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Abstract: Medical X-ray examinations play an important role in diagnosis of many diseases. It is used as an important tool in the health care of Saudi Arabia and worldwide population, and it may constitute the largest man-made source of exposure to ionizing radiation. The use of X-rays without restrictions may expose patients to high radiation doses more than the allowed rates for human which expose them to danger. Moreover, the worldwide studies have emphasized tremendous variations in patient doses between different X-ray departments, in addition to establish a reference radiation dose level for each human organ. The aim of the present research work was an assessment of the patient dose levels during X-ray diagnostic imaging in King Khaled Hospital, and comparing the results with the estimated radiation dose levels in local and International places using TLD reader and TL dosimeters. Moreover, to determine a reference radiation dose level for each human organ. Thus, the routine X-ray examinations in some human organs such as chest (AP and LAT), knee (AP and LAT), spine lumbar sacral (AB and OBL; LAT and OBL), spine cervical (AP and OBL; LAT and OBL), shoulder (AP and LAT), and mammogram (AP and OBL) of adult patients over than 18 years in King Khald University Hospital (KKUH) were investigated. It became evident from the results of the present study that the radiation doses for chest in PA and LAT, knee in AP and LAT, spine lumber sacral in AP-OBL and LAT-OBL, spine cervical in AP-OBL and LAT-OBL, and mammogram in AP and OBL positions were different in KKUH and other local places [Security Forces Hospital (SFH); King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia] and International places [International Atomic Energy Agency (IAEA); European Commission (EC); Health Physics Society (HPS); United Kingdom (U.K.); China; Victoria; Greece; Taiwan; Canada; Italy; Malaysia]. The reference radiation dose levels for chest in PA position and LAT projection were 0.32 ± 0.05 mGy (mean ± SE) and 1.02 ± 0.38 mGy, respectively. The reference radiation dose levels for knee in AP position and LAT projection were 0.28 ± 0.02 mGy and 0.29 ± 0.05 mGy, respectively. The reference radiation dose level for spine lumber sacral in AP-OBL position and LAT-OBL projection were 9.19 ± 2.69 mGy and 21.22 ± 3.85 mGy, respectively. The mean radiation dose levels for spine cervical in AP-OBL position and LAT-OBL projection were 2.28 ± 1.56 mGy and 5.79 ± 4.85 mGy, respectively. The mean radiation dose level for mammogram in AP position and OBL projection were 1.09 ± 0.15 mGy and 1.34 ± 0.21 mGy, respectively. These results suggest that the estimated mean radiation dose level for a specified human organ in different positions could be considered as a reference radiation dose level for the same human organ. Moreover, the experimental procedures, physical factors, and patient data should be fixed and specified during each human organ examination by X-ray.

Assessment of Patient Doses Levels during X-ray Diagnostic Imaging using TL Dosimeters and Comparison with Local and International levels

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Abstract

Medical X-ray examinations play an important role in diagnosis of many diseases. It is used as an important tool in the health care of Saudi Arabia and worldwide population, and it may constitute the largest man-made source of exposure to ionizing radiation. The use of X-rays without restrictions may expose patients to high radiation doses more than the allowed rates for human which expose them to danger. Moreover, the worldwide studies have emphasized tremendous variations in patient doses between different X-ray departments, in addition to establish a reference radiation dose level for each human organ. The aim of the present research work was an assessment of the patient dose levels during X-ray diagnostic imaging in King Khaled Hospital, and comparing the results with the estimated radiation dose levels in local and International places using TLD reader and TL dosimeters. Moreover, to determine a reference radiation dose level for each human organ. Thus, the routine X-ray examinations in some human organs such as chest (AP and LAT), knee (AP and LAT), spine lumbar sacral (AB and OBL; LAT and OBL), spine cervical (AP and OBL; LAT and OBL), shoulder (AP and LAT), and mammogram (AP and OBL) of adult patients over than 18 years in King Khald University Hospital (KKUH) were investigated. It became evident from the results of the present study that the radiation doses for chest in PA and LAT, knee in AP and LAT, spine lumber sacral in AP-OBL and LAT-OBL, spine cervical in AP-OBL and LAT-OBL, and mammogram in AP and OBL positions were different in KKUH and other local places [Security Forces Hospital (SFH); King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia] and International places [International Atomic Energy Agency (IAEA); European Commission (EC); Health Physics Society (HPS); United Kingdom (U.K.); China; Victoria; Greece; Taiwan; Canada; Italy; Malaysia]. The reference radiation dose levels for chest in PA position and LAT projection were 0.32 ± 0.05 mGy (mean ± SE) and 1.02 ± 0.38 mGy, respectively. The reference radiation dose levels for knee in AP position and LAT projection were 0.28 ± 0.02 mGy and 0.29 ± 0.05 mGy, respectively. The reference radiation dose level for spine lumber sacral in AP-OBL position and LAT-OBL projection were 9.19 ± 2.69 mGy and 21.22 ± 3.85 mGy, respectively. The mean radiation dose levels for spine cervical in AP-OBL position and LAT-OBL projection were 2.28 ± 1.56 mGy and 5.79 ± 4.85 mGy, respectively. The mean radiation dose level for mammogram in AP position and OBL projection were 1.09 ± 0.15 mGy and 1.34 ± 0.21 mGy, respectively. These results suggest that the estimated mean radiation dose level for a specified human organ in different positions could be considered as a reference radiation dose level for the same human organ. Moreover, the experimental procedures, physical factors, and patient data should be fixed and specified during each human organ examination by X-ray.

Keywords: X-rays; diagnostic imaging; TlDs; Harshaw 3500 reader.

Abbreviations used: posterior anterior (PA); anterior posterior (AP); lateral (LAT); oblique (OBL); King Khald University Hospital (KKUH); Security Forces Hospital (SFH); King Abdulaziz City for Science and Technology (KACST); International Atomic Energy Agency (IAEA); European Commission (EC); Health Physics Society (HPS); United Kingdom (U.K.); Entrance skin dose (ESD); United States of America (USA); Time temperature profile (TTP); Acquisition setup (ACQ); thermolumencence dosimeters (TLDs); Reader calibration factor (RCF); Element correction coefficient (ECC).

