EVALUATION OF RADIATION DOSE TO PATIENTS DURING ABDOMINAL EMBOLIZATIONS

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ABSTRACT

BACKGROUND: Abdominal embolization procedures performed using digital subtraction angiography (DSA) is on the increase in the present-day scenario owing to their diagnostic and therapeutic values. These procedures involve prolonged fluoroscopy times and may tend to impart high radiation dose to patients if adequate radiation safety measures are not taken. AIM: To evaluate radiation dose imparted to patients and the work practices involved therein during abdominal embolization procedures. MATERIALS AND METHODS: Forty-two patients who underwent abdominal embolizations performed using DSA equipment were included in the study. Dose area product (DAP) was measured using DAP meter and values obtained were used for calculating entrance surface dose (ESD). Work practices of personnel involved in conducting the procedure were evaluated based on the choice of field sizes, selection of appropriate fluoro-modes, and optimization techniques. RESULTS AND CONCLUSIONS: The mean ESD values during hepatic embolization, renal embolization, splenic artery embolization and transarterial chemoembolization (TACE) were 1.2, 1.01, 1.19, and 1.03, respectively. No deterministic effects of radiation, such as transient or main erythema, were noticed for a few patients whose doses exceeded the threshold doses.

Key words: Abdominal embolization, Dose area product, Radiation dose

INTRODUCTION

Interventional procedures constitute a considerable fraction of investigations pursued in many hospitals and such procedures often replace complex surgical procedures; hence use of these procedures is increasing.^[1] In the

Correspondence Dr. Roshan S. Livingstone, Department of Radiodiagnosis, Christian Medical College, Vellore 632004, India. E-mail: roshanlivingstone@yahoo.com light of the above need, it is observed that there is a tendency to use obsolete types of equipments, which are not intended for such procedures. Radiation dose to patients during complex radiological interventions need to be given proper consideration because they involve prolonged fluoroscopic screening and large number of image acquisitions and the patient can suffer from injuries to the skin.^[2-5]

The entrance surface dose (ESD) is estimated in order to assess the possibility of skin dose exceeding the threshold for deterministic

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529

effects.^[6] Deterministic risks are those for which, beyond a dose threshold, the magnitude of damage is proportional to dose. Deterministic risks are of greater concern in interventional procedures because singlefraction dose thresholds for transient and main erythema are of the order of 2-6 Gy, and 3 Gy for temporary epilation.^[7] Apart from deterministic risks, stochastic risk is also a matter of concern this does not have a threshold. Taking this into consideration, it is necessary to optimize radiation dose imparted to patients by adopting dose reduction techniques so as to maintain radiation dose as low as reasonably achievable and with adequate image quality. Establishing reference levels for interventional radiology examinations presents a problem because patient numbers are limited and these interventional procedures are often performed at a few specialist centers.^[8]

Abdominal embolizations are usually using digital subtraction performed angiography (DSA) equipment. Because exposure parameters are varied throughout these examinations and X-ray beam is moved over different regions of interest, dose area product (DAP) meters are the preferred methods of dose assessment.[8-11] The DAP is particularly useful for assessing and comparing radiation dose from screening procedures and provides useful indication of the overall patient exposure than measurement of surface dose to particular organs.^[12] This study intends to evaluate the radiation dose imparted to patients during abdominal embolizations and analyze the work practices of personnel involved in performing these procedures in order to ensure judicious use of radiation with a view to maximize the benefits and minimize the risk.

MATERIALS AND METHODS

Abdominal embolizations were performed using The Siemens Multistar T.O.P (Ax) DSA equipment equipped with an under-couch Xray tube. The minimum filtration of the X-ray beam was 2.5-mm AI with an additional added filter of 0.2-mm Cu. The DSA equipment had several image intensifier formats (IIFs) or field sizes, such as 40, 28, 20 and 14. Choice of using these IIFs was at the discretion of the personnel performing the procedure. A 40-cm IIF was used while tracing the path of the catheter from the region of femoral puncture because it required a large field of view. A 28cm IIF was used for tracing the path of the catheter wherever better image resolution was required: 20-cm and 14-cm IIFs were used during road mapping, image magnification, and for superior image quality. Various fluoroscopic pulse modes such as 3, 7.5, 15, and 30 / were available on the equipment. Pulse modes of as 3, and 15/were used while tracing the path of the catheter during fluoroscopy screening. A continuous fluoro mode was selected whenever superior image resolution was required, and this was at the discretion of personnel performing the procedure. During continuous fluoro mode, the tube current varied from 1.5 to 5 mA. To acquire radiographic images, frame rates of 0.5, 6, 15, and 30 / were selected according to the necessity of information to be elicited during the study. The nominal focus to image intensifier distance (FID) ranged from 100 to 115 cm. The distance between the X-ray tube and the table top ranged from 75 to 95 cm,

