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# Radiation Exposure Dose of a Surgeon Performing Lateral Access Spine Surgeries such as Lateral Lumbar Interbody Fusion and Lateral Corpectomy and Replacement

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## Abstract

Minimally invasive spinal fusion techniques such as lateral access spine surgeries, including lateral Lumbar Interbody Fusion (LIF) and Lateral Corpectomy and Replacement (LCR), are widely recognized for their usefulness and are used extensively. However, since these surgeries involve X-ray fluoroscopy, radiation exposure to healthcare providers must be investigated. In this study, the intraoperative exposure dose was measured at four sites on the surgeon's body in 50 lateral access spine surgeries (35 LIF, 15 LCR) to calculate the effective dose. Four sites were the area outside the neck protector (neck-unprotected), the area within the chest protector (chest-protected), the area outside the ventral waist protector (ventral waist-unprotected), and the area within the ventral waist protector (ventral waist-protected). The exposure dose was significantly greater at the ventral waist-unprotected area than at the other three sites ($p<0.05$), and significantly greater at the ventral waist-protected area than the neck-unprotected and chest-protected areas ($p<0.05$). There was a significant correlation between effective dose and patient body mass index. The effective dose for the surgeon performing lateral access spine surgeries was fully within the safety standards specified in the International Commission on Radiological Protection guidelines. However, the exposure dose at the surgeon's ventral waist area was high, and the surgeon's effective dose was correlated with patient obesity, indicating the need for appropriate measures to reduce radiation exposure in accordance with the exposure site and individual patients.

**Keywords: Lateral lumbar interbody fusion; Lateral corpectomy and replacement; Lateral Access Spine**

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## Introduction

With the improvements in peripheral equipment and devices, minimally invasive procedures for spinal fusion are developing rapidly. Minimally Invasive Posterior Lumbar Interbody Fusion (MIS-PLIF) [1] and Minimally Invasive Transforaminal Lumbar Interbody Fusion (MIS-TLIF) [2] have become widely performed as types of posterior access spine surgeries using percutaneous pedicle screws [3] to treat degenerative lumbar disease. Moreover, the usefulness of devising a minimally invasive technique for posterior spinal fusion to treat conditions such as spinal injuries, metastatic spinal tumors, and spinal infections has also been reported [4-6]. Recently, ASA new approach for minimally invasive spinal fusion, lateral access spine surgeries such as lateral Lumbar Interbody Fusion (LIF) and Lateral Corpectomy and Replacement (LCR) have become recognized for their usefulness and have been widely introduced in the surgical setting [7,8]. This procedure involves a lateral approach to the intervertebral disc and vertebral body through the psoas major muscle through a small skin incision; however, unlike posterior access surgery, it has advantages in that osteotomy is not necessary, and a minimally invasive spinal correction and fusion can be achieved by inserting a large cage while avoiding surgery of the dural tube [9]. On the other hand, since lateral access spine surgery as a general rule is a procedure that is performed under X-ray fluoroscopy, the effect of radiation exposure to healthcare providers is a serious concern. With the widespread use of lateral access spine surgery, one must examine the radiation exposure to healthcare providers; however, detailed studies are rare. In the present study, the intraoperative radiation exposure dose of a surgeon performing lateral access spine surgeries was measured, and the characteristics and effective doses of exposure sites, as well as factors that affect safety and the exposure dose in surgeons, were examined.

## Materials and Methods

This study was approved by the ethics committee of the Jikei University School of Medicine (approval number: 29-083(8699)). The study included lateral access spine surgeries performed by the same surgeon using a surgical X-ray fluoroscopy machine between January 2016 and January 2019. There were 50 patients, including 15 men and 35 women, with a mean age of 73 years (range: 57 to 88 years). The surgeries were 35 LIFs and 15 LCRs. The mean patient Body Mass Index (BMI) was 23.3 kg/m$^2$ (14.7 to 34.3 kg/m$^2$). The mean intraoperative radiation exposure time was 340 seconds, and the mean number of disc fusions was 2.1(Table 1).

