FLUOROSCOPY PROTOCOL FOR INVASIVE BACK PAIN MANAGEMENT PROCEDURES

B. VAN DER MERWE AND H. FRIEDRICH-NEL

ABSTRACT

The aim of the study was to determine radiation dose levels around the theatre table, on either side of the C-Arm, so as to establish whether the radiation dose received by staff during back pain procedures falls within the limits set by the International Commission of Radiological Protection (ICRP). In order to apply the ALARA principle, the possibility of lowering the radiation dose in the neurological theatre was explored. Measurements were executed by means of Thermoluminescent detectors (TLDs) that indicated that the radiation dose was higher on the x-ray tube side of the C-Arm when compared to the Image Intensifier (II) side. Radiation dose levels with the x-ray tube above the table during back pain procedures in the current theatre exceeded the occupational annual recommendation of 500mSv to the neurosurgeon's hands, as recommended by the ICRP. The opposite is true with the II positioned above the table. A protocol is proposed in terms of positioning of staff and orientation of the C-Arm in order to apply the ALARA principle during back pain procedures.

Keywords: Back pain management; TLD dose measurements; Fluoroscopy; ALARA principle

1. INTRODUCTION

Invasive back pain management procedures include radio frequency neuroablation (nerves are destroyed by means of heat, generated by an electrical current) of a caudal, facet joint and sacroiliac joint injection. During these procedures, fluoroscopy is utilised to ensure the correct needle placement for the accurate delivery of the injectate [1]. The duty of a radiographer is to be prudent so as to minimise radiation exposure to the patient and staff because the basis of modern radiation protection is to keep the level of exposure “As-Low-As-Reasonably-Achievable” (ALARA) [2]. With the ALARA principle in mind, the question was whether theatre staff a few metres from the x-ray source and the neurosurgeon standing in close proximity to it, received the lowest possible exposure during back pain management procedures.

The scatter levels from the patient emitted during exposure are the main source of the radiation doses received by staff during fluoroscopy [3]. Due to the cumulative effect of radiation, staff members who are chronically exposed to low doses of radiation are vulnerable to the stochastic effect of radiation [4]. Protection against radiation is mandatory and radiological protection aims to avoid the deterministic effect by setting dose limits below organ thresholds.
and thus limiting the risks of stochastic effects [2]. The recommended effective dose limit for radiation workers differs from the allowed public dose and is set at 20mSv per year, not to exceed 100mSv over five years. A further provision is that the effective dose should not exceed 50mSv in one year. Specific higher dose limits for radiation workers are determined for the lens of the eye at 150mSv/year, with the skin and hands at 500mSv/year respectively [5].

In this theatre used for neurological invasive back pain management procedures, the x-ray tube was positioned above the patient to satisfy the preference of the neurosurgeon for various reasons - effortless visualisation of the C-Arm monitor and increased distance of the x-ray apparatus from the sterile area without over magnification of the x-ray image on the monitor [6]. The placement of the needle in a sterile environment often requires that the x-ray tube be positioned above the table so that a space is created between the sterile area and the x-ray tube, to minimise magnification of the vertebra, especially with an overweight patient. The main reason for the C-Arm tube to be positioned above the table, however, is to speedily alter the C-Arm position over the patient from a vertical posterior-anterior (PA) position into a horizontal lateral position. The theatre table in the current theatre did not accommodate the movement of the C-Arm through the arc underneath the table. Although the American Association of Physicists in Medicine (AAPM) Report [7] indicates that the operator should stand closer to the II side of the C-Arm (in the lateral position) to lower radiation doses, it is not always practically possible or comfortable to position the neurosurgeon on the II side or to place the II above the table.

The aim of the study as described in this article was to determine radiation dose levels around the theatre table, on either side of the C-Arm, in order to establish if the radiation dose received by staff during back pain procedures are within the acceptable limits in accordance with the International Commission of Radiological Protection (ICRP) [5]. The objectives of the study were to determine the radiation doses the neurosurgeon received when standing on either side of the C-Arm, the x-ray tube or Image Intensifier (II) and to determine whether the position of the neurosurgeon’s stance in relation to the C-Arm affects the radiation dose he receives. Protocols with regard to the position of the C-Arm in relation to the neurosurgeon and other staff during back pain management procedures are proposed to comply with the ALARA principle.

