Radiation Safety Issues in Fluoroscopy During Percutaneous Nephrolithotomy

Pratik Kumar

Introduction: Fluoroscopy-guided intervention during percutaneous nephrolithotomy (PCNL) has become the order of the day. During this procedure, both the patient and the physician are exposed to some radiation. Measurement of radiation doses in patients and personnel are important. Patient radiation doses are used for comparison with other centers for achieving the best possible radiation practice. In addition, there are performance checks for the fluoroscopy machines so that x-ray emitting machines should work at the optimum level ie, producing good images at minimum possible radiation doses.
Materials and Methods: This is a review of literature and discussion on radiation dose to patients and personnel, and on basic radiation safety tenets and their application in urological interventions of PCNL procedure.
Results: Radiation doses during PCNL have gone down over the time due to advances in technology. However, as radiation is hazardous, there is no room for complacency. A hospital's medical physicist may ensure even further reduction of x-ray dose by carrying out regular dosimetry and quality assurance tests on the fluoroscopy machines. A survey meter may provide an easy and quicker but not-so-accurate method for occupation exposure determination.
Conclusion: The practice of PCNL procedures seems to be quite safe with radiation point of view. The quick, easy, and economical method of estimation of radiation dose using survey meter may need further calibration with the standard thermoluminescence dosimetry method. Setting optimum x-ray parameters, incorporation of filters, and quality assurance tests are a few areas where medical physicists may help in further reduction of radiation doses.

Keywords: radiation dose, percutaneous nephrolithotomy, fluoroscopy, thermoluminescent dosimetry

Urol J. 2008;5:15-23.
www.uj.unrc.ir

Medical Physics Unit, Institute Rotary cancer Hospital, All India Institute of Medical Sciences, New Delhi, India

Corresponding Author:
Pratik Kumar, PhD
Medical Physics Unit, Institute Rotary Cancer Hospital, All India Institute of Medical Sciences, New Delhi, India
Tel: +91 11 2659 4448
Fax: +91 11 2658 8641
E-mail: drpratikkumar@gmail.com

Received September 2007
Accepted January 2008

INTRODUCTION

Fluoroscopic imaging during minimally invasive urological procedures has become an integrated part of the practice. Fluoroscopy in endourology is used for guidance, image formation, verification of catheter placement, and localization of kidney calculi in extracorporeal shockwave lithotripsy (SWL). Percutaneous nephrolithotomy (PCNL) is a modality for treating large kidney calculi (2 cm in diameter or larger) for which SWL has failed. During PCNL, fluoroscopy is used for calculus localization and also for making tract to the calculus. These procedures are generally carried out by urologists or by a team of radiologists and urologists. The longer use of fluoroscopy may entail higher x-ray radiation dose to the patient and the staff. This places an extra responsibility upon the urological staff performing fluoroscopic intervention to assess the radiation safety status in PCNL procedures.

X-ray radiation which is used during the fluoroscopy to visualize inside the body is called ionizing radiation as it may ionize the interacting medium (here the human body) by knocking off an electron from the atom and thereby causing tissue damage. Radiation is a form of energy and ionizing properties of x-ray photons is solely due to their energy. Other nonionizing forms of radiation of the same family (called electromagnetic radiation) are microwave, radiofrequency, and light. A certain amount of unavoidable ionizing radiation exposure to all inhabitants of this earth comes all the time from cosmic rays and the radioactive substances in the earth crust and building material. This is called "background radiation." Although the amount of this background radiation varies from place to place, the average value of annual whole body radiation exposure due to background is estimated to be 1 mSv to 2 mSv.[1] Many a medical exposures are much less than this kind of radiation. The risk of radiation at low dose is still debatable. The majority of the estimates of the risk at low doses have been derived from the risks at high doses (like atom bomb survivors in Japan) by extrapolating it linearly to lower doses. Presently, it is considered prudent to follow linear extrapolation risk estimate for low-level radiation although that may be an overestimation of the radiation risk.