Introduction:

X-ray has a high value in imaging technology for medical diagnostic purposes since Wilhelm Roentgen discovery of X-rays in 1895. Relatively high values of radiation exposure have been considered a necessary consequence of cardiac angiographic procedures (Cusma et al., 1999; Pattee et al., 1993). With increasing complexity of the procedures, there has been growing concern regarding the magnitude of the exposure to operators and patients (Zorzetto et al., 1997; Bakalyar et al., 1997; Watson, 1997; Patte et al., 1993). The studies about diagnostic doses in different countries have shown dissimilarity in diagnostic doses for every human organ (NG et al., 1998; Padovani et al., 1987). For example in the United States of America (USA) there is a difference in the dose of ovary about three times more (United State Department of Health and Human Services, 1981). It has been reported that the dose for the same examination may vary tremendously and the difference between the lowest and the highest ovary dose was about two to three orders of magnitude (CEC 1985). In a random sample of 20 U.K. hospitals, the ratio of maximum and minimum dose values vary from about 20 for the effective dose equivalent of lumber spine examination to over 1600 for lung dose during a barium meal were reported (Faulkner and Wall, 1988). In England, lumber spine has suffered 30 mGy for LAT position (Bauer et al., 1998) while the same position in other study has suffered 22.8 mGy (Faulkner and Wall, 1988), but the same organ with the same position has suffered 10.53 mGy in China (Li et al., 2001), 8.96 mGy in Victoria (Cardillo et al., 1997), 8.9 mGy in Saudi Arabia (Al-Habeeb, 2005), and 8.3 mGy in Poland (Servomaa, 2001). Moreover, many specialized organizations in the radiation protection have been published recommendations to limit these doses for protecting the patients, for example International Commission on Radiological Protection (ICRP 2007), World Health Organization (WHO 1982), International Atomic Energy Agency (IAEA 2004; IAEA 2004), Health Physics Society and European Commission (European Commission, 2000). All these organizations require minimizing as much as possible radiation doses received by patients as low as reasonably achievable (ALARA). In the recent years, these variations in dosimetric quantities observed in various countries have led to establish reference levels by the various organizations (Tung et al., 2001; Oresegun et al., 1999). These guidelines have stimulated worldwide interest in patient doses, and several major dose surveys have been conducted in many countries (Geleijns et al., 1998; Karl, 2004). Thus, in the present research work an assessment of the patient dose levels during X-ray diagnostic imaging in KKUH (Saudi Arabia) was studied using Harshaw TLD reader and TL dosimeters, and compared with the results obtained from local places [Security Forces Hospital (SFH); King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia] and International places [International Atomic Energy Agency (IAEA); European Commission (EC); Health Physics Society (HPS); United Kingdom (U.K.); China; Victoria; Greece; Taiwan; Canada; Italy; Malaysia]. Moreover, a reference radiation dose level for each human organ was estimated.

Material and methods:

Prepare TLD Dosimeters

TLDs used in the current work were Harshaw TLDs 100 made of Lithium Fluoride: Magnesium, Copper, Phosphor (LIF: Mg, Cu, P). It have several features, its effective atomic number was Z_{eff}

8.2, its size was 3.1 mm x 3.1 mm x 0.9 mm, thickness 0.9 mm and with light output equivalent to that obtained from 1R of gamma radiation. It can be used to measure doses as law as µGy with a very good linear dose response in range up to 10 Gy. The thermal luminescence major peak was at a wavelength equals 4000 A^0 with a negligible fading. The time between irradiation and readout of all dosimeters was consistent in order to keep fading the same from one calibration to the next. The specific length of this time was not as important as its consistency. The fade time was not less than thirty minutes. Otherwise, any length of time that suits the operations was acceptable, but it must be consistent from one time to the next.

Time Temperature Profile Setup (TTP)
TTP defines the temperature to which TL material is heated as a function of time (Saint Gobain Crystals and Detectors, 2001). To determine how long and to what temperature your dosimeters are heated, chose a name to your TTP or select what you need from the title field. Change these regions; preheat, acquire, and anneal, calibration and factors. So, preheat temperature = 50, and time = 0; Acquire: maximum temperature = 260-300, time= 26.67-33.33, and at a rate = 10; Anneal temperature = 260-300, and time = 0

Acquisition Setup (ACQ)
From ACQ icon access ACQ setup dialog box, Chose name to the ACQ or select what we need from the title field, and chose the purpose for using the dosimeters by choosing one mode from these five modes; Anneal dosimeters, generate calibration dosimeters, calibrate dosimeters, calibrate reader, and read dosimeters.

Anneal Dosimeters
Chose the mode anneal dosimeters in ACQ, click read, a box will appear. Inter group ID and acquisition setup. Chose if it is chipset or manual, then press start to start read until we finish all readings. In the present study the manual process was chosen, and sometimes an oven was used to anneal the dosimeters.

Generate Calibration Dosimeters
Aim: Generate calibration dosimeter mode was used to select some of TLDs to calibrate the reader later. In this stage an element correction coefficient was done. **Method:** To generate set of calibration dosimeters, you must firstly clear them of any residual or spurious TL signals, then expose them to a known source of radiation (Saint Gobain Crystals and Detectors, 2001). Chose ACQ mode as generate calibration dosimeters, and then click read to read all TLDs until we finish all readings. Go to search in main menu, the response database will appear, chose all calibration dosimeter readings, and then highlight the group recorded.

Reader Calibration OR Calibrate Reader
Aim: The purpose for reader calibration is to maintain a consistent output from the reader over a period of time based on a convenient local source of radiation. The calibration factor for reader is known as reader calibration factor (RCF). RCF converts the raw charge date from the photomultiplier tube in nanocoulombs to dosimetric units. This option mode is to generate RCF for each dosimeter. RCF is defined as an average response of the reader to a subset of calibrated dosimeters expressed in dosimetric units (Saint Gobain Crystals and Detectors 2001). **Method:** Chose ACQ mode as calibrate reader, and read the golden dosimeters only. Form search in main manu find the response database, chose all records in this stage, and highlight all the records. Select calibration from main manu, chose a TTP title, a suitable value for irradiation and units then compute RCF.

Dosimeters Calibration or Calibrate Dosimeters

Aim: The purpose of calibrating TLDs is to ensure that all dosimeters in a system will give essentially the same response to a given radiation exposure, because of the natural variation in TL material responsiveness and in the physical mass of manufactured TL chips, there is a variation in response of as much as 30 % from a mean population of dosimeters. The calibration factor for dosimeters is called element correction coefficient (ECC). ECC is used as a multiplier with the reader output (in nanocoulombs) to make the response of each dosimeter comparable to an average response of a designated group of dosimeters maintained as calibration dosimeters. Thus, this option mode creates ECC for each dosimeter in the system. **Method:** To calibrate a group of dosimeters, you must firstly clear them of any residual or spurious TL signals, and then expose them to a known source of radiation (Saint Gobain Crystals and Detectors 2001). Chose ACQ mode as calibrate dosimeters and apply RCF. Read TLD, from search in main manu find the response database, chose all records. From main manu click calibration, chose dosimeter calibration, then enter a suitable irradiation value and compute ECC. Where:

$$\text{Exposure} = \text{ECC} \times \text{Charge} / \text{RCF}$$

Read Dosimeters

Chose the mode read dosimeters in ACQ, click read, then read until finish all the readings. It is noted that the readings taken in anneal dosimeters mode are not used in calibrate reader mode (Saint Gobain Crystals and Detectors, 2001).