2. METHOD

Thermoluminescent detectors (TLDs) were used to collect data in the form of counts, which could be translated into radiation doses that the neurosurgeon, the radiographer and the patient receive. TLDs were placed on the pelvis, chest and finger in the beam of the neurosurgeon during back pain procedures. TLDs on the chest and pelvis of the radiographer determined
radiation levels close to the x-ray source opposite the neurosurgeon. TLDs on the patient recorded the radiation dose to the area of the patient which was irradiated. The x-ray tube was routinely placed above the table (over couch x-ray source) during the procedures. Another set of measurements was conducted with the x-ray tube under the table. The differences in dose to the neurosurgeon when standing on either side of the C-Arm, x-ray tube side or II side, were compared. The C-Arm fluoroscopic system (Instrumentarium Imaging, Ziehm 8000, manufactured October 2003) with a filtration of 4mm Al and maximum 100kV, was operated in an automatic brightness control mode.

To prepare the TLDs (Lithium Floride Chips TLD-100), each group of TLDs was initially annealed in an oven and irradiated with a 90Sr/90Y radioactive source to the same dose. It was read out in a TLD reader (Toledo 654, Vinent 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 1%. The sensitivity uncertainty of the total set of the TLDs was estimated to be 1%. The calibration factor per batch was obtained by irradiating 7 TLDs in a 100kV orthovoltage beam that had been calibrated against a secondary standard dosimeter. The TLDs were calibrated at 100kV, as this was the nearest available energy to the average kilovoltage for the LAT projection in this study.

19 TLDs were marked, placed in protective sachets and utilised as follows: Seven TLDs were calibrated to ensure accurate measurements as well as for background radiation measurement purposes. During each procedure, five TLDs were placed on the neurosurgeon in charge of the procedure. Two TLDs were placed in the pelvis area, opposite the umbilicus, two on the right upper corner of the theatre shirt pocket; and one on the proximal phalanges of the index finger holding the needle in the x-ray beam. Four TLDs were placed on the radiographer, two on the left upper corner of the lead apron and two opposite the umbilicus on the outside of the apron. Three TLDs were placed on the patient in each beam field with the surgeon's field of view - for example, anterior on the patient when the x-ray tube was under the theatre table, anterior-posterior (AP) or posterior on the patient when the x-ray tube was positioned above the theatre table (PA). The TLDs were changed to the side of the patient, to be closest to the x-ray tube side of the C-Arm, during lateral views. The TLDs on the patient were placed in the sachets on the edges and in the centre of a 15cm narrow ruler. The ruler was sterilised with 90% alcohol spray every time before use. The doctor cleaned the injection area before the radiographer placed the ruler on the patient's area of interest. The PA TLDs were placed in the middle of the spine with the centre of the strip on the level of the 4th lumbar vertebra, opposite the upper margin of the iliac crest. The lateral marker strip centre was placed at the level of the coccyx, the bottom part of the 15 cm strip on the level of the femoral greater trochanter. No sterility was needed in the lateral region because the injection occurred in the middle of the spine and the lateral TLDs were placed on the side of the patient.
Once the patient was sedated and the procedure started, the radiographer and the neurosurgeon placed the TLDs in the anatomical positions indicated on the TLDs (i.e. Doctor Chest, Patient). The TLDs all remained in position for the entire duration of the procedure. The radiographer operated the x-ray unit by positioning the x-ray tube to display the anatomical part (facets) and the neurosurgeon placed the needle into the joint or space to inject the appropriate injectate. On completion of the procedure, the radiographer placed all the TLDs back into the appropriate containers so as to be kept away from the x-radiation. The TLDs were read out in a TLD reader measured after a batch of 10 patients for each of the surgeons on either side of the C-Arm.

Additional information was captured/recorded for each procedure on a spreadsheet designed for the study. The exposure factors namely kV, mA and screening time were recorded for the PA and LAT views as indicated automatically by the C-Arm console after irradiation (screening). The patient size (Body Mass Index - BMI) and the number of injections (hits) executed per patient were also recorded.

