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Radiation Dose and Lifetime Risk of Cancer Incidence and Mortality in Patients Undergoing 16 Slice CT Emergency Examinations

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Abstract*:*In this paper, we evaluate the patients effective and organ radiation dose in different CT emergency procedures and the associated lifetime risk of cancer incidence and mortality. The data were collected from 150 CT examinations. For each examination, we have collected CT exposure parameters including the number of series, tube voltage, various tube current values, patient age, gender, scan rotation time, slice width, number of slices, pitch, scan length, CT dose index (CTDIvol) and the Dose Length Product (DLP). Effective and organ doses were evaluated using DLP and k Coefficients from the European Guidelines and CT-Expo Software. Lifetime risk of cancer incidence and mortality were estimated using BEIR VII report conversion factors.

Keywords*: *Clinical Engineering, Computed Tomography, Radiation Doses, Radiation Protection.

I. INTRODUCTION

Nowadays, radiological procedures play an increasingly vital role in patient management. CT is the technique of choice for a wide range of indications in emergency department, the use of this technique has grown dramatically in the past decade and has been the worldwide trend [4]–[9] and take up to 50% of the total medical radiation dose [8].The increased demand for CT particularly raises the question of a potential health impact from the associated radiation exposure for patients, medical and paramedical staff.

Focusing on the most common CT procedures (Head, Chest, Abdomen, Lumbar Spine and CT KUB), this work was aimed at assessing patient effective and organ doses and the associated radiation risks. The study, which included 150 patients (mean age 40 years and weight range 60 – 80 Kg) involved the use of a calibrated CT scanner "General Electric CT 540 16-slice" at the emergency radiology department, exposures parameter data were collected and analyzed, patients effective doses were calculated using DLP and K conversion factors from ICRP 103 [6] and compared to international Diagnostic

Reference Levels DRL, organ dose evaluation was performed using CT-Expo Software [7] and converted into lifetime risk of cancer incidence and mortality using a conversion factor from the latest BEIR VII report.

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II. MATERIALS AND METHODS

A. Dose Survey

In this study, all examinations were performed with 16-Slice CT using various CT procedures, exposure parameters for 150 adult patients were collected (tube voltage, various tube current values, patient age, gender, scan rotation time, slice width, number of slices, pitch, scan length, CTDIvol , DLP). All of this data were displayed on the CT equipment console.

B. Percentiles calculation for diagnostic reference level

DRLs for CT protocols were estimated at the 75th percentile of the mean doses for a sample of patients close to the standard size, typically 70 kg or, in some countries, 60–70 kg. The distributions of the CTDIvol, DLP of the examinations were analyzed and the 75th percentiles were calculated and compared to DRLs from the French Order of May 23, 2019 on the procedures for evaluating ionizing radiation doses delivered to patients during radiological procedures, radioguided interventional practices or nuclear medicine and updating the associated diagnostic reference levels [1].

C. Effective and organ doses estimation method

The effective dose has been estimated using DLP and k Coefficients from the European Guidelines by this method:

$$E = K\ Coefficient \times DLP \qquad (1)$$

DLP is defined as the product of the volume CTDI and the irradiated scan length.

$$DLP = CTDIvol \times irradiated\ length \qquad (2)$$

Where CTDIvol is the volume computed tomography dose index and K is a conversion factor from European Commission EC [2] and National Radiological Protection Board NRPB-W67 [3], depending on the region of the body (Table- I).

Table- I: Value of conversion factor from European Commission EC [2] and National Radiological Protection Board NRPB-W67 [3]

Anatomic Region	K Conversion Coefficients [mSv / (mGy x cm)]	Phantom[a] (cm)
Head	0.0021	16
Head and neck	0.0031	16
Neck	0.0059	32
Chest	0.014	32
Abdomen	0.015	32
Pelvis	0.015	32
Chest, Abdomen and Pelvis	0.015	32

[a.] The phantom size is specified for the CT dose index measurements on which DLP is based.

