Skin doses in fluoroscopically guided interventional procedures in back pain management

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Abstract: Patient doses in common fluoroscopically guided interventional procedures in back pain are usually expressed as exposure time per procedure while actual skin dose values from direct measurements are unknown. In this study, the radiation doses delivered to 27 patients, who underwent one or more of these procedures totaling 49 procedures, were measured using thermoluminescent dosemeters (TLD). The mean of the maximum skin doses was 20.2mGy (range, 1.1-93.9mGy) for epidural injections, 48.9mGy (range, 2.9-210.4 mGy) for facet joint injections, 37.4mGy (range, 4.4-94.8mGy) for sacroiliac joint injections and 14.3mGy (range, 5.5-27.0mGy) for radiofrequency neurotomy. The exposure time per procedure ranged from 1.0 to 135.0 seconds. Although there was a large variation in the maximum skin dose per procedure these values were lower than the mean skin dose reported in coronary angiography procedures.
Keywords: Patient and staff radiation dose.

Introduction

Fluoroscopic techniques are vital for interventional procedures in the management of back pain. Most of these procedures require accurate needle placement for the administration of local anesthetic with or without steroid injections to the region generating the pain, consequently erroneous needle placement will reduce the effectiveness of the intervention. Needle insertion is widely performed with the guidance of fluoroscopy and the precision of this technique, as compared to blind insertion, has been reported [1].

In fluoroscopically guided interventional techniques, assessment of patient and staff radiation doses is necessary for potential risk estimation and optimization of these procedures. Radiation levels to patients and staff are relative to the exposure times but the duration of fluoroscopy depends on the complex nature and clinical protocol of the procedures [2,3].

Several authors have evaluated occupational dose levels to physicians performing fluoroscopically guided interventional procedures in pain management clinics [4 - 9]. These studies show that occupational dose levels to physicians are within regulated acceptable dose limits when adequate radiation protection measures have been implemented. Manchikanti *et al* [7] reported an average occupational dose per procedure to the lower part of the body ranging from 0.02 to 0.21mrem (0.2 x 10-3 to 2.1 x10-3mSv) underneath the lead rubber apron and 1.4 to 5.4mrem (14 x 10-3 to 54 x10-3mSv) outside the apron. Based on a workload of 3,000 procedures per year, they concluded that the occupational doses of the interventionalists in pain management were considerably less than the annual effective whole body dose limit of 5rem [10] (50mSv). These radiation levels are significantly below the level of apprehension, nevertheless these authors strongly recommended the implementation of the ALARA (as low as reasonable achievable) principle due to the uncertainties in the cumulative effects of low levels of radiation. In these publications radiation levels to patients are expressed as exposure time per procedure while actual skin dose values from direct measurements are unknown. Exposure time per procedure is not a good estimator of maximum skin dose because the level of exposure to patients during fluoroscopy is a combination of many variables, such as the performance of the fluoroscopic imaging system, the fluoroscopy mode, the size of the patient and the number of procedures in a target region. Large variations in exposure time per procedure have also been reported in these publications. In fluoroscopically guided sacroiliac joint injections, Dussault, *et al* [11] for example, reported a mean fluoroscopic time of 108 seconds (range, 36-328 seconds) as compared to 15 ± 4.89 seconds cited by Manchikanti, *et al* [7].

Maximum skin dose for a specific clinical procedure can be assessed with film dosimetry or thermoluminescent dosimetry [12 -14], but with an over the couch X-ray tube and an under the couch image intensifier it is not practical to measure entrance skin dose with film dosimetry. In pain management procedures, the variation in beam parameters and orientations during these interventions, are not comparable to those used in cardiological procedures, consequently the maximum skin dose can be estimated from TLDs attached to the irradiated area. The limitation of this method is the underestimation of maximum skin doses in instances when the TLDs have not been placed in the area that receives the highest skin dose.

The aim of this study was to determine maximum skin doses in fluoroscopically guided interventional procedures in back pain management and to compare these values to maximum skin doses reported in coronary angiography (CA), given that CA is considered as an high dose procedure.

Materials and methods

The study was approved by the Ethics Committee of the University of the Free State and complied with the ethics standards for clinical research based on FDA, ICH GCP and Declaration of Helsinki guidelines, *the Clinical Trials Guidelines, 2000*, Department of Health South Africa, and the Medical Research Council guidelines on *Ethics for Medical Research*.