Biostaticicians of the Department of Biostatistics, University of the Free State (UFS) analysed the data to calculate median dose values and determine p-values for significance.

Consent from the patient was not required for the reasons that all patient-related information was confidential and no specific patient information was required for the project. The study did not influence the radiation dose to patients in any way, as the standard imaging protocols were adhered to. The customary patient treatment procedures were not jeopardised by the study. The Ethics Committee of the UFS confirmed that the ethical principles of the study fell within the accepted standards (ETOVS NR 155/06). Permission to execute the study was obtained from the theatre management, the neurosurgeon and staff in the specific theatre.

3. RESULTS

The study included 39 patients undergoing treatment for back pain by means of fluoroscopic interventions. The procedures of this current study mostly consisted of lumbar facet injections with the C-Arm in the PA and both oblique positions combined with a lateral position during the caudal injection. However, the injections differ for each patient. The neurosurgeon may for instance determine that, for the specific patient’s pathology, the radio frequency option is the procedure of preference. During radio frequency procedures for neurosurgeon 1, no caudal injection was administered. The C-Arm was only positioned in the PA position because no LAT view was necessary. The radio frequency routine of neurosurgeon 2 comprised of PA, oblique and lateral projections routinely combined with SI joint injections. This latter work routine resulted in more hits (3 for each SI joint and 1 for the caudal) per patient.
The median screening time for the AP and PA sides was 2.1 and 2.4 minutes per patient. The median BMI values of the patients were 26 and 28. The median values of the “hits” were 11 and 13, indicating the number of injections per procedure. The kV values for the PA and the lateral views were higher with the x-ray tube side of the C-Arm positioned above the patient. For both sides of the C-Arm, the kV was lower than 100kV. The C-Arm used in the study records only a maximum value of 6mA; the median mA values during the procedures were above 5.3mA. The next section represents the results of the median dose values of the TLD measurements of the neurosurgeon, radiographer and patient with the x-ray tube side of the C-Arm above the theatre table.

3.1. Median dose values of TLD measurements that the staff/patient received with the x-ray tube above the theatre table (PA)

Table 1 represents the median values of the measurement results pertaining to the 20 procedures done by both neurosurgeons, with the x-ray tube side of the C-Arm positioned above the table. The table represents a summary of the readings for the doctors (N=4) and patients (N=6) combined. The results in the table indicate that, with the x-ray tube above the patient, the radiographer received the highest dose at the pelvis with a median value of 0.29mSv. That means 0.03mSv per patient (0.29 divided by 10). The pelvis of the neurosurgeon received the highest dose of 0.23mSv per patient compared to the chest with a median value of 0.20 mSv per patient. The patient received a median dose of 36.1 mSv with the x-ray tube positioned above the table. The median dose to the neurosurgeon’s finger was 6.6mSv per patient. Should the neurosurgeon treat 300 patients per year, it is possible that the annual ICRP limit of 500mSv may be exceeded, as the dose to the skin can then be estimated as 1980mSv (6.6 x 300) per year should he not make use of lead rubber gloves to protect his hands from radiation.

Table 1: TLD values of staff and the patient with the X-ray tube above the theatre table (n=20)

<table>
<thead>
<tr>
<th>TLD placement</th>
<th>N</th>
<th>Minimum (mSv)</th>
<th>Median value (mSv)</th>
<th>Maximum (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R pelvis</td>
<td>4</td>
<td>-0.022</td>
<td>0.290</td>
<td>0.626</td>
</tr>
<tr>
<td>R chest</td>
<td>4</td>
<td>-0.028</td>
<td>0.137</td>
<td>0.730</td>
</tr>
<tr>
<td>Dr finger</td>
<td>2</td>
<td>9.170</td>
<td>65.684</td>
<td>122.199</td>
</tr>
<tr>
<td>Dr pelvis</td>
<td>4</td>
<td>1.664</td>
<td>2.275</td>
<td>3</td>
</tr>
<tr>
<td>Dr chest</td>
<td>4</td>
<td>1.900</td>
<td>2.021</td>
<td>2.318</td>
</tr>
<tr>
<td>Patient</td>
<td>6</td>
<td>209</td>
<td>361.7</td>
<td>598</td>
</tr>
</tbody>
</table>

R=radiographer  Dr=neurosurgeon

250
3.2. Median dose values of the TLD measurements that the staff/patient received with the x-ray tube under the theatre table (AP)

Table 2 represents the median values of the measurement results pertaining to the 19 procedures done by both neurosurgeons with the II side of the C-Arm positioned above the table. The TLDs were measured after a batch of 10 patients for each of the surgeons on either side of the C-Arm. The following table represents a summary of the readings for the doctors (N=4) and patients (N=6) combined.

