

Protecting Surgeons' Fingers from Radiation Exposure during Lumbosacral Selective Nerve Root Block

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Abstract:

Introduction: Fluoroscopy-guided selective nerve root block (SNRB) is useful for the diagnosis and treatment of nerve root pain. However, the procedure exposes the surgeon's hands to radiation. Therefore, the purpose of this randomized prospective study was to assess the radiation exposure per unit time of the surgeon's fingers during performance of a lumbosacral SNRB and to calculate the annual exposure time limits for four hand-protection methods.

Methods: We prospectively recruited patients scheduled for an SNRB and measured the radiation exposure using a ring-type passive radiation dosimetry device attached to the distal phalanx of the index finger of the hand performing the needle placement. Patients were randomly divided into the following four groups: a) the direct exposure group, b) the 0.03-mmPb glove group, c) the 0.25-mmPb glove group, and d) the forceps group (in which the needle was held using forceps such that the fingers did not enter the irradiation field).

Results: We recruited 40 consecutive patients (16 men and 24 women), with a mean age of 69 years. In all cases, SNRB was successfully performed without complications. The average exposure per hour for each of the four groups was as follows: 0.67 ± 0.56 mSv/s in the direct exposure group, 0.12 ± 0.07 mSv/s in the 0.03-mmPb glove group, 0.019 ± 0.02 mSv/s in the 0.25-mmPb glove group, and 0.001 ± 0.004 mSv/s in the forceps group ($p < 0.01$). The average annual exposure time limit was 12.4 min in the direct exposure group, 67.9 min in the 0.03-mmPb glove group, 7.5 h in the 0.25-mmPb glove group, and 5.0 days in the forceps group.

Conclusions: Using a radiation reduction glove or forceps greatly decreased the radiation exposure and increased the annual exposure time limit for SNRB.

Keywords:

radiation exposure, lumbosacral selective nerve root block, finger, radiation reduction gloves, forceps, annual limits of exposure time, fluoroscopy, International Commission on Radiological Protection (ICRP)

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Introduction

A lumbosacral selective nerve root block (SNRB) is frequently used for the diagnosis and treatment of nerve root pain. Generally performed under X-ray fluoroscopy¹⁻³⁾, SNRB exposes surgeons to radiation. A significant relationship between occupational radiation exposure and cancer has been reported^{4,5)}. The International Commission on Radiological Protection recommends a maximum equivalent dose of radiation to the hands during planned exposure situations of 500 mSv/year⁶⁾. Yet, the exposure of the hands of sur-

geons who perform fluoroscopically-guided spinal procedures, including SNRB, routinely has been estimated at 1,472 mSv/year⁷⁾. Although ultrasound-guided SNRB was shown to be as effective as the fluoroscopy-guided method for the cervical spine, the rate of successful needle positioning in the lumbosacral spine with ultrasound guidance is only 63-89%^{8,9)}. Therefore, fluoroscopy-guided SNRB is recommended for the lumbosacral spine, requiring the use of a device to protect the surgeons' hands from radiation exposure. However, to date, the effectiveness and complications of using such devices have not been evaluated *in vivo*.