Assessment of X-ray examinations in some Human Organs

Only one of the hospitals of King Saudi Arabia was selected and X-ray examinations were assessed using Harshaw reader 3500 and TL dosimeters. The routine X-ray examinations in some human organs such as chest (AP and LAT), knee (AP and LAT), spine lumbar sacral (AB and OBL; LAT and OBL), spine cervical (AP and OBL; LAT and OBL), shoulder (AP and LAT), and mammogram (AP and OBL) of adult patients over than 18 years in KKUH were investigated. KKUH was selected to participate in the survey, and the selection of this hospital was based on the convenience and the willingness of the hospital to participate in the survey. Thus, Twenty readings for each human organ in KKUH were studied. TLDs were prepared by annealing, were placed in a black plastic to isolate them from any external radiation, and were saved in a box made from lead. TLDs were assigned and placed in the center of field of view of X-ray beam to get an entrance skin dose (ESD) for each patient. For every image, some physical factors such as TLD number, tube current, tube potential, beam field of view, distance to patient, and thickness of image region that might influence patient dose were recorded. Other date related to patient such as patient weight, length and age were recorded. After we finish, each TLD was returned back to the black plastic, and TLDs were read by Harshaw reader. To assess the patient radiation dose levels in KKUH during X-ray diagnostic imaging, the results obtained in KKUH were compared with the measured radiation dose levels in local places (SFH and KACST) in Saudi Arabia and International places (IAEA; EC; HPS; U.K.; China; Victoria; Greece; Taiwan; Canada; Italy; Malaysia) using Harshaw TLD reader and TL dosimeters. Moreover, a reference radiation dose level was estimated as an average value for each human organ.

Results:

Table 1 shows patient radiation dose level during X-ray examination and some of the physical factors recorded for every patient organ during each field of view: The physical factors recorded for each field of view were human organ position, tube potential, tube current, field size, distance to patient, thickness of image, in addition to some data of the patient such as age, length, weight, and measured dose.

Table (1) patient dose level during X-ray diagnostic imaging in KKUH as well as some of the physical factors recorded for every patient during each field of view:

Organ	Position	Potential (kVp)	Current (mAs)	Field Size (cm2)	Distance Patient (cm)	Age (years)	length (cm)	Weight (Kg)	Dose (mR)	Dose (mGy)
Chest	PA	90	5.843	40.99 × 40.98	173.05	38.55	155.05	66.6	15.40	0.135
	LAT	89.9	454.66	40.9 × 41	173.05	40.15	158.035	71.3	25.58	0.224
Knee	AP	70	12.325	34.6 × 32.3	97.915	45.15	156.5	72.895	34.76	0.305
	LAT	70	13.74	31.4 × 27.6	101.855	50.45	160	78.5	38.12	0.334
Spine Lumbar Sacral	AP- OPL	79.25	27.68	40.1 × 31.2	105.74	40.05	158.6	72.545	74.72	0.655
	LAT- OPL	85.45	41.81	39.35 × 28.51	112.395	43.9	158.95	77.59	133.91	1.173
Spine Cervical	AP-OPL	75.25	18.49	30.99 × 26.13	171.95	45.1	157.6	68.275	19.97	0.175
	LAT-OPL	75.75	14.33	31.24 × 25.89	173.8	45.2	156.65	70.075	22.88	0.201
Shoulder	AP / LAT	70.25	14.88	27.61 × 29.21	174.25	50	158.9	72.55	9.23	0.081
Mammogram	AP	28.3	67.85	_	52.45*	47.45	160.15	74.85	155.34	1.361
	OPL	29.25	86.13	_	67.95*	47.85	160.55	72.8	197.44	1.729

Table (1): Abbreviations: anterior posterior (AP); posterior anterior (PA); lateral (LAT) projection; oblique (OBL) projection; * thickness to the organ.

Patient doses levels during X-ray diagnostic imaging in KKUH compared with local and International radiation dose levels were shown in table (2).

Table (2) patient doses levels during X-ray diagnostic imaging in KKUH compared with local and International radiation dose levels

Organ	Position	KKUH (mGy)	SFH[15] (mGy)	KACST[75] (mGy)	IAEA[84] (mGy)	EC[37] (mGy)	HPS[41] (mGy)	U.K.[48] (mGy)	China[52] (mGy)	Victoria[24] (mGy)	Greece[48] (mGy)	Taiwan[69] (mGy)	Canada[48] (mGy)	Italy[61-69] mGy	Malaysia[58] mGy
Chest	PA	0.13	0.22	0.4	0.4	0.3	0.02	0.16	0.34	_	0.69	0.52	0.11	0.57	0.28
	LAT	0.22	_	0.4	1.5	1.5	0.04	0.57	_	_	2.9	_	_	_	_
nee	AP	0.3	0.26	_	_	_	_	_	_	_	_	_	_	_	_
	LAT	0.33	0.24	_	_	_	_	_	_	_	_	_	_	_	_
Spine Lumbar Sacral	AP-OBL	0.65	5.23	40	10	10	0.7	6.1	5.18	3.17	18.9	5.91	3.34	8.9	10.56
	LAT- OBL	1.17	8.9	40	30	30	_	16	10.53	8.96	44.9	18.9	_	26.7	18.6
Spine Cervical	AP-OBL	0.17	0.67	10	_	_	_	_	0.28	_	_	1.55	_	_	1.02
	LAT-OBL	0.2	0.995	30	_	_	_	_	0.36	_	_	1.61	_	_	1.6
Shoulder	AP - LAT	0.08	_	_	_	_	_	_	_	_	_	_	_	_	_
Mammogram	AP	1.36	_	1.3	1	_	0.7 (4 views)	_	_	_	_	_	_	_	_
	OBL	1.73	_	1.3	1	_	_	_	_	_	_	_	_	_	_

Abbreviations: King Khald University Hospital (KKUH) in Saudi Arabia; Security Forces Hospital (SFH) in Saudi Arabia; King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia; International Atomic Energy Agency (IAEA); European Commission (EC); Health Physics Society (HPS); United Kingdom (U.K.).

The mean radiation dose level, lower radiation value, higher radiation value, and range of radiation values for each human organ during X-ray diagnostic imaging in KKUH were shown in table (3).