Table 2: TLD values of staff and the patient with the II above the theatre table (n=19)

<table>
<thead>
<tr>
<th>TLD placement</th>
<th>N</th>
<th>Minimum (mSv)</th>
<th>Median value (mSv)</th>
<th>Maximum (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R pelvis</td>
<td>4</td>
<td>-0.018</td>
<td>0.280</td>
<td>0.720</td>
</tr>
<tr>
<td>R chest</td>
<td>4</td>
<td>-0.005</td>
<td>0.288</td>
<td>0.581</td>
</tr>
<tr>
<td>Dr finger</td>
<td>2</td>
<td>0.371</td>
<td>0.842</td>
<td>1.313</td>
</tr>
<tr>
<td>Dr pelvis</td>
<td>4</td>
<td>0.384</td>
<td>0.962</td>
<td>1.566</td>
</tr>
<tr>
<td>Dr chest</td>
<td>4</td>
<td>0.163</td>
<td>0.475</td>
<td>1.007</td>
</tr>
<tr>
<td>Patient</td>
<td>6</td>
<td>7.8</td>
<td>59.3</td>
<td>171.6</td>
</tr>
</tbody>
</table>

R = radiographer, Dr = neurosurgeon

Table 2 indicates that the radiographer received a median dose of 0.28 mSv at the pelvis area comparable with the value of the x-ray tube side. The chest of the radiographer received a median dose of 0.29 mSv (0.03 mSv/patient) - a higher value than with the x-ray tube positioned above the table. The neurosurgeon's pelvis area received a higher median dose than the chest but lower if the x-ray tube were to be positioned above the table, namely 0.09 mSv per patient. The median dose to the neurosurgeon's finger is lower per patient at a value of 0.08 mSv compared to the x-ray tube side value of 6.6 mSv per patient. Should the neurosurgeon treat 300 patients per year, the annual ICRP limit of 500 mSv to the hands will be not be exceeded, as the skin dose can then be estimated (300 x 0.08 mSv) as 24 mSv per year. TLD dose values of the pelvis and chest areas of the neurosurgeons, measured with the C-Arm positioned with the II above the patient, seem lower than with the x-ray tube positioned above the patient. Figure 1 is an indication of the difference in the median values of the doses on the x-ray tube and II side of the C-Arm.
Figure 1: The pelvis and chest dose values of the neurosurgeons with x-ray tube and II respectively above the table

The median values of the radiation doses to the neurosurgeon’s chest were 2.02mSv (0.2 mSv per patient), with the x-ray tube positioned above the table and 0.48mSv (0.04mSv per patient) with the II above the table (p-value=0.02). The median radiation doses to the pelvis areas were 2.3mSv (0.23mSv per patient) with the x-ray tube above and 0.96mSv (0.09mSv per patient) with the II above the theatre table (p-value=0.12). The dose to the neurosurgeon’s hand, as indicated in Figure 2, confirmed a lower dose on the II side of the C-Arm.

Figure 2: The finger dose values of the neurosurgeons with the x-ray tube and II respectively above the table
The median value of the radiation dose to the finger of the neurosurgeons was 65.68 mSv with the x-ray tube positioned above the theatre table and 0.84 mSv with the II positioned above the table (p-value = 0.12).

3.3. Median dose values of the patient and the staff with the x-ray tube and the II respectively above the theatre table

The radiation dose values to the radiographer’s pelvis and chest areas, on both sides of the C-Arm, are indicated in Figure 3. The radiation dose to the chest of the radiographer is higher with the x-ray tube positioned under the table. The radiographer was positioned on the console side of the C-Arm. The median value of the radiation dose to the radiographer’s chest area was 0.14 mSv with the x-ray tube side above the table and 0.29 mSv with the II above the table (p-value = 0.77). The median value of the radiation dose to the radiographer’s pelvis was 0.28 mSv with the x-ray tube above the table and 0.28 mSv with the II above the table (p-value = 0.7).

