Estimating Effective Doses of Critical Organs Due to Abdomen and Pelvic CT Scans using ImPACT Dose Tool

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DOI: http://dx.doi.org/10.13005/bpj/793

(Received: August 15, 2015; accepted: September 20, 2015)

ABSTRACT

Using computed tomography (CT) scans in clinical diagnosis has been dramatically increased during recent years. This technique is associated with high levels of radiation dose to patients compared to other imaging methods. Therefore, using accurate and precise methods of estimating the absorbed dose in CT scans is of prime importance. The present study aims to estimate the absorbed and effective doses due to abdomen and pelvic CT scans using ImPACT dose tool. Demographic data and dosimetry data the CT scan of the abdomen and pelvis for 52 patients were used to calculate the critical organs' absorbed and effective doses. The data of CT scans were registered into ImPACT dose tool. In addition, a new equation for estimating the body effective dose using body mass index (BMI) was proposed. The findings showed that the absorbed dose of the most organs was within the dose thresholds recommended by the ICRP103. In addition, the averaged effective dose was less than the predicted value by ICRP-103. Furthermore, a new equation was proposed to estimate the effective dose of the body as a function of patient's BMI. The estimated values by this equation were well in agreement with the calculated dose by ImPACT (R^2>0.95). Using our proposed equation for the effective dose calculation, the effective dose of a patient during an abdomen and pelvis CT scan can be estimated.

Keyword: Computed Tomography, Organs Dose, Effective Dose, ImPACT Dose Tool,

INTRODUCTION

The widespread use of Computed Tomography (CT) scans has probably represented the most important advance in diagnostic radiology. CT images are like an anatomical cut of the body in which all parts can be sanitized[1]. In the method of CT scan, X-rays are used for imaging of the body. These detailed images are from conventional X-rays. However, compared with plain radiographs, CT scans involve much more radiation dose that it would lead to a significant increase in exposure[2]. The main advantage of CT compared to conventional radiology is removing the superposition of different structures and providing high quality images, especially in low-contrast soft tissues. Along with all the benefits that CT-scan has, the dose is much higher than other radiology procedures[3]. The received dose of human from a chest X-ray is 0.04 msv that this amount is equal to the amount of dose that people will receive within a week of CMB while the dose from a CT scan of the head is equal to msv 1.8 that is roughly equivalent to a dose which a human will receive during 10 months of CMB[4].

CT scans, compared to other imaging techniques of X-ray, impart higher dose to patients so there should be a proportion between the benefits and risks of using CT scans. For effective control of the CT scan dose risks, people who work in the field of health care should estimate and follow-up the dose that patients receive from CT scan test[5]. In 1989, the National Organization for radiation Protection of Great Britain (NRPB) reported that 20% of the national cumulative dose of England caused by all medical examinations with X-ray alone through CT scan, while a CT scan tests only formed 2% of the total Test. Follow the increasing scanners of CT scan in England and technical tools growth, further investigation showed that the share of CT scans in cumulative dose increased to 40%[6]. Moreover, the NRPB in 1997 declared that patients' dose of the test results of a CT scan in the abdomen and pelvis has increased by 35% during a ten year period[7].

Monte Carlo simulation is usually used for dosimetry of different imaging and treatment techniques based on ionizing radiation[8-10]. An easy way to compare the patient's dose in different imaging methods such as CT scan is the use of an effective dose (Effective Dose)[11]. The effective dose is a single parameter to indicate the relative risk of exposure with ionizing radiation. This risk parameter shows harmful biological effects of exposure to non-uniform part of the body, in terms of whole body irradiation and currently is the best criterion to determine the quantity of accidental risks in diagnostic radiology[12] In addition, knowing the effective dose of a radiological examination will provide the possibility to compare with other imaging methods, other typical risks, and background radiation[13]. By increasing the body size and the subsequent increase in body mass index (BMI), the parameters of the device radiation increases until the image that is capable of detecting, will be obtained. Thus, obese patients (high BMI) compared to patients with normal body size, will receive higher dose[14, 15]. Therefore, the present study aims to calculate the effective dose of patients underwent abdomen and pelvic CT scans as a function of person's BMI. Using this estimation of effective dose we can predict the effective doses of each organ prior to any CT scan to improve management of .

