Estimation of Radiation Dose in Conventional Radiography.

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Abstract *: Plain radiography constitutes a major proportion of the radiological investigations, and thus contributes significantly to the radiation burden received by the patient. The entrance surface dose (ESD) estimates the radiation received by the patient during the radiographic examination. As conventional radiography is still widely used in India and no dose reference levels (DRL) exist for our country we conducted a study in a tertiary care hospital to estimate the ESD for 500 patients undergoing ten common conventional radiological examination, to determine the dose variation for a specific exam and also to compare the entrance surface dose (ESD) with the established international dose reference levels.There was an increased mean ESD in six (Chest P.A, KUB, Pelvis A.P, L.S Spine A.P, Skull A.P and Lateral) out of the ten commonly done radiographic views. This was due to the use of slow film screen combination, old x-ray machines having low tube output, and an approximate measurement of tube output by pocket dosimeter. The high doses in Skull radiography (both A.P and Lateral view) was due to the practice of using routine grids for obtaining Skull radiographs. Most of the radiographic examinations showed a large variation of factor 1.7 to 8 which was due to variation in patient's weight, BMI, and thickness of the body part. Radiographs obtained by different radiographers using different x-ray machines using manual selection of parameters also contributed to this variation. Our study reiterates the need for more extensive and large scale surveys in Indian hospitals to work with the aim of developing the dose reference levels for safeguarding patients from unnecessary excess radiation.*

INTRODUCTION

The use of ionizing radiation in the field of radiology contributes significantly to the source of radiation exposure of the population. Despite the concern of radiation exposure to the patients, the benefits far outweigh the risks involved with radiography and therefore even though a wide range of imaging techniques are available today, plain radiography still constitutes a major proportion of the radiological investigations. At least 60-80% of all diagnostic imaging examinations are radiographic examinations[1].

Over the past few year radiography has evolved from analogue film screen technique to digital acquisition especially in the western world. However, due to the high cost of installing digital radiography, conventional film screen method is still popular in the developing world. An optimum exposure within a narrow range is the pre-requisite to obtain a good quality image in conventional film screen radiography. Failure to do so leads to repeat examination resulting in increased patient dose.

The Entrance Surface Dose (ESD) is an easily measurable quantity of the x-ray dose received by the patient and used to compare the radiation exposure in various radiographic examinations. The radiation dose assessment is of extreme importance and has led to initiation of various surveys to calculate the entrance surface dose received by the patients during conventional radiography.

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In 1982, the International Commission on Radiological Protection (ICRP) stated that the dose to patients from a given type of examination may vary between hospitals by a factor of 2 to 10[2]. This initiated establishment of reference dose levels (DRL) for different x-ray examinations to limit the radiation to "As Low As Reasonably Achievable".

The importance of DRL was first discussed and recommended by the International Commission of Radiological Protection (ICRP).[2] There are enough studies to suggest that comparison of patient exposure with established Dose Reference Levels (DRL) lead to a decrease in patient dose[3-5].

No DRL have been established in India to serve as a guide to limit the exposure during the radiological examinations. This study was conducted with the aim of estimating the Entrance Surface Dose (ESD) received by the patient during common conventional plain radiographic examinations, to determine the dose variation for a specific exam and also to compare the entrance surface dose (ESD) with the established international dose reference levels.

MATERIAL AND METHODS

Study Design

After obtaining approval from the institutional ethical committee a prospective cross sectional study was conducted from September 2010 to February 2012 to calculate the ESD received by patients undergoing conventional plain radiographic examinations in the department of Radiology & Imaging of U.C.M.S. & G.T.B.

Hospital, a tertiary care centre.

50 radiograph each of the ten commonly done views including chest PA view, skull AP & Lat views, Abdomen KUB, pelvis AP, Lumbo-sacral spine AP & Lat views, cervical spine lat view, PNS view, and Extremities / joints. A total of 500 radiographic exposures were considered for the final study. Ethical clearance was obtained from the institutional committee.