Table (3): mean radiation dose level (mean ± SE), lower radiation value, higher radiation value, and range of radiation values for each human organ during X-ray diagnostic imaging in KKUH

Human organ	Mean ± SE	Lower radiation value (mGy)	Higher radiation value (mGy)	Range of radiation values (mGy)	N (radiation values)
Chest (PA)	0.32 ± 0.05	0.02	0.69	0.67	13
Chest (LAT)	1.02 ± 0.38	0.04	2.9	2.86	7
Knee (AP)	0.28 ± 0.02	0.26	0.3	0.04	2
Knee (LAT)	0.29 ± 0.05	0.24	0.33	0.09	2
Spine lumbar sacral (AB-OBL)	9.19 ± 2.69	0.65	40	39.35	14
Spine lumbar sacral (LAT-OBL)	21.22 ± 3.85	1.17	42.56	43.73	12
Spine cervical (AB-OBL)	2.28 ± 1.56	0.17	10	9.83	6
Spine cervical (LAT-OBL)	5.79 ± 4.84726	0.2	30	29.8	6
Shoulder (AP-LAT)	0.08 ±	0.08	0.08	0	1
Mammogram (AP)	1.09 ± 0.15	0.7	1.36	0.66	4
Mammogram (OBL)	1.34 ± 0.21	1	1.73	0.73	3

Radiation doses for chest in PA and LAT positions in different local and International places were shown in Figs. 1 and 2, respectively. Figs. 1 and 2 indicate that the radiation doses for chest were different in local and International places. The mean radiation dose for chest in PA position was 0.32 ± 0.05 mGy (mean ± SE), lowest radiation value was 0.02 mGy in HPS, highest radiation dose was 0.69 in Greece, range of radiation values was 0.67 mGy, and the radiation dose in KKUH was 0.13 mGy as shown in Fig. 1. The mean radiation dose level for chest in LAT projection was 1.02 ± 0.38 mGy, lowest radiation dose was 0.04 mGy in HPS and the highest radiation dose was 1.5 mGy in IAEA and EC, and the radiation dose in KKUH was 0.22 mGy as shown in Fig. 2.

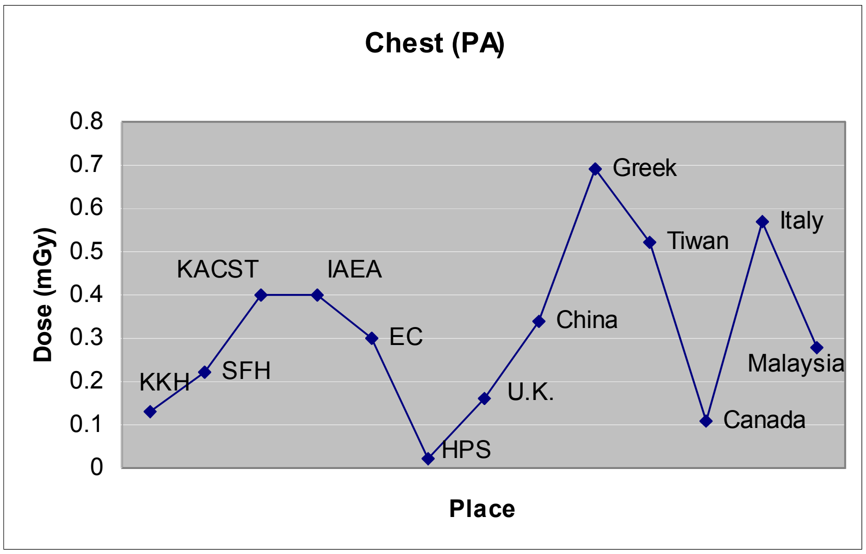

Figure (1): Dose for chest in posterior anterior (PA) position in different places

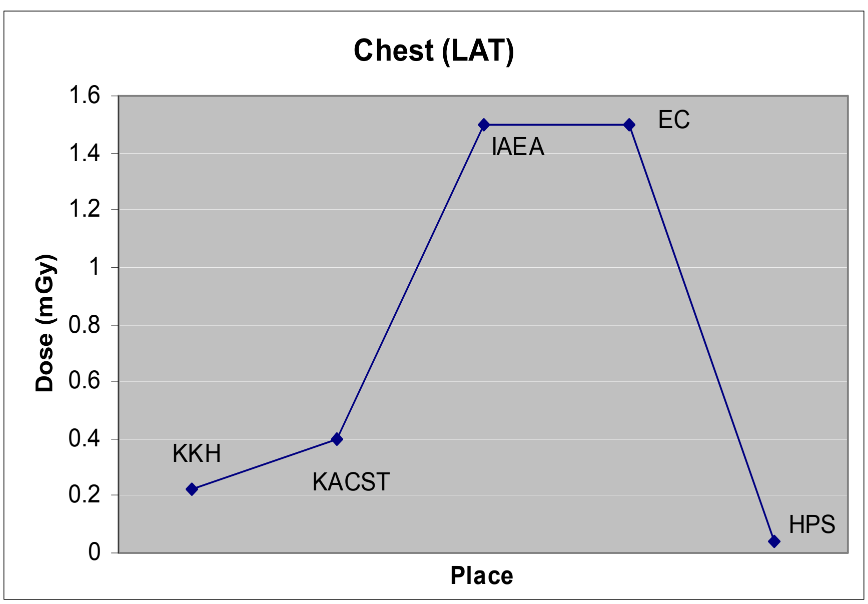

Figure (2): Dose for chest in lateral (LAT) projection in different places

Radiation doses for knee in AP and LAT positions in KKUH and SFH were shown in Figs. 3 and 4, respectively. Figs. 3 and 4 indicate that the radiation doses for knee were different in KKUH and SFH. The mean radiation dose for knee in AP position was 0.28 ± 0.02 mGy, lowest radiation dose was 0.26 mGy in SFH, highest radiation dose was 0.30 mGy in KKUH, and the range of radiation dose was 0.04 mGy as shown in Fig. 3. The mean radiation dose for knee in LAT projection was 0.29 ± 0.05 mGy, lowest radiation dose was 0.24 mGy in HPS, and highest radiation dose was 0.33 mGy in KKUH, and range of radiation dose was 0.09 mGy as shown in Fig.4.