The aim of this paper is to review the status of radiation doses during PCNL procedures and also to sensitize urologists and other staff about the radiation risk they are involved, ways to reduce radiation dose, and the significance of the routine quality-assurance tests of the fluoroscopy machines. An extensive literature survey was carried out to know the status of radiation dose to the patient and the staff during PCNL. The author has already carried out the dosimetry of radiation dose in PCNL,[2] the results of which are discussed in this paper. The paper also provides the basic concept of radiation and radiation protection for better understanding of the subject.

PERCUTANEOUS NEPHROLITHOTOMY AND RADIATION

There could be variation in procedures among different hospitals. However, the final mean radiation dose to the patient and the urologist was taken as the benchmark parameter for the comparison. At our center, the whole procedure of PCNL is carried out by urologists with the active assistance of anesthesiologist as the patient remains anesthetized during cystoscopy, ureteral catheterization, and ultimately, calculus removal. The establishment of the tract and dilation is done under multidirectional fluoroscopy equipped with a monitor. The urologist wears a 0.5-mm lead equivalent apron and thyroid collar as a radiation protection measure, while others assisting in the procedure wear only a lead apron. The x-ray machines are generally C-arm fluoroscopes with an undercouch x-ray tube, an image intensifier tube over the patient, and a monitor in front of the urologist. However, overcouch x-ray tube versions are also available in the market. The machines may have an automatic brightness control mode. This mode controls the x-ray parameters (x-ray tube kilovolt potential and current) automatically in real time depending upon the thickness and x-ray attenuation properties of the body part. At some centers, urologists may use radioprotective gloves during the procedure.

At our center, first of all, a retrograde ureteral catheter is placed in the renal pelvis/superior calyx of the anesthetized patient under fluoroscopic guidance. Then, the patient is turned to the prone position and location of the calculus in the kidney is confirmed using an iodinated contrast medium and fluoroscopy. The urologist establishes the tract by puncturing the desired calyx and dilating the tract again under fluoroscopy. The calculus is fragmented by pneumatic lithotripsy and fragments are extracted with forceps. Fluoroscopy is again used to survey for any left-over calculus.

Measurement of radiation dose to human body during medical exposure is called *radiation dosimetry*. Dosimetry may be carried out to know the patient skin entry radiation dose and also the occupational radiation dose received by the urologists and the assistant physicians during PCNL.

DOSIMETRY METHODS

Thermoluminescent Dosimetry

One way to measure skin doses in patients or occupational workers is using thermoluminescent dosimeter (TLD). When the TLD material is exposed to radiation, it absorbs energy and stores it in the form of excited electrons in the crystalline lattice. After exposure, these TLD chips are heated to a high temperature (of the order of 250°C) in a controlled manner. On heating, the excited electrons fall back to their normal orbital state with the emission of visible light. The intensity of the light is measured by a photomultiplier tube system and is proportional to the radiation dose received by the TLD material. The TLD-100 is lithium fluoride and this variety of TLD is tissue-equivalent for the radiation. Therefore, the doses received by the TLD-100 chips may be regarded as the doses received by the human skin. The TLD requires a calibration process before it may be used in routine dosimetry. For calibration, the TLD chips are exposed to the known doses and then heated/read in the TLD reader. The corresponding light emitted by the TLD chips is noted down in terms of signal intensity. The curve between the known radiation doses and the corresponding signal intensity is known as *calibration curve*. The calibration curve of the TLD-100 chips for our already published study is shown in Figure 1. Unknown doses to the TLD chips placed during this study were read from this calibration curve. These TLD chips can be reused after annealing. Annealing is a process of heating these used TLD chips to a very high temperature for about 2 hours in order to remove all previously stored or residual radiation doses.