Selection of patients

Adult patients of either sex referred for conventional radiography were included, whereas, patients less than 18 years and pregnant patients were excluded from the study. Non- consenting patients were also excluded.

The radiograph was obtained as per the clinician's requisition. Data regarding the patient's age, sex, weight, height, was recorded and the Body Mass Index (BMI) calculated. The acquisition parameters were also recorded -kilovolt peak value

(kVp), milli ampere time product (mAs), focus to film distance (FFD), thickness of the body part radiographed.

Equipment

Conventional radiographic examination was carried using the following x-ray machines: a) Wipro GE MST-DX525/HORIZON (800 mA), b) Wipro GE MST-Dx525/PRESTIGE (500 mA), c) Siemens POLYDOROS Sx65/MULTIX 3D (800 mA), d) Siemens 6R/Bucky Table X-ray machine(500mA)

Calculation of X-Ray tube output

Pocket dosimeter was used to measure the output of the machine in mR /mAs at 100 cm distance using 50 kVp – 100 kvp. The appropriate pocket dosimeter was placed on a low scattering material (cardboard) on the X-ray table under the central beam axis at a X-ray tube focal spot-detector distance of 100 cm and the radiation field size was adjusted to cover the pocket dosimeter . The tube potential was set at 50 kVp and mAs value depending upon the X-Ray machine and limit of pocket dosimeter. A radiographic exposure was made and the dosimeter reading recorded twice and the average calculated. The X-ray tube output was determined as the ratio of average dosimeter reading to the tube current-time product used for tube voltages 50-100 kVp in steps of 10 kVp. The values of the X-ray tube output per mAs were plotted against the tube potential, to obtain the calibration curve for the x-ray machine (fig. 1 a, b, c & d).

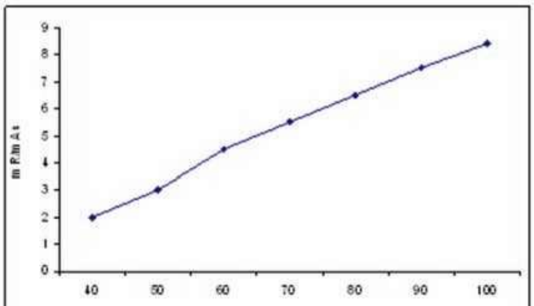

Fig. 1a : Calibration curve for X-ray machine Wipro GE MST-DX525/ HORIZON (800mA)

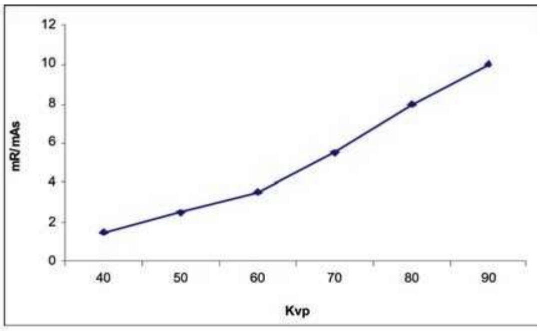

Fig. 1b : The calibration curve for X-ray machine Wipro GE MST-Dx525/ Prestige (500 mA)

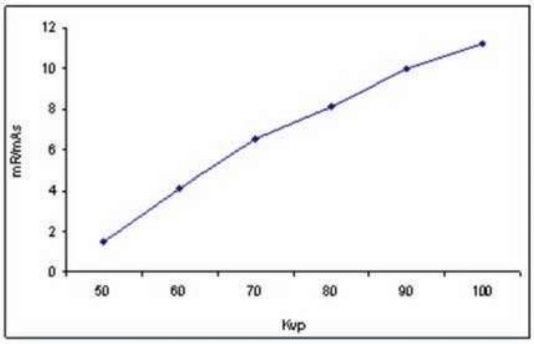

Fig. 1c : The calibration curve for X-ray machine Siemens POLYDOROS Sx65/MULTIX 3D (800 mA machine)