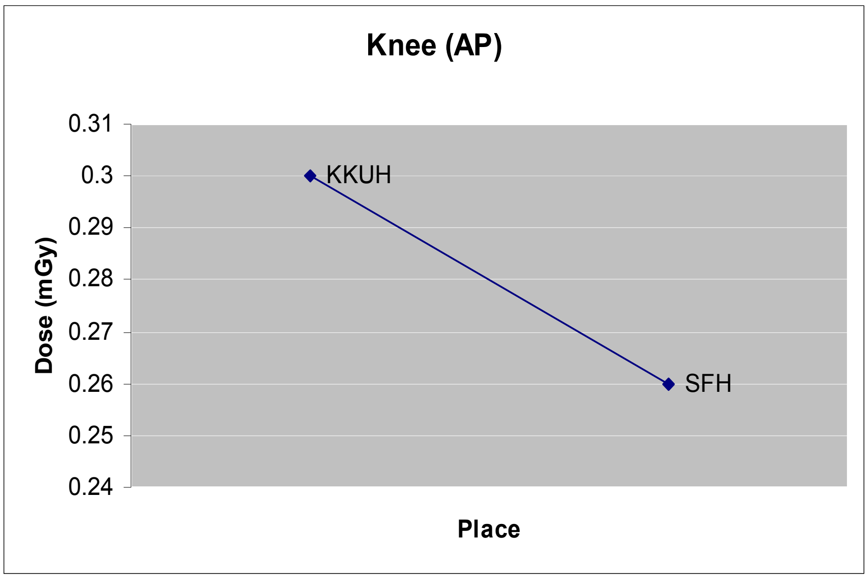

Figure (3): Dose for Knee in anterior posterior position (AP) in different places

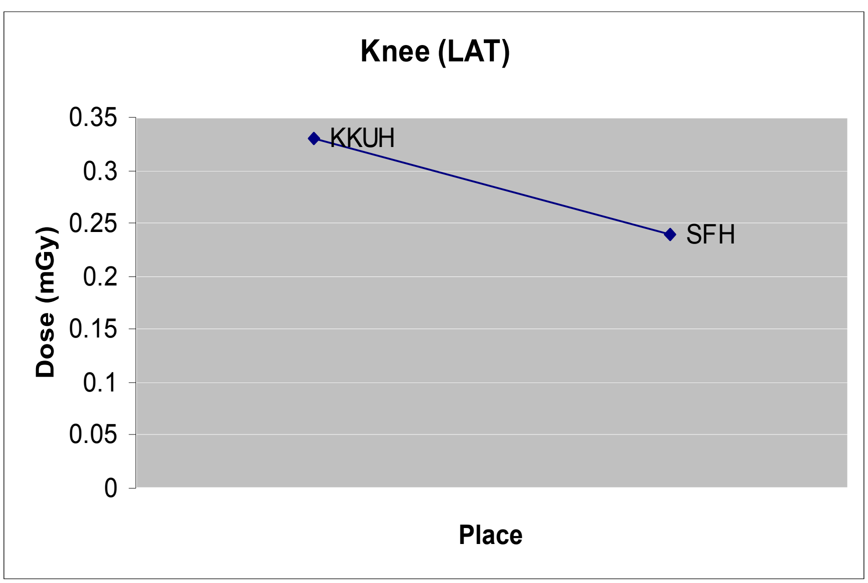

Figure (4): Dose for knee in lateral position (LAT) in different places

Radiation doses for spine lumber sacral in AP-OBL and LAT-OBL positions in different local and International places were shown in Figs. 5 and 6, respectively. Figs. 5 and 6 indicate that the radiation doses for spine lumber sacral were different in local and International places. The mean radiation dose for spine lumber sacral in AP-OBL position was 9.19 ± 2.69 mGy, lowest radiation dose was 0.65 mGy in KKUH, highest radiation dose was 40 mGy in KACST, and range of radiation dose values was 39.35 mGy as shown in Fig. 5. The man radiation dose for spine lumber sacral in LAT- OBL projection was 21.22 ± 3.85 mGy, lowest radiation dose was 1.17 mGy in KKUH, highest radiation dose was 44.9 mGy in Greece, and range of radiation dose values was 43.73 mGy as shown in Fig. 6.

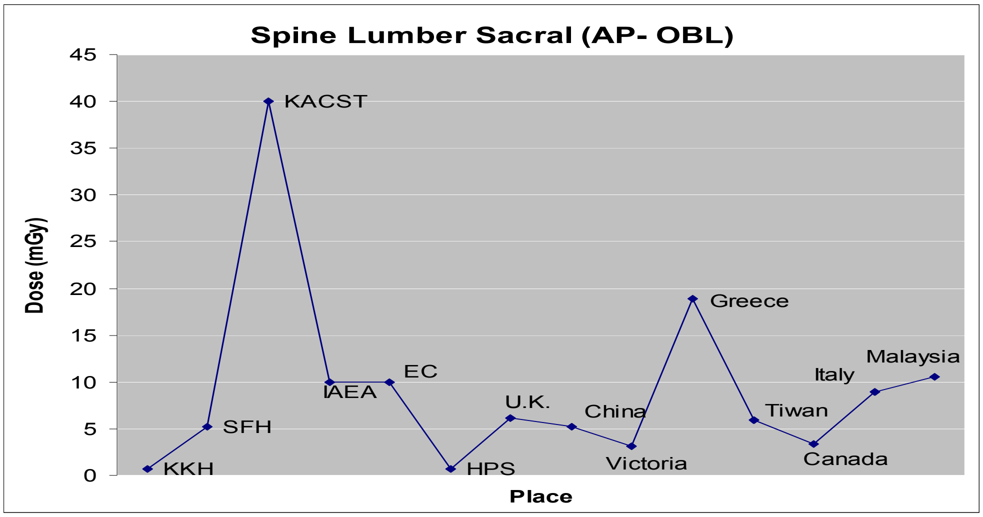

Figure (5): Dose for spine lumber sacral in anterior posterior-oblique (AP-OBL) position in different places

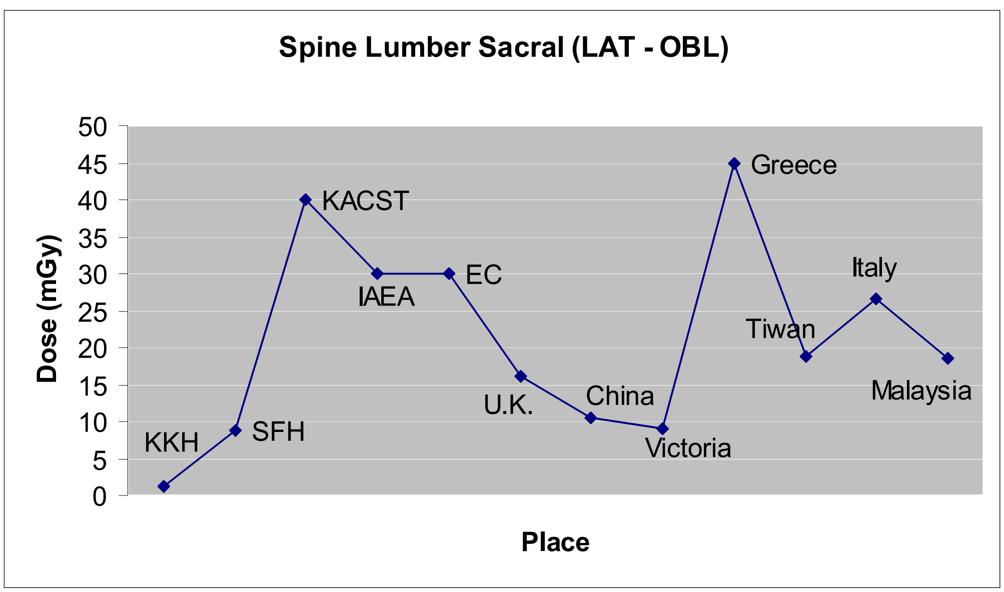

Figure (6): Dose for spine lumber sacral in lateral-oblique (LAT- OBL) position in different places

