



## DIAGNOSTIC RADIOLOGICAL EXPOSURE LEVELS IN SIX SELECTED HOSPITALS OF FAISALABAD, PAKISTAN

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A study has been carried out to determine the x ray exposure received by the patients in the six selected government and private hospitals in the city of Faisalabad, Pakistan. The objective was to assess the radiation protection status during diagnostics x ray examination in different hospitals of the city. The exposure to x rays of various organs of human body based on sex, age and weight was measured using the ion chamber pocket dosimeters. The doses received by the patients have been compared with those recommended by the International Atomic Energy Agency (IAEA). It was observed that patients and the technical staff of the hospitals were ignorant of radiation health hazards. The voltage and current parameters of x ray machines were not set properly. X ray films were not adequately processed. The x ray exposure values showed vast diversifications from organ to organ and hospital to hospital.

**Keywords:** Diagnostic, Radiology, X rays, Radiation exposure, Body organs, Pocket dosimeter.

### 1. Introduction

The mankind is being exposed to natural radiation since its creation on the earth. Natural radiation includes the outer space cosmic rays and the terrestrial radiation on the earth [1]. In addition to the natural radiation sources, the man-made sources of radiation badly affect the persons exposed to such radiation. Among the man-made sources of radiation, x rays have played a vital role in various disciplines of science [2-4].

In 1895, Wilhelm Conrad Roentgen discovered x rays that are in use since then. Now-a-days, x rays are being used: (a) in crystallography of minerals using x ray diffraction technique, (b) in industry for non-destructive testing of materials and machinery using x ray radiography, (c) in hospitals to diagnose fractures of bone and diseases of other human organs, and radiotherapy of cancerous patients, etc. [5]. The medical applications of x rays started immediately after their discovery. Now it has become an indispensable tool of medicine, enabling physicians to diagnose the diseases of bones,

lungs and other human body organs [6].

X rays exposure like other ionizing radiation can injure the living cells and produce profound biological effects in the living organisms. Excessive exposures of human being to ionizing radiation produce immediately serious radiation burns and generate delayed somatic and genetic effects. During the first decade after the discovery of x rays, the scientists and technicians suffered injuries and even lost their lives due to repeated exposure to radiation. In spite of the harmful effects, x rays have proved to be much useful for diagnostic purpose and are being used extensively worldwide in hospitals, diagnostic and research laboratories, etc. Due to this reason International Commission on Radiological Protection (ICRP) has introduced the concept of ALARA (as low as reasonably achievable). Ascetic radiation effects are irreversible and commutative; it is strongly recommended by ICRP that every effort should be made to reduce exposure to x rays to the lowest possible level [7, 8]. In different countries of the world many surveys have been conducted to assess the dose levels during x ray examination of

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Table 1. Maximum voltage and maximum current that can be applied to the x-ray units used in various hospitals of Faisalabad.

Hospital	X-Ray Unit	Maximum Voltage (kV)	Maximum Current (mA)
H-1	Toshiba	120	500
H-2	Toshiba	120	500
H-3	Hitachi	120	500
H-4	Toshiba	120	500
H-5	Seimens	125	500
H-6	Shimadzu	150	500

patients [8–10].

Different types of dosimetry systems can be applied to measure x ray dose. Ionization Chambers are gas filled radiation detectors, which can measure x ray dose over a wide range [1]. Pocket dosimeter is a special kind of ion chamber that works on the principle of ionization of chamber–gas with x rays and discharging of the electrolyte by the ions. The dosimeter is calibrated in terms of exposure in mR (milli–Roentgen) and can conveniently be applied to measure x ray exposure.

Keeping in view the concept of ALARA and work done by other investigators [11,12], a study was carried out in six selected hospitals in Faisalabad City to assess the x ray doses received by various organs of the human body using Pocket Dosimeters.