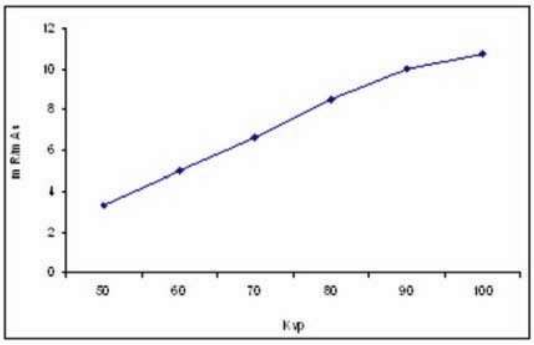

Fig. 1d : The calibration curve for X-ray machine Siemens 6R/Bucky Table X-ray machine (500mA)

Calculation of Entrance Surface Dose (ESD)

The entrance surface dose received by the patient was calculated by using formula given below:

ESD = OP X mAs X $(100/FSD)^2$ X BSF x F
ESD = Entrance Surface Dose
OP = Out Put Of The Machine
mAs = Product of Mili Ampere & Seconds
FSD = Focal Skin Distance (In Cms)
FSD = FFD – Thickness of the Part to be Radiographed (in cms)
FFD = Film Focal Distance (in cms)
BSF = Back Scatter Factor (1.35)
F = Conversion Factor (Rad / Roentgen) =0.92 *

The values of ESD were used to determine the Minimum ESD, Maximum ESD, Mean ESD, Max /min ESD ratio and the percentage variation in ESD for each of the ten radiographic examinations.

The mean value and the standard deviation for the various patient and exposure factors were also determined.

The Mean ESD for the various examinations was compared with the international DRL - British Safety Standards (BSS), Commission of European Countries (CEC), National Radiological Protection Board (NRPB) and the International Atomic Energy Agency (IAEA) (Fig. 2)

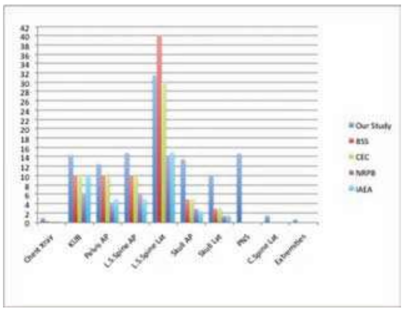

Fig. 2 : Bar diagram showing the mean ESD in comparison to the DRL given by various international bodies

RESULTS

We collected data for 500 conventional radiographic examinations for 10 commonly done views. The views taken were Chest PA view, Skull AP view, Skull Lat view, Abdomen Supine/ KUB view, Pelvis AP view, Lumbo-sacral Spine AP view, Lumbo-sacral Spine Lat view, Cervical Spine Lat view, Para Nasal Sinus, and Extremities, using conventional film screen method.

All the patient parameters (Table1) and exposure parameters (Table 2) were recorded.

***Table 1:** Patient parameters in various radiographic examinations*

S. No.	Radiographic View	No. of Pt	Weight (Kg)		BMI (Kg/m^2)		Thickness of Body Part (cm)	
			Mean	SD	Mean	SD	Mean	SD
1	Chest PA	50	52.3	11.06	20.35	4.22	21.92	4.01
2	Extremities	50	56.4	11.35	23.32	4.48	7.6	3.76
3	KUB	50	55.8	8.30	22.00	3.03	19.2	4.7
4	Pelvis AP	50	55.6	9.72	22.17	3.31	18.57	3.9
5	L.S. Spine AP	50	58.1	11.16	22.40	3.49	19	3.7
6	L.S. Spine Lat	50	58.1	11.16	22.40	3.49	29.5	3.2
7	Skull AP	50	57.4	12.34	21.98	4.32	18.7	2.08
8	Skull Lat	50	57.4	12.34	21.98	4.32	16.07	2.08
9	Para nasal Sinus	50	59	12.83	23.10	4.36	19.5	2.25
10	Cervical Spine Lateral	50	50	9.56	20.15	2.94	10	1.13