Radiation doses of spine cervical in AP-OBL and LAT-OBL positions in different local and International places were shown in Figs. 7 and 8, respectively. Figs 7 and 8 indicate that the radiation doses for spine cervical were different in local and International places. The mean radiation dose for spine cervical in AP-OBL position was 2.28 ± 1.56 mGy, lowest radiation dose was 0.17 mGy in KKUH, highest radiation dose was 10 mGy in KACST, and range of radiation dose values was 9.83 mGy as shown in Fig. 7. The mean radiation dose level for spine cervical in LAT- OBL projection was 5.79 ± 4.85 mGy, lowest radiation dose was 0.2 mGy in KKUH, highest radiation dose was 30 mGy in KACST, and range of radiation dose values was 29.8 mGy as shown in Fig. 8.

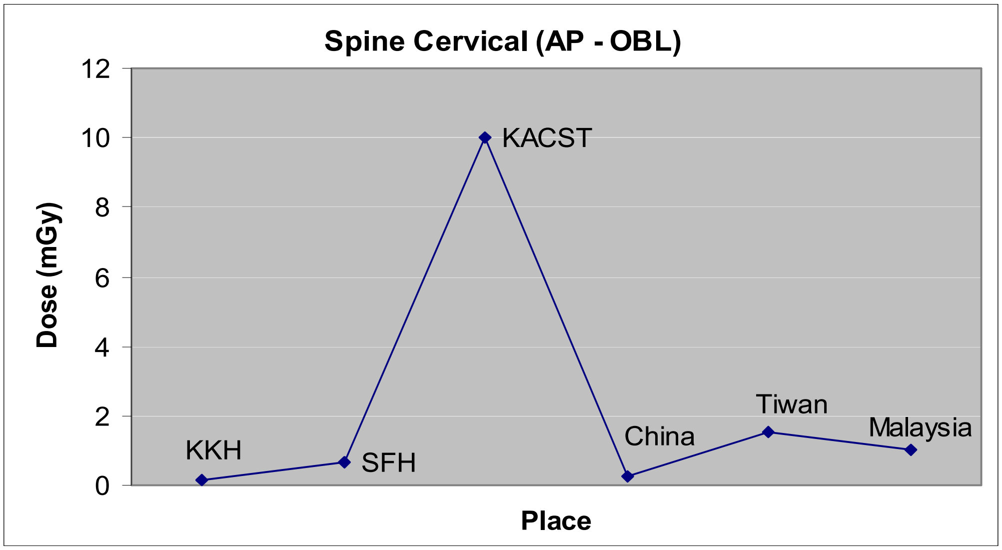

Figure (7): Dose for spine cervical in anterior posterior-oblique (AP-OBL) position in different places

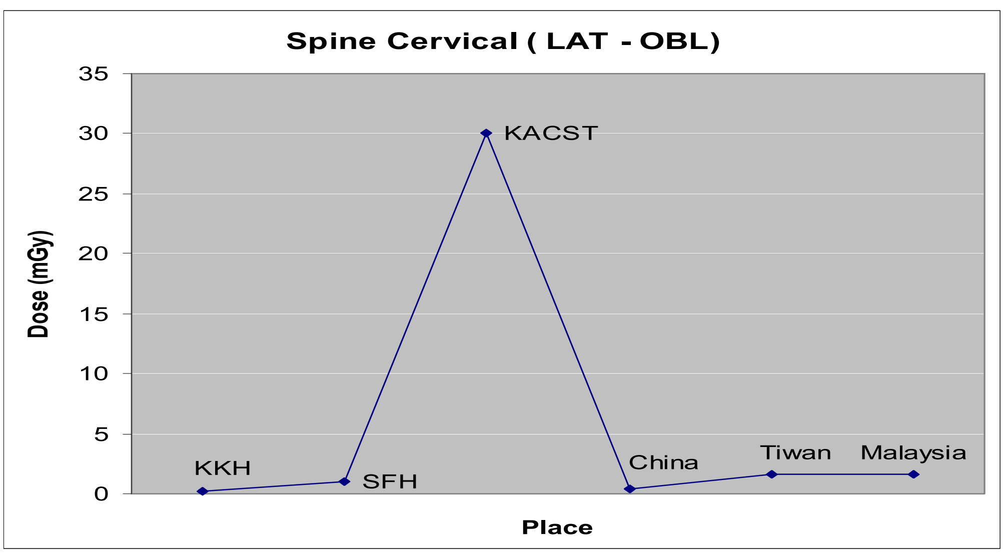

Figure (8): Dose for spine cervical in lateral-oblique (LAT- OBL) position in different places

Radiation doses of mammogram in AP and OBL positions in different local and International places were shown in Figs. 9 and 10, respectively. Figs. 9 and 10 indicate that the radiation doses for mammogram were different in local and International places. The mean radiation dose for mammogram in AP position was 1.09 ± 0.15 mGy, lowest radiation dose was 0.7 mGy in HPS, highest radiation dose was 1.36 mGy KKUH, and range of radiation dose values was 0.66 mGy as shown in Fig. 9. The mean radiation dose for mammogram in OBL projection was 1.34 ± 0.21 mGy, lower radiation dose was 1.0 mGy in IAEA, highest radiation dose was 1.73 mGy in KKUH, and range of radiation dose values was 0.73 mGy as shown in Fig. 10. The radiation dose for shoulder AP-LAT was 0.08 mGy in KKUH.

