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Surgeon and patient radiation exposure in minimally invasive transforaminal lumbar interbody fusion

Clinical article

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Object. Minimally invasive transforaminal lumbar interbody fusion (TLIF) is an increasingly popular procedure. The technique involves use of fluoroscopy to assist with pedicle screw (PS) placement. The potential exists for both the surgeon and the patient to become exposed to significant amounts of radiation. The authors undertook this study to quantify the radiation dose to the surgeon and patient during minimally invasive TLIF.

Methods. The authors undertook a prospective study of 24 consecutive patients who underwent minimally invasive TLIF. All surgeries were performed by the senior author (R.K.B.), who used techniques previously described. The surgeon wore a radiation monitor under an apron-style lead shield at waist level, at an unshielded collar location, and as a sterile ring badge containing a thermoluminescent dosimeter on the dominant (right) hand ring finger. Dosimeter readings were obtained for each case. A total of 33 spinal levels were treated in 24 patients. All treated levels were between L3–4 and L5–S1. In all cases of 1-level disease, 4 PSs were placed, and in all cases of 2-level disease, 6 screws were placed.

Results. Mean fluoroscopy time was 1.69 minutes per case (range 3.73–0.82 minutes). Mean exposure per case to the surgeon on his dominant hand was 76 mRem, at the waist under a lead apron was 27 mRem, and at an unprotected thyroid level was 32 mRem. Mean exposure to the patient's skin was 59.5 mGy (range 8.3–252 mGy) in the posteroanterior plane and 78.8 mGy (range 6.3–269.5 mGy) in the lateral plane.

Conclusions. To the authors' knowledge, this is the first study of radiation exposure to the surgeon or patient in minimally invasive TLIF. Patient exposures were low and compare favorably with exposures involving other common interventional fluoroscopically guided procedures. Surgeon exposures are limited but require careful monitoring. Annual dose limits could be exceeded if a large number of these and other fluoroscopically guided procedures were performed. *(DOI: 10.3171/SPI.2008.4.08182)*

Key Words • fluoroscopic guidance • minimally invasive surgery • radiation safety • transforaminal lumbar interbody fusion

Minimally invasive TLIF is a procedure that has been increasing in popularity.[1,4,5,8,10] The technique involves limited soft-tissue dissection, and as such, standard anatomical landmarks are either not exposed or are poorly visualized. The original description of the technique involves percutaneous placement of screws.[4] So-called mini-open techniques have also been described.[7] Both techniques typically involve fluoroscopic guidance for screw placement. The potential exists for significant radiation exposure to both the surgeon and patient. There are no published articles that address radiation exposure during this procedure. We undertook the present study to quantify radiation dose to the surgeon and patient in minimally invasive TLIF.

Abbreviations used in this paper: PA = posteroanterior; PS = pedicle screw; TLIF = transforaminal interbody fusion.

Methods

We conducted a prospective study of 24 consecutive patients who underwent minimally invasive TLIF. Institutional review board approval was obtained prior to initiating the study. All patients gave informed consent. Minimally invasive TLIF was performed in all cases by the senior author (R.K.B.), who used techniques previously described.[1,5] In all cases, an X-Tube retractor was used for exposure, a Capstone cage (with either bone morphogenetic protein or iliac crest autograft) was used for interbody fusion, and Sextant PSs were used for in-

strumentation (Medtronic). All patients had degenerative disease, including spondylolisthesis, instability, or painful degenerative segments. All patients had 1- or 2-level disease.

A General Electric 9900 Elite C-arm system with 12-, 9-, and 6-in field size capability was used for intraoperative imaging. The C-arm system, which had successfully undergone a full medical physics compliance survey, was operated in its normal automatic brightness mode for control of exposure rate and image quality. The distance from the target to each patient's entrance surface, was carefully recorded. The typical kVp and mA values of operation were recorded for each patient for both the PA and lateral projections. Patient exposure for each of the 24 cases was recreated for each projection by operating the C-arm in the manual mode and setting the system to the kVp and mA recorded at the time of the procedure. A calibrated Radcal 1015C Radiation Monitor with a 10 × 6 six-ml ion chamber was placed at the exact target-to-skin distance measured during the actual procedure for each patient, and projection and the resulting mGy/minute (R/minute) were determined. The total exposure was then extrapolated from the total fluoroscopy time. The one valid assumption made was that the fluoroscopy time was evenly divided between the PA and the lateral projections. In addition a spreadsheet was created to calculate the same information from a standard measurement of output from the C-arm. This spreadsheet provided a second method by which to check for correlation of the dose information measured. The C-arm was in the source inferior position for all cases. Only single-shot pulsed imaging was performed. All imaging was undertaken in either the true PA or true lateral projection.