The TLD chips can be pasted to the fingers of the dominant hand of the urologist. Whenever radioprotective gloves are used, the TLD chips should be pasted on the fingers under the gloves, so that the radiation dose to fingers can be measured. The TLD chips over the gloves

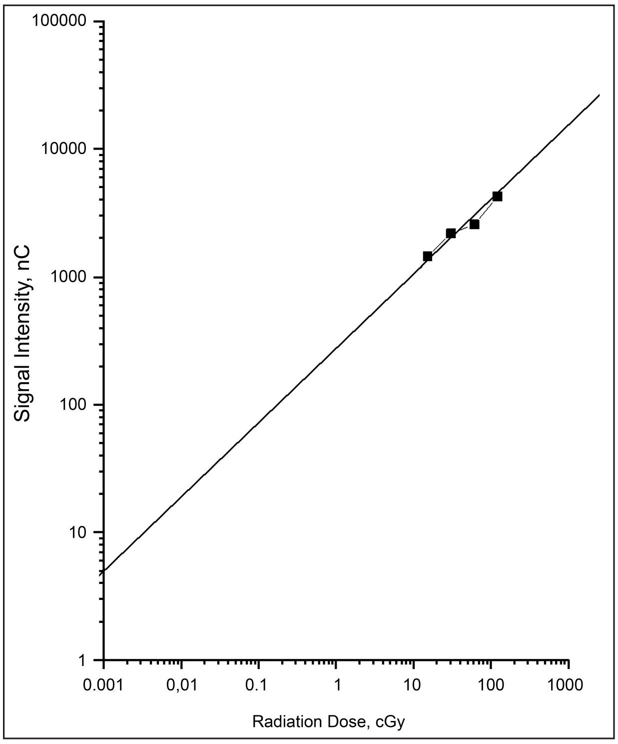

Figure 1. Calibration curve for measurement of radiation dose by thermoluminescent dosimeter.

provide the idea of doses to fingers in case gloves are not used. However, one should keep in mind that x-ray parameters (kilovolt potential and milliamperes times × time in seconds) may be slightly lower in case of bare hands than with radioprotective gloves due to x-ray attenuation if automatic brightness control is operational.

Dose-Area Product Meter

Another means for arriving at the radiation dose to the patient during fluoroscopy is the *dose-area product* (DAP) meter. The x-ray dose decreases as the distance from x-ray tube increases (inverse square with distance [d], ie, $1/d^2$). As x-ray diverges with distance, the x-ray field (x-ray area or x-ray beam size) increases. X-ray field size increases proportionally to the square of the distance from the x-ray tube. Therefore, product of the dose and x-ray field size is independent of the distance from the tube, and it has a unit of $cGy.cm^2$ or $Gy.m^2$ (ie, dose × area) (Figure 2). This DAP value can be measured by a plate ionization chamber fitted to x-ray collimators. Some of new fluoroscopy machines have built-in DAP meter.

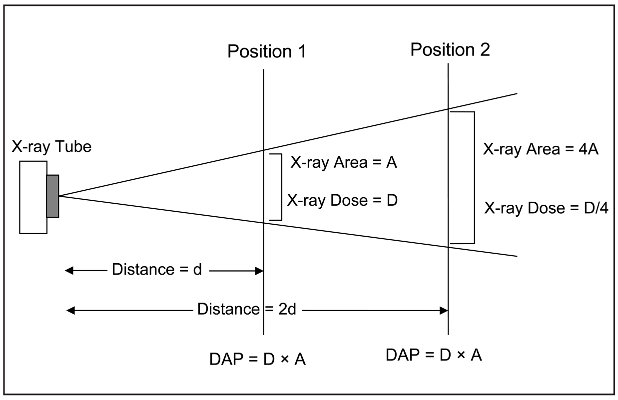

Figure 2. Concept of dose-area product (DAP) measurement in fluoroscopy. Position 1 is at distance d from x-ray tube. Let the x-ray area be A, and dose, D, at Position 1. Position 2 is at 2d distance (double of Position 1) from the x-ray tube. X-ray area at Position 2 will be 4 times ie, 4A due to divergence of the beam, but the x-ray dose will reduce to one-fourth, ie, D/4 due to doubling of the distance. However, the DAP will remain the same at Position 1 and Position 2. It shows that DAP value is independent of the distance from the x-ray tube, and therefore, it can be measured any where in the x-ray beam. The DAP meter can be fitted in the x-ray tube housing or collimator, as well.