depending on the personnel performing the procedure.

Dosimetry and calculations

Radiation dose imparted to patients were measured using DAP meter (Diamentor, PTW Freiburg, Germany) fitted on top of a collimator. The DAP meter readings were in agreement with ionization chamber (Victoreen X-ray exposure meter capable of making measurements from 0.001 to 2R with reproducibility within ± 3% (Nuclear Associates USA). Calibration of the DAP meter was done by company engineers every six months in collaboration with medical physicists of the radiology department. The DAP values, exposure factors used, IIFs selected, and duration of the study were displayed on the control console of DSA equipment, and these parameters were recorded during the course of study.

The calculation of ESD from the measured values of DAP requires the field dimension and focus to skin distance (FSD).^[11] For estimating the ESD, the average beam area for each field size was measured and the DAP values obtained was divided by the beam area.^[13] The method of estimating ESD from DAP values assumes a single nominal geometry or each procedure, the resulting uncertainties in the ESD estimates owing to realistic deviations in the FSD and FID from their nominal values are of the order of 30%. Changes in image intensifier IIF or use of additional collimation can introduce uncertainties of upto 40%. These errors could be regarded as acceptable and are comparable to those in other methods of estimating ESD.^[11] The difficulty in assessing direct ESD using a DAP meter is that the DAP values obtained from it did not include the back scatter factor (BSF). Hence, it was necessary to assess the BSF separately and include it in the calculation of ESD.^[14] The backscatter factors during the abdominal embolization varied from 1.27 to 1.39.

Abdominal embolizations, Hepatic embolization

This is a therapeutic procedure performed on patients reported with intra-abdominal bleed owing to pseudoaneurysms involving the hepatic artery branches and hepatic trauma. The pseudoaneurysms were embolized using platinum coils and the trauma with gel foam particles and coils. The length of this procedure depended on the site and nature of the vascular anatomy.

Renal embolization

This is a therapeutic procedure performed on patients with hematuria following percutanoeus nephrolithotomy, renal biopsy, pre-operative embolization for renal tumors, and also used as an option for controlling severe hypertension in patients with chronic renal failure scheduled for a renal transplant. The length of this procedure depended on the site of bleeding, number of vessels involved, and the vascularity of the tumour.

Splenic artery embolization

This therapeutic procedure involved trapping the aneurysm with fibered platinum coils after selectively cannulating the splenic artery using a microcather. This procedure was invariably performed on patients with pancreatitis and gastointestinal bleed. The length of the procedure depended upon the

531

530

complexity of the arterial anatomy and number of coils used to trap the aneurysm.

Transarterial chemoembolization (TACE)

This is a therapeutic procedure where chemotherapeutic drugs were instilled directly into the hepatic tumors after super selectively cannulating the branches of the hepatic artery using micro-catheters. After instillation of the drug, the feeding artery was blocked with gel foam particles. The length of this procedure depended on the complexity of the arterial anatomy and number of vessels involved.

For all the abdominal embolizations, retrograde femoral access was adopted and the arteries were cannulated using catheters and microcathers under fluoroscopic guidance. Non-iodinated contrast (iohexol) was instilled through the artery into the regions of interest and images were acquired. For certain procedures, gel foam, polyvinyl alcohol particles, or platinum-fibered coils were introduced. The projection "abdomen posterior anterior" was considered most suitable for these procedures.