***Table 2:** Exposure parameters for radiographic examinations*

View	No. of Pt	FFD	kVp				mAs				ESD (mGy)					% variation of ESD
			Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	Max / Min	SD	
Chest PA	50	180	58.36	54.00	66	3.73	18.40	14	28	4.1	0.98	0.6	2.22	3.7	0.396	72.29
Extremities	50	100	54.7	46.00	70	6.20	12.84	6	20	4.7	0.68	0.2	1.64	8	0.432	87.80
KUB	50	100	82.08	77.00	96	4.23	88.10	60	160	18.9	14.44	7.9	40.83	5.16	7.718	80.65
Pelvis AP	50	100	81.1	71.00	90	2.82	83.20	63	128	13.7	12.60	6.24	31.10	4.98	6.868	79.94
L.S. Spine AP	50	100	83.1	77.00	96	4.71	90.30	77	128	13.8	14.88	10.36	31.10	3	5.040	66.69
L.S. Spine Lat	50	100	91.7	80.00	96	4.32	126.70	96	160	15.79	31.61	16.69	49.9	2.99	8.298	66.89
Skull AP	50	100	82.1	68.00	90	5.07	83.31	30	96	18.3	13.51	3.44	19.96	5.8	4.108	82.77
Skull Lat	50	100	79.8	66.00	81	3.51	70.22	24	96	16.15	10.09	2.43	12.36	5.08	2.918	80.34
PNS	50	100	82.8	81.00	90	3.63	89.12	77	96	8.02	14.77	10.77	20.11	1.86	2.662	46.44
C.Spine Lat	50	100	61.06	55.00	66	3.15	21.56	18	28	3.03	1.46	1.13	2.01	1.77	0.262	43.78

Our study group comprised of 263 male patients and 237 female patients with the M:F ratio of 1.1:1 The age group ranged from 18 to 88 years. The mean patient weight ranged from 50 $\pm$ 9.56 Kg to 59 $\pm$ 12.83 Kg, while the mean BMI ranged from 20.15 $\pm$ 2.94 to 23.32 $\pm$ 4.48 in our study. The thickness of the body part radiographed was minimum for extremities 7.6 $\pm$3.76 to a maximum of 29.5 $\pm$3.2 for the lumbo-sacral spine lateral view.

All the radiographic exposures were made at Focal Film Distance (FFD) of 100 cm except chest X-Ray where FFD was 180 centimeters.

Out of a total of 500, 150 radiographs (Chest, extremities, and Cervical spine) were done without use of grid and showed much lower mean ESD in comparison to the grid examinations.

The minimum and the maximum ESD was calculated for specific radiographic examination. The variation in ESD was determined in terms of maximum to minimum ratio (Fig. 3a) and percentage variation (Fig. 3b) for each specific examination.