Survey Meter

Still another way to have an inkling of radiation doses at different points in the room is using a portable dose-rate meter which is, again, a portable ionization chamber. This is called *survey meter* as it is used to survey the radiation area. It gives the radiation dose reading in terms of rate, ie, dose per hour (cGy/h). Unlike DAP meter which can measure only direct radiation falling on the patient, dose-rate meter can measure the scattered dose reaching to the personnel standing nearby. However, dose-rate meter's reading is not considered as reliable as the TLD or the DAP meter for dosimetry purposes.

Film Dosimetry

The patient's skin radiation dose may be determined using newer type of radiochromic films, as well. Radiochromic films are nearly opaque, of bright yellow color, self-developing (needs no processor), and light insensitive (unlike other films, they can be used in light and hence handling is easy). These films may be placed on the couch and under the patient, so that the patient lies on the films. For an undercouch x-ray tube, the x-ray passes through the couch and radiochromic film and then reaches the patient's skin. The radiochromic films develop dark grey shade (black area) upon x-ray exposure due to polymerization process. The degree of blackness (optical density) is an indicator of the amount of exposure, and it can be measured with a reflective densitometer or a scanner after carrying out the proper calibration. The radiochromic films are also tissue-equivalent for radiation, and this means that the radiation dose measured by these films is equivalent to the dose received by the skin. These films are available in a bigger size of 14 × 17 in, so that shift in the couch and/or x-ray tube during PCNL procedure can be covered in the film. Unlike in the case of small TLD chips of 2 × 2 mm, there is no danger of the x-ray beam falling outside the big films.

DOSIMETRY RESULTS

Table 1 shows the radiation doses to patients and personnel during PCNL reported in the studies dates published from 1984 to 2006.[2-12] Most of the authors have used the TLD to measure radiation dose which is a standard practice. We also carried out the dose measurement in PCNL which was published in 2006.[2] Table 2 shows the details of doses we reported in this study. The mean PCNL procedure time was 75 minutes (range, 30 to 150 minutes), and the mean exposure to fluoroscopy x-ray was 6.04 minutes (range, 1.80 to 12.16 minutes) per PCNL at our center. We also used a hand-held radiation survey meter to map the spatial scattered radiation distribution pattern around the patients. It gave an indication of trunk radiation dose to different personnel standing around the patient undergoing PCNL. The dose depends upon the distance of the measurement point from the scatterer (ie, the patient's body at the couch), angle of incident radiation to the patient's body, and the angular position of the personnel relative to the angle of incident radiation to below the couch. The doses measured by survey meter at these points are given in Table 2. These readings were based upon the mean radiation exposure time in 50 cases, and therefore, represent mean doses during PCNL cases.

Table 1. Radiation Dose to Patient and Personnel per Percutaneous Nephrolithotomy Procedure in Literature*

Author (Year)	Patient Skin Dose	Occupational Study: Personnel	Occupational Study: Dosimeter Position	Occupational Study: Dose	Comments
Kumari et al (2006)[2]	0.59 mSv	Urologist Urologist Anesthetist	Fingers Trunk Trunk	360 µSv 56 µSv 2.38 µSv	TLD Dose rate meter Dose rate meter
Hellawell et al (2005)[3]	…	Urologist Urologist Urologist Urologist	Lower Leg Feet Eyes Hands	11.6 µGy 6.4 µGy 1.9 µGy 2.7 µGy	TLD TLD TLD TLD
Allen et al (2005)[4]	406 cGy/cm^2	…	…	…	DAP meter
Hellawell et al (2002)[5]	4.5 mSv	…	…	…	DAP meter
Giblin et al (1996)[6]	…	Urologist Assistant Anesthetist	Head and Neck Head and Neck Head and Neck	11000 µSv/h 500 µSv/h 900 µSv/h	Dose rate meter Dose rate meter Dose rate meter
Bowsher et al (1992)[7]	…	Urologist Urologist	Fingers Forehead	145 µSv 120 µSv	TLD TLD
Page and Walker (1992)[8]	…	Urologist Urologist Urologist	Eye Hands Thyroid	320 µSv 520 µSv 270 µSv	TLD TLD TLD
Law et al (1989)[9]	…	Urologist Urologist	Index Finger Thyroid	340 µSv 34.6 µSv	TLD TLD
Geterud et al (1988)[10]	250 mGy	Urologist Urologist Urologist Anesthetist	Left Hand Thyroid … Thyroid	630 µGy 130 µGy 16 µSv 25 µGy	TLD TLD Effective Dose TLD
Rao et al (1987)[11]	10.2 mSv	Urologist	Fingers	5800 µSv	TLD
Bush et al (1984)[12]	250 mSv	Urologist	Collar Level	100 mSv	TLD outside lead apron

*TLD indicates thermoluminescence dosimetry and DAP, dose-area product. Ellipses indicate that the parameter was not measured or not applicable.