The surgeon wore Luxel radiation dosimeters provided and analyzed by Landauer, Inc., beneath a 0.5-mm lead-equivalent lead apron at the waist level, at an unshielded collar location, and as a sterile thermoluminescent ring badge on the dominant (right) hand ring finger. Dosimeter readings from the monitor provider were reported in units of mRem. These were obtained for each case separately. One collar badge was lost during processing. Therefore, data on neck exposure were based on 23 cases. Fluoroscopy was not used during interbody cage placement. During PS placement, the surgeon stood in an operator position ipsilateral to the particular screw being placed, as per routine. Short bursts of fluoroscopy were used rather than using long continuous periods. Intraoperative EMG monitoring was used during all cases, as an adjunct to fluoroscopy to confirm adequate hardware placement.

Results

A total of 33 spinal levels were treated in 24 patients. All treated levels were between L3–4 and L5–S1. In all cases of 1-level disease 4 PSs were placed, and in all cases of 2-level disease 6 screws were placed. Surgeon exposures are summarized in Table 1. Patient exposures are presented in Table 2. Mean fluoroscopy time was 1.69 minutes per case (range 0.82–3.73 minutes). Mean exposure per case to the surgeon's dominant hand was 76 mRem, at the waist under a lead apron was 27 mRem, and at an unprotected thyroid level was 32 mRem. Mean maximum patient skin exposure was 59.5 mGy (range 8.3–252 mGy) in the PA plane and 78.8 mGy (range 6.3–269.5 mGy) in the lateral plane.

TABLE 1

*Summary of radiation exposure levels in the treating surgeon performing TLIF**

Case No.	Levels Treated	Surgeon Exposure (mRem)		
		Collar Badge	Waist Badge	Ring Badge
1	2	28	9	150
2	1	8	3	30
3	1	22	19	24
4	2	22	20	46
5	2	34	24	63
6	1	NA†	29	23
7	1	31	29	38
8	1	29	28	30
9	1	40	28	40
10	1	38	37	40
11	1	42	40	40
12	2	38	37	80
13	2	57	51	150
14	2	65	62	200
15	2	79	18	80
16	1	17	58	40
17	1	17	14	40
18	2	20	36	220
19	1	21	21	50
20	1	16	0	80
21	2	33	28	100
22	1	2	0	70
23	1	32	23	71
24	1	45	24	120
mean	33 (total)	32	27	76

* NA = not applicable.
† Badge lost in processing.

Discussion

Minimally invasive approaches to lumbar spinal fusion are becoming increasingly popular. The surgery involves PS placement without the benefit of visualization of standard anatomical landmarks. Fluoroscopic guidance is commonly used to help ensure adequate hardware placement. This results in potentially significant radiation exposure to both the surgeon and patient. Unfortunately, no data exist in the literature to help quantify this exposure.

The maximum allowed annual radiation exposure for radiation workers is 5 Rem to the body and 50 Rem to an extremity.[8] Using these numbers, a surgeon would exceed exposure limits to the torso after 194 cases and exceed exposure to the hand after 664 cases. If thyroid shielding were not used, exposure limits to the thyroid would be exceeded after 166 cases. Use of thyroid shielding would, however, make this exposure substantially less. In previous studies on radiation exposure to the surgeon's thyroid in other types of fluoroscopically guided surgery, investigators have found significant reduction by using a thyroid

TABLE 2

Summary of radiation exposure levels in patients undergoing TLIF

Case No.	Patient Skin Exposure (mGy)	
	PA	Lat
1	252	208.6
2	12.3	30.1
3	18.2	30.5
4	20.2	45.1
5	73.9	76.7
6	23.4	51.7
7	17.2	22.5
8	8.3	6.3
9	8.3	10.7
10	21.3	33.6
11	55.4	39.1
12	60.1	66.7
13	187.1	131
14	93.3	278
15	90.7	89.7
16	12.4	43.3
17	20.4	26.7
18	143.2	269.5
19	21.1	29.0
20	72.9	69.6
21	105.3	190.6
22	55.9	75.7
23	35.5	40.5
24	20.2	24.5
mean	59.5	78.8

shield. The authors of 2 recent studies found from 23 to 415 times less radiation exposure to the thyroid when lead shielding was used.[6,13] It is unlikely that many surgeons annually perform minimally invasive TLIF cases in excess of these numbers. However, 2 caveats exist. First, a surgeon may also perform other interventional procedures requiring fluoroscopic guidance, such as vertebroplasty or kyphoplasty.[11] Total exposure from all cases would need to be monitored. Second, the data presented here may not be representative of fluoroscopic exposure times for all surgeons. If a surgeon used more average exposure time per case, exposure per case would also be correspondingly increased.