MATERIALS AND METHODS

Current commercial CT scanners give dosimetry descriptors will for each scan including the CT dose index ($CTDI_{VOL}$ in mGy) and Dose-Length Product (DLP in mGy.cm)[16]. Using these data, available at the end of each scan, is a common method to estimate the effective dose. We used the DLP, mA_{eff}, and other relevant parameters to enter in ImPACT dose tool to calculate the absorbed dose of organs. The doses of critical organs of body including brain, thyroid, breasts, lungs, liver, stomach, large intestine (divided into lower and upper sections, testicles, ovaries, bladder, bone marrow, spleen, pancreas, adrenals, kidneys, small intestine, uterus prostate, gall bladder, heart, and lymph nodes.

CT scan

The CT scanner was a 64-slice scanner (Siemens Somatom Sensation 64-slice CT scanner). The scanning parameters for abdominal and pelvic scan used in this study was mAs = 150, kv = 120, pitch = 1 and collimation = 10mm.

Weighting factors of ICRP 103 Report

ICRP, in its 103rd report in 2007, declared a new weighting factor of different tissues (17). The main change in this Report compared to Report No. 60, was for gonadal tissue and the breast. In this breast weighted factor changes, increased from 0.05 to 0.12 and Gonad weighted factor reduced from 0.12 to 0.08 that it shows the ICRP knows in its new report the sensitivity of breast tissue to radiation is more than Gonad sensitivity (18).

ImPACT Dose Tool

Doses of critical organs and effective dose for adult patients that performed the abdomen and pelvis CT scan were calculated by ImPACT dose tool version 1.0.4. ImPACT CT patient dosimetry calculator is a computer application in which data sets of Monte Carlo will be used for dose calculation in the CT scan tests[19]. Although the calculations are usually used for tissues and effective dose, the difference in the size of the patient (BMI) is not considered.

Organs Dose and Effective Dose Calculation

Fifty two adult patients that underwent abdomen and pelvic CT scan were investigated. To calculate the dose of these people through the ImPACT dose tool, the data of the scanning parameters such as Kv, mAs, pitch, collimation, as well as scan output parameters including DLP and mA_{eff} that are reported at the end of each scan by the scanner were recorded. By entering the scanning conditions and output after scanning in ImPACT software, tissue dose and effective dose of patients were calculated. In addition, height and weight of the patients were measured and the relation between the effective dose, estimated by ImPACT tool, and BMI of each patient was investigated using a linear regression model.

RESULTS

In this study, the body organs' doses as well as the effective dose of 52 adult patients who underwent abdomen and pelvic CT scans were calculated. In addition, the relation between BMI with the CT scanning parameters and effective dose were reviewed. Figure 1 shows the organs' doses during CT scan.

The estimated effective doses of critical organs showed that the effective dose increases with increasing BMI where this increase shows a linear relation with increasing BM (Figure 2). In addition to the organs' dose, the effective dose of patients was calculated. The averaged effective body dose was 6 mSv. After calculating the effective dose, the relation between there quantity of effective dose, o BMI was determined that the chart of these changes shows in the forms of graphs 2 and 3 and

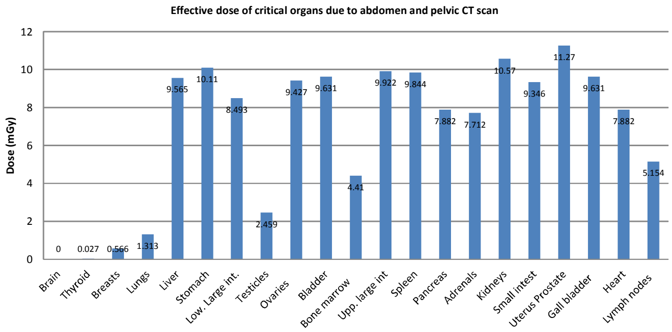

Fig. 1: Effective doses of critical organs of the body due to abdomen and pelvic CT scan computed by ImPACT