Table 2. Radiation Dose Per Percutaneous Nephrolithotomy Procedure in Author's Previous Study[2]*

	TLD (mSv)		Survey Meter (µSv)	
Subject	Position	Dose (Range)	Position	Dose (Range)
Patient	Skin (kidney level)	0.56 (0.2 to 1.6)	…	…
Urologist	Fingers	0.28 (0.02 to 0.6)	Trunk level	24.9 (7.4 to 50.2)
Residents	Fingers	0.36 (0.06 to 2.2)	Trunk level	12.0 (3.6 to 24.3)
Technical assistant	…	…	80 cm from patient	2.6 (0.8 to 5.3)
Anesthetist	…	…	152 cm from patient	1.7 (0.5 to 3.5)
Staff at gate	…	…	200 cm from patient	0.2 (0.04 to 0.3)

*TLD indicates thermoluminescence dosimetry. Ellipses indicate that the parameter was not measured or not applicable.

DISCUSSION

Effects of Radiation

Biological effects of radiation exposure can be generally classified into stochastic and deterministic effects. Deterministic effects have a threshold dose below which there is no effect, but above it, all exposed people would bear the effects. The severity of these effects increases with dose. Formations of cataract after exposure to eye lens and skin erythema are such examples. Consequently, certain sensitive organs have been given a limit of annual radiation dose for professional radiation worker. Stochastic effects have no threshold dose and the relationship between dose and radiation effect is probabilistic. The probability of occurrence of the effect increases with dose. Cancer induction and genetic effects in the next progeny are of stochastic effects. It is evident from the above definitions that smaller radiation doses which are generally encountered in many diagnostic procedures may not exceed the threshold dose for deterministic effects, but there exists a probability (although small) for stochastic effects.

Radiation Quantity and Units

Radiation exposure in air is measured in *Roentgen*, and the symbol of which is "R." The absorbed dose to an organ or skin is measured in terms of *rad* (radiation absorbed dose) that is equivalent to 100 erg of energy deposited in 1 g of material (tissue).[13] The international unit for rad is gray (Gy); 1 Gy equals 100 rad. Some types of radiation such as alpha ray coming out from radioactive material are more ionizing than x-rays. Radiation effects depend upon the ionizing properties of radiation as well. All ionizing waves have been given a weight called *radiation weighting factor*. Taking this factor into account, the quantity of radiation is called *equivalent dose* which is the absorbed dose multiplied by radiation weighting factor. The unit for equivalent dose is sievert (Sv). The x-ray has a radiation weighting factor of 1, and therefore, its absorbed dose (Gy) is equal to equivalent dose (Sv). On the other hand, organs of the body differ between themselves in terms of sensitivity to radiation; therefore, a *tissue weighting factor* is also used for comparing whole body radiation dose and organ doses. When sensitivity of the organ is also taken into account, the radiation quantity is called *effective dose* that is achieved by the multiplication of equivalent dose and tissue weighting factor. The unit for effective dose is also seivert.

The *International Commission on Radiation Protection* (ICRP) recommends an effective dose of 20 mSv per year over a defined period of 5 years on average as the occupational dose limit.[14] Similarly, the ICRP recommends the annual limit for equivalent dose in the lens of the eye at 150 mSv, in the skin at 500 mSv, and in the extremities at 500 mSv for the staff. There is no dose limit for a patient undergoing radiation investigation or therapy provided the practice is justifiable on the basis of medical benefits outweighing the radiation risk. However, for both patients and staff, the radiation dose should be *as low as reasonably achievable* (ALARA). The ALARA principle indicates that near-zero radiation target may be unreasonable (in view of all pervading background radiation), prohibitively expensive and cumbersome, and may deny potential benefits to patients. Therefore, a judicious and cautious approach for using radiation in medicine is always warranted.