During the surgery, the surgeon wore protective glasses (Protect leaded eyewear 0.75 mmPb; Maeda Co., Tokyo, Japan), a neck protector (Hagoromo 0.25 mmPb; Maeda Co.), and a protective apron (Hagoromo 0.25 mmPb; Maeda Co.). A pocket dosimeter (MYDOSE mini, PDM127-B-SZ; Hitachi Aloka Medical, Tokyo, Japan) was attached to four places on the surgeon's body (area outside the neck protector, neck-unprotected; area within the chest protector, chest-protected; area outside the ventral waist protector, ventral waist-unprotected; and area within the ventral waist protector, ventral waist-protected) to measure the surgeon's intraoperative exposure dose during lateral access spine surgery under X-ray fluoroscopy. The effective dose was calculated from the measurements.

The intraoperative positions of the patient and surgeon were as follows. As shown in Figure 1, the patient was placed in a right lateral recumbent position, the surgeon stood dorsal to the patient, and the X-ray fluoroscopy equipment was set up ventral to the patient. The procedure was performed with a left lateral approach to the spine through the retroperitoneal route via the psoas major muscle. In LIF, a surgical X-ray fluoroscopy, C-arm radiographic imaging unit (SIREMOBIL compact L; Siemens Healthcare, Munich, Germany), was used with one-shot imaging for dilator placement (lateral view), retractor placement (lateral view), intervertebral disc intervertebral discectomy (AP view), cartilage endplate dissection (AP view), and cage placement (AP view), with care such that the surgeon's fingers did not enter the irradiated area to avoid direct radiation exposure (Figure 2). In LCR, intervertebral discectomy of the disc above and below the resected vertebral body was performed under X-ray fluoroscopy, similarly to LIF, and corpectomy was subsequently performed, followed by the placement of an expandable cage (AP view) (Figure 3).

The effective dose was calculated from the radiation exposure dose at each site on the surgeon's body. Effective dose =0.08 Ha + 0.44 Hb + 0.45 Hc + 0.03 Hm (Ha, 1cmdose equivalent at the head and neck area; Hb, 1 cm dose equivalent at the chest area; Hc, 1 cm dose equivalent at the abdominal area; and Hm, 1 cm dose equivalent at a site in which the maximum is reached).

For comparing exposure doses, Friedman's test was used to compare all four body parts as a non-parametric paired comparison of multiple groups. When the overall comparison of the four body parts was significant, post hoc comparisons were performed with pair wise comparisons of the four body part groups (comparisons between all two-group combinations). To correct for multiplicity problems with a pair wise comparison test, the significance probability was adjusted with the Bonferroni method. In the correlation analysis, Spearman's rank correlation coefficient (ρ) was used with a non-parametric rank correlation coefficient. Using the test of non-correlations, the significance of the correlation coefficient was determined. All analyses were two-tailed, and p<0.05 was considered significant.

**Table 1:** Summary of cases of lateral access spine surgery.

| | BMI (kg/m$^2$) | Exposure time (sec) | Disc fusion |
|---|---|---|---|
| LIF (n=35) | 23.7 | 295 | 1.9 |
| LCR (n=15) | 22.3 | 445 | 2.5 |
| Total (n=50) | 23.3 | 340 | 2.1 |

