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Biological effective dose, cumulative radiation dose, risk of malignancy and mortality rate estimation in adult patients who have a history of cancer and exposed to recurrent computed tomography

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ABSTRACT

Computed tomography is commonly used for the initial diagnosis of a tumour to provide information about the stage of cancer & to assess whether the disease is responding to treatment. Leukemia & solid tumour may have developed as a result of exposure to a low dose of diagnostic ionizing radiation so another primary tumour may develop as a result of radiation exposure. We used information in the patient sheet to measure patient effective radiation dose(E) in millisievert (mSv) & calculate cumulative dose by summation of dose over three years, estimated life attributed risk & mortality rate. The results of the current study revealed that_from 50 patients 37 (74%) of them were female & 13 (26%) of them were male, age range 23- 80yr, breast cancer was the commonest cause of malignancy follow by lung cancer. Cumulative dose in mSv/yr rang 12-80 mSv, about 43(86%) of our patients exposed to more than 20mSv /yr & 7(14%) of them expose to 20 & less than 20 per year. Collective dose in three years' range was 35-250 mSv mean 97 ± 37 Estimated radiological effective dose was more than 100 mSv in 22 (44%) per three years & 28(56%) of them had less than 100mSv. Life attributed risk for incidence of cancers was 1:285 -1:40 & mortality rate 0.21%-1.5%. A high percentage of patient 86% with cancer receive high radiation dose annually from CT scan more than considerable safe radiation dose for a worker in this field and 44% of our patient expose to cumulative dose more than 100 mSv per three which is also excess allowed dose for the radiological worker.

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INTRODUCTION

Computed tomography is commonly used for the initial diagnosis of the tumour, to provide information about the stage of cancer & to assess whether the disease is responding to treatment. Radiation dose from diagnostic imaging techniques is not monitoring in patients undergo recurrent exposure to radio-diagnosis imaging like X-ray, computed tomography (CT scan) & angiography, in recent years a number of international bodies like BEIRVII (Seventh Biologic Effect of Ionizing Radiation), ICRP (International Commission on Radiological Protection) & other developed radiation risk models for measuring risk of radiation. Evidence suggest an increased lifetime risk of malignancy of 1% per 100 millisievert (mSv), the recommendations in BEIR VII report are to restrict healthcare and radiation worker to maximum dose of 20 mSv per year or to 100 mSv over five years period (Fujikawa et al., 2008; NRC, 2006; Wrixon, 2008). Leukemia & solid tumor may developed as a result of exposure to low dose of diagnostic ionizing radiation, radiation risk models that developed by BEIRVII & ICRP allow for calculation of the Lifetime Attributed Risk (LAR) of radiation-induced cancer & mortality rate as a function of effective dose, BEIR VII reported a LAR for incidence of all cancers of 0.012% per mSv and LAR for mortality from all cancers of 0.006% per mSv (averaged over all age & in both sex) while the ICRP found the LAR for incidence of all cancer to be 0.017% per mSv and LAR for mortality from cancer 0.004% per mSv. The biologically effective dose of CT scan ionizing radiation highly depends on patient size, age, gender, CT machine parameters & technology of the scanner. LAR is difficult to be estimate & quantitive radiation cancer risk with ionizing radiation is not easy to measure (NRC, 2006; Wrixon,2008; ICRP, 2007; Imaging guideline, 2013; Shrimpton; 2004). Absorbed dose use to measure the amount of energy absorbed by a material per unite kilogram of mass its unite is my(milligray), it isn't mean whether the radiation dose is really absorbed by body or radiosensitivity while effective CT scan radiation dose measured in mSv, represent a whole – equivalent absorbed dose by body which is used to produce collective, cumulative radiation dose & to estimated risk of malignancy from the radiation, dose length product (DLP) represent the absorbed dose in mGy use to measure the effective dose in mSv depending on standard method by using body–region specific conversion coefficient (Brenner and Huda, 2008; Shrimpton; 2009; European Commission, 1999). Netherlands Commission on Radiation Dosimetry categorized the risk of malignancy in adults who exposed to diagnostic radiology according to their age & gender to five categories according to radiation dose & its corresponding risk of malignancy (NCRD, 2016).