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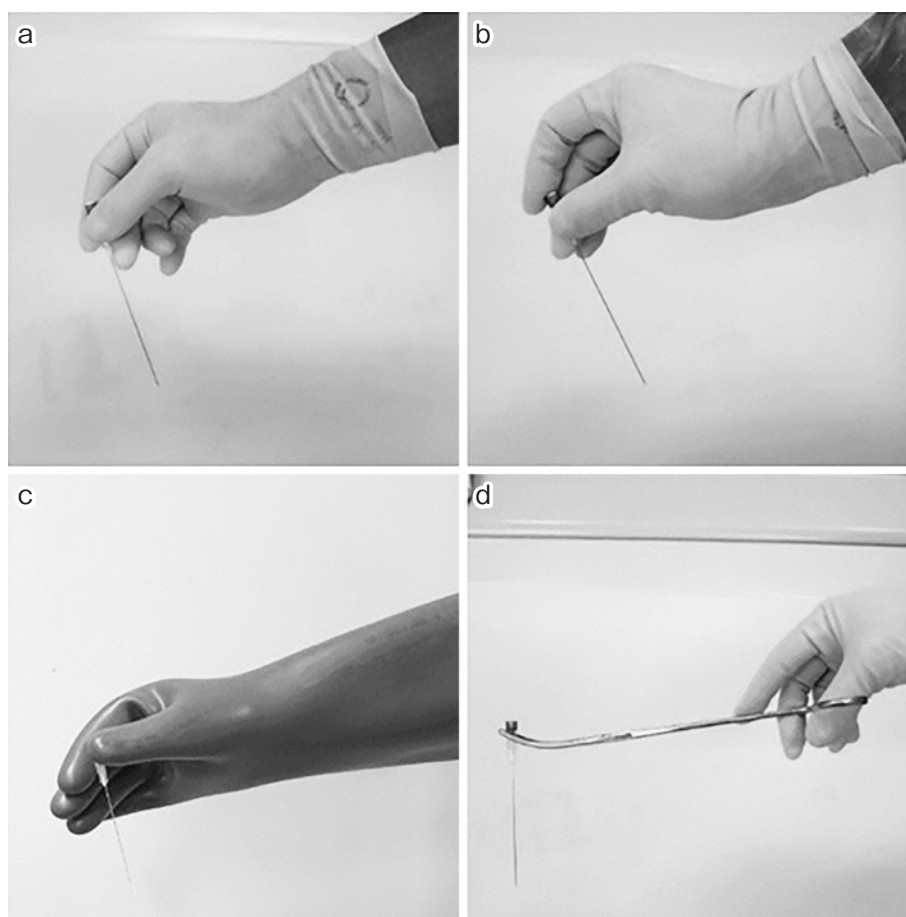


Figure 1. The group allocation was as follows: a) direct exposure, using a sterile glove; b) 0.03-mmPb glove group; c) 0.25-mmPb glove group; and d) forceps group, used in combination with the 0.03-mmPb glove.

Therefore, the purpose of this study was to assess the radiation exposure per unit time of the surgeon's index finger during SNRB, and to calculate the annual exposure time limits for four protection methods.

Materials and Methods

This study was approved by the institutional ethics board of our hospital. We prospectively recruited patients scheduled for a SNRB between January 2017 and March 2017. Written informed consent was obtained from each patient.

The two orthopedic surgeons who performed the SNRBs wore a ring-type passive radiation dosimetry device (Chiyoda Technol Corporation, Tokyo, Japan) on the distal phalanx of the index finger of the hand performing the needle placement for measurement of both direct and scattered radiation exposure. For all SNRB procedures, the patients were placed in a semi-prone position, with a 89-mm-long 23-gage spinal needle (TOP Corporation, Tokyo, Japan) inserted obliquely above the nerve root and advanced in a straight manner until radiating pain was obtained. During the procedure, the surgeon frequently used a "hands-off technique" to limit the radiation exposure as much as possible. A hands-off technique involves keeping the hands away

from the irradiation field during fluoroscopy, advancing the needle only in the absence of irradiation.

The 40 consecutive patients were randomly divided into the following four groups according to the radiation protection method used, with 10 patients per group: a) the direct exposure group, in which only a sterile glove was worn; b) the 0.03-mmPb reduction glove group, in which a 0.03-mmPb radiation reduction glove (Maeda Corporation, Tokyo, Japan) was worn under a sterile glove; c) the 0.25-mmPb glove group, in which a sterilized 0.25-mmPb radiation reduction glove (Maeda Corporation, Tokyo, Japan) was worn; and d) the forceps group, in which the needle was held using 25-cm-long forceps (TKZ-F2600-D-3; Takasago Medical Industry Co., Ltd., Tokyo, Japan), such that the fingers did not enter the irradiation field, while wearing a 0.03-mmPb radiation reduction glove (Fig. 1).

A single over-tube fluoroscope (Winscope 6000 DBX-6000A; Toshiba Medical, Tochigi, Japan) was used for continuous fluoroscopic guidance. All fluoroscopic videos were recorded using a Blu-ray hard disk recorder (BD-S550; Sharp Corporation, Osaka, Japan), and the penetration time (time until the needle caused radiating pain) was calculated from the recording. Exposure doses per second were calculated by dividing the exposure dose by the penetration time.