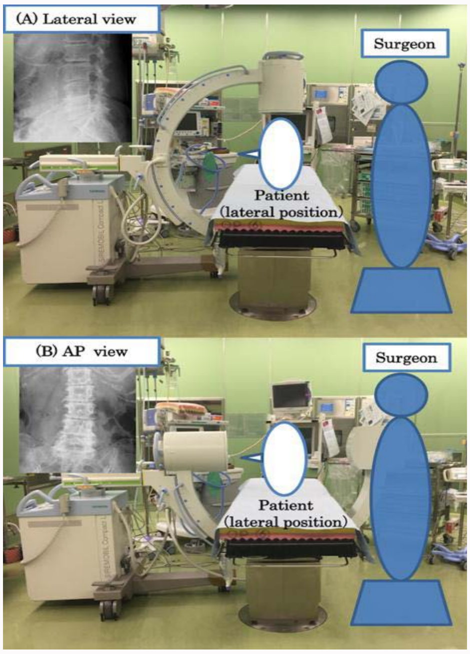


**Figure 1:** Intraoperative position of lateral access spine surgery. (A) Lateral view. (B) Anteroposterior (AP) view.

## Results

The surgeon's exposure doses from LIF are shown by site. The mean exposure dose was 0.034 ± 0.061 mSv at the neck-unprotected, 0.009 ± 0.016 mSv at the chest-protected, 0.550 ± 0.617 mSv at the ventral waist-unprotected, and 0.040 ± 0.034 mSv at the ventral waist-protected areas. The mean effective dose was 0.026 ± 0.021 mSv. The surgeon's exposure doses from LCR are shown by site. The mean exposure dose was 0.011 ± 0.006 mSvat the neck-unprotected, 0.004 ± 0.002 mSv at the chest-protected, 0.882 ± 0.534 mSv at the ventral waist-unprotected, and 0.066 ± 0.055 mSv at the ventral waist-protected areas. The mean effective dose was 0.034 ± 0.027 mSv. The surgeon's exposure doses from both lateral access spine surgeries are shown by site. The mean exposure dose was 0.027 ± 0.052 mSv at the neck-unprotected, 0.007 ± 0.013 mSv at the chest-protected, 0.650 ± 0.608 mSv at the ventral waist-unprotected, and 0.048 ± 0.043 mSv at the ventral waist-protected areas. The mean effective dose was 0.028 ± 0.023 mSv (Table 2).

In the statistical analysis by site for LIF, the exposure dose was: significantly greater at the ventral waist-unprotected area than at the other three areas (p<0.05); significantly greater at the ventral waist-protected area than at the neck-unprotected and chest-protected areas (p<0.05); and significantly greater at the neck-unprotected area than at the chest-protected area (p<0.05) (Figure 4). With LCR, the exposure dose was: significantly greater at the ventral waist-unprotected area than at the neck-unprotected and chest-protected

**Table 2:** Surgeons' mean radiation doses of different areas and mean effective doses in lateral access spine surgery (mSv).

| | Ventral waist-unprotected | Ventral waist-protected | Neck-unprotected | Chest-protected | Effective dose |
|---|---|---|---|---|---|
| LIF | 0.550 ± 0.617 | 0.040 ± 0.034 | 0.034 ± 0.061 | 0.009 ± 0.016 | 0.026 ± 0.021 |
| LCR | 0.882 ± 0.534 | 0.066 ± 0.055 | 0.011 ± 0.006 | 0.004 ± 0.002 | 0.034 ± 0.027 |
| Total | 0.650 ± 0.608 | 0.048 ± 0.043 | 0.027 ± 0.052 | 0.007 ± 0.013 | 0.028 ± 0.023 |

**Table 3:** Correlation analysis between effective dose and each variable in lateral access spine surgery (N=50).

| | Variable | ρ | P-value |
|---|---|---|---|
| Effective dose | BMI | 0.415* | 0.003 |
| Effective dose | Exposure time | 0.21 | 0.143 |
| Effective dose | Number of disc fusions | 0.141 | 0.33 |

*Significant correlation

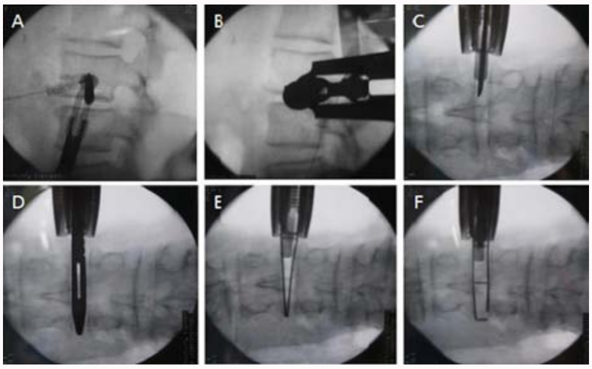


**Figure 2:** Use of fluoroscopy in lateral Lumbar Interbody Fusion (LIF). Placement of dilator (A), confirmation of the retractor position (B), dissection of cartilage endplate (C), insertion of trial implants (D), and placement of the cage (E,F).