PATIENTS AND METHODS

A prospective study took place from January 2015 to March 2019 was performed at about 50 patients who have a history of malignancy all of them have repeated CT scan in Al-Diwaniya Teaching Hospital during these years by using (Somatom Definition 64 slices Siemens CT scan). We used much information in the patient sheet that found in CT software (patient protocol) to measure patient dose included CTDI (computed tomography dose index) which represents the amount of energy deposited per unit mass & DLP take into account length of scan it represents the result of CTDI multiply by the length of scan in cm. We measure effective radiation dose (E) in mSv used data obtain from patient information sheet by multiple DLP which is represent absorbed radiation dose in mGycm by conversion factors (k) which is the tissue weighted factor based on region of body scan for adults, (E=DLP x k) k value for head & neck 0.0031, for head 0,0021, for neck 0,0059, for chest 0,014, for abdomen 0.015 & for trunk 0.015 than calculate cumulative dose by summation of dose over three years. To measure the estimated risk of cancer the cumulative radiation dose convert to estimated life attributed risk by using the standard conversion (0.0001/mSv) which was latest reported by BEIR committee than we measure mortality rate using standard conversion (0.00006/mSv) depending on BEIR VII strategies (NRC, 2006). In this study, we used age & gender-adjusted risk categories that published in Netherland Commission on Radiation Dosimetry in 2016 in order to categories risk of malignancy in our patients (NRC, 2006). We exclude the patients who do one or more of CT scan study outside our hospital because we can't measure effective radiation dose as we can't obtain DLP also we exclude all patients who didn't complete 3 years' study with us for any reason included death or leaving follow up.

Statistical analysis

Data were analyzed using SPSS version 22.0 and Microsoft Office Excel 2010. The numeric variable was expressed as mean ± SD whereas categorical variables were expressed as number and percentage. The level of significance was considered at P-value of .0.05.

RESULTS

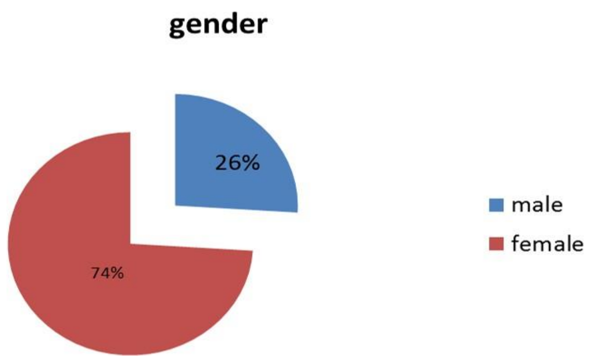

Figure 1: Distribution of patients according to gender

From 50 patients 37 (74%) of them were female & 13 (26%) of them were male.

Table 1: Distribution of the patients according to the age

Age	No.(%)
20-37	7(14%)
38-49	8(16)
50-61	20(40%)
62-73	13(26%)
74-83	2(4%)
Total	50(100%)

Age range 23- 80yr, age mean 55year ± 13.3 SD

Table 2: Distribution of the study sample according to the type of tumor

Type of tumor	No.%
Breast cancer	21(42%)
Lung cancer	9(18%)
Urinary bladder cancer	5(10%)
Prostate cancer	4(8%)
Ovarian cancer	4(8%)
Lymphoma	3(6%)
Nasopharyngeal tumor	1(2%)
Salivary tumor	1(2%)
Bone tumour	1(2%)
Total	50(100%)

Breast cancer was the commonest cause of malignancy follow by lung cancer & urinary bladder tumour.

Table 3: Estimated effective radiation doses per single scan

mSv/exa	Pat. No.
3-6	16(32%)
7-11	29(58%)
12-16	4(8%)
16-20	1(2%)
Total	50(100%)

Estimated effective radiation dose per single scan Range 3-20mSv, mean 8 ±3 SD

Table 4: Biological radiation dose in mSv according to the part of the body that scan

Part of the body that scan	No. & % of the patient	Radiation dose /scan
Abdomen, pelvis & neck CT scan	3(6%)	6-20mSv
Abdomen & pelvis CT scan	39(78%)	5-13mSv
Head CT scan	1(2%)	5mSv
Chest CT scan	7(14%)	4-7mSv

Table 5: Estimates of effective radiation doses per year

Cumulative dose of mSv /year	Patient No.(%)
12-15	2(4%)
16-36.7	32(64%)
36.7-58.3	15(30%)
58.3-80	1(2%)
Total	50(100%)

Cumulative dose in mSv/yr rang 12-80 mSv its mean 32±12

Table 6: Number of patients exposed to less or more than 20mSv/yr

Radiation dose in mSv/yr	Patient no. (%)
>20 mSv	43(86%)
≤20 mSv	7(14%)

About 43(86%) of our patients expose to more than 20mSv/yr & 7(14%) of them expose to 20 & less than 20 per year.

Collective dose in three years' range was 35-250 mSv mean 97±37. The estimated radiological effective dose was more than 100 mSv in 22(44%) per three years & 28(56%) of them had less than 100mSv. LAR for incidence of cancers was 1:285 - 1:40& mortality rate 0.21%-1.5%.