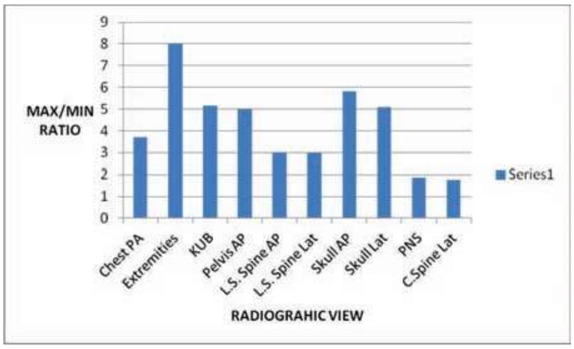

***Fig. 3 a:** ESD variation as Max/ min ratio for the various radiographic examination*

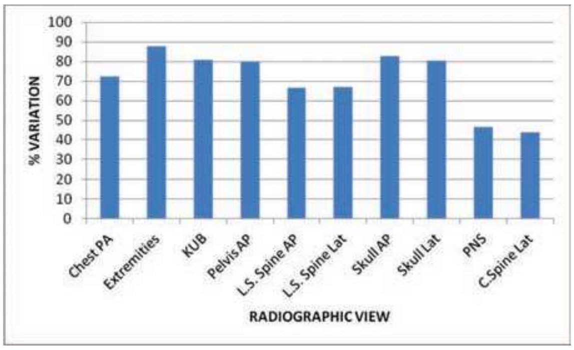

***Fig. 3 b:** Percentage ESD variation of different radiographic examinations*

A large variation was seen in the radiographic examinations of Extremities, Skull A.P, KUB, Skull Lat, and Pelvis A.P in the decreasing order. The maximum variation was noted in Extremities (8), Skull A.P (5.8) followed by KUB (5.16) and Pelvis A.P (4.98) and minimum variation is seen in radiographic examination of Cervical Spine Lateral view (1.77).

The maximum percentage variation was noted in the radiographs of the extremities (87.80%) followed by skull AP (82.77%) and lateral (80.34%), KUB (80.65%) and pelvis AP (79.94%) views. Radiographs of the chest (72.29%) and both AP (66.69%) and lateral (66.89%) views of the LS spine also showed high variation in the exposure levels. Substantial difference in the radiation was also noted in the remaining PNS (46.44%) and cervical (43.78%) radiographs. Therefore, the percentage variation varied from 43.78% to 87.80% for the various radiographs.

The mean ESD ± SD for 10 specific radiographic examinations was calculated and compared with the available DRL from four international regulatory bodies- BSS, CEC, NRPB, and IAEA (Table 3 and Fig.2). We could compare our results in 7 radiographic examinations only. As no DRL are available for X-ray of PNS, extremities and cervical spine lateral view the comparison could not be done for these views. The mean ESD for Extremities and Cervical Spine Lateral view was 0.68±0.432 mGy and 1.46±0.262 mGy respectively and that for PNS was 14.77±2.662 mGy.

The mean ESD of our study exceeded the DRL range as per the four international regulatory bodies in all the nine views except in Lumbo-sacral spine lateral view.

DISCUSSION

In our study we estimated the ESD for a total of 500 exposures for the ten common plain radiographic examinations of adult patients.

The mean ESD calculated for chest in this study was 0.98 ±0.39 mGy. In the study done by M.A. Halato et al[6] results indicates that the mean ESD for chest examination done in two different hospitals was 0.27 mGy and 0.54 mGy. According to Marie Jeane et al[7] chest radiographic examination have dose up to 2.4 mGy and also showed a large variation of dose. Our study also showed higher doses than international reference levels of 0.3mGy given by BSS and CEC and 0.2mGy as recommended by IAEA and NRPB.

The mean ESD for KUB radiograph was 14.44 mGy with a standard deviation of 7.71. The radiation dose was higher in our study as compared with the international DRL of 10 mGy.

The mean ESD for pelvis was 12.60±6.868 mGy which was marginally more than the international levels of 4-10 mGy. The mean ESD for pelvis as estimated by Marie Jeane et al[7] was 23.2 mGy, which is much higher than the recommended DRL before implementing the corrective measures.

The radiographic examinations of Lumbosacral Spine A.P and Lateral view had a mean ESD of 14.88 ± 5.040 mGy and 31.61 ± 8.298 mGy respectively. This dose was higher for AP view from 10 mGy as given by BSS and CEC but equivalent to 30 mGy for lateral view.

In the radiographic examination of Skull AP and lateral views the mean ESD calculated was 13.51±5.040 and 10.09± 2.91 mGy respectively. According to the DRL, dose for Skull A.P should fall between 2.5 to 5 and that for lateral view 1.5 to 3 mGy. Marie Jeane et al in their study estimated the mean ESD in Skull to be 9.3 mGy before implementing quality check program. The mean ESD of Skull Lateral in our study is 10.09 mGy with standard deviation of 2.91, which was above the recommended levels as also in AP view of the skull. The mean ESD calculated for PNS was 14.77 ± in this study but as no DRL exist comparison was not possible.