Figure 3: The chest and pelvis dose values received by the radiographer with the x-ray tube and II respectively above the table

In all instances, placement of the TLDs on the patient (prone) was on the skin facing the x-ray tube. According to Figure 4, the radiation dose to the patient with the x-ray tube above the table is five times higher than with the II positioned above.

Figure 4: The radiation dose values of the patient with the x-ray tube and II respectively above the table
The median values of the radiation dose to the patient were 361.7mSv with the x-ray tube positioned above the theatre table and 59.3mSv with the II positioned above the table (p-value=0.0039).

The results obtained from the TLD measurements of doses received by the participating neurosurgeons, patient and the radiographer indicated a trend of lower median dose measurements with the II above the table. This aspect will be considered when the protocol for fluoroscopy during back pain management procedures is discussed in the next section.

4. DISCUSSION

The measurement results of the neurosurgeons will be discussed followed by the dose to the radiographer and neurosurgeon. The importance of C-Arm orientation and staff positioning will receive attention before comparing the results with other studies.

The TLD measurements for the two neurosurgeons indicated that the radiation dose values to the neurosurgeon’s hands, pelvis and chest were higher with the x-ray tube over couch position compared to the II over couch position of the C-Arm. The significant difference in the median values of the radiation doses to the neurosurgeon’s chest were 2.02mSv, with the tube positioned above the table and 0.48mSv with the II above the table (p-value=0.02).

The median radiation doses to the pelvis areas of the neurosurgeons were 2.3mSv with the x-ray tube above and 0.96mSv with the II above the theatre table (p-value=0.12). The median value of the radiation dose to the finger of the neurosurgeons was 65.68mSv with the x-ray tube positioned above the theatre table and 0.84mSv with the II positioned above the table (p-value=0.12). Due to the sample size, the p-values < 0.15 could be an indication of statistical significance. A larger study group to include more measurement periods will address the statistical data, but repetition of the cycles to include more patients will imply measurements with the x-ray tube positioned above the table. This will suggest that the ALARA principle is not applied.

The radiation dose to the hand is of importance during the PA and oblique views because, with the lateral view, the hand was not directly positioned in the x-ray beam, as was the case with the PA and oblique views. The median ionizing radiation dose to the neurosurgeon's hands was 78 times less on the II side with values of 6.6mSv per patient on the x-ray tube side of the C-Arm, compared to 0.08mSv to the hand on the II side of the C-Arm. The median dose values of the neurosurgeon’s finger, pelvis and chest area are a confirmation that, during back pain management procedures, the x-ray tube side of the C-Arm must be positioned under the theatre table to lower radiation to the neurosurgeon.
The median values of the radiation dose to the patient were 361.7 mSv with the x-ray tube positioned above the theatre table and 59.3 mSv with the II positioned above the table (p-value=0.0039). The large difference between the entrance doses to the patients was unexpected because of the automatic exposure control. The difference may be ascribed to an inconsistent positioning of the TLDs on the stomach of the patient, especially when overweight. Another factor that requires consideration is the distance of the patient from the x-ray source. The pelvis of the radiographer received a comparable median dose on the II and tube side of the C-Arm. Although the radiation dose to the radiographer’s chest measured with the TLDs was unexpectedly higher with the II side positioned above the table, a maximum median value of 0.08 mSv per patient was recorded for all orientations of the C-Arm.

C-Arm orientation

Fluoroscopy training recommends positioning of the x-ray tube with the II above the table [7]. The AAPM report also indicates that the radiation dose on the II side during the lateral view might have a five times lower value than on the x-ray tube side. The difference can be ascribed to the three times higher scatter radiation from the patient on the entrance surface than from the exit surface of the patient [8]. Thus, positioning of the x-ray tube during fluoroscopic procedures needs meticulous focus. It is furthermore important that the II is positioned as close to the table and thus to the patient, as possible [9].