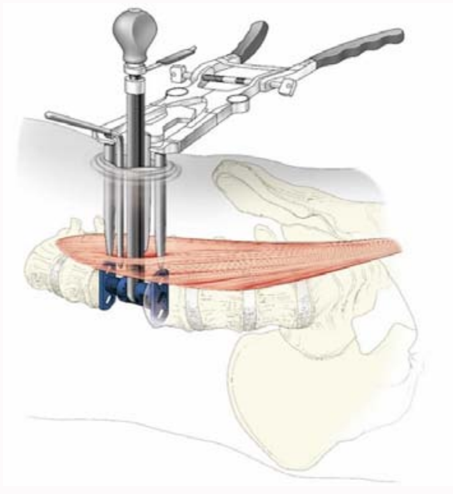

**Figure 3:** Lateral Corpectomy and Replacement (LCR).

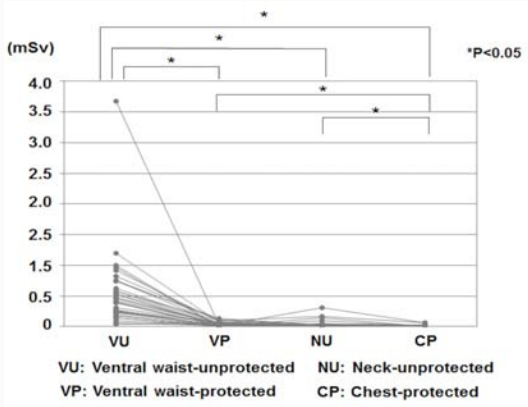


**Figure 4:** Comparison of surgeons' radiation doses of different areas in lateral Lumbar Interbody Fusion (LIF) (N=35).

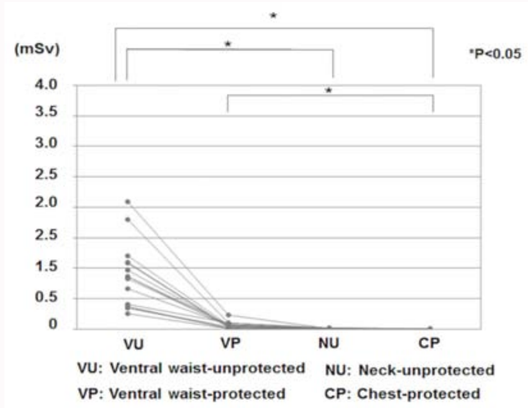


**Figure 5:** Comparison of surgeons' radiation doses of different areas in Lateral Corpectomy and Replacement (LCR) (N=15).

areas (p<0.05); and significantly greater at the ventral waist-protected area than at the chest-protected area (p<0.05) (Figure 5). In all lateral access spine surgeries, the exposure dose was: significantly greater at the ventral waist-unprotected area than at the other three areas (p<0.05); significantly greater at the ventral waist-protected area than at the neck-unprotected and chest-protected areas (p<0.05); and significantly greater at the neck-unprotected area than at the chest-protected area (p<0.05) (Figure 6).

Correlation analyses between effective dose and each variable in all lateral access spine surgeries showed that effective dose was significantly correlated with the patients' BMI, but not with exposure time or number of disc fusions (Table 3).

## Discussion

In this study, the surgeon's radiation exposure dose was measured during 50 lateral access spine surgeries at a total of 200 sites both within and outside the protectors. The mean exposure dose was 0.027 ± 0.052 mSv at the neck-unprotected, 0.007 ± 0.013 mSv at the chest-protected, 0.650 ± 0.608 mSv at the ventral waist-unprotected, and 0.048 ± 0.043 mSv at the ventral waist-protected areas. Taher et al. [10] investigated the exposure from LIF in 18 cases and reported that LIF surgeons were exposed to low-level radiation, specifically 0.44 ± 0.49 mrem at chest-protected, 2.31 ± 4.50 mrem at gluteal region-unprotected, 4.20 ± 7.76 mrem at axilla-unprotected, 2.19 ± 2.07 mrem at thyroid-unprotected, 2.64 ± 2.76 mrem at eye-unprotected, and14.62 mrem at hand ring dosimeter-unprotected areas. The International Commission on Radiological Protection (ICRP) recommends measuring the exposure dose both inside and