Table 2: risk of malignancy according to age & gender categories reported by BEIR7

Risk category	No.(%)	Risk of cancer
1	0	1/1000 000
2a	4(8%)	1/100 000
2b	15(30%)	1/10 000
3a	2(4%)	1/1000
3b	29(58%)	1/100
Total	50(100)	

Twenty-nine (58%) of patients are within the category of 3b

In this study, only 3(6%) patients develop second primary two of them have soft tissue sarcoma & only one has lymphoma all of them have radiotherapy.

DISCUSSION

Cancer is the 2nd most common cause of death in the world (second only to cardiovascular disease), many study concentrated on patients how had history of cancer & undergo multiple CT scan for diagnosis, staging & follow up recurrence of tumor in order to estimate the risk to have further malignancy as the patients exposed to ionizing radiation from medical imaging (Brendon et al., 2011; Salminen et al., 2017; IARC, 2011). Female percent was the higher in our result (74%) as breast cancer was at the 1st of the list (42%) which goes with Mary C et al. who reported that breast cancer is the most commonly diagnosed cancer in the women

Table 7: cumulative radiation dose / 3 years, LAR & mortality rate

Patient no.%	Dose(mSv)/3yr	LAR		Mortality rate
3(6%)	35-50	0.35%-0.5%	1:285-1:200	0.21%-0.3%
25(50%	51-100	0.5%-1.2%	1:200-1:100	0.3%-0.6%
19(38%)	101-150	1.2%-1.5%	1:100-1:66	0.6%-0.9%
2(4%)	151-200	1.5%-2.4%	1:66-1:50	0.9%-1.2|%
1(2%)	200-250	2.4%-2.5%	1:50-1:40	1.2%-1.5%
50(100%)	Total			

worldwide (Lord, 2017). The mean age of the patient was 55years ± 13.3 SD that go with the age incidence of cancer in adult over all the world 45-64 years (Mary et al. 2017), that is increasing the risk of malignancy according to the latest BEIR report the risk of malignancy is more in young age prior to 70 years because of higher sensitivity of their organs to radiation & to longer life expectancy through which a malignancy may be occurring. (NRC, 2006). According to the body part scan with CT scan, increasing scan area will have exposed the patient to higher radiation dose (combined CT scan of the neck, chest, abdomen & pelvis) expose the patient to higher radiation dose about 6-20mSv follow by chest and abdomen 5-13mSv that's go with Aaron S who reported that CT radiation dose increase with increase in the body size & size of exposed part of the body (Aaron, 2013).

In this study about (86%) of patients exposed to more than 20mSv /yr & 44% of our patients exposed to more than 100 mSv/ 3years while BEIR 7 report (Seventh Biologic Effect of Ionizing Radiation) restrict healthcare and radiation worker to a maximum dose of 20 mSv per year or 100 mSv over five years' period (NRC, 2006), that mean higher percent of our patients expose to more than allowed radiation dose. The best information about radiation exposure and the risk of malignancy is obtained from atomic bomb survivor data, which is shown a statistically significant relation between cancer incidence &radiation exposure dose above 100 mSv. (NRC, 2006). Developing of cancer vary with the amount of exposure, but there is no exposure threshold below which there is no risk of developing cancer, exposure to very small radiation dose carries a risk of cancer even its extremely small risk. (Martin, 2012). In the current study, the risk of malignancy was estimated by life attributed risk that ranges from one per 285 to one per 40 depending on cumulative radiation dose measure per three years. Half of our patients have life attributed risk of malignancy 0.5%-1.2% which is equal to 1:200-1:100 & mortality rate from fatal cancer 0.3%-0.6% which is close to the results of many studies (Aaron, 2013, Salminen et al., 2017, Aaron, 2009). According to age & gender-adjusted risk categories that reported by EEIR 7(NRC, 2006) more than half of our patients, 29(58%) were in category 3b (incidence of cancer 1/100) which exceeds the maximum allowed dose level that the worker in the radiological field may expose annually. There is a highly significant association between the type of cancer & radiation dose with a p-value of less than 0.001. Limitation of this study was that we measure cumulative radiation dose only per three years for many causes (patient leave follow up or patient's death) some patients have further radiation dose in next years. Finally, we should note that the patient who had cancer & receives radiotherapy whole body will expose to 50-70 mSv & when the dose near the target (about 10cm) can even be a factor 10 higher, (NRC, 2006) therefore additional risk from diagnostic radiation exposure will be negligible.

CONCLUSION

We conclude that in our hospital high percent of patient 86% with cancer receive high radiation dose annually from CT scan more than considerable safe radiation dose for a worker in this field and 44% of our patient expose to cumulative dose more than 100 mSv per three which is also excess allowed dose for the radiological worker.

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