Fluoroscopic imaging is widely used for urological interventions. There are wide variations in practices followed in different institutions and countries. In some places, radiologists are also involved, while at our center, only urologists carry out the procedures. Therefore, nontraditional radiation workers like urologists, residents of urology, technologists, anesthesiologists, and operating room staff should be aware of radiation doses they are involved. Practice of measurement of radiation dose also sensitizes them towards the need of continuous vigil for radiation safety and also removes any unfounded fear of radiation. As practices differ from place to place, it is important to know the dose, so that the reference dose for a particular practice in a particular region may be developed and the practice may be compared with other regions as well. In fact, radiation dose to the patient during PCNL is such an important parameter that it may indicate the efficiency of the process. It has been reported that a novice urologist may achieve competency (based upon the operative time) after 60 cases of PCNL, but the excellence (based upon patients' radiation dose) can be achieved only after 115 cases.[4] This underlines the importance of the measurement of radiation dose during PCNL cases at every center. Table 1 gives the radiation doses to patients and personnel reported by different studies. Patients' skin dose reported in our earlier paper (0.59 ± 0.37 mSv per PCNL) is quite lower than reported in late 1980s (10 mSv to 250 mSv).[10-12] Probably, it is due to technological advances of fluoroscopic automatic brightness control and incorporation of filters. Fluoroscopy time of 6.04 minutes in this study is slightly higher than the range of 2 to 4.4 minutes reported earlier and essentially indicates that the procedure has not changed much in terms of duration of fluoroscopic imaging over time.[7,9]

Exposure doses to the fingers of urologists and assisting urology residents in our earlier work were 0.28 mSv and 0.36 mSv, respectively. Assisting urology residents received higher doses, since they were involved in fluoroscopy-guided retrograde passage of the ureteral catheter in addition to assisting in PCNL procedure. In our setup, urologists are involved in tract dilation and removal of calculus. Exposure doses to urologists' fingers in our work was in the similar range to those of other studies, except one which cited the figures dose at 5.8 mSv per PCNL.[4,10-12] The ICRP-60 report states that the annual dose limit to the extremities to be taken as 500 mSv.[14] It shows that performing even 1000 PCNL procedures annually would keep the urologists' finger dose well within this limit.

Our previous study explored the utility of radiation survey meter to arrive at an idea of trunk radiation dose for various occupational workers. It is evident that the trunk mostly receives the secondary scattered dose and the use of survey meter may yield a quick, easy, economical, but less accurate method of measurement of radiation dose. However, in the absence of costly but established TLD system, the survey meter may prove handy. The trunk level radiation dose to the urologists measured by survey meter in this study was found to be 24.9 μSv per PCNL which was in the range of doses measured by TLD placed at the thyroid, forehead, and collar levels reported in literature (34.6 μSv to 270 μSv per case).[3,5,7-10,12] However, further simultaneous TLD-based and survey-meter-based confirmatory experiments of dosimetry are needed to arrive at some definite conclusion regarding survey meters' use in knowing the approximate dose during intervention.

All these measurements of radiation dose with TLD in our published work were carried out after taping it over the lead gloves if worn. Therefore, it means that fingers' absorbed dose in PCNL would be further reduced if the glove is worn as some urologists did. All urologists, assistant urologists and technologists wore lead apron and some even wore thyroid shield and lead goggles. Further reduction in dose may be achieved by proper collimation of radiation field and also by using some fluoroscopic drapes and radiation shield as demonstrated by some studies.[6,15] These are good-work practices and should be encouraged further in order to reduce population dose and to observe the ALARA principle.