In the institution where the study was undertaken the majority of procedures for pain management are epidural, facet and sacroiliac joint injections. Patients are referred to the institution by their general practitioners or physiotherapists. The medical personnel consist of a neuroradiologist, radiographer and a nurse. In most of these procedures the patient lies in a prone position and needle placement is performed with the guidance of a mobile C-arm fluoroscopic system (Instrumentarium Imaging, Ziehm 8000) with a half value layer of 3.2mm Al at 80kV. It is operated under continuous fluoroscopy in an automatic brightness control mode, with an over couch X-ray tube and an under couch image intensifier. Usually posterior anterior (PA) or both PA and oblique views are required for accurate needle placement in these procedures but only lateral projections are essential for epidural injections.

TLD dosimetry

Lithium fluoride chips (TLD-100) were used for maximum skin dose determination. Each group of TLDs was initially annealed in an oven and irradiated with a $^{90}Sr/^{90}Y$ radioactive source to the same dose. They were read out in a TLD reader (Toledo 654, Vinten Instruments). The annealing and irradiation procedures were repeated five times to determine the

reproducibility and the standard deviation of each TLD within the group. Individual reproducibility was better than 5% and the standard deviation less than 3%. The calibration factor per batch was obtained by irradiating four TLDs from each batch concurrently alongside an ionization chamber that had been calibrated against a secondary standard dosimeter. TLDs were calibrated at 80kV as it was the average kilovoltage for the lateral projections in this study.

Patient dosimetry

Entrance skin doses were determined for the PA and lateral projections. Two chips were placed in a radio-opaque plastic sachet and four sachets were used for each projection. For the PA projections, sachets were placed as close as possible to the spinal levels of interest whilst making sure that they did not interfere with the needle placement procedure whereas for the lateral projections they were positioned close to the entrance point of the central beam of the X-ray unit where the highest intensity of radiation was expected. TLD readings were corrected for background. The region of interest, type of procedure, number of procedures, kilovoltage, milliamperage (mA) and exposure time were recorded for each projection. Oblique views were considered as PA projections. Patient data collected included the height, mass and gender. Body mass indices were calculated.

Statistical analysis

Parameters describing the demographic characteristics and sample size of study are expressed as the mean standard deviation (SD) where applicable, whilst dosemetric parameters, such as fluoroscopy time and maximum skin dose per procedure, are stated as the mean and range of measured values. The range indicates the minimum and the maximum values.

Results

A total of 27 patients participated in this study. The mean age and mass of this study group were 46.5 18.0yrs and 79.8 28.3kg respectively. The mean body mass index was 26 6.3kg/m^2 for females and 25.6 5.4kg/m^2 for males. The mean tube potential was 63.3kV (range, 54 - 93kV) for PA projections and 79.6kV (range, 55 - 110kV) for lateral projections. Table I shows the dose distribution and fluoroscopy times for the different procedures. For multiple procedures the fluoroscopy time was recorded for the lateral PA projections. In Table II the mean values and the range of the fluoroscopy time are compared with published data for similar procedures. In this study the category of epidural injections was not stated.

Discussion

The assessment of fluoroscopy time per procedure from multiple procedures has been widely utilized [4,6,7,15] to evaluate radiation levels to patients during pain management procedures. This approach is reasonable because some patients may require more that one procedure for a successful outcome.

The mean value for maximum skin doses for facet joint injection was 48.9mGy with a range of 2.9 mGy to 210.4 mGy. For epidural and sacroiliac joint procedures the mean skin doses were 20.2mGy and 37.4mGy respectively with a maximum of 93.9 mGy for epidural procedures and 94.8 mGy for sacroiliac joint procedures. Generally skin doses in the PA projections were higher than skin doses in the lateral projections due to longer fluoroscopy times in the former projections. Vassiliev,*et al* [15] measured entrance skin doses on varying thicknesses of plexiglass, simulating the thicknesses of the patients in the central beam axis. The mean values of entrance skin dose per procedure published by these authors were higher than mean skin doses recorded in this study as evident in Table II. In both studies dose values were below the threshold level for deterministic effects, which is approximately 2Gy [19]. Some of the dose values from Vassiliev, *et al* [15] exceeded the range of skin doses (2.4 - 427.5mGy) for coronary angiography (CA) procedures as recorded by Miltiadis, *et al* [14], however mean values were less than the mean maximum skin dose (280mGy for CA) reported by Trianni, *et al* [16].

The mean value and range of fluoroscopy time per procedure for epidural injection in this study were similar to values reported in other publications [6,8] although higher values have been cited by Yili, *et al* [9] (Table III). For sacroiliac joint injection the mean value and range of fluoroscopy time per procedure were 67s (range 9 - 120s). This is of the same magnitude as values of Yili, *et al* [9] whilst Dussault, *et al* [11] reported 108s (range 36 - 328s).