RESULTS

Out of the 42 patients who underwent abdominal embolizations, 10 were female patients and the rest were males. Table 1 shows exposure parameters used during abdominal embolizations. The exposure parameters such as kilovolts and milliamperes used during fluoroscopy screening were not included in Table 1 because these factors varied rapidly when the IIFs were changed. The exposure factors and related parameters during image acquisition are shown in Table 1. Although personnel operating the equipment selected a nominal tube potential of 70 kV in the DSA equipment during abdominal embolizations. During fluoroscopic screening and image acquisition, tube potential varied between 70 kV and 110kV depending upon the thickness of the patient and selection of IIFs. The mean time duration of fluoroscopic screening and image acquisition for the patients who underwent hepatic embolization, renal embolization, splenic artery embolization, and TACE were 16.67, 21.52, 21.94 min and 22.72 min, respectively. The number of images acquired during renal embolization was higher than the rest of the embolizations.

Results from Table 2 show DAP and ESD values during abdominal embolizations. The ESD values are contribution from fluoroscopy screening and image acquisition. Though the time duration for image acquisition was less than that of the fluoroscopic screening, percentage contribution of radiation dose from image acquisition was more than that from fluoroscopic screening. The hepatic and splenic artery embolizations recorded the maximum DAP values compared with the other embolizations.

DISCUSSION

The abdominal embolizations were performed on patients referred by clinicians who warranted radiological intervention. The length of the procedure and the fluoroscopy time duration varied for each embolization and this depended on the patient-related factors, viz., feeding arteries (based on the number of arteries to be intervened, size of the vessels, and orientation of the vessel), size of the tumo, co-operation of the patient, and skill of the radiologist. Majority of the abdominal embolizations were performed as emergency procedures which had high surgical risks.

The number of renal embolization procedures performed using the DSA equipment in the current study was higher than procedures such as the hepatic embolization, splenic artery embolization, and TACE. The tube potentials used during image acquisitions ranged from 70 to 110 kV and the tube current varied from 150 to 500 mA. In the study conducted by Ruiz Cruces *et al.*,^[15] during abdominal angiography procedures, the tube potentials and tube current used during radiography were 78 kV and 471 mA,

respectively. It is noteworthy in this context that the exposure factors used during abdominal angiogram or abdominal embolizations is similar. Table 1 shows the total fluoroscopy time duration for abdominal embolizations ranging from 3.9 to 44.16 min and this was within the range of 6.6–58.8 min as reported by McParland.^[16]

Results from Table 2 shows that high radiation doses imparted to patients were from hepatic embolization and splenic artery embolizations. In comparison with the other embolizations in the current study, minimum and maximum DAP values of 18.79 Gy cm² and 395.33 Gy cm², respectively were recorded during hepatic embolization. The reason behind this high DAP value involved in the hepatic embolization was owing to the

Table 1: Exposure parameters during various abdominal embolizations

Procedure	No. of		Expos					
	cases	Mean kV	Mean mA	Frames Mean (Range)	No of ⁱ mages (min) Mean (Range)	Time duration (min) Mean Range)	Fluoroscopy screening time duration (min) Mean (Range)	Total time duration (min) Mean (Range)
Hepatic embolization	9	79	357.57	773 (390–1177)	16.7 (10–27)	1.87 (0.84–3.22)	14.91 (3.06–26.63)	16.67 (3.9–27.7)
Renal embolization	17	81	327.25	832 (254–3105)	18.12 (9–41)	1.77 (0.73–3.58)	19.76 (6.57–40.58)	21.52 (7.3–44.16)
Splenic artery embolization	7	80	462.4	486.29 (346–793)	17.14 (14–21)	1.37 (0.93–2.14)	20.56 (12.8–29.4)	21.94 (14.8–30.5)
TACE	9	77	347.47	706.22 (456–1248)	15.56 (8–27)	1.39 (0.63–2.35)	21.33 (6.75–30.95)	22.72 (8.7–32.7)