Patient exposures in this study were reasonably low. The maximum skin dose in any plane was 269.5 mGy. The threshold for the lowest dose associated with deterministic radiation effects is 2000 mGy, resulting in early transient skin erythema.[12] Our maximum skin dose was an order of magnitude below this threshold. Higher exposures occur with longer procedural times but are also associated with patient size. Larger patients require greater kVp and mA levels for adequate image quality. Their wider bodies also physically put the skin in proximity to the x-ray source. Increasing the distance from the source to the patient will reduce skin doses.[2] Although our exposures were significantly below the threshold for deterministic radiation effects, the longer-term stochastic effects of low-dose radiation exposure are less well understood and therefore unknown.[12,14]

We believe that the use of intraoperative neuromonitoring has contributed to our relatively short fluoroscopy durations. Use of neuromonitoring with our previously described technique provides adjunctive information on the relative positioning of the pedicle access needle and tap.[1] This allowed us to acquire only a limited number of radiographs. Radiographs serve as confirmation of an adequate trajectory as opposed to being the sole determinant. As a result of neuromonitoring, we did not use continuous fluoroscopy, which, had we done so, would have dramatically increased radiation exposure to both patient and surgeon. Our belief that use of neuromonitoring has reduced our radiation exposure times is unproven and may be the subject of future studies.

Overall fluoroscopic times and patient exposures compared favorably with commonly performed cardiac interventions and neurovascular interventions. Chida et al.[2] have calculated a mean fluoroscopic time of 37.4 minutes in 172 cases of percutaneous coronary intervention and a mean skin dose of 1454 mGy. In 28 cases of radiofrequency cardiac catheter ablation, they found a mean total fluoroscopic duration of 120.8 minutes and a mean maximum skin dose of 635 mGy. In a study of 42 patients undergoing embolization of cerebral aneurysms, D'Ercole et al.[3] estimated a mean maximum skin dose of 1160 mGy. Patient radiation exposure was substantially less in our study than in these other well-accepted procedures.

Very limited data exist on radiation exposure to surgeons in traditional, open PS placement. In a cadaveric study, Rampersaud et al.[9] reported a mean dose to the neck of 8.3 mRem/minute and a mean hand dose of 58.2 mRem/minute. The dose received by the thyroid was much higher when the surgeon stood ipsilateral to the source rather than contralateral because of increased scatter on the x-ray entrance side of the patient. Thyroid doses ipsilateral to the beam were 53.3 mRem/minute and only 2.2 mRem when standing contralateral to the beam source. In our study, the surgeon had to stand ipsilateral and contralateral to the entrance side an equal number of times owing to the technical demands of the procedure. Interestingly, our hand doses were very similar to those reported in Rampersaud and colleagues' cadaveric study. Our thyroid doses were also similar to the mean of their ipsilateral and contralateral beam source doses.

Exposure to the surgeon's waist under lead shielding was significantly higher than anticipated. Apron shielding was used, instead of a wrap-around shielding device. It is possible that the surgeon was not always positioned optimally to maximize shielding from the beam source because of the physical requirements of the surgery. A beam back-scatter phenomenon could have exposed the surgeon's waist area beneath the lead shielding when positioned ipsilateral to the beam source. It is possible that use of a wrap-around shield would reduce exposure to the surgeon's body due to the circumferential, instead of uniplanar, protection provided. We are currently examining this issue in a follow-up study.

Conclusions

To our knowledge, this is the first study on radiation exposure to the surgeon or patient in minimally invasive

TLIF. Patient exposures are low and compare favorably with exposures with other common interventional fluoroscopically guided procedures. Surgeon exposures are limited but require careful monitoring. Annual dose limits could be exceeded if a large number of these or other fluoroscopically guided procedures are performed.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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