For radiofrequency neurotomy, the mean value and range of exposure time were comparable to those cited by Manchikanti, *et al* [6]. In this study the mean value and range of fluoroscopy time per procedure for facet injection was higher than values published by Manchikanti, *et al* [6] but were comparable to those of Yili, *et al* [9]. However, Ioannis, *et al* [17] reported a higher mean fluoroscopy time.

The differences in fluoroscopy time and maximum skin dose per procedure between different institutions can be associated with the inherent uncertainties in fluoroscopically guided procedures, which are related to differences in clinical protocol, the complex nature of a procedure, the size of the patients imaged and expertise of the medical personal. Yili, *et al* [9] reported longer fluoroscopy time in university teaching hospitals as compared to private practices. This is an indication of the large variation in maximum skin dose per procedure between the two settings. In addition, other factors contributing to the variation in maximum skin dose are inaccuracy in TLD dosimetry and poor estimation of the accurate location of the region with the highest concentration of radiation, thus underestimating the value of the maximum skin dose.

The ultimate goal in any radiological protection program is the implementation of the ALARA principle. Vano, *et al* [18] investigated parameters influencing occupational and patient radiation doses in interventional cardiology. They quantified relative changes in the magnitude of entrance skin dose with respect to changes in fluoroscopy mode, size of the image intensifier and patient thickness in interventional cardiological procedures. Their findings should be similar to any fluoroscopically guided interventional procedure, consequently any dose saving program in fluoroscopically guided interventional procedures in pain management must take into consideration the selection of optimal operating parameters.

TABLE I. The mean values and range of maximum skin dose (mGy) per procedure and fluoroscopy time (seconds).

Procedures	Number of procedures	Projection	Maximum skin dose (mGy) per procedure		Fluoroscopy time (seconds)	
			Mean	Range	Mean	Range
Facets joint injection*	18	PA	48.9	2.9-210.4	89.4	2.1-135.0
Epidural injection**	18	LAT	20.2	1.4-93.9	9.7	1.0-40.0
Epidural injection only	2	LAT	5.5	1.1-9.6	8.1	1.0-16.0
Sacroiliac joint injection***	4	PA	37.4	4.4-94.8	67.0	9.0-120.0
Epidural injection****	4	LAT	11.7	0.3-49.9	9.5	2.0-21.0
Radiofrequency neurotomy	3	PA	14.3	5.5-27.0	11.5	1.4-30.0

** Facet joint injection dosimetric parameters from facet/epidural injection. *** Sacroiliac joint injection dosimetric parameters from sacroiliac/epidural injection. ** Epidural injection dosimetric parameters from facet/epidural injection. **** Epidural injection dosimetric parameters from sacroiliac/epidural injection.*

TABLE II. Comparison of mean values and range of maximum skin dose (mGy) per procedure with published data from a phantom study (15). The range is presented in parenthesis.

Reference	Sacroiliac joint injection	Caudal epidural steroid injection	Transforminal epidural steroid injection
This work*	37.4(4.4-94.8)	20.2(1.1-93.9)	20.2(1.1-93.9)
Vassiliev D *et al* [15]	108(18-312)	114(11-867)	171(19-1024)

** The category of epidural injection was not stated.*

TABLE III. Comparison of mean values and range of fluoroscopy time (seconds) with previously published data. The range is presented in parenthesis.

Reference	Facet injection	Epidural injection	Sacroiliac joint injection	Radiofrequency neurotomy
This work	89.4 (2.1 -135.0)	9.7(1.0-40.0)	67.0(9.0-120.0)	11.5(1.4-30.0)
Manchikanti *et al* [6]	5.7 ± 0.09 (1-14)*	10.9 ± 0.72(3-32)**		12.7 ± 1.49(6-23)***
Manchikanti *et al* [7]			15 ± 4.89	
Botwin *et al* [8] ****		12.55(2-33)		
Yili Zhou *et al* [9]	81.5 ± 12.8	46.6 ± 4.2	50.6 ± 41.9	
Dussault *et al* [11]			108(36 -328)	
Ioannis *et al* [17]	288.0			

** Study was on lumbar facet joint nerve blocks.*
*** Study was on lumbar transforaminal epidurals.*
**** Study was on medial branch neurotomy.*
***** Study was on caudal epidurals.*

Conclusion

Although the sample size of this study was relatively small, namely 27 patients, as compared to other studies [5 - 8,10,11,17], the distribution of fluoroscopy time per procedure was of similar magnitude. The mean values and range of maximum skin dose per procedure in this study were lower than the mean value in CA procedures although results reported by Vassiliev, *et al* [15] indicate the possibility of skin doses exceeding those in CA procedures.

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