Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(2), 1914-1918 | ISSN:2251-6727

Dose Comparison of Obese and Non-Obese Patients During CT Abdomen Scan: Review Study

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(Received: 07 January 2024 Revised: 12 February 2024 Accepted: 06 March 2024)

KEYWORDS

CT

Dose

Obese

Effective Dose

Risk Index

Size Specific Estimate

BMI

CTDI

DLP

Abdomen

ABSTRACT:

Introduction: Dose is the matter of concern as the role of CT imaging is increasing day by day due to its rapid scanning and 3 D cross section imaging. CT represents approximately 10% of X-ray based examination which accounts for almost 50% radiation dose associated with total medical imaging. Amount of dose also depend on patient size. Patients having more body fat are assumed to have more radiation dose due to attenuation and scattering.

Objectives: Purpose of the study is to find out the radiation dose variation on the basis of Body Mass index and patient dimensions (Anteroposterior & Lateral diameter of abdomen).

Methods: All of the original research articles were explored to find the relation of patient size with dose during CT abdomen scan. The articles were differentiated on the basis of Prisma technique. The patients which are clinically referred for CT abdomen were included and some studies were anthropomorphic phantom based. Patient's data include height, weight, age, sex is collected. The following parameters were included: Body mass index (BMI), Anteroposterior & Lateral diameters, subcutaneous fat thickness, cross sectional area Scan is performed and CT dose index (CTDI), dose length product (DLP), were recorded and effective dose, size specific effective dose (SSDE) is calculated by using size specific conversion factor.

Results: Before calculating the radiation dose of patient, the patient's size, weight, BMI, adipose tissue thickness & circumference are some major factors that interferes the amount of dose. It is found that oversized patients receive significantly higher doses than small size patients. It is an interesting fact that during CT abdomen scan of obese patients, there is no significant increase in organ doses because somewhere extra subcutaneous and visceral fat layers in obese patients. To balance the amount of dose and image quality, modified protocols using low kV techniques or ATCM (automated tube current modulation) were used.

Conclusions: Patient size, BMI, cross section area all parameters should be used to calculate effective dose. Increased cross section area, directly increase the exposure parameters and large dose to thick patients.

1. Introduction

In medical imaging there is use of ionizing radiation which is govern by ALARA (low as reasonably achievable) principle which states that whenever ionizing radiation has to be applied to living tissues, exposure should be kept minimum so that optimum quality diagnostic information should be obtained. [1]When radiations pass through the body some of radiation is absorbed and contribute to patient absorbed dose. The use of ionizing radiation in diagnostic examinations should provide high benefit v/s risk ratio. The whole-body dose is measured as effective dose whose units are millisievert (mSv). It represents how sensitive different tissue to radiation & risk to entire body.[2] Risk refers to the possible chances of biological effects later in life like cancer.

Computed tomography

CT is now days the main tool in radiology in daily clinical work. Computed tomography (CT) also known as computerized axial tomography is an imaging modality uses X-rays to produce cross sectional images of body. During this procedure a narrow beam of X-ray is aimed at a patient and quickly rotated around the body producing signals that are processed by computer to generate cross sectional images or slices.[3] These successive slices are then collected and by using algorithms are reconstructed into 3D image of cross section. It provides more information than traditional X-ray imaging. They are sometime called CAT (Computer Assisted Tomography).[4] The first CT scanner was built by a British engineer Godfrey Hounsfield of EMI laboratory in 1972. He co invented the technology with physicist Dr. Allan Cormack. The first CT scanner was installed between 1974 to 1976. The original scanner was dedicated only for the head imaging. The whole-body imaging was widely available in 1976 & CT became widely available by 1980.[5]

Abdomen

The abdomen is the cavity of the body present between thorax and pelvis. Abdominal muscles are present in front of the cavity and spine in the posterior region. The upper boundary of abdominal cavity is diaphragm that is present on thorax side and no such boundary is present between abdominal cavity and pelvis.[6] It is the most complex structure contains many vital organs of the gastrointestinal, urinary, endocrine, reproductive system. A CT scan of the abdomen may be performed to assess the abdomen and its organ for any abnormalities and other conditions particularly when another types of examination such as x rays or physical examination, is not conclusive. [7]It is used to detect any problem or disease in stomach, liver, gall bladder, small or large bowel or other internal organs present in abdominal cavity. CT scan is also preferred because it is fast, accurate and non-invasive method of diagnosis. It is also used in case of emergency to detect any internal injury or bleed more accurately in a very short period of time enough to help saving lives.[8] Most common indications of routine CT abdomen are infections (such as appendicitis, polynephritis), inflammatory bowel disease (like Crohn's disease / ulcerative colitis), lymphomas, stones and injuries to internal organs (abdominal aortic aneurysms)

