Measurement of Kidneys' Dose in Three Hospitals during Chest and Abdomen Radiographic Examinations

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Abstract: ***The study involved 60 patients; their ages were between (20_80) years, who underwent Chest and Abdominal radiographic examinations in three hospitals at Khartoum state (A, B and C). The objective of this study was to measure of the kidneys' dose in three hospitals during chest and abdominal radiographic examinations .The data were collected using a sheet for all patients in order to maintain consistency of the information the age, exposure factors and type of examination were recorded. The examinations were collected according to the availability. After treating data with Cal Dose software, the ESAK and kidneys' dose were recorded. The percentage of kidneys' dose, the average, maximum and minimum of all data group were determined. Patient who underwent abdominal radiographic examination had higher ESAK values than those who underwent chest radiographic examinations ,.Also was found that no regular quality control measurements were done to those hospitals and the output was different from one hospital to another a matter which caused variations in the values of ESAK and kidneys' dose in each hospital. Kidneys' dose during chest and abdominal radiographic examinations had no considerable effect on the patients unless; the examinations are repeated many times in short intervals. Also comparisons of doses received during the study and the reference values were shown .The study concluded that: Differences were observed between the values of ESAK and kidney's dose in each hospital for different examinations; these differences were due to differences in setup, exposure factors to the same exam in each hospital and the output of the machine.***

Key words: Measurement, Kidneys, Dose, CALDOSE, ESAK

1. Introduction

Diagnostic X-ray examinations play an important role in the health care of the population in Sudan and worldwide. These examinations may involve significant irradiation of the patient and probably radiation exposure for the population. Radiation has been long known to be harmful to humans. The radiation exposure received in X-ray examinations is known to increase the risk of malignancy as well as, above a certain dose, the probability of skin damage and cataract. This deposition of energy is characterized as radiation dose, and if it occurs in the living tissue of individuals, the endpoint effects will be biological changes, most of which are undesirable. Understanding these interactions leads naturally to the determination of radiation exposure and dose, and the units used to define them. The biological effect of radiation depends on the total energy of radiation absorbed (in joules) per unit mass (in kg) of tissue or organ. This quantity is called absorbed dose and is expressed in Gray (Gy) [1]. If a patient is exposed to an X-ray beam, some X-ray photons will pass through the patient without any interaction, and therefore will produce no biological effect. On the other hand X-ray photons which are absorbed may produce effects. Absorbed dose of radiation can be measured and/or calculated and form basic evaluation of the probability of radiation induced effects. In evaluating biological effects of radiation after a particular exposure of the body, further factors such as the varying sensitivity of different tissues, and absorbed doses to different organs have to be taken into consideration. To compare risks of partial and whole body irradiation in diagnostic radiology effective dose is commonly used [2]. Today's diagnostic radiology, there is a growing concern about radiation exposure. [3, 4] This can be seen in the recommendations of the International Commission on Radiation Protection (ICRP) and many other international publications. All these recommendations advice that X-ray examinations should be conducted using techniques that keep patients doses as low as compatible with the medical purposes of the examinations. Patient dose is often described by the patient's entrance surface dose, which is measured on the patient's skin at the center of the x-ray beam. An alternative is to take free-in-air measurements without the contribution of backscatter radiation from the patient and express in term of incident air kerma (INAK) [5]. ESAK entrance surface air kerma (the kerma in air on the x-ray beam axis at the patient's skin) is normally used to set absorbed dose and can be used as a means of risk assessment. Radiation dose to different dose to various organs or tissues in the body cannot measure directly undergoing x-ray examinations, but they can be estimated with reasonable accuracy if sufficient data on the x-ray examination parameters are available .CALDOSE is a software tool that provides the possibility to calculate incident air kerma (INAK) and entrance surface air kerma (ESAK), as two important quantities used in X-ray diagnosis, based on the output of the X-ray equipment. Additionally, the software uses conversion coefficients (CCs) to assess absorbed dose to organs and tissues of the human body, the effective dose as well as the patient's cancer risk for radiographic examinations [6].

Effect of radiation on the kidneys: The kidney is an organ of intermediate radiosensetivity. It is mainly a late responding tissue, although functional and histological changes may be observed within a few weeks of irradiation. The low tolerance of kidney to irradiation first appreciated from the study of patients who underwent irradiation of abdominal was metastases from testicular cancer [7].