In the theatre that was utilised for the current study, however, the theatre table did not accommodate the x-ray tube positioning under the table comfortably during back pain management procedures. The main reason was that, with the available theatre table, the x-ray tube was close to the patient if positioned under the table, causing a magnified view of the spine. To address the magnification, the table had to be elevated. However, due to the increased bed height, it became rather challenging for the neurosurgeon to administer spinal injections. The bulkiness of the II above the table then obscured comfortable viewing of the monitor.

The II was not positioned close to the patient because the neurosurgeon preferred the space for the sterile needle placement with resulting magnification of the spinal image. The C-Arm adjustment from the AP position to the lateral position was time-consuming due to the fact that the C-Arm had to slide through the arc under the table. The table had to be raised to an even higher level to make adjustment under the table possible for the lateral position. Adjustment of the C-Arm over the patient into the lateral position as a second option meant that the C-Arm had to be removed from under the table and the table had to be lowered again. Besides the fact that this manoeuvre was time consuming, the sterile area was, as a result of this, a point of concern. These circumstances resulted in the x-ray tube being routinely
positioned, contrary to recommendations, above the table (over couch) before the current study.

Positioning of the staff

The neurosurgeon preferred to stand opposite the radiographer, away from the console side of the C-Arm, because there was more space on the opposite side for the sterile trolley with the syringes and needles to be positioned close to him. According to theatre protocol, the radiographer also needed space to alter the C-Arm position and had to be at a distance of 30cm from the sterile trolley. It was thus not only more comfortable, but more practical to have the neurosurgeon opposite the console side. The neurosurgeon remains standing on one side of the patient as it seems impractical (time-consuming) to position the neurosurgeon on the alternative side during the procedure for the other Posterior Oblique (PO) view.

Other studies

The hand of the neurosurgeon holding the needle was directly exposed to the x-ray beam and this requires definite focus during back pain management procedures. Whilst positioning a pedicle screw in a cadaveric model, the average hand dose rate recorded was 58.2mrem per minute (0.6mSv/minute) [10]. The TLD measurements of the current study confirmed the radiation dose value to the neurosurgeon's hands per patient as between 0.084mSv (II above the patient) and 6.5mSv (x-ray tube above the patient). Considering the median exposure time of 2.4 minutes per patient, this means an average of 0.03mSv per minute per patient with the II above the table and 2.7mSv/minute on the x-ray tube side. In the current study the doses on the x-ray tube side were higher than those recorded in the study done by Zeiller and others [10] and may be ascribed to the hand of the neurosurgeon being directly in the beam during the PA and PO views. The procedure of the current study was executed by altering the C-Arm in the PA, oblique and lateral positions. Most of the back pain management hits (injections) take place in the PA views. During the lateral view, the hand was not placed directly in the path of the x-ray beam. With the II side above the table in the current study, lower doses were recorded than in the mentioned study because the hand of the neurosurgeon was not placed in the position closest to the x-ray tube side. Another possible reason is that, during the screw placement of the Zeiller study [10], mostly lateral views were required and these are associated with higher levels of radiation exposure “due to greater soft tissue penetration required to obtain images.”

At the Florida Spine Institute, the average exposure per procedure, with an average duration of 15s, was 0.7mrem at the ring badge (0.007mSv) and 0.003mSv at the outside apron badge [11]. The median exposure per procedure in this current study to the hand of the neurosurgeon with the II positioned above the table was 0.084mSv per 2.4 minutes, thus 0.035mSv
/min (0.084mSv divided by 2.4 minutes). The ring badge dose of 0.007mSv in 15 s implies 0.028mSv/min (0.007 x 4). These two values to the hands are comparable. Outside the apron on the chest level the highest median dose was 0.06mSv per patient for 2.4 minutes, thus 0.025mSv/minute. Therefore a value of 0.012mSv per minute outside the apron was measured lower than the current study.

The median radiation exposure time of 2.4 minutes recorded in this study is longer than the 15.6s for the transfemoral injections recorded by Botwin et al. [11] and the 8.9±0.4 seconds exposure per patient described by Manchikanti et al. [1]. Mean fluoroscopic times for lumbar facet injections were 81.5±12.8 seconds in university teaching hospitals [4]. From the above-mentioned studies, it is clear that there is a difference in fluoroscopic exposure time amongst surgeons. The current study did not separate caudal epidurals, facet joint block or sacroiliac injections, but the pain injection routines consisted of a combination of the above-mentioned injections and could explain the longer fluoroscopic times. The median number of hits (11-13) per procedure indicated the length of the procedure compared to a single caudal epidural injection (hit). The surgeons in the current operating theatre utilised the C-Arm during fluoroscopy in the PA, oblique and lateral positions and not only the lateral, as associated with a caudal epidural.

