of group S in the last 3 months was 11.89 ± 9.04 (0-30) and 26.34 ± 14.67 (1-63), respectively.

Discussion

Nail and skin lesions on the thumbs of spine surgeons were compared with those of workers that are not exposed to radiation. The results of this study suggest the possibility of radiation-induced nail and skin damage of the thumbs on the dominant hands of spine surgeons. We also found a correlation between the years of surgeon experience and nail and skin damage. This suggests the existence of possible ad-

verse effects of long-term radiation exposure.

Irradiation of the skin may cause acute effects[8-10]. The effect depends on the amount of radiation and the conditions of exposure. In the case of a single short-time exposure, the "threshold dose" that causes erythema on the skin is 6 to 8 Gy for X-ray or γ-ray exposure. In these cases, the earliest change that can be observed is transient erythema, which appears and disappears within hours. Two to four weeks later, one to several episodes of darker, longer-lasting erythema appears. At higher doses, hair loss, dry dermatitis, wet dermatitis, and epidermal necrosis occur. Late effects include the occurrence of skin cancer.

Generally, nail pigmentation (melanonychia) is a benign nail lesion caused by pigmented nevus of the nail matrix. However, it is sometimes caused by repeated stimulation, radiation exposure, and UV irradiation and is related to skin, endocrine, and metabolic diseases[11,12]. If the width of pigmentation is 6 mm or more or if the filaments have brown spots on the contours and fingertips, the pigmentation may be associated with malignant lesions. Squamous cell carcinoma (SCC) and Bowen's disease are the most common malignant tumors of the nail and are usually slow growing[13]. SCC tends to occur most commonly on the fingernails of elderly men and mainly on the thumb. Several factors have been proven to favor its development, such as exposure to ionizing radiation[14], high risk human papillomavirus, and chronic trauma. SCC is often associated with the longitudinal band of melanonychia or erosion of the nail bed. We developed a scoring system to evaluate subclinical nail and skin damage on the basis of the clinical manifestations of SCC.

The results of this study suggest that the dominant hand may have been exposed to more radiation compared with the non-dominant hand. Since several spine surgeries and examination procedures are performed using the dominant hand, the dominant hand may be more exposed compared with the non-dominant hand. Since all subjects were right-handed, we cannot ignore a possible effect of radiation exposure on dermatitis and also an effect of using the right hand daily.

According to a systematic review, there is a general trend toward higher surgeon experience, which is significantly associated with reduced usage of the image intensifier and the consequent radiation exposure during orthopedic procedures[15]. However, long-term accumulation of radiation increases with the number of years of surgeon experience, which is associated with the nail and skin damage observed in this study.

This study has several limitations. First, no scoring system for assessing the association between long-term low-dose radiation exposure and damage to the nail and skin exists. In this study, the nail and skin conditions were evaluated and compared using three items, but their validity as items for evaluating the effects of radiation exposure has not been established. Since the dominant hand is more commonly used than the non-dominant hand, its effect cannot be ruled out. However, in this study, both items 1 and 3 in group S had higher scores than in group C. Thus, items 1 and 3 were considered to be appropriate for evaluating the effects of radiation exposure on the nail and skin. The results of inter-observer reliability showed that the kappa coefficient was moderate for items 1 and 3 but poor for item 2. A better scoring system should be established. Second, the relationship between score, radiation dose, and carcinogenicity is unclear. Moreover, we could not measure the actual radiation exposure dose of the spine surgeons. Since the radiation exposure dose varies depending on the type of procedure, exposure time, equipment used, etc., it is difficult to estimate the radiation exposure dose retrospectively. By investigating the number of examinations and surgeries performed under radiation exposure in the last three months of 40 spine surgeons, we estimated the radiation exposure dose to the fingers. According to references 6 and 7, the radiation exposure dose to the fingers in one selective nerve root block is 2.3 to 13.2 mSV. Based on the data, the effective dose of radiation exposure for 1 year on the fingers of 40 spine surgeons is estimated to be 351.7 to 2018.5 mSV. This may exceed the International Commission on Radiological Protection recommended limit of 500 mSV[9], indicating that the 40 spine surgeons surveyed were suitable subjects. It also indicated the need to alert spine surgeons to protect their fingers from radiation exposure. Future prospective studies are needed to investigate the actual radiation exposure dose and changes in nail and skin lesions. Finally, this is a cross-sectional study; thus, we could not determine whether nail or skin lesions are reversible or not. Longitudinal studies are required to elucidate the association between nail and skin lesions and radiation exposure.

Conclusions

The present study revealed that the dominant side in group S had a significantly higher score than the non-dominant side and the dominant side in group C, suggesting the possibility of radiation damage to the dominant side in group S. Further studies are required in order to elucidate the relationship between the score, radiation exposure dose, and carcinogenicity.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Ethical Approval: This study was approved by the institutional ethics committee of Kyoto University (R2271).

Informed Consent: Informed consent was obtained by all participants in this study.

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