## 2. Experimental Methods

In order to study the x ray exposure variations received by the patients during exposure to x rays, six hospitals in government and private sector were selected. The names of the hospitals were kept in secret, hence labeled as H-1, H-2, H-3, H-4, H-5 and H-6. Maximum voltage and maximum current applied to the x rays units manufactured by various companies has been mentioned in Table 1.

X ray exposure measurement survey was carried out with the pocket ionization chamber dosimeters model 541/A mark Victoreen. The dosimeters were calibrated on a German calibrator, naming FAG dosum test FH 390 K with 0.33 MBq Cs-137, on weakly basis. The

calibration was also verified by using the inverse square law for gamma rays.

The dosimeters were charged with a battery make FAG before distribution to the hospitals. In total 90 dosimeters were distributed for this study. In every hospital, 15 dosimeters were handed over to the personnel responsible for x ray examination in the hospitals. The dosimeters were kept adjacent to the organs to be x rayed. Distance of the dosimeter from the x ray machine window was noted. The age, weight and sex of the patient, and the operating parameters (kV and mAs) of the x ray machine were also recorded.

## 3. Results and Discussion

A large number of patients were x-rayed daily in the hospitals selected for the present study. Therefore, a large number of human body organs alongwith dosimeters were exposed to x rays. The records of x ray exposure were prepared for the exposed organ for every hospital under study. The results of x ray exposure versus applied voltage and current of x ray machines are given in Table 2. The results in this table consist of only those organs that were examined at least in two hospitals under consideration. Some of the organs were examined almost in all the hospitals under investigation and their results have been compared graphically in Fig. 1 with the standard exposure values recommended by IAEA [13].

The comparison for the x ray exposure in various hospitals, as seen from Table 2, shows that high dose levels to various organs were found in hospital H-5. The x ray exposure to most of the organs in that hospital was more than the