On comparison with the DRL given by the international regulatory bodies our study revealed a higher mean ESD in six radiographic exams- Chest PA view, Skull AP view, Skull LAT view, Abdomen Supine/ KUB view, Pelvis AP view and Lumbo-sacral Spine AP view, equivalent in lateral view for Lumbo-sacral spine. (Table 3)

Table 3 : Mean ESD in our study in comparison to BSS, CEC, NRPB and IAEA international regulatory bodies

	Dose Reference Level						
S.No	Exam	Our study	BSS	CEC	NRPB	IAEA	Range*
1	Chest PA	0.98±0.396	0.3	0.3	0.20	0.2	0.2-0.3
2	KUB	14.44±7.718	10	10	6.00	10	6-10
3	Pelvis AP	12.60±6.868	10	10	4.00	5	4-10
4	L.S. Spine AP	14.88±5.040	10	10	6.00	5	5-10
5	L.S. Spine Lat	31.61±8.298	40	30	14.00	15	15-40
6	Skull AP	13.51±4.108	5	5.0	3.00	2.5	2.5-5
7	Skull Lat	10.09±2.918	3	3.0	1.50	1.5	1.5-3
8	PNS	14.77±2.662	-	-	-	-	
9	C.Spine Lat	1.46±0.262	-	-	-	-	
10	Extremities	0.68±0.432	-	-	-	-	

** Range as per all the four international regulatory bodies*

The Skull radiographs both A.P and Lateral views have shown unusually high mean ESD in our study. Review of the radiographic practice followed in the hospital revealed the use of regular grids rather than special Skull radiography grids for obtaining x-rays of the skull. Similar reason can be cited for the high mean ESD obtained in radiography of the PNS as well.

The variation in our study for specific x-ray exams has been expressed as max/min ESD ratio (Fig. 3a) and percentage variation of ESD (Fig. 3b) for each examination as expressed in parenthesis below. The maximum variation (max/ min ratio, % variation) is noted in Extremities (8, 87.80%), Skull A.P (5.8, 82.77%) & skull lateral (2.918, 80.34%) followed by KUB (5.16, 80.65%) and Pelvis A.P (4.98, 79.94%). Radiographs of the chest (3.7, 72.29%) and both AP (3.0, 66.69%) and lateral (2.99, 66.89%) views of the LS spine also showed high variation in the exposure levels. Substantial difference in the radiation was also noted in PNS (2.662, 46.44%) and cervical (1.7, 43.78%) radiographs. Therefore, the percentage variation of ESD was from 46.44% to 87.80% and the maximum to minimum ratio varied from factor of 1.77 to 8 for the various radiographs in our study. In a United Kingdom 2000 national survey, the variations expressed in terms of maximum-to-minimum ratio (max/min) ranged from 52 to 283 [3]. Research made in national level in various parts of the world indicates that the patients doses vary from one radiography room to another adjacent one to 20 times[8] .

The reasons for the high mean ESD was the (the included) use of pocket dosimeter for estimating the x-ray tube output of the x-ray machines, use of slow speed of film and old x-ray machines with low x-ray output. The use of slow speed (100) films requires higher exposure factors for obtaining a good quality radiographs and old x-ray machines had low x-ray tube output and require more exposure factors to achieve the desired results. However, the DRL presented by IAEA has been calculated using a film-screen combination of 200, which will result in a corresponding increase in the radiation dose by a factor of 2 in our study. Considering the variability in radiographic practice from the practices followed in the developed countries giving the reference DRL for plain radiographic examinations, the increased mean ESD in conventional radiography in our study can be justified.

Cynthia H. Mc Collough[9] advocated that diagnostic reference levels are not the suggested or ideal dose for a particular procedure or an absolute upper limit for dose. Rather they represent the dose level at which an investigation of the appropriateness of the dose should be initiated along with an image quality assessment. The primary value of DRL is to identify dose levels that may be unnecessarily high i.e. to identify those situations where it may be possible to reduce dose without compromising the required level of image quality. Determination of patient doses or entrance surface air kerma values and their comparison with diagnostic reference levels are an important part of the optimization process in diagnostic radiology. Comparison of average dose levels from a specified radiographic procedure with diagnostic reference levels identifies unusually high for that particular exam [10/9], and thus guides towards decreasing the radiation dose while maintaining the image quality. The additional advantage of dose reduction can be an increased X-ray tube life, although there are limited data to support this assumption[11].