Variables in the environment and differences in the pain procedure protocols of individual surgeons made it impossible to compare exactly the different studies. The fact remains, however, that the TLD measurements of this study represent the dose that the neurosurgeon received during the back pain procedures in this specific theatre.

In the present study, the difference in radiation dose measured to the hands and the body of the neurosurgeon with the x-ray tube under the table compared to the doses with the x-ray above the table, has already played a role in convincing the neurosurgeons to modify the C-Arm positioning protocol for back pain procedures in this specific theatre. The enforcement of the C-Arm positioning protocol (II above) for back pain management procedures during the course of the study was implemented and accepted in the specific theatre with only minor adjustments needed.

The special screening table made the positioning of the II above the table and the application of the ALARA principle practical by easing positioning of the arc of the C-Arm. The theatre layout was changed to position the C-Arm monitor above the patient's head to in order to make visualisation effortless. The anaesthetist equipment was moved slightly to the side. The II is positioned closer to the sterile area compared to the distance with the x-ray tube above the table, but the distance between the II and the patient gave the neurosurgeon enough space to work in a sterile environment. The magnification due to the II patient distance was accepted and preferred above the higher dose levels of the PA view. Magnification of the image due to the II
distance from the patient so as to provide space to the injection area is only applicable with overweight patients. The neurosurgeon accepted that, due to the magnification, both sides of the facet joints are not simultaneously visible. Slight movement of the II from the left to the right include visualisation of the left and right facets.

5. **PROTOCOL DESIGN**

The fact that staff in this theatre customised a screening table dedicated for use in back pain management procedures needs to be taken into consideration by the reader. This table allowed effortless movement of the C-Arm arc under the table and undemanding positioning of the x-ray tube under the patient. The table height was fixed throughout the procedure, saving time while adjusting positions for the purpose of this study. The sterile area was not compromised. The table made it possible to position the x-ray tube under the table during back pain procedures. No additional pads for patient comfort were placed between the patient and the table, except sponge pillows.

**Position of the C-Arm**

The position of the C-Arm refers to the x-ray tube over couch (PA) or x-ray tube under couch position (AP).

**AP Position**

The ideal is to position the II above the patient, as close as possible to the patient without hampering needle placement into the facets of the spine. It is important to make sure that the x-ray tube is at a distance of 30 cm from the patient under the table. Because of the height of the customised table in this specific theatre, the x-ray tube can be placed at a 30 cm distance from the patient. Figure 5 indicates the position of the neurosurgeon, the monitor and the C-Arm position. The nurse is not close to the table.

![Figure 5: Ideal AP positioning of the C-Arm with the II above the theatre table](image-url)
The ideal is to position the II above the patient, as for the AP view. The 
neurosurgeon stands as close to the II as possible. In this specific theatre both 
oblique views were used during the procedure. It was impractical to make the 
neurosurgeon move over to the opposite side when the II was altered so as to 
be further away from the neurosurgeon. The neurosurgeon in this specific 
threatre remained on one side but the dose values were still lower than with the 
x-ray tube above the table. Figure 6 is a visual presentation of the oblique 
position of the C-Arm, as well as the positions of the neurosurgeon, the 
 radiographer and the monitor. The II is positioned as close to the patient as 
possible.

![Image of C-Arm and patient]

**Figure 6**: Ideal oblique positioning of C-Arm with the II above the theatre table

**Lateral position**

During back pain management procedures in the specific theatre the II was 
placed above the table.