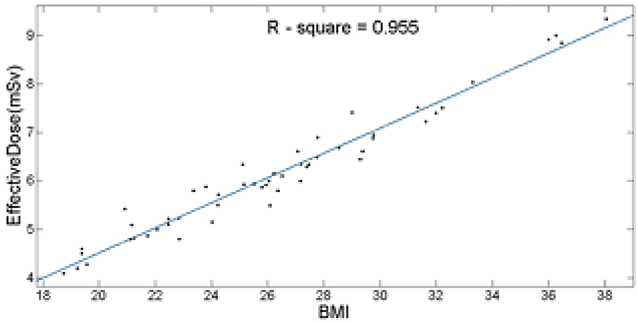

Fig. 2: Variations of effective dose against BMI. A linear regression model was used to correlate the estimated effective doses by ImPACT tool (dotted points) with a proposed linear equation (dashed line) (R^2=0.955)

4 and in any form changes equation according to BMI, has been brought.

$$\text{Effective Dose(mSv)} = 0.257 \text{ BMI} - 0.637 \quad ...(1)$$

DISCUSSION

In this study, brain received the lowest (0 mSv) and prostate the highest dose (11.27 mSv). As it is clear from Figure 1, the tissues that are within the scan area such as kidney, pancreas, stomach, liver, and ovaries receive a higher dose to other tissues. The heart is not located within the scan area, but received relatively high doses that may be due to its proximity to the diaphragm where scan starts from there and also probable errors in determining the exact starting point of scanning has been occurred. The effective dose as biologically relative risk estimation can be quantified and measured[9]. The results of this study attest to the fact that the effective dose is a derived parameter that can be calculated from a different process and methods. In this study, for calculating the organs and effective dose, the ImPACT software is used that this software is widely used in medical dosimetry and can calculate many CT scan scanners dose.

As shown in Figure 2, using a patient's height and weight, we can estimate the effective dose of that patient due to an abdomen and pelvis CT scan. To do this, inserting the $BMI = \frac{(kg)\, weight}{(m)\, height^2}$ in equation (1), the effective dose will be achieved. Except for KV which is fixed, the greater a patient's BMI, the greater the exposure parameters are used for CT scan.

As Figure 2 shows, increasing in BMI increases the effective dose which is in agreement with the findings of previous studies[20-22]. Israel *et al.,* used the dosimetry data of a 64-slice scanner calculated the absorbed doses of different organs with the ImPACT tool and examined the relation between weight and dose. They concluded that increasing weight increases the patient's dose so that changing weight from 60 kg to 100 kg doubled the patient's dose[23]. Our findings are in agreement with the Israil et al findings. The average effective dose in the current study is 6 mSv that is consistent with the results of Thomas. He also obtained the average effective dose in CT scan of the abdomen and pelvis for adults' 5.9 mSv[13]. Using our proposed equation based on the patient's weight and height, we can accurately the absorbed and effective doses of CT scans so that the estimated doses were in good agreement with the results of the ImPACT ($R^2 > 0.95$). Therefore, physicians can use the equation (1) to estimate the effective dose of the body in a CT scan of the abdomen and pelvis.

Figure 3 shows the direct relation between the effective mA with increased BMI. Increasing the patient's size and BMI will cause during preparing Topogram, further weakening occurs in the beam, but when scanning and preparing the final images, those parts of the scanning area that were more massive and caused more weakening, more mA will be used for Drawing images. By equation (2) we can estimate the effective mA without a CT scan for preparing the individual's CT images (R2 0.94). The higher use of mA will increase the created dose per length (DLP), that this increased dose per length as shown in Figure 4 is due to high individual's BMI or general fat (R2 0.96). Equation 3 can calculate the established dose during a scan with knowing the BMI. According to the above content, equation 2 and 3 are two equations to predict the resulted parameters of the CT scan based on BMI without being radiated and scanned in that person. Equation (1) may be a good alternative to estimate the effective dose according to BMI instead of ImPACT calculations for scanners and scanning conditions in this study.

CONCLUSION

The results of this study indicate a direct relation between BMI with the absorbed dose of organs and body effective dose as well as its impact on the body effective dose and define an equation for estimating body effective dose of it. In addition, the resulted parameters of the patient's scan were reviewed and explained the effect of BMI on other parameters of the scan.

ACKNOWLEDGMENTS

This study was extracted a master thesis in Medical Physics which was financially supported by Ahvaz Jandishahpur University of Medical Sciences (Grant No.: U-94064).

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