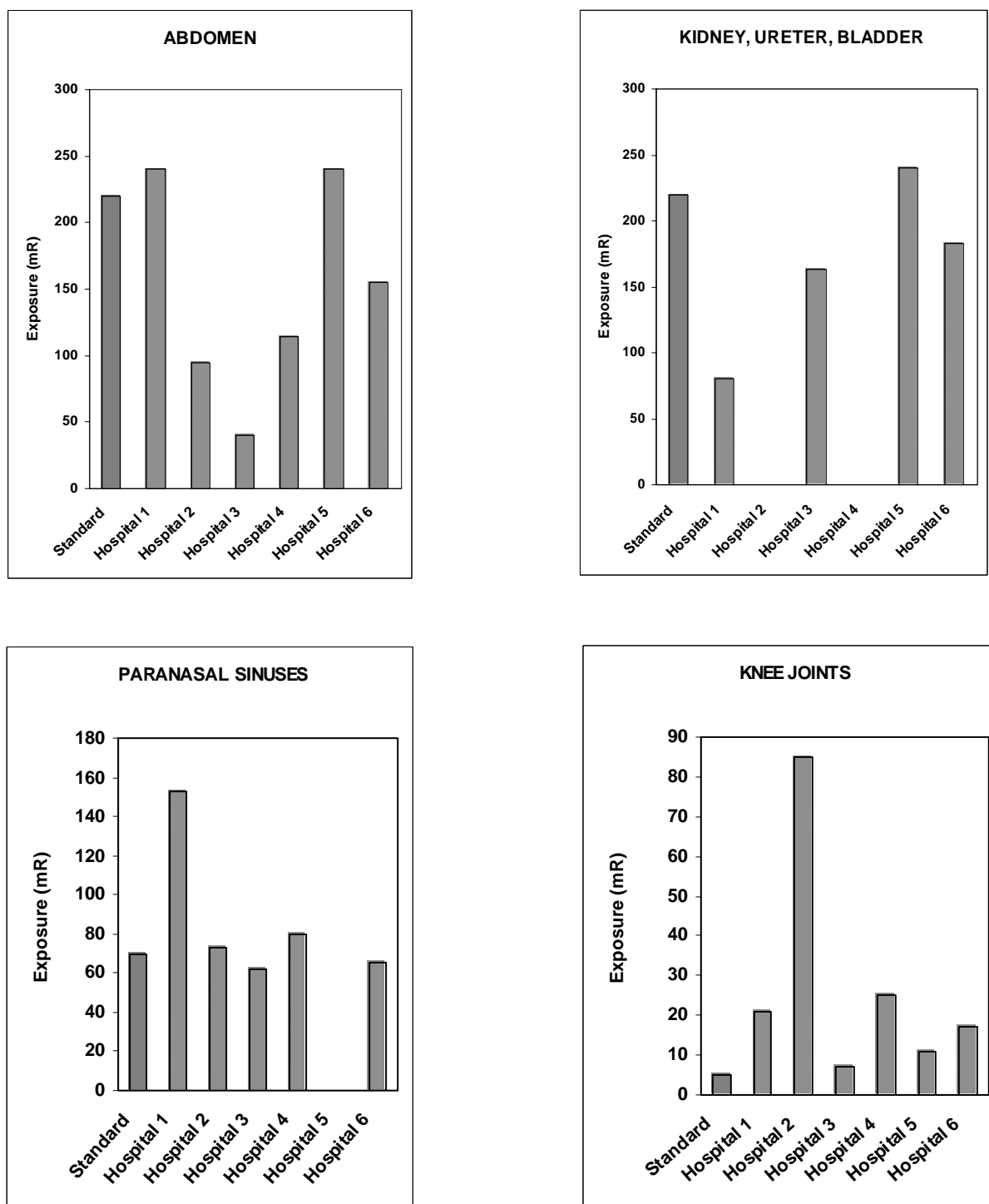


Figure 1. Comparison of x-ray exposure levels of various body organs with standard exposures (mR) for different radiographic examinations conducted in various hospitals of Faisalabad.

Table 2. Comparison of representative (standard) exposure levels (mR) with organ exposure for different radiographic examinations conducted in various hospitals of Faisalabad City, Pakistan.

Organ Examined	Parameter	Exposure (mR)						
		Standard	H-1	H-2	H-3	H-4	H-5	H-6
Abdomen	Exposure	220	200	95	40	115	200	155
	mAs		100	65	30	60	300	136
	kV		100	65	65	72	80	60
Femur	Exposure			17		42		12
	mAs			80		50		21
	kV			40		70		46
Foot	Exposure	5	20		21			
	mAs		24		80			
	kV		60		65			
Hand, Forearm	Exposure	5		17			10	15
	mAs			60			10	21
	kV			35			62	60
Intravenous Pyelogram (IVP)	Exposure	210			200	200		
	mAs				60	30		
	kV				85	80		
Kidney, Ureter, Bladder (KUB)	Exposure	220	80		163		200	183
	mAs		35		60		450	153
	kV		70		70		80	60
Knee Joint	Exposure	5	21	85	7	25	11	17
	mAs		80	120	10	80	12	21
	kV		70	60	60	70	70	57
Lumbo Sacral (Lumber Spine)	Exposure	250	182					200
	mAs		60					500
	kV		80					70
Paranasal Sinuses	Exposure	70	153	73	62	80		65
	mAs		80	60	50	80		51
	kV		90	80	75	75		70
Pelvis	Exposure	45			45	73		37
	mAs				50	80		21
	kV				70	80		70
Skull	Exposure	200				200	125	
	mAs					100	80	
	kV					80	64	
Spine (dorsal)	Exposure	180					200	90
	mAs						450	60
	kV						86	72
Wrist	Exposure	5	13	11				
	mAs		20	60				
	kV		50	40				

(more than 200 mR).

recommended levels of IAEA. The hospital H-2 showed lower x ray exposure as compared to other hospitals under study. In all the hospitals, where the organs of low exposure (Foot, Hand, Knee joint, Wrist, etc.) have been examined with x rays, the exposure to the organs were more than the standard values. For the highly exposed organs (Abdomen, K.U.B., I.V.P, Skull etc.) the x ray exposures were almost equal or slightly less than the recommended (standard) values.