Radiation Dose

As CT utilization increases, concern about radiation dose has also increases. CT represents approximately 10% of X-ray based examination which accounts for almost 50% radiation dose associated with total medical imaging. Use of CT grows continuously by 10-15% per year. Approximate effective radiation dose from CT abdomen or pelvis is 7.7 mSv which is equal to radiation dose from natural background radiation in 2.6 years. [9]There are some advancements in recent times such as automatic exposure control, automatic tube potential selection, iterative reconstruction has reduced the radiation dose in adults and children while maintaining diagnostic image quality.

The effective dose value may vary from person to person depending on person's size, weight, thickness, age etc.

Body Mass Index

Patients with more thickness, involving excessive amount of body fat are suffering from obesity. It is

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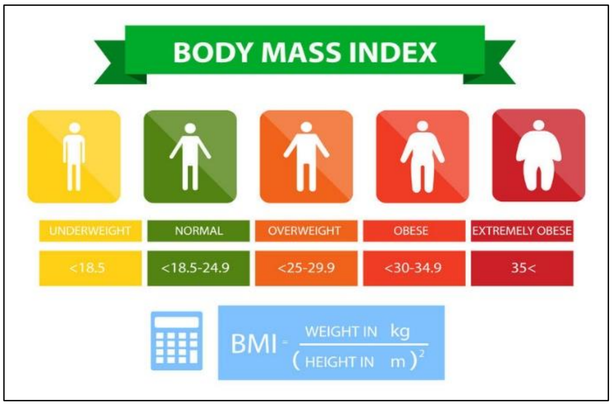
JCHR (2024) 14(2), 1914-1918 | ISSN:2251-6727

calculated by body mass index.[10] Body mass index is a value derived from the height and weight of the patient. It is defined as body mass divided by square of body height and is expressed in kg/m2.[11] Person having BMI over 25 is considered as overweight and over 30 is consider as obese as shown in figure 1.1. The issue has risen in such a high proportion that over 4 million people dying per year because of obesity. The rate of increase of obese patient in developing country is 30% more than developed ones.[12]



Relation of obesity with Dose

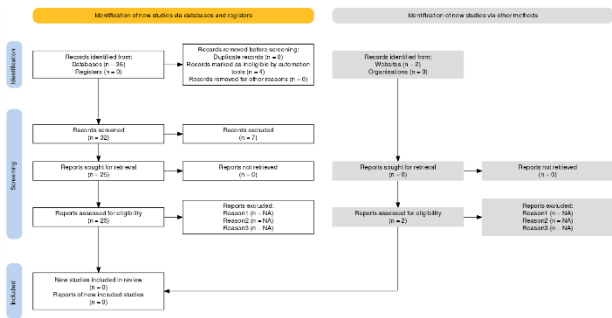
The rise in obesity has also impacted the amount of radiation dose received during diagnostic imaging. At routine dose to obese patients the more radiation is contributed to scattering and cause noise in image. To acquire good image quality for obese patients the exposure parameters have to be increased or modified which leads to increase the risk of high dose. Obesity has also impact on conversion coefficients which cannot be calculated by only body diameter.[13] Thus, patient size is important consideration during CT examination.

Dose calculation

The effective dose (E) indicates the difference in tissue sensitivity to ionizing radiation when exposed to different type of radiation. It is the weighting summation of different organ dose values. $E = \sum H \times WT$ where $H = \sum D \times WR$. During calculation of effective dose both the type of tissue and type of organ are taken under consideration. There are 2 most common methods of effective dose calculations. One is software-based monte Carlo method and other is simple method by using dose length product (DLP) and age & region-specific k coefficients.[14]

2. Methods

All of the original research articles were explored to find the relation of patient size with dose during CT abdomen scan. The articles were differentiated on the basis of Prisma technique. The patients which are clinically referred for CT abdomen were included and some studies were anthropomorphic phantom based. Patient's data include height, weight, age, sex is collected. The following parameters were included: Body mass index (BMI), Anteroposterior & Lateral diameters, subcutaneous fat thickness, cross sectional area Scan is performed and CT dose index (CTDI), dose length product (DLP), were recorded and effective dose, size specific effective dose (SSDE) is calculated by using size specific conversion factor.