In the urinary tract, the kidneys are the most sensitive organ, the bladder and the ureters are more resistant [8]. Strong evidence has been recorded of a possible connection between kidney cancer and exposure to ionizing radiation. This evidence is based upon studies conducted at Los Alamos National Laboratory, studies of nuclear workers at other sites, and others exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that radiation can cause cancer of the kidneys and other urinary organs. Kidney cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, incidence of kidney cancer has been relatively low for Los Alamos County while mortality has been in the top third of New Mexico counties. Incidence and mortality due to kidney cancer in Rio Arriba County has been comparable to other New Mexico counties. Incidence means new cases of cancer, while mortality means deaths due to cancer [9].

2. Materials and Methods

This study was conducted in three hospitals at Khartoum state and was performed in three months.

2.1Materials

2.1.1 X-ray machines

Three different X-ray machines in different radiology department at three hospitals were used as described in Table (1).

Table 1: Demonstrates specification of the X-ray machines used in the study

Hospital	Manufacturer	Type	Focal Spot(mm)	Filtration (mm Al)	Max KVp	Max mAs	Installation year
A	Shimadzu	Fixed	0.5	2.5	150	500	2005
B	Shimadzu	Fixed	0.5	2.5	120	500	2005
C	Shimadzu	Fixed	0.5	2.5	150	500	2010

2.1.2 CALDOSE

Aiming of speeding up the process of organ dose measurement software CALDOSE,running on windows platform was used to calculate ESAK and organ doses for all patients who underwent the examinations.

CALDOSE determines organ doses and ESAK for each examination based on the mAs(tube current), FDD(field to detector distance), kVp (tube voltage) ,type of examination and the output of the machine.

CALDose_X is a software tool that provides the possibility to calculate incident air kerma (INAK) and entrance surface air kerma (ESAK), two important quantities used in X-ray diagnosis, based on the output of the X-ray equipment. Additionally, the software uses conversion coefficients (CCs) to assess absorbed dose to organs and tissues of the human body, the effective dose as well as the patient‟s cancer risk for radiographic examinations. The CCs, ratios between organ and tissues absorbed doses and measurable quantities, have been calculated with the FAX06 and the MAX06 phantoms for 34 projections of 10 commonly performed X-ray examinations, for 40 combinations of tube potential and filtration ranging from 50 to 120 kVp and from 2.0 to 5.0 mm aluminium, respectively, various field positions, for 29 selected organs and tissues and simultaneously for the measurable quantities: INAK, ESAK and kerma area product (KAP). Based on the X-ray irradiation parameters defined by the user, CALDose_X shows images of the phantom together with the position of the X-ray beam. By using true to nature vowel phantoms, CAL Dose_ X improves earlier software tools, which were mostly based on mathematical MIRD5-type phantoms, i.e.poor representations of human anatomy [6].

2.1.3 RAD-CHECK

RAD-CHECK was used to measure the radiation doses coming out of the x-ray tube machines corresponding different KVs in order to estimate the doses when date used in the software. The RAD-CHECK™ PLUS (see Figure 3.1) is a battery operated, portable unit which measures the output radiation of diagnostic x-ray equipment. The exposure is displayed on a 3 1/2 digit liquid crystal display (LCD) as either:

1.Exposure, in Roentgens (0.001 to 1.999 R) or SI units of milligrays (0.01 to 19.99 mGy). 2. Rate, in Roentgens per minute (0.01 to 19.99 R/min) or Si units of milligrays per minute (0.1 to 199.9 mGy/min)[10].

2.2 Methods

2.2.1 Data Collection

The study involved 60 patients, their ages were between (20_80) years, underwent Chest and Abdominal radiographic examinations in three hospitals at Khartoum state (A, B and C).The data were collected using a sheet for all patients in order to maintain consistency of the information. The age, exposure factors and type of examination were recorded. The examinations were collected according to the availability.

2.2.2 Method of data collection

Information about "Age, gender (Kvp and mAs) were collected for 60 patients their age were between (20-80) ,whom had chest and abdominal radiographic examinations in three hospitals at Khartoum state.

2.2.3 Method of data analysis and Dose measurement

Information was treated with CALDOSE software to calculate ESAK and organ doses, where the organ under study was the kidney.

CALDOSE determined organ doses and ESAK for each examination based on the mAs (tube current), FDD(field to detector distance), kVp (tube voltage) ,type of examination and the output of the machine. RAD-CHECK was used to measure the radiation doses coming out of the X-ray tube machines corresponding different KVp.

2.2.4 Method of data storage

The data were stored securely in password personal computer (PC).