Patient organ dose evaluation was performed using CT-Expo Software (V 2.5 2017) [7] , an MS Excel application written in Visual Basic for the calculation of patient dose in CT examinations. It is based on computational methods that were used to evaluate the data collected in both German surveys on CT exposure practice in 1999 and 2002. The software allows for the calculation of the following dose quantities:

- Weighted CTDI
- Volume CTDI
- Dose length product
- Organ doses
- Effective dose (according to ICRP 60 and 103)

In contrast to similar programs for CT dose calculations, CT-Expo offers the user a number of unique features, such as:

- Dose calculations for all age groups (adults, children, neonates)
- Dose calculations for each gender
- Dose calculations for all existing scanner models
- Correction of scanner-specific influences
- Correction of over-beaming effects
- Assessment of dose contribution resulting from scan projection radiographs

The scans of body parts examined were matched to phantoms, with the start and end of scans defined. Exam-technique parameters were used to estimate organ doses.

D. Cancer risk estimation

Since experimentation on human beings is of course impossible, the link between radiation and cancer comes mainly from observational studies comparing people who have been exposed to high doses of radiation to people who have been less exposed.

Lifetime Attributable Risk of cancer incidence and mortality has been estimated using values from BEIR VII report [5], a radiation risk model developed based on epidemiological data from radiation-exposed populations and aims to estimate cancer risk induced by exposure to low-linear energy transfer radiation. Model for solid cancers were further developed according to site (Stomach, colon, liver, lung, breast, prostate, ovary bladder, thyroid, and others) and was derived from the Japanese atomic bomb cancer incidence data from the period 1958-1998.

From the measured organ doses, the risks of cancer induction were calculated by applying the methods introduced in the report above-mentioned in the form of Lifetime Risk of Cancer Incidence and Mortality [5].

III. RESULTS

A. DLP values compared to DRLs and mean effective dose.

In this study, a total of 150 CT studies were included, radiation doses and the corresponding cancer risks were estimated for different procedures (Brain, Chest, Abdomen, Abdomen and Pelvis, Lumbar Spine), the ages of the patients ranged between 45 to 65 years.

The effective dose has been estimated for the aforementioned procedures based on the data collected (CTDIvol, DLP, and Scan length) .

For each examination, the distribution of the dose-length-products will be illustrated by a graph. The reader should remember that the variability observed in these graphs, the dispersion of all the data was estimated by calculating, for each type of examination:

- 75th percentile of the DLP distribution, a value commonly used for the establishment of Diagnostic Reference Levels (DRLs)
- 25th percentile of the DLP distribution, a value also used as part of the optimization of radiological practices.
- Average PDL distribution, which allows the estimation of the average effective dose.

Table 1 present DLP (25^{th}, 75^{th}, and 50^{th} percentile values compared with DRLs), and effective dose (mSv) values for each examination.

Table- II: Statistical analysis of patient dose information

Anatomical region	DLP (mGy * cm)			DRLs[b] (mGy * cm)	E (mSv)
	25^{th} Percentile	Median	75^{th} Percentile		
Head (2 acquisitions)	872	970	1066	850 (per acquisition)	2.03
Chest	207	239	281	350	3.5
Abdomen	264	333	403	625	5.12
CT KUB (3 acquisitions)	939	1176	1480	625 (per acquisition)	18.11
Lumbar Spine	582	866	1052	725	13.3

[b.] DRLs are taken from the French Order of May 23, 2019 on the procedures for evaluating ionizing radiation doses delivered to patients during radiological procedures, radioguided interventional practices or nuclear medicine and updating the associated diagnostic reference levels.

B. Organ doses

Organ doses were calculated with CT EXPO software, for lung, bladder, breast, colon and thyroid, considering their high radiosensitivity and the high cancer incidence in these locations.

Table- III: Calculated organ doses from various CT examination protocols.