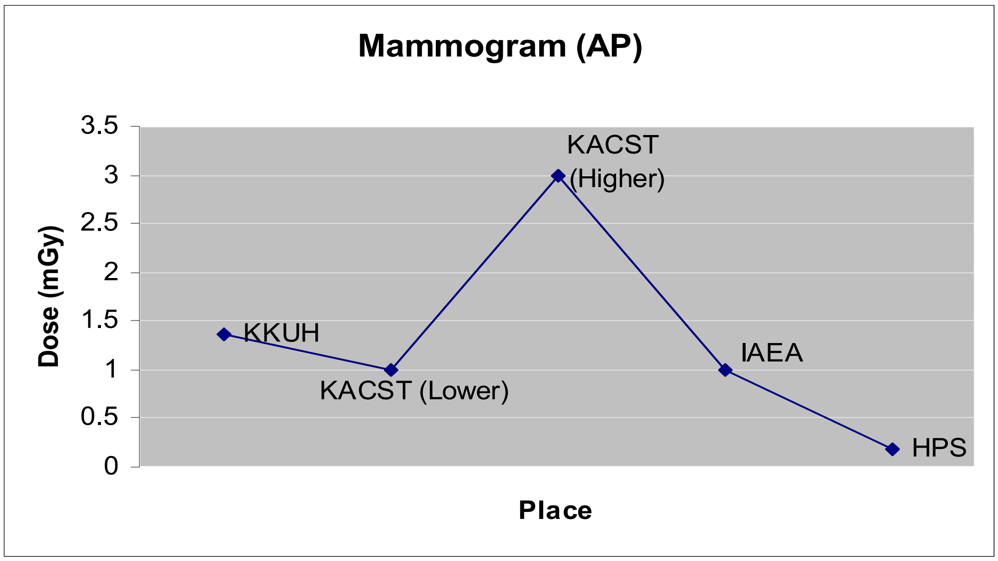

Figure (9): Dose for mammogram in anterior posterior (AP) position in different places