3. Results

The data were collected from three hospitals at Khartoum state in the department of radiology. The study involved 60 patients underwent chest and abdominal radiographic examinations .Data were classified into six age groups, Table(2) and table (3) show the classifications of patients according to age, gender and examination.

Table 2: Demonstrates the classifications of patients according to age and gender

Age	*Male*	*Female*	*Total*
20-30	9	6	15
30-40	6	5	11
40-50	3	5	8
50-60	0	4	4
60-70	5	2	7
70-80	6	7	15

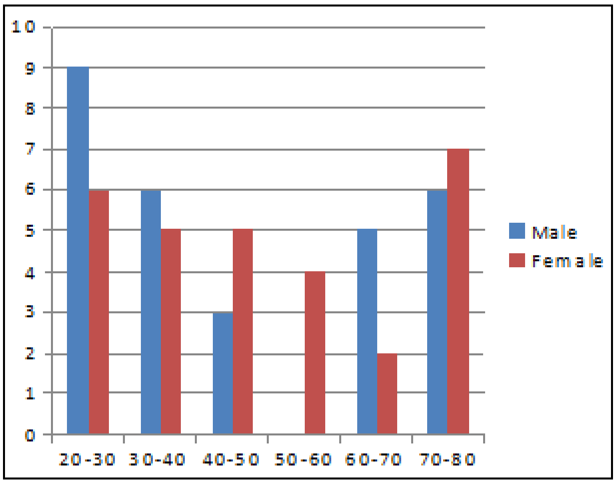

Figure 1: The classifications of patients according to age and gender

Table 3: Demonstrates the classifications of patients according to the examination and gender

Examination	Male	Female	Total
Chest	25	24	49
Abdominal	5	6	11

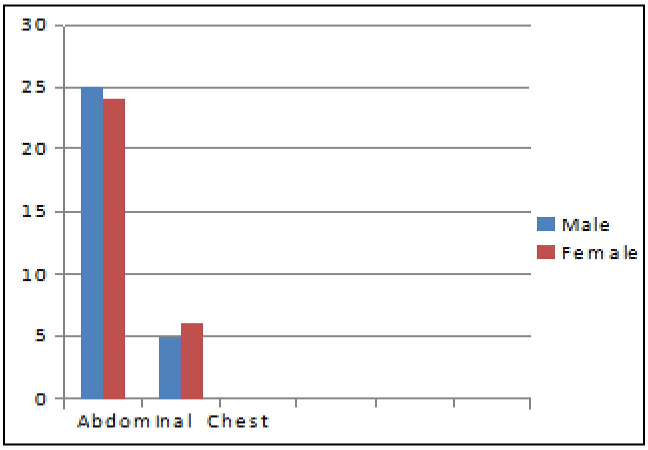

Figure 2: The classifications of patients according to the examination and gender.

Hospital A:

Table 4: Demonstrates the output of the machine among different kilo voltages in hospital A.

Kvp	mAs	Distance (cm)	Reading (mGy)
60	5	100	110
70	6.3	100	180
80	8	100	290
90	7.1	100	320
100	9	100	520
110	10	100	700
120	8	100	620

Hospital B:

Table 5: Demonstrates the output of the machine among different kilo voltage in hospital B.

Kvp	mAs	Distance (cm)	Reading (mGy)
60	4	100	40
70	5	100	70
80	5.6	100	120
90	11	100	320
100	18	100	710
110	40	100	1950
120	63	100	3920

Hospital C:

Table 6: The output of the machine among different kilo voltage in hospital C

Kvp	mAs	Distance (cm)	Reading (mGy)
60	8	100	340
70	16	100	840
80	18	100	1230
90	36	100	3100
100	40	100	4200
110	44	100	5490
120	25	100	3640

After treating data with Cal Dose software, the ESAK and kidneys' dose were recorded. The percentage of kidneys' dose, the average, maximum and minimum of all data group were determined .The result shown on the following tables were arranged according to hospitals and age groups.

Hospital A

This study involved 10 patients who underwent chest radiographic examination, 40% of patients were men and 60% of patients were women. ESAK and kidneys' dose were measured for all patients; the results are shown on table (7) and table (8).