Role of Medical Physicists

The hospital's medical physicists are involved with the x-ray engineer and the urologists to set the optimum milliampere tube-current, so that doses to the patient and the personnel may reduce further without compromising the image quality. In fact, there is a scope to identify the limit to achieve a suitable image for diagnosis at lower radiation and avoiding the images which may be more than the requirement but at higher doses. In other words, optimization of fluoroscopic image quality may be able to avoid undesirable radiation to patients and personnel alike. Application of additional filters may also be explored to reduce the doses further. The hospital medical physicists may carry out a quality assurance test for matching of radiation field (exposed area) with the displayed field of view (FOV) in fluoroscopy which generally has an undercouch x-ray tube and overcouch image intensifier. Fluoroscopy has a fixed FOV (circular or rectangular area appearing on the monitor) which means that it can only show that body part on the monitor which falls within its FOV. Any radiation hitting the image intensifier outside the FOV is wasted but adds to the radiation dose to the patient's and the scattered radiation dose to the personnel. The radiation field should not exceed 3% of the x-ray

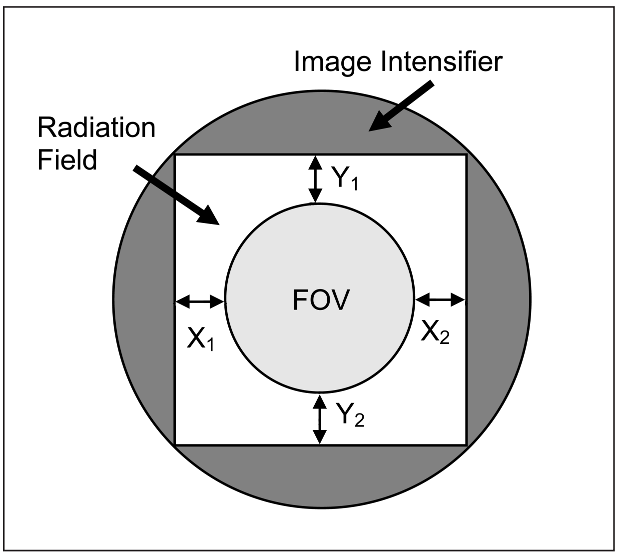

Figure 3. Schematic diagram of quality assurance test for matching x-ray field with the field of view (FOV) in fluoroscopy. The inner circle is the FOV and the outer rectangular area is the x-ray field. The error (excess of x-ray field over the FOV) on x-axis is X1+X2 and that on y-axis is Y1+Y2.

to the image intensifier distance on any side of the FOV (Figure 3).[16] The author of the present paper found that the results for this experiment were beyond the limit for 2 out of 3 fluoroscopy machines, and consequently they were rectified by the engineers.

There are other quality assurance tests as well to check the performance of fluoroscopy machines. These are checking of the performance of the automatic brightness control (wherever available); checking the focal spot size (x-ray target or source size) which should be 1.2 mm and 0.5 mm for large and small focuses, respectively; checking the resolution of the system, so that details of the image is visible at minimum possible radiation dose; and checking the possible image distortion and monitor resolution. The patient skin entrance radiation dose rate should not exceed 10 rad per minute except during film recording of fluoroscopic images or when an optional high level control is activated. The dose rate should be measured at 30 cm from the input surface of image intensifier in C-arm fluoroscope and at 1 cm above the table top in undercouch tube fluoroscope. The minimum permissible distance between x-ray source and the patient couch (skin) is 30 cm for mobile fluoroscope and 20 cm for image-intensified fluoroscopes used for specific surgical applications. Even innocuous-looking lead apron should be checked at least once a year for any crack and hole to prevent any leakage of radiation through these defects. Lead aprons should never be kept folded when not in use, rather they should be hanged on the hanger and put on a pedestal stand to prevent any crack at the place of fold.

Nowadays, angiography machines (which use fluoroscopy for cardiac and hepatobiliary therapeutic and diagnostic interventions) have pulsed fluoroscopy instead of continuous fluoroscopy and it helps to reduce the radiation dose to a large extent. Incorporation of pulsed fluoroscopy in all interventional x-ray machines may be investigated in order to reduce the radiation dose further. Other measures included in newer machines are displays of fluoroscopy time, total DAP values and estimated skin dose, incorporation of region-of-interest fluoroscopy which has a low noise image in the center and surrounded by a low dose (noisy) region, and last image hold. Some manufacturers provide additional shielding in the room (as ceiling-suspended lead glass) to optimize the occupational protection.