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3. Discussion

Generally, dose levels in CT are below threshold levels but may trigger the gene mutations or carcinogenesis. During dose calculation the effective dose must be quantified in order to find amount of risk of stochastic effects.[16] The data suggests that before calculating the radiation dose of patient, the patient's size, weight, BMI, adipose tissue thickness & circumference are some major factors that interferes the amount of dose. Each organ absorbs radiation dose differently depending on the anatomical location, density and the distance from source of primary radiation. More dense parts contribute to more radiation dose.[17] The exposure parameters are directly proportional to cross sectional area of patient. It is found that among all the parameters total adipose is the strongest predictor of DLP.[18] Fully irradiated organs were strongly correlated to patient's perimeters, on the other hand partially irradiated organs do no show dependency on patient's perimeter. [19]In case of CT abdomen scan stomach and spleen shows more contribution to radiation dose. Patient size is major factor in determining amount of radiation dose received by

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JCHR (2024) 14(2), 1914-1918 | ISSN:2251-6727

patient during scan. Large size of patients shows some limitations during scan due to beam hardening (because of limiting field of view & inadequate penetration) which can increase the noise level.[20] In order to acquire good image quality, exposure factors get manipulated by using ATCM method. ATCM allows to acquire images with good preset image quality regardless the size of patient, which led to increase the radiation dose to patient. [21]The study supports the theory that oversized patients receives significantly higher doses than small size patients. It is an interesting fact that during CT abdomen scan of obese patients, there is no significant increase in organ doses because somewhere extra subcutaneous and visceral fat layers in obese patients cause more photons attenuation and act as a barrier and result in high skin entrance dose due to shielding effect.[22] It is found that in obese patients, deep organs receive 50% less radiation dose than superficial organs during scan. [23]The effective dose calculation includes dose delivered to the organs which are sensitive to radiation and its biological effects i.e., fat is not included in this category. Thus, fat is not clinically important to radiation risk but distal fat which is closest to image receptor, increases the dose to skin and core organs by acting as additional attenuator and need of increased x-ray output to balance target exit dose. So, patient's supine position is efficient during scan to limit the increased dose due to fat attenuation. [24]The studies demonstrate a correlation between BMI, total adipose tissue and dose calculation parameters such as DLP among which total adipose tissue is a strong predictor of DLP. [25]when using ATCM methods both DLP and CTDI increased with patient cross section area. For the accurate estimation of SSDE the BMI and patient size can be used. There is no need to find AP & LAT diameter for SSDE calculation.[26] Dose is generally calculated by using DLP in relation with cross section area which can be altered because of scan length difference which is due to patient height. A short obese patient and tall thin patient may have same cross section area but thin patient is exposed to high DLP because of longer scan length. Therefore, study shows that scan length would be included during dose calculations.[27] DLP is then converted into effective dose by using conversion factors recommended by ICRP. A study suggests that conversion factors should be specifically specified to both the sexes and paediatric patients.[15] To balance the amount of dose and image quality, modified protocols using low kV techniques or ATCM (automated tube current modulation) were used. According to ALARA principal radiation dose should be as low as reasonably achievable without interfering with image quality. Modified protocols for CT of obese patients help to reduce radiation dose without compromising image quality.[21] The use of low kV techniques and IR reduces the image noise up to 60% and a significant decrease in patient dose. The reduction of 30-60% in dose was noted when low KV techniques i.e., 100kV-120kV and modified protocols were used. [28]It is necessary to use anatomical region-specific conversion factor to calculate effective dose from DLP.

4. Conclusion

Radiation dose is concerning factor when we talk about CT scan which is also influenced by patient's BMI, cross section area, size and orientation during the scan. Therefore, these parameters should be considered during radiation dose calculation because they directly affect the amount of effective dose received by patient. Exposure parameters also increased with increase in cross section area and scan length. The obese patients having more BMI & fat, receives more amount of radiation dose as compared to thin patients because of more attenuation of photons. The amount of CTDI should be reviewed before examination and can be altered on the basis of age/size of patient.

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