Table 7: Demonstrates the measurement of ESAK in hospital A during chest radiographic examination

Age group	Maximum ESAK (mGy)	Minimum ESAK (mGy)	Average (mGy)
20-30	1.63	0.77	0.85
30-40	0.930	0.21	0.48
40-50	-	-	-
50-60	-	-	-
60-70	-	-	-
70-80	0.47	0.47	0.47

Table 8: Demonstrates the measurement of the kidneys' dose in hospital A during chest radiographic examination

Age group	Maximum kidneys' dose (mGy)	Minimum kidneys' dose (mGy)	Average (mGy)	Maximum kidneys' dose %	Minimum kidneys' dose %	Average %
20-30	0.28	0.06	0.12	1.56	1.36	1.43
30-40	0.14	0.02	0.32	1.63	1.36	1.44
40-50	-	-	-	-	-	-
50-60	-	-	-	-	-	-
60-70	-	-	-	-	-	-
70-80	0.06	0.06	0.06	1.46	1.46	1.46

Hospital B: This study involved 21 patients who underwent chest radiographic examination, 61.9% of patients were men and 38.1% were women. ESAK and kidneys' dose were measured for all patients (tables 9 and 10). In this hospital there was variation between the values of ESAK and kidney's dose for each patient who underwent the same exam, the variation was due to exposure factors used(Kvp and mAs) and patients age and gender.

Table 9: Demonstrates the measurement of ESAK in Hospital B during chest radiographic examination

Age group	Maximum ESAK (mGy)	Minimum ESAK (mGy)	Average (mGy)
20-30	0.25	0.16	0.20
30-40	0.20	0.11	0.17
40-50	0.19	0.17	0.18
50-60	0.19	0.17	0.18
60-70	0.27	0.08	0.17
70-80	0.20	0.15	0.17

Table 10: Demonstrates the measurement of kidneys' dose in hospital B during chest radiographic examination

Age group	Maximum kidneys' dose (mGy)	Minimum kidneys' dose (mGy)	Average (mGy)	Maximum kidneys' dose %	Minimum kidneys' dose %	Average %
20-30	0.03	0.01	0.02	1.47	1.37	1.41
30-40	0.17	0.01	0.08	1.42	1.36	1.38
40-50	0.04	0.02	0.03	1.40	1.32	1.35
50-60	0.04	0.04	0.04	1.32	1.32	1.32
60-70	0.04	0.01	0.02	1.44	1.33	1.38
70-80	0.04	0.02	0.02	1.40	1.32	1.37

There were no patients for abdominal radiographic examinations in this hospital at the time of the research due to a problem in the output of the machine.

Hospital C: This study involved 39 patients who underwent chest and abdominal radiographic examination.18 patients who underwent chest radiographic examination at hospital C, 44% of patients were men and 56% were women. ESAK and kidneys' dose were measured for all patients, the results are shown on tables (11) and (12). 11 patients who underwent abdominal radiographic examination at hospital C, 45% of patients were men and 55% of patients were women. ESAK and kidneys' dose were measured for all patients; the results are shown on table (11) and table (12).

Table 11: Demonstrates the measurement of ESAK in Hospital C during chest radiographic examination

Age group	Maximum ESAK (mGy)	Minimum ESAK (mGy)	Average (mGy)
20-30	0.81	0.16	0.47
30-40	0.85	0.79	0.82
40-50	0.71	0.30	0.51
50-60	0.20	0.14	0.17
60-70	0.46	0.46	0.46
70-80	0.91	0.05	0.50

Table 12: Demonstrates the measurement of the kidneys' dose in hospital C during chest radiographic examination

Age group	Maximum kidneys' dose (mGy)	Minimum kidneys' Dose (mGy)	Average (mGy)	Maximum kidneys' Dose %	Minimum kidneys' Dose %	Average %
20-30	0.14	0.02	0.07	1.60	1.33	1.47
30-40	0.22	0.10	0.16	1.43	1.41	1.42
40-50	0.14	0.07	0.09	1.60	1.36	1.45
50-60	0.05	0.00	0.02	1.39	1.33	1.36
60-70	0.12	0.12	0.12	1.32	1.32	1.32
70-80	0.11	0.02	0.17	1.60	1.32	1.42

Table 13: Demonstrates the measurement of ESAK in hospital C during Abdominal radiographic examination

Age group	Maximum ESAK (mGy)	Minimum ESAK (mGy)	Average (mGy)
20-30	7.27	3.11	5.19
30-40	5.10	4.70	4.90
40-50	7.84	7.82	7.83
50-60	-	-	-
60-70	-	-	-
70-80	5.17	3.49	4.24

Table 14: Demonstrates the kidneys' dose in hospital C during Abdominal radiographic examination