The operating parameters, kilovolts (kV) and milli-ampere-seconds (mAs) set at the x ray machines in the hospitals under investigation are also given in Table 2. It is observed that the values of mAs and kV show large variation and there was no clear-cut rule to set these parameters. In some hospitals the setting of values of kV and mAs was very high for an organ whereas it was quite low for the same organ in the other hospitals. In all the hospitals no guidance-manual was used for the adjustment of kV and mAs values on the x ray

machines. The exposures were high from the x ray unit where mAs were kept large.

During the experimentation in the hospitals, the unawareness of the x ray technicians and the general public about the hazards of radiation was noted. The technicians working with x rays were not aware of the radiation protection concepts and standards. They had no concept to protect the other parts of body of the patient and the general public in the x ray rooms. They did not even bother to shield themselves from x rays. The pregnant women and the baby children accompanying them were not safe from the radiation.

The government hospitals were over-crowded. The x rays units were used extensively. The film processing and developing facilities were not used properly. Same chemical solution was used for many days without checking the effectiveness of the solution. Therefore the quality of the image became poor. The patients were x rayed at even higher radiation dose and the processing used to be done without changing the chemical solution.

Protective aprons for the radiographers were present in all the hospitals but only the radiographers of hospitals H-2 and H-3 used apron during x ray examination. Protective barriers were provided in every hospital. The radiographers did not care to use film badges or pocket dosimeters to estimate the total dose received by them. In hospital H-2 there were more than one x ray units at the same place and x rays exposures were sometimes taken simultaneously which increased the exposure level in the working area.

The hazards of x rays also depend upon the age, weight and sex of a patient. Children are more sensitive to ionizing radiation than aged persons. But the factors of age, weight and sex have not been taken into consideration in the x ray shots. X ray exposure for different body organs versus age of the patients is given in Table 3. The standard or entrance exposure for Hand, Fore arm, Knee joint, and Foot has been recommended upto 5 mR. As can be seen from the table, the x ray dose to all these organs is quite higher than the standard value. Moreover for the examination of same organ in the same hospital the x ray exposure was different and the variation was due to different settings for kV and mAs on the same machine. The entrance exposures for Abdomen, Kidney, Ureter, Bladder is 220 mR and that for Intra Venous Pyelogram is 210 mR. Luckily, in all the hospitals the x ray exposure was less than the

standard values except that in hospital H-5 where the exposure was beyond the maximum limit of a pocket dosimeter. The values of x ray exposures were different in different hospitals for the patients of same age even quite different in the same hospital for the same organ.

#### 4. Conclusions

The pilot project study indicates that the radiation protection measures were not taken into account in each of the surveyed hospitals. Protective aprons, dosimeters and film badges, even present in the hospitals, were not worn by the radiation workers. The patients were kept completely ignorant from the ionizing radiation. The large variation of radiation dose to a particular organ in each selected hospital is mostly due to bad selection of voltage and current parameters on the x ray machines. The standard doses were not taken into consideration while exposing a person to x rays. Children and adults are treated in the same manner. The repeated use of chemicals for the processing and development of the x ray films adversely affected the quality of the image. Therefore, the persons had to be x rayed again and again at even higher radiation doses. The low dose organs were given more than the twice of the recommended dose for them. In some hospitals, especially in the government hospitals, the radiation protection facilities were available but not used by anybody.

#### 5. Suggestions and Recommendations

Keeping in view the irregularities in radiation protection procedures and standards some suggestions and recommendations are forwarded for betterment of the human beings. The diagnostic radiology protection can be achieved by following ways:

##### 5.1. Training of x ray radiological workers

The personnel working on x ray units must be trained for the (a) proper use of x ray machines and adjustment of its parameters, (b) health physics and radiological protection procedures and standards for patients, and (c) selection and application of proper chemicals for processing and development of x ray films

Diagnostic radiological protection courses should be a regular feature in the hospitals to educate their workers about the latest developments in the radiation protection standards and limits. In Pakistan, PNRA (Pakistan Nuclear

Table 3. X-ray exposure of different body organs versus age of patients in various selected hospitals of Faisalabad City, Pakistan.