The neurosurgeon was placed opposite the radiographer so that they faced 
each other. The adjustment of the C-Arm into the lateral position meant that 
the neurosurgeon was placed at the x-ray tube side of the C-Arm. The 
measurement results for the TLDs indicated a lower dose to the 
neurosurgeon, although he was on the x-ray tube side. The hand of the 
neurosurgeon is not directly in the beam with the x-ray tube in the lateral 
position. The ideal will be to have the neurosurgeon and the radiographer on 
the console side of the C-Arm so that the neurosurgeon will be closest to the II 
during the lateral view (see Figure 7). The neurosurgeon must be on the II side 
of the C-Arm so as to adhere to the ALARA principle.
Figure 7: Ideal lateral positioning of the C-Arm with staff on the II side

During procedures such as laminectomy or spinal fusion operations, fluoroscopy is utilised to determine the level of operation or screw placement. Only lateral views are normally required and the radiographer must plan in advance to position the C-Arm with the II side closest to the neurosurgeon and the scrub nurse.

Recommended areas for staff in theatre

The anaesthetist is normally placed at the head of the table in order to monitor the patient. It is possible to position the anaesthetist and corresponding equipment closer to the II side of the C-Arm during back pain management procedures. Another idea is to position the anaesthetist behind the ventilation machine or to place an extra lead barrier - in the form of a lead apron hanging over a drip stand - between the anaesthetist and the x-ray source for utmost shielding from the x-ray radiation.

Nurses in the theatre must be positioned on the II side during the lateral view and also at a distance not closer than 2m to the x-ray source with a 0.25mm lead equivalent (PB) apron. The nurse closest to the table should make use of a lead apron with a 0.35mm Pb equivalent during back pain management procedures.

6. CONCLUSION

The TLD results indicated that, when compared to the Image Intensifier side, the radiation dose was higher on the x-ray tube side of the C-Arm. The radiation dose was higher at the height closest to the x-ray source. The radiation dose received by the patient was higher with the x-ray tube positioned above the table (PA). The radiation dose to the surgeon's hand and body was higher with the x-ray tube positioned above the table (PA). Radiation dose levels with the x-ray tube above the table during back pain procedures in the current theatre exceeded the occupational annual recommendation of 500 mSv to the neurosurgeons hands, as recommended by the ICRP. The
opposite is true with the II positioned above the table. The radiation
distribution measured in the specific theatre, with the x-ray tube positioned
above the table, confirmed that the hands of the neurosurgeon executing
injections during back pain management fluoroscopy are at risk to exceed the
radiation dose limit as set by the ICRP. The research question was answered
positively in that the x-ray tube under couch orientation has the potential to
limit dose levels during back pain procedures.

The measurement values resulted in a proposed protocol in terms of
positioning of staff and orientation of the C-Arm in order to apply the ALARA
principle during back pain procedures. The protocol indicated that the current
C-Arm orientation had to be changed to position the II above the theatre table
during back pain management procedures. The neurosurgeon must be
positioned at the II side of the C-Arm during the lateral views. Full body lead
protection of 0.35mm lead equivalent is mandatory. The assisting permanent
staff in the theatre must be positioned at the furthest distance possible from
the x-ray source and must wear a full body protective apron (0.25mm Pb) with
a dosimeter badge. Tableside fluoroscopy receives among the highest
occupational radiation exposures within the health system [12]. The culprit is
scatter. Scatter radiation is highest near its source, the beam entry point on the
patient. Because of tissue attenuation, radiation doses are significantly lower
on the II side than on the x-ray tube side of the C-Arm.

Orientation of the C-Arm and positioning of staff on the II side are not the only
radiation protection measures that need to be put into place during
fluoroscopy so as to adhere to the ALARA principle. The good news is that by
implementing the guidelines proposed in the article the radiation dose to the
patient, the neurosurgeon, the radiographer and theatre staff can be lowered
during fluoroscopy procedures. One needs to constantly look for quality and
to improve through learning [13]. In order to improve the workplace or
ourselves, radiographers should have the right to explain why extra attention
is given to this study. To ask the question: "How can I improve what I am
doing?" is the only way to influence social change [14]. Lower radiation levels
to staff imply lower radiation levels to the patient. Thus, the creation of a safer
work environment for staff and patients in this specific theatre where
neurological procedures are performed has the possibility to improve the
quality of life for the patient as well as the staff.

7. REFERENCES

Manchikanti, L, Cash, KA, Moss, TL & Pampati, V. 2003. Effectiveness of
protective measures in reducing risk of radiation exposure in interventional