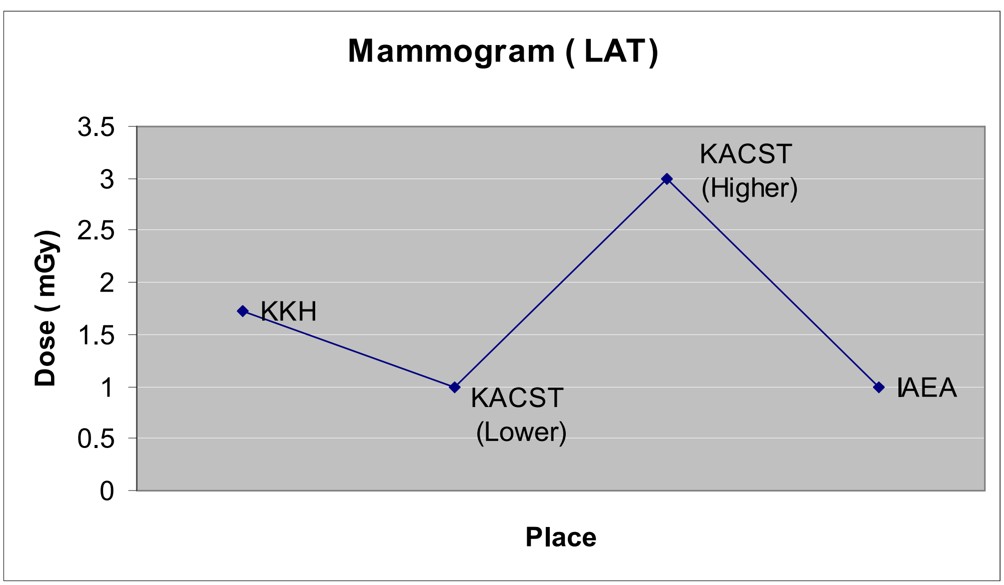

Figure (10): Dose for mammogram in lateral (LAT) position in different places

Discussion and conclusions

X-rays play an important role in the health care of the population in Saudi Arabia and worldwide, it may involve significant irradiation of the patient, and it may constitute the largest man-made source of exposure to ionizing radiation. In the present study, the routine X-rays examinations in some human organs such as chest (AP and LAT), knee (AP and LAT), spine lumbar sacral (AB and OBL; LAT and OBL), spine cervical (AP and OBL; LAT and OBL), shoulder (AP and LAT), and mammogram (AP and OBL) of adult patients over than 18 years were investigated in KKUH. The results obtained were compared with the measured radiation dose levels in local places (SFH; KACST) in Saudi Arabia and International places (IAEA; EC; HPS; U.K.; China; Victoria; Greece; Taiwan; Canada; Italy; Malaysia). The present study demonstrates that the radiation doses for chest in PA and LAT, knee in AP and LAT, spine lumber sacral in AP-OBL and LAT-OBL, spine cervical in AP-OBL and LAT-OBL, and mammogram in AP and OBL positions were different in the local and the International places. The previous studies about diagnostic doses in different countries have shown dissimilarity in diagnostic doses for every human organ (Al-Habeeb, 2005; Li et al., 2001; Servomaa, 2001; Bauer et al., 1998; NG et al., 1998; Cardillo et al., 1997; Faulkner and Wall, 1988; Padovani et al., 1987; CEC 1985; Aldeich et al., 1981; United State Department of Health and Human Services, 1981). As ESD results obtained with all dosimeters were similar, it is suggested as one of the possible causes for these changes that it is not easy to find similar results for the same conditions due to problems with the classification of the radiological procedures as, for example, patient size, examination technique, clinical condition as well as the skill of the radiologist. As another possible cause, some physical factors such as kind of TLD, tube current, tube potential, beam field of view, distance to patient, thickness of image region, and frequency of radiation dose might influence patient dose. Moreover, other date related to patient such as patient weight, length and age. Another question has been reported considering the magnitude of the total procedure exposures, it has been expected to report a high frequency of skin effects (Cusma et al., 1999). The increase in exposure with patient size agrees with the results reported by Boone and Levin, 1991 who looked at the changes in scatter radiation to personnel as patient thickness increases. If all the radiation has delivered over the same area of skin as illustrated in the comprehensive analysis by Stern et al. 1995, the distribution of X-ray exposure during a typical catheterization procedure varies greatly over the range of typical views. It has been reported that comparison of doses with two typical exposures at 120 kVp and 70 kVp shows that the high kVp technique delivers a higher ESD, ovary dose, and testes dose (Fung, 2004). Hence, from the radiation protection perspective, a high kVp technique with grid for chest PA radiography is not recommended. Early studies that investigated radiation exposure during cardiac angiography in relatively large numbers of patients were limited to approximating the value of X-ray exposure using indirect measures. These approaches do not take into account variations in patient size, position of the patient relative to X-ray tube and detector and the angulations of the X-ray image intensifier relative to the patient (Cusma et al., 1999). It has been reported that different types of TLDs gave different responses, and TLDs induced an over response in the range from 16 to 145 keV where the photoelectric effect was strong (Cusma et al., 1999). So, Harshaw TLDs 100 made of Lithium Fluoride: Magnesium, Copper, Phosphor (LIF: Mg, Cu, P) were used in the present study. These TLDs 100 has a good tissue equivalence, low correction factors and excellent linearity in the TL response as a function of different X-ray energies in the range from 0.05 to 1 Gy. The equivalence to the human tissue allows a very precise and accurate measurement of the absorbed dose, which is of primary importance in many applications of ionizing radiations, particularly in clinical applications as well as in therapeutic treatments and radio diagnostic examinations. Furthermore, the high sensitivity is also important for environmental applications, where the dose levels are normally very low. These TLDs 100 were more capable of detecting radiation at μGy levels and it can be appropriately applied to monitor staff or patient dose from both scattered and direct beam radiations in one single radiological procedure such as cardiac catheterisation and interventional (Zorzetto et al., 1997). So, these detectors may have a prominent role in environmental radiation monitoring applications in places such as nuclear power plants, X-ray rooms and radiation laboratories both for short or long term monitoring. It has been reported that the technique used with TLDs (LiF: Mg,Cu,P) has almost been optimized in the field of radiation dosimetry and these materials were regarded as a well established tool in radiation dosimetry with its very favourable dosimetric characteristics such as high sensitivity, tissue equivalence, low minimum detectable dose, very good linearity over a wide dose range and a relatively flat energy response (Fung et al., 2004). Moreover, it can be applied in particular in low radiation dose level measurements as in medicine and environment. The present study also demonstrates that radiological installation should be kept under strict surveillance with regard to radiological protection and quality control of the equipments and patient dose measurements in conjunction with checks on image quality will provide valuable guidance on optimization of radiological technique to ensure that the required diagnostic information is obtained with minimum radiation hazard to patient. It has been reported that largest portion of the total dose from medical radiation sources arises from diagnostic radiology due to their relatively high frequency and the personal annual effective dose averaged over the population from all diagnostic examinations was 1.1 mSv (Park, 2000). In the recent years, these variations in dosimetric quantities observed in various countries have led to establish reference levels by the various organizations. These guidelines have stimulated worldwide interest in patient doses, and several major dose surveys have been conducted in many countries (Geleijns et al., 1998; Karl, 2004). The present study suggests choosing mean radiation dose level for each human organ as a reference radiation dose level, because most of the measured radiation dose values in the local and International places were around the mean value. Thus, the estimated reference radiation dose level for chest in PA position and LAT projection were 0.32 ± 0.05 mGy and 1.02 ± 0.38 mGy, respectively. The estimated reference radiation dose level for knee in AP position and LAT projection were 0.28 ± 0.02 mGy and 0.29 ± 0.05 mGy, respectively. The reference radiation dose level for spine lumber sacral in AP-OBL position and LAT-OBL projection were 9.19 ± 2.69 mGy and 21.22 ± 3.85 mGy, respectively. The reference radiation dose level for spine cervical in AP-OBL position and LAT-OBL projection were 2.28 ± 1.56 mGy and 5.79 ± 4.85 mGy, respectively. The reference radiation dose level for mammogram in AP position and OBL projection were 1.09 ± 0.15 mGy and 1.34 ± 0.21 mGy, respectively. The present study also demonstrates that the radiation dose level measured for a human organ in a specified hospital or a country may be lowest radiation dose, however, the radiation dose level measured for other human organ in the same hospital or country may be highest radiation dose value, for example, lowest radiation dose values were measured for spine lumbar sacral AB-OBL and LAT-OBL and spine cervical AP-OBL and LAT-OBL in KKUH, while highest radiation dose values were measured for mammogram AP and OBL in the same KKUH. Also, lowest radiation dose value was measured for mammogram OBL in IAEA, while highest radiation dose value was measured in chest LAT in the same IAEA. Moreover, highest radiation dose levels were measured in some countries such as Greece (chest PA; spine lumbar sacral LAT-OBL), EC (chest LAT), and KACST (spine lumbar sacral LAT-OBL; spine cervical AP-OBL and LAT-OBL). As another possible cause for these changes, it is suggested that used experimental procedures, physical factors, and patient data should be fixed and specified during each human organ examination by X-ray, e.g., it should be changed from organ to other to get the lowest radiation dose required. Among possible factors of importance which were not dealt in the present study, the effect of routine X-rays examinations on fetes, children, teenagers, and teeth. Further research needs to be continued to investigate the effects of different kinds of TLDs materials on sensitivity, tissue equivalence, detectable dose, linearity over a wide dose range and energy response, and on the manufacturing process to improve the problems of this TL phosphor, namely high residual signal after readout and the limitation of heating above 240 °C.

Recommendations

Popularization this study to all hospitals of Saudi Arabia and to make this technique available to all radiologists, promotion of all hospitals to become interest with patient dose level for each human organ and to allow equipments such as Harshaw reader and Harshaw TLDs 100 to be available in every hospital. For higher radiation dose levels received by TLDs, repeated anneals was found effective. The number of repeats required depends on the dose level received and could be easily assessed by the evaluation of the residual dose at any time by a quick readout with the glow-curve appeared directly on the TLD reader display screen. To ensure accurate dose measurements, it is recommended that after initialisation of TLDs, it should be calibrated at specific low, medium and high dose levels all the time and these dose records are kept and traceable. Using TLDs with 8 cycles of anneal initialisation demonstrate the favourable unique dosimetric characteristics of these TLDs as favoured by previous researchers (Fung, 2004). The anode heel effect can be exploited by placing the head of a female patient at the cathode end of X-ray tube to achieve a significant dose reduction to the ovaries and hence a lower effective dose in lumbar spine radiography, e.g., patients in particular females should be positioned with the head placed towards the cathode end of X-ray tube for this radiological examination. Comparison of radiation doses with two typical exposures at 120 kVp and 70 kVp shows that the high kVp technique delivers a higher ESD, ovary dose, and testes dose. Hence, from the radiation protection perspective, a high kVp technique with grid for chest PA radiography is not recommended. Although all researchers agree that the highest quality diagnostic images are the primary consideration during angiography, any precautions that can reduce unnecessary exposure should be taken into consideration. Thus, careful monitoring of the performance of equipments used in diagnostic imaging, especially X-ray tube and TLD reader should be performed. Harshaw TLDs 100 (LIF: Mg, Cu, P) were more capable of detecting radiation at μGy levels, it can be appropriately applied to monitor staff or patient dose from both scattered and direct beam radiations in one single radiological procedure such as cardiac catheterisation and interventional. TLDs 100 have a prominent role in environmental radiation monitoring and it can be applied in particular in places such as nuclear power plants, X-ray rooms and radiation laboratories both for short or long term monitoring.

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