Entrance Exposure	Organ Examined	Age (years)	H-1	H-2	H-3	H-4	H-5	H-6
			Received Exposure (mR)					
5 mR	Foot	20	15					
		20	20					
		50			21			
	Hand	11			15			10
		18			9			
		28						15
	Knee Joint	40			17			10
		21					10	
		26	21					13
	Forearm	30			65			
		47				25		
		47				21		
		50			5		11	
		50			7			
		51			85			17
43						7		
Wrist	50	10						
	50	13						
	51		11					
210-220 mR	Abdomen	27			40			
		37	197					
		40	200			115		155
		40	95					
		52					200*	
	Intra-Venous Pyelogram	15			151			
		15						180
		17						183
		20			163			175
		20			79			
		37					200	
		38					200	
		43	80					
		50					200	
		60				200		
60				200				

\*Indicates more than 200 mR

Regulatory Authority) is responsible for radiation protection activities. Diagnostic radiological protection refresher courses should be organized by PNRA. The other training place is PIEAS (Pakistan Institute of Engineering and Applied Sciences), where already similar courses are offered from time to time.

5.2. Radiation protection awareness of general public

The harmful effects of ionizing radiation must be brought into the knowledge of general public by electronic and print media. The patients must be told about the harmful effects of atomic and nuclear radiation before exposing them to x rays.

Repetition of exposure to x rays must be discouraged.

5.3. Provision of radiological dosimetry equipment in hospitals

Radiation detection and dosimetry equipment must be provided to the personnel dealing with x ray units. The use of equipment must be made compulsory for radiation workers.

5.4. Inspection of diagnostic radiological units by PNRA

PNRA inspectors should frequently inspect the diagnostic radiological units. Arrangements for the rectification of the irregularities must be done.

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### References

- [1] IAEA, Environmental contamination following a major nuclear accident. Proceedings of an International Symposium Vol. 11. International Atomic Energy Agency, Vienna, Austria (1990).
- [2] Jobbons, The late effects of acute external exposure to ionizing radiation in man. Radiation Research Biomedical, Chemical and Physical Perspective. Academic Press Inc., New York (1975).
- [3] IAEA, A fact of life. International Atomic Energy Agency, Vienna, Austria (1979).
- [4] G.G. Poretti, Phys. in Medicine and Bio. **30**, No. 10 (1985) 1017.
- [5] J.S. Laughlin, Radiat. Res. **144**, No. 2 (1995) 129.
- [6] D.S. Fei, Chinese J. Radiobio. **23**, No. 2 (1989) 104.
- [7] ICRP, Radionuclide release into environment: Assessment of Doses to Man, International Commission on Radiological Protection, ICRP Publication No. 29 (1978).
- [8] UNSCEAR, Sources, effects and risks of ionizing radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, Report to General Assembly, with annexes (2002).
- [9] R.H. Eillis, Nuclear Technology for Engineers. McGraw Hill Book Company, Inc., New York (1959).
- [10] K.Z. Morgan, McGraw Hill Encyclopedia of Science and Technology, McGraw Hill, Inc, Philippines Vol. 4 (1977) 304 – 305.
- [11] Rueter et. al. Calculated an average radiation exposure value of chest, lumboacral, spine and abdominal x ray examinations (1990).
- [12] A. Stewart, Summary of personnel monitoring experience of four large hospitals in Houston, U.S.A. (1990).
- [13] IAEA, International basic safety standards for protection against ionizing radiation and for safety of radiation sources; Safety Series No. 115-1, International Atomic Energy Agency, Vienna, Austria, 1994.