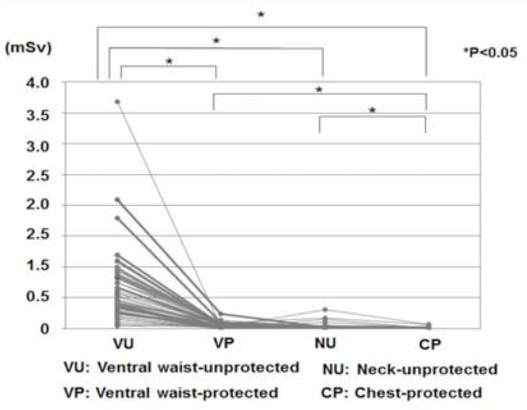


**Figure 6:** Comparison of surgeons' radiation doses of different areas in lateral access spine surgery (N=50).

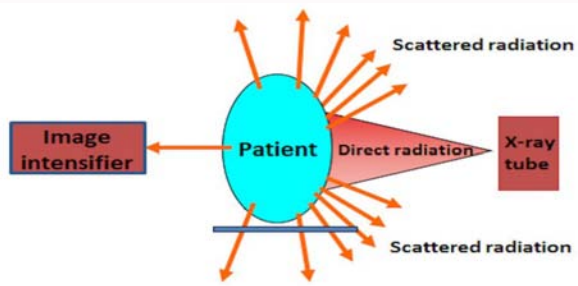


**Figure 7:** Schematic of direct radiation and scattered radiation in lateral access spine surgery.

outside the protector area, which allows for the calculation of the effective dose that equates to the whole-body exposure dose [11]. The mean effective dose according to the present results was 0.028 ± 0.023 mSv, a level that is fully within the safety standards of the International Commission on Radiological Protection (ICRP) guidelines [12]. Based on the effective dose limit recommended by the ICRP (20 mSv/year), surgeons could, in theory, perform 714 lateral access spine surgeries/year according to the calculations from this study. Moreover, the effective dose for undergoing chest CT is 6.6 mSv [13], equivalent to 286 times the dose in a lateral access spine surgery, indicating that both LIF and LCR were associated with a low whole-body exposure dose to the surgeon.

There are two types of radiation exposure to surgeons: direct radiation and scattered radiation (Figure 7). Direct radiation can be circumvented by avoiding placing the body in the irradiation field. Exposure to surgeons is primarily scattered radiation that arises from radiation passing through the patient; thus, management of scattered radiation exposure is essential. To reduce scattered radiation, it is necessary to position the X-ray tube as far away as possible from the patient and for the surgeon to use appropriate protective gear. Previous reports often did not investigate the effective dose due to an insufficient number of measurement sites or only one measurement site inside the protector [14,15]. The present study found that the exposure dose differed depending on the part of the body, even in areas within the protector. In the case of lateral access spine surgery, the exposure dose at the surgeon's ventral waist could be reduced to 1/14 with the protector; however, the ventral waist-protected area had an approximately 7-fold higher exposure compared to the chest-protected area, demonstrating that the exposure dose is high at the ventral waist area. Funao et al. [16] reported that the surgeon's exposure dose with MIS-TLIF was 0.10 ± 0.01 mSv at the area outside the chest protector and 0.15 ± 0.01 mSv at the area outside the genital protector, although the percentage of the surgeon's exposure dose at the ventral waist tended to be greater with lateral access spine surgery than with MIS-TLIF. This is probably because the AP view is used more frequently with lateral access spine surgeries. With the AP view, the surgeon's ventral waist area is likely to be most affected by scattered radiation, since the surgeon is positioned dorsal to the patient, who is in a lateral recumbent position, receiving irradiation from the dorsal side. Given this finding, it is extremely important in lateral access spine surgeries to take measures against exposure to the ventral waist area with potentially effective techniques, such as making the surgeon's ventral waist protector cover the entire circumference or doubling the protector. Moreover, because there is a high dose of scattered radiation in the direction of the X-ray tube with the AP view, it may be effective to change the surgeon's standing position, for instance standing by the X-ray image intensifier, since the exposure dose increases when standing on the side of the X-ray tube, in order to reduce the amount of radiation exposure.

On the other hand, the X-ray fluoroscopy equipment automatically adjusts the voltage and current of the X-ray tube to reduce noise. For this reason, a high X-ray irradiation dose is necessary in obese patients to attain X-ray fluoroscopic images with satisfactory resolution [16]. It has been shown previously that BMI is correlated with the exposure dose of the body surface area [17], and that BMI is a more decisive factor for exposure dose than radiation exposure time [18]. The present study also showed that effective dose is significantly correlated with patients' BMI in lateral access spine surgeries, although it was not significantly correlated with exposure time or with the number of disc fusions. Since attention is particularly required in obese patients also in lateral access spine surgery, it is necessary to take further measures to reduce radiation exposure to healthcare providers.

## Conclusion

This study demonstrated that the surgeon's effective dose in lateral access spine surgeries such as LIF and LCR is fully within the safety standards of the ICRP guidelines. In lateral access spine surgeries, the surgeon's exposure dose at the ventral waist area is high, indicating the importance of measuring intraoperative exposure dose at that site, as well as suitably protecting that site from radiation. Moreover, because the surgeon's effective dose is correlated with patient obesity, it is necessary to take measures to reduce radiation exposure that are appropriate for each case.

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