Anatomic region	Organ	Organ dose (mSv)	
		Female	Male
Head	Thyroid	60	50
Chest	Lung	8.8	8.6
	Breast	8.5	------
CT KUB (kidneys, ureters and bladder)	Colon	13.4	12.2
	Bladder	15.5	14.8
Abdomen (2 acquisitions)	Colon	8	7.3
	Bladder	9.1	8.7
Lumbar Spine	Colon	11.2	9.8
	Liver	24.1	22.3

C. Cancer risk

As described in the Biologic Effects of Ionizing Radiation (BEIR) VII report [5] the radiation-induced cancer risk in a population exposed to a known radiation dose over a specified anatomic region can be estimated. For each anatomic region, organs that received the highest dose were selected, the BEIR VII models were used to estimate the lifetime risk for cancer incidence and mortality resulting from calculated doses of ionizing radiation as shown in Table- IV.

Table- IV: Estimated life time risk of cancer incidence and mortality.

Organ / Procedure	Organ Dose (mSv)		Lifetime Risk of Cancer Incidence (Per 100 000 persons exposed)		Lifetime Risk of Cancer Mortality (Per 100 000 persons exposed)	
	Female	Male	Female	Male	Female	Male
Thyroid /Head CT	60	50	8	2	***	***
Breast / Chest CT	8.5	----	12	----	3	---
Lung / Chest CT	8.8	8.6	20	9	19	9
Bladder / KUB CT	15.5	14.8	12	12	4	3
Colon / Lumbar Spine CT	11.2	9.8	9	12	4	9
Liver / Lumbar Spine CT	24.1	22.3	3	5	2	4

*** Values are unavailable in the Beir Report

IV. DISCUSSION

A. Effective and organ doses

After evaluating the total effective dose from multiple Ct Scan examinations at different localizations, it was found that most patients received effective doses within a range of 2.03 to 18.11 mSv, this variation depended greatly upon differences in scan length and exposure factors such as tube current, with automatic mAs varying in accord with patient habitus and body thickness. The highest effective doses were found in CT KUB and Lumbar Spine, with 18.11 mSv and 13.3 mSv, respectively (Fig. 1), the lowest doses were for the brain and chest with 2.03 mSv and 3.5 mSv. Nevertheless, it was found that most DLP values for selected exams are lower than chosen DRLs.

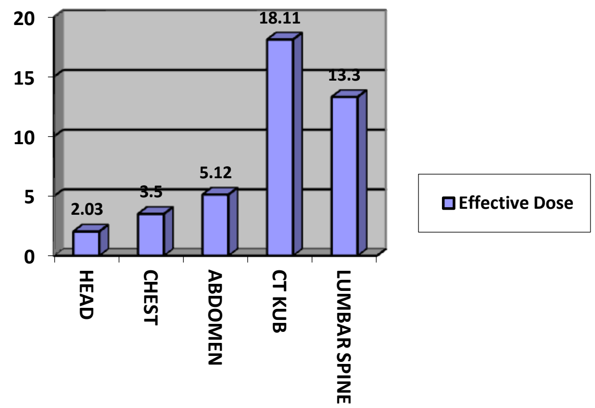

Fig. 1.Patients effective dose for each procedure

From the different anatomical regions explored; the doses differ considerably from one organ to another. The organs that received the highest doses were Thyroid and Liver for women, with 60 mSv and 24.1 mSv respectively. The organs that received the lowest organ dose were breast and lung for men and women undergoing chest examinations (Fig.2).

The dose received by the thyroid is higher than calculated dose from others reports and studies, this is due to the fact that brain emergency protocol cover, in some cases, cervical spine for clinical consideration and can be repeated several times because of patient movement.