Age group	Maximum kidneys' dose (mGy)	Minimum kidneys' dose (mGy)	Average (mGy)	Maximum kidneys' dose %	Minimum kidneys' dose %	Average %
20-30	0.44	0.23	0.33	1.39	1.32	1.36
30-40	0.27	0.24	0.26	1.39	1.38	1.39
40-50	0.77	0.58	0.66	1.40	1.35	1.38
50-60	-	-	-	-	-	-
60-70	-	-	-	-	-	-
70-80	0.44	0.20	0.28	1.31	1.40	1.38

Table 15: Demonstrates the Comparison between the values at the three hospitals with international diagnostic reference levels

Hospital	Examination	Maximum (mGy)	Minimum (mGy)	Average (mGy)	Reference values
A		0.85	0.47	0.60	.2*
B	Chest x-ray	0.20	0.17	0.18	.2*
C		0.82	0.17	0.49	.2*
C	Abdominal	4.24	7.83	5.54	5*

*=NRPB 1999-2000 (22)

Table 16: Demonstrates the Comparison between the kidney's dose value at the three hospitals

			kidneys' dose				
Hospital	Examination	Maximum mGy	Maximum mGy	Average mGy	Maximum %	Minimum %	Average %
A		0.32	0.32	0.16	1.46	1.43	1.44
B	Chest	0.08	0.08	0.03	1.41	1.32	1.37
C		0.17	0.17	0.10	1.47	1.32	1.41
C	Abdominal	0.66	0.66	0.38	1.39	1.36	1.38

4. Discussion

81.7% of patients who underwent chest radiographic examination for different reasons and 18.3% of patients just underwent abdominal radiographic examination as shown in table (3) . Here doctors preferred Ultrasonography rather than x-ray in this case its high ability to demonstrate the tissue .RAD-CHECK was used to measure the radiation doses coming out of the x-ray tube machines corresponding different KVp, whose results are shown on the following tables arranged according to hospitals.

From tables (7) and (8) in hospital A there was a variation between the values of ESAK and kidney's dose for each patient who underwent the same exam, the variation included the exposure factors used (Kvp and mAs)and patients age and gender. There were no patients for abdominal radiographic examination in this hospital at the time of the research due to technical problems.

From tables (11 , 12, 13and 14) there was a variation between the values of ESAK and kidney's dose for each patient who underwent the same exam, also in the value of ESAK ,which was higher during abdominal radiographic examination comparing to chest radiographic examination. The variation and the differences were due to the difference in exposure factors used (Kvp and mAs) examination type and patients age and gender.

From table (14) hospitals had a variation in the values for the same exam. Hospital B had a lowest value during chest radiographic in comparison with the other hospitals and reference level. Hospital A and C showed higher values comparing to the diagnostic the reference level. The variation due to the difference setup from one hospital to another was also due to exposure factors used (Kvp and mAs).

From table 15 kidneys received different amount of radiation during chest and abdominal radiographic examinations, depending on the type of examination, output of the machine, patient information and exposure factors used (Kvp and mAs). The dose which was received by kidneys during these exams was less than 2% so it had no considerable effect on the patient unless; the examinations are repeated many times in short intervals. The value of entrance surface air kerma ESAK and kidneys' dose for 60 adult patients who underwent chest and abdominal radiographic examination were assessed. As seen most of the patients were ages ranged between (20-30) and (70_80).from the result variations in the values of entrance surface air kerma (ESAK)and kidneys' dose from one hospital to another were observed also in some hospitals the dose was higher than the international diagnostic reference level. The variation due to the difference setup from one hospital to another for the same exam also due to exposure factors used (Kvp and mAs).

To justify the difference the effect of exposure factors and patient's age and gender should be considered. Patient who underwent abdominal radiographic examination had higher ESAK values than those who underwent chest radiographic examinations ,.Also was found that no regular quality control measurements were done to those hospitals and the output was different from one hospital to another a matter which caused variations in the values of ESAK and kidneys' dose in each hospital. Kidney's dose during chest and abdominal radiographic examinations had no considerable effect on the patients unless; the examinations are repeated many times in short intervals.

5. Conclusion

From the result and discussion stated above a lot of work should be done to narrow the gap between the values of ESAK and kidney's dose to the same exam in each hospital. Differences were observed between the values of ESAK and kidney's dose in each hospital for different examinations; these differences were due to differences in setup, exposure factors to the same exam in each hospital and the output of the machine. Also comparisons of doses received during the study and the reference values were shown.

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