The large variation in our study can be explained by the variation in the patient factors- BMI and weight of the patient. Srivastava et al [12] in their study estimated the entrance surface dose (ESD) and the correlation between ESD and thickness of body part, weight, and height of the patients undergoing routine x-ray examinations. ESD for chest PA view, L.S. spine lateral, and Pelvis shows some dependence on patient thickness.

Other factors responsible for the variation were radiographs obtained by different radiographers having variable knowledge/ skill and in different rooms using different machines for same view, manual selection of parameter without use of any DRL and varying processing conditions for different x-ray rooms. Absence of dose reference levels for obtaining radiographs further accounted for the radiation dose variation in our study.

Entrance surface dose variations could be attributed to different levels of training in radiology, the choice of radiographic technique, the film-screen combination type in use, the status of Quality Assaurance program implementation, human physique, and, importantly, the status of implementation of radiation protection standards [11].

The high exposure levels in our study compared to the international levels in a few examinations can be explained by the local radiographic practices and large variation in the specific exam points towards the scope for working to avoid the unnecessary radiation exposure to the patient.

The limitation of our study was that a pocket dosimeter was used to determine the exposure and thus the output of the X-ray machine. As it gives an approximate and not an absolute value of exposure, the ESD in our study cannot be directly compared with the international reference levels which have been estimated by absolute dosimetry.

CONCLUSION

In conclusion it can be stated that multiple factors lead to a great variation of the radiation dose to the patients for a specific radiographic examination. Estimating the ESD is an important way to identify reasons for excessive exposure and thus apply measures to control the quality of the X- ray services within the hospital. It further emphasizes that each radiology setup should establish their own DRL suiting their own radiographic techniques and practices in order to optimize the patient protection by detecting radiographic malpractices and machine malfunction for quality assurance in every x-ray establishment.

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LITERATURE REVIEW

IDENTIFICATION OF URINARY PROTEINS POTENTIALLY ASSOCIATED WITH DIABETIC KIDNEY DISEASE

RK Marikanty, MK Gupta, SVB Cherukuvada, SSS Kompella, et.al *Indian J. Nephrology 2016 ; 26; 434-445*

Diabetic nephropathy (DN) is the most common cause of chronic kidney disease. Although several parameters are used to evaluate renal damage, in many instances, there is no pathological change until damage is already advanced. Mass spectrometry-based proteomics is a novel tool to identify newer diagnostic markers. To identify urinary proteins associated with renal complications in diabetes, we collected urine samples from 10 type 2 diabetes patients each with normoalbuminuria, micro- and macro-albuminuria and compared their urinary proteome with that of 10 healthy individuals. Urinary proteins were concentrated, depleted of albumin and five other abundant plasma proteins and in-gel trypsin digested after prefractionation on sodium dodecyl sulfate polyacrylamide gel electrophoresis. The peptides were analyzed using a nanoflow reverse phase liquid chromatography system coupled to linear trap quadrupole-Orbitrap mass spectrometer. We identified large number of proteins in each group, of which many were exclusively present in individual patient groups. A total of 53 proteins were common in all patients but were absent in the controls. The majority of the proteins were functionally binding, biologically involved in metabolic processes, and showed enrichment of alternative complement and blood coagulation pathways. In addition to identifying reported proteins such as á2-HS-glycoprotein and Vitamin D binding protein, we detected novel proteins such as CD59, extracellular matrix protein 1 (ECM1), factor H, and myoglobin in the urine of macroalbuminuria patients. ECM1 and factor H are known to influence mesangial cell proliferation, and CD59 causes microvascular damage by influencing membrane attack complex deposition, suggestive their biological relevance to DN. Thus, we have developed a proteome database where various proteins exclusively present in the patients may be further investigated for their role as stage-specific markers and possible therapeutic targets.