Table 1. Demographic Data for Each Group.

	Direct	0.03-mmPb glove	0.25-mmPb glove	Forceps	P-value
Age (years)	73.0±11.1	68.1±14.5	65.5±16.9	69.2±17.7	n.s.
Sex (n)	male, 5; female, 5	male, 2; female, 8	male, 4; female, 6	male, 5; female, 5	N/A
Height (cm)	159.3±8.6	153.8±8.6	156.3±8.3	157.5±8.4	n.s.
Weight (kg)	60.6±6.4	60.1±8.3	58.3±11.2	56.9±11.2	n.s.
Body mass index (kg/m ²)	24.2±2.2	25.3±1.8	24.9±5.7	22.8±3.0	n.s.
Blocked nerve root site					N/A
L2 (n)			1	1	
L3 (n)	1		1	1	
L4 (n)	4	2	2	4	
L5 (n)	4	7	6	4	
S1 (n)	1	1			
Diseases					N/A
Lumbar spinal stenosis (n)	8	9	7	8	
Lumbar disc herniation (n)	1	1	2	1	
Lumbar spondylolysis (n)	1		1	1	

L2-5, second to fifth lumbar nerves; S1, first sacral nerve; n.s., not significant; N/A, not applicable

Table 2. Measurement Results for Each Group.

	Direct	0.03-mmPb glove	0.25-mmPb glove	Forceps	P-value
The average exposure dose (mSv)	13.2±16.3	3.3±2.6	0.49±0.71	0.06±0.19	<0.01
The average penetration time (s)	18.7±15.9	24.8±17.8	25.5±26.9	21.2±14.1	0.88
The average exposure dose per second (mSv/s)	0.67±0.56	0.12±0.07	0.019±0.02	0.001±0.004	<0.01
The average annual exposure time limit (s)	745 (12 minutes)	4,079 (68 minutes)	26,987 (8 hours)	429,750 (5 days)	

The exposure dose, penetration time, and exposure dose per second were compared across the four groups using the Kruskal-Wallis test for multiple comparisons. A p-value < 0.05 was considered to be statistically significant.

Results

We enrolled 40 consecutive patients scheduled for SNRB, 16 men and 24 women, with a mean age of 69 years (range, 24-94 years). The underlying cause of radiating pain included the following: lumbar spinal stenosis in 32 cases; lumbar disk herniation in five cases; and lumbar spondylolysis in three cases. Table 1 shows the demographic data for each group. Among the four groups, there were no significant differences in age, weight, height, and body mass index. The SNRB was successfully performed in all cases, without complications, such as nerve root injury or great vessel injury.

The average exposure doses for the four groups were as follows: 13.2 ± 16.3 mSv in the direct exposure group, 3.3 ± 2.6 mSv in the 0.03-mmPb glove group, 0.49 ± 0.71 mSv in the 0.25-mmPb glove group, and 0.06 ± 0.19 mSv in the forceps group. The between-group difference in the exposure dose was significant (p < 0.01). The average penetration time was comparable across the four groups (p = 0.88): 18.7 ± 15.9 s in the direct exposure group, 24.8 ± 17.8 s in the 0.03-mmPb glove group, 25.5 ± 26.9 s in the 0.25-mmPb

glove group, and 21.2 ± 14.1 s in the forceps group. Accordingly, the average exposure dose/s was significantly different across the four groups (p < 0.01): 0.67 ± 0.56 mSv/s in the direct exposure group, 0.12 ± 0.07 mSv/s in the 0.03-mmPb glove group, 0.019 ± 0.02 mSv/s in the 0.25-mmPb glove group, and 0.001 ± 0.004 mSv/s in the forceps group. Therefore, the average annual exposure time limit was also different for the four groups (Table 2): 12.4 min for the direct exposure group, 67.9 min for the 0.03-mmPb glove group, 7.5 h for the 0.25-mmPb glove group, and 5.0 days for the forceps group. Notably, the radiation exposure dose was 0 mSv in one case in the direct exposure group, four cases in the 0.25-mmPb glove group, and nine cases in the forceps group. In these cases, the annual exposure dose limit (500 mSv) could not be divided by the exposure dose per hour, and therefore, the standard deviation of these cases could not be calculated.