Table 2: DAP and ESD values for various abdominal embolizations

Examination	Fluoroscopy DAP	Image acquisition	Total DAP	Total ESD
	(Gy cm²)	DAP (Gy cm²)	(Gy cm²)	(Gy)
	Mean ± S.E	Mean ± S.E	Mean ± S.E	Mean ± SE
	(Range)	(Range)	(Range)	(Range)
Hepatic embolization Renal embolization Splenic artery embolization TACE	28.77 ± 7.73 $(4.83-65.33)$ 36.71 ± 6.74 $14.89-123.1)$ 34.82 ± 6.59 $(3.81-54.1)$ 52.92 ± 9.66 $(6.02-95.68)$	133.19 ± 42.06 $(10.19-379.67)$ 101.9 ± 14.36 $(35.03-256.89)$ 127.35 ± 41.96 $(58.66-349.46)$ 88.88 ± 20.1 $(10.51-198.35)$	$\begin{array}{c} 161.97 \pm 45.98 \\ (18.79-395.33) \\ 138.61 \pm 16.68 \\ (60.84-299.75) \\ 162.17 \pm 45.6 \\ (62.47-394.25) \\ 141.8 \pm 24.97 \\ (43.64-292.16) \end{array}$	$\begin{array}{c} 1.2 \pm 0.88 \\ (0.13-2.99) \\ 1.01 \pm 0.92 \\ (0.43-2.13) \\ 1.19 \pm 0.84 \\ (0.44-2.98) \\ 1.03 \pm 0.18 \\ (0.31-2.11) \end{array}$

533

use of large field area of irradiation without precise collimation. The mean DAP value for hepatic embolization in the present study was 161.97 Gy cm² — higher than DAP value of 81.68 Gy cm² reported by Vano et al.,[17] The DAP values during abdominal therapeutic procedures (excluding hepatic and renal) reported by McParland ranged from 42 to 609 Gy cm^{2[16]} The mean DAP of 315 Gy cm² (range 11-854 Gy cm²) as reported by Brambilla et al.,[18] for abdominal interventions was higher than those reported here. It should be noted that there is a possibility of radiation levels to reach high levels especially during procedures involving abdominal region. Here study, the mean DAP values for renal embolization, spenic artery embolization, and TACE were 138.61, 162.17, and 141.8 Gy cm², with no specific data available in literature to compare the results of this study.

The ESD values during abdominal embolizations ranging from 0.13 to 2.99 Gy raises a possibility of the occurrence of deterministic effects of radiation because for early transient erythema the threshold dose is 2 Gy and for temporary epilation, the dose is 3 Gy.^[7] The maximum ESD of 2.99 Gy during hepatic embolization for a patient reported in the current study did not suffer from any deterministic effects of radiation though the threshold dose for temporary epilation was 3 Gy.^[7]

Work practices by personnel involved in conducting the procedure was to be evaluated in order to bring about the concept of as low as reasonably achievable. During this study, dose reduction techniques such as precise beam collimation, selection of IIFs, maintaining appropriate distances between image intensifier and tube, and other related parameters were adopted. Pulsed fluoroscopy with 15 /ps requires 54%, 7.5 /ps 27%, and 3 /ps provides adequate image quality with only 10% of the standard dose.^[18] It is also possible to save up to 90% of the fluoroscopy dose in interventions and angiographies when using the pulsed fluoroscopy modes available.^[19]

Because these embolization procedures have the tendency to impart high radiation dose to patients, appropriate recommendations should be given to the interventional team regarding selection of IIFs, number of frames used, and time duration. It is noteworthy in this context that image acquisition comprises a major fraction of radiation dose to patients and as a result, one mode of reducing the radiation dose is to inject contrast in synchronous to taking mask image rather than waiting for the mask image to appear and then injecting contrast medium. While tracing the path of the catheter, proper collimation of the X-ray beam is necessary to avoid screening in unwanted areas that were not in the area of interest. Continuous use of IIFs which involve image magnification and better image resolution will increase radiation dose to a larger extent. Judicious choice of IIF such as a 40 cm IIF without adversely affecting the diagnostic information the radiologist is looking for could make a significant contribution to dose reduction.^[14] Though strict radiation safety protocols are adopted in the DSA equipment, chances of recruiting higher exposure factors and radiation doses are possible if proper quality assurance is not performed to these higher end modalities.

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Interventional techniques using radiation are now practiced by clinicians of many specialities. Most clinicians are unaware of the potential for radiation injury.^[20] Those who perform these interventions should make use of DAP meter readings and dose reduction techniques to establish radiation doses as low as reasonably achievable. A systematic review of radiological procedures through structured audit practice would facilitate development of new standards on radiation protection and improve the outcome of patient care.^[21]

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