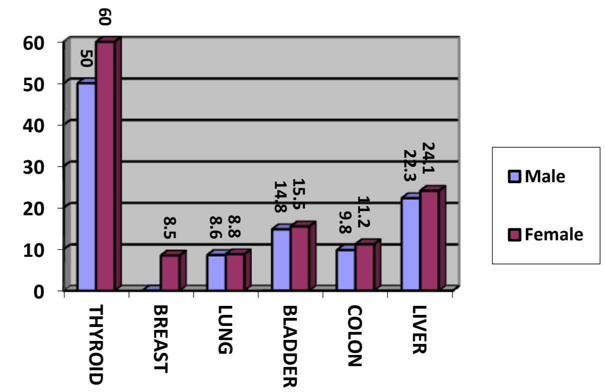

Fig. 2.Patients organ dose

B. Comparison of results

Comparing our calculated effective doses values for chosen CT protocols against the value reported on other studies, closed values has been found for head, chest and abdomen. However, calculated effective doses for CT KUB and SPINE are higher than other studies values, this is justified by the fact that the number of examinations per protocol can be increased in certain areas of the body, taking into account the difficult conditions and the state of patients received in emergency departments.

Table- IV: Comparison of our calculated values of effective doses with other relevant studies and reports

	Head	Chest	CT KUB	Abdomen	Lumbar Spine
UNSCEAR [10]	2.4	7.8	---	---	5
NSRD [11]	1.5	4.6	---	---	4.3
HPA [11]	1.4	6.6	---	---	6.9
Netherland [11]	1.5	4.6	---	---	4.3
Malaysia [13][12]	1.9	7.9	6.2	8.3	---
This study	2.3	3.5	18.11	5.12	13.3

C. Cancer risk

The goal of this study was to determine the risk from radiation exposure resulting from multiple Ct scan examination and for different organs.

Of the 100,000 persons exposed, the highest lifetime risk of cancer incidence has been found to be 20 for lung and 12 for Breast in women undergoing chest examinations, and 12 for bladder in men and women undergoing CT KUB examination.

Our study showed that the highest Lifetime Risk of Cancer Mortality CT scan radiation exposures were found for lung and colon cancer.

Considering all cancer sites together,the examinations that conferred the highest Lifetime Risk of Cancer Mortality were Chest and Lumbar Spine CT.

These results don't consider the repetition of CT acquisitions due to motion artefact and other parameters, which can increase the risk.

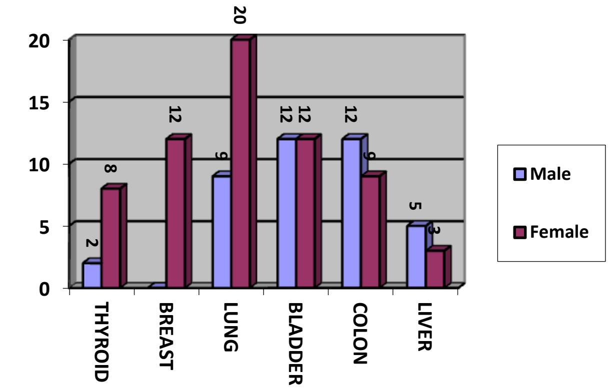

Fig. 3.Lifetime Risk of Cancer Incidence (Per 100 000 persons exposed)

D. Summary

Selected patients received effective doses within a range of 2.03 to 18.11 mSv. From the different anatomical regions explored the organs that received the highest doses were thyroid and Liver for women, with 60 mSv and 24.1 mSv respectively. The highest lifetime risk of cancer incidence has been found to be 20 for lung and 12 per 100,000 persons exposed for breast in women undergoing chest examinations, and 12 per 100,000 persons exposed for bladder in men and women undergoing CT KUB examination. This risk can increase considerably in emergency departments with the repetition of Ct acquisitions due to motion artefact and other parameters.

V. CONCLUSION

In this work, we have evaluated the patient's doses for the most performed CT procedures. The greatest effective doses were those obtained during CT KUB and lumbar procedure, while the high risk of cancer incidence was found for lung and bladder.