Discussion

Several recommendations have been made to prevent occupational radiation exposure^{6,10}. However, direct radiation exposure of the hands is unavoidable during SNRB due to the requirement to manipulate the needle within the field-of-view (FOV). In this study, we demonstrate that the amount of direct radiation exposure of the hand during lumbosacral SNRB is extremely high, such that the average annual expo-

sure time limit for SNRB is very short (12.4 min). We further demonstrate the importance and effectiveness of wearing a radiation reduction glove and of using forceps to decrease the radiation exposure and greatly increase the annual exposure time limit for SNRB.

The attenuation rate of radiation reduction gloves has been reported to range between 25.8% and 87%¹¹⁻¹³, with the attenuation rate decreasing as a function of increasing voltage. However, no study has actually measured the attenuation rate of radiation reduction gloves at the fingertips *in vivo*. We detected an attenuation of 82% when using the 0.03-mmPb glove and 97% when using the 0.25-mmPb glove. Although the attenuation rate of the 0.25-mmPb glove is considered excellent, the glove is difficult to use because of its heavy fabric, which hampers the needle manipulation. In fact, the use of radiation reduction gloves is associated with a substantial increase in the radiation dose due to the automatic exposure control system^{6,14,15}. Pasciak et al. reported the increase in the patients' exposure to the needle penetration to range between 0% to approximately 500%, depending on factors such as the patients' body mass and the fluoroscopic technique. Based on their findings, Pasciak et al. concluded that the use of radiation reduction gloves might be contraindicated^{14,15}. In light of these findings, the use of radiation-attenuating gloves outside the FOV, such as in our forceps group, would be most appropriate.

Although the use of forceps for radiation protection during fluoroscopic spine surgery has previously been documented¹⁶, that of forceps for SNRB has not been reported. It seems that it is considered difficult to hold and control the soft needle in the paraspinal muscle using forceps during SNRB. However, we did not identify any complications in the forceps group in our study, with the needle penetration time for the forceps group being similar to that for the other groups. This may be because it was easy to achieve root block in an oblique manner via which we advanced the needle in a straight line to the nerve root, rather than in a frontal manner via we hit the needle once to the transverse process and then turned the angle caudally and inward to the nerve root. This result suggests that using forceps could have a leading role in performing SNRB in the future. It will be necessary to accumulate further evidence and develop a device that can grip the needle more safely and securely than hand-held forceps.

As the spinal needle is usually held between the index finger and the thumb, we measured the radiation exposure to the tip of the index finger, which is the most exposed aspect of the hand. Interestingly, previous studies have measured exposure during SNRB either at the proximal phalanx or at the wrist, which provided exposure values lower than those obtained in our study. For example, Yamane et al.¹⁷ reported an exposure of 0.83 mSv per SNRB procedure, measured using a dosimetry device on the proximal phalanx of the middle finger, compared with the 13.2 mSv per SNRB procedure that we measured at the distal phalanx of the index finger.

As the surgeon used a hands-off technique as much as possible during the procedure to limit the radiation exposure, there were cases in which the exposure dose/exposure time was "0," even in the direct exposure group. However, as our study included older individuals with degenerative lumbar spine disease, prolonged insertion time was needed for the needle to reach the appropriate position due to osteophytes. Therefore, the average exposure times for the four groups were relatively long, approximately 20 s.

A limitation of our study is that we measured the exposure dose only for the surgeon's index finger and not the exposure to the patient at the site of the needle insertion, which may have been increased by the use of radiation-attenuating gloves and forceps. Future studies are needed to evaluate the full clinical utility of radiation-attenuating devices in terms of automatic exposure control during fluoroscopy-guided SNRB.

In conclusion, using a radiation reduction glove and forceps greatly decreased the radiation exposure of the surgeon's index finger and increased the annual exposure time limit for SNRB.

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

Author Contributions: Hirotsugu Omi wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

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