The occupational workers who regularly work in fluoroscopy environment may be brought under regular personal dosimetry program of the country. In India, *Bhabha Atomic Research Centre* conducts TLD badge service where a designated medical radiation worker wears a TLD personal badge during his/her radiation job. This TLD badge is read for radiation doses at every 3 months and dose data are complied and stored for annual and life-time radiation dose.

CONCLUSION

This study reviewed radiation dose to the patient's skin during PCNL based on the reports in the literature. It was found that doses have gone down with the advent of technology. However, keeping ALARA principle in mind, all personnel should use radiation protective gadgets and the people not involved directly in the procedure should stand at a feasible distance from the patients undergoing PCNL. The author's earlier study showed that a dose rate meter (survey meter) may also be used for arriving at an estimate of personnel dose after proper comparative calibration with TLD. This method would be fast, easy, and economical as compared to TLD. Also, this method would be suitable for smaller centers with no expensive TLD system. The hospitals' medical physicists may help further in reduction of radiation dose by undertaking a few additional explorations as suggested by this paper.

CONFLICT OF INTEREST

None declared.

REFERENCES

1. Hendee WR. Real and perceived risks of medical radiation exposure. West J Med. 1983;138:380-6.
2. Kumari G, Kumar P, Wadhwa P, Aron M, Gupta NP, Dogra PN. Radiation exposure to the patient and operating room personnel during percutaneous

nephrolithotomy. Int Urol Nephrol. 2006;38:207-10.

3. Hellawell GO, Mutch SJ, Thevendran G, Wells E, Morgan RJ. Radiation exposure and the urologist: what are the risks? J Urol. 2005;174:948-52.
4. Allen D, O'Brien T, Tiptaft R, Glass J. Defining the learning curve for percutaneous nephrolithotomy. J Endourol. 2005;19:279-82.
5. Hellawell GO, Cowan NC, Holt SJ, Mutch SJ. A radiation perspective for treating loin pain in pregnancy by double-pigtail stents. BJU Int. 2002;90:801-8.
6. Giblin JG, Rubenstein J, Taylor A, Pahira J. Radiation risk to the urologist during endourologic procedures, and a new shield that reduces exposure. Urology. 1996;48:624-7.
7. Bowsher WG, Blott P, Whitfield HN. Radiation protection in percutaneous renal surgery. Br J Urol. 1992;69:231-3.
8. Page JE, Walker WJ. Complications attributable to the formation of the track in patients undergoing percutaneous nephrolithotomy. Clin Radiol. 1992;45:20-2.
9. Law J, Inglis JA, Tolley DA. Radiation dose to urological surgeons during X-ray fluoroscopy for percutaneous stone extraction. Br J Radiol. 1989;62:185-7.
10. Geterud K, Larsson A, Mattsson S. Radiation dose to patients and personnel during fluoroscopy at percutaneous renal stone extraction. Acta Radiol. 1989;30:201-5.
11. Rao PN, Faulkner K, Sweeney JK, Asbury DL, Sambrook P, Blacklock NJ. Radiation dose to patient and staff during percutaneous nephrostolithotomy. Br J Urol. 1987;59:508-12.
12. Bush WH, Brannen GE, Gibbons RP, Correa RJ Jr, Elder JS. Radiation exposure to patient and urologist during percutaneous nephrostolithotomy. J Urol. 1984;132:1148-52.
13. Iverson C, Flanagin A, Fontanarosa PB, et al. American Medical Association manual of style. 9th ed. Philadelphia: Lippincott Williams & Wilkins; 1999. p. 505-6.
14. International Commission on Radiological Protection [homepage on the Internet]. Summary Recommendation [cited 2008 Feb 1]. Available from: http://www.icrp.org/docs/Summary_B-scan_ICRP_60_Ann_ICRP_1990_Recs.pdf
15. Yang RM, Morgan T, Bellman GC. Radiation protection during percutaneous nephrolithotomy: a new urologic surgery radiation shield. J Endourol. 2002;16:727-31.
16. Granger WE Jr, Bednarek DR, Rudin S. Primary beam exposure outside the fluoroscopic field of view. Med Phys. 1997;24:703-7.