Based on the results obtained, and the high cumulative rates observed of multiple or repeated examinations, patients may have a high risk for subsequent radiation-induced carcinogenesis from cumulative CT scan radiation exposure.

There are multiple factors influencing effective and organ doses received from CT scan, some of them can't be managed, while others are controllable such as positioning and acquisition parameters. Optimizing these parameters can significantly reduce the radiation dose without impacting image quality. In addition to this, other practices can be adopted in CT emergency examinations such as reducing the number of repeated exams due mainly to the movement of restless patients, using suitable means of restraint or by involving the patient's accompanying persons in accordance with radiation protection standards.

Justification and optimization of emergency CT procedures are highly recommended for the purpose of reducing the dose as much as possible without impacting image quality, as well as the establishment of National Diagnostic Reference Levels (DRLs).

REFERENCES

1. Minister of Health and Solidarity of France. (20119, May 23). Order, approving decision No. 2019-DC-0667.Available: https://www.legifrance.gouv.fr/eli/arrete/2019/5/23/SSAP1915191A/jo/texte
2. P. Shrimpton, "Assessment of patient dose in CT. In: EUR. European guidelines for multislice computed tomography funded by the European Commission 2004: contract number FIGMCT2000-20078-CTTIP,"Luxembourg, Luxembourg: European Commission, 2004:Appendix C.
3. P.Shrimpton, M.Hillier andM.Lewis and M.Dunn, "Doses from computed tomography (CT) examinations in the UK: 2003 review,"National Radiological Protection Board,Chilton, UK, 2005, report NRPB-W67.
4. ES. Amis, PF. Butler, KE. Applegate, et al, "American College of Radiology white paper on radiation dose in medicine,"Journal of the American College of Radiology, Vol. 4 No. 5, May 2007, pp. 272–84.
5. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation; National Research Council, "Health risks from exposure to low levels of ionizing radiation: BEIR VIIphase 2,"National Academy of Sciences, Washington, 2006, ISBN: 0-309-53040-7.
6. ICRPpublication 103, "The 2007 recommendations of the International Commission on Radiological Protection,"published for the International Commission on Radiological Protection by Elsevier, March 2007.
7. G. Stmm andHD. Nagel, "CT-Expo V 2.3 A Tool for Dose Evaluation in Computed Tomography User's Guide," April 2014. Available at: http://eduhioa.no/MABIO5000/CT-Expo%20Manual%20(E)%20V2.3.pdf.
8. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), "Sources, effects and risks of ionizing radiation,"2017, Report to the General Assembly, with Scientific Annexes. Available at:www.unscear.org/docs/reports/2006/07-82087_Report_2006_Web.pdf.
9. Health Affairsat the Intersection of Health, Health Care and Policy, 2008, Vol. 27, No. 6, pp–1466.
10. D.Hart, B.Wall, M.Hillier, P.Shrimpton, "Frequency and collective dose for medical and dental x-ray examination in the UK, 2008," Health Protection Agency, Chilton, UK, 2010.
11. A. Schilham, P. Stoop, M. Prokop, and J. Geleijns, "A national survey on radiation dose in CT in The Netherlands," Insights Imaging, Vol. 4, No. 3, 2013, pp. 383–390.
12. M.K.A.Karim, S.Hashim, K.A.Bakar, D.A. Bradley, W.C.Ang, N.A.Bahrudin and M.H.A.Mhareb, "Estimation of radiation cancer risk in CT-KUB", Radiation Physics and Chemistry, Vol. 137, August 2017, pp. 130–134.
13. M.K.A. Karim, S. Hashim, K.A.Bakar, D.A. Bradley, K.A.Bakar, M.R. Haron and Z. Kayun, "Radiation doses from computed tomography practice in Johor Bahru, Malaysia,"Radiation Physics and Chemistry, Vol. 121, 2016, pp. 69–74.

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