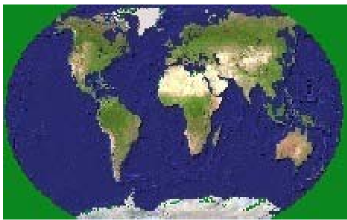

International Journal of
Multidisciplinary
Research and Development

Volume: 2, Issue: 10, 262-266
Oct 2015
www.allsubjectjournal.com
e-ISSN: 2349-4182
p-ISSN: 2349-5979
Impact Factor: 5.742

Mudassir Umar Ali
Msc Physics (Medical
physics), Department of
Physics & Department of
Radiology and Imaging
Sharda University and
Sharda Hospital, Greater
Noida Knowledge Park III,
Gutam Buddha Nagar
201308, Uttar Pradesh India.

Role of CTDI to estimate patient dose from a single slice to multi slice CT scanners

Mudassir Umar Ali

Abstract

The purpose of this study was to provide additional information on the Role of CTDI in Estimating the Patient Dose in CT scanners. The CTDI ($CTDI_{vol}$) which is the radiation output of a CT scanner for a single slice or multi slice CT scanners is derived from the 32cm or 16cm diameter body and head phantom respectively, CTDI is not an Estimate of a patient dose in each scanner since the patient characteristics are not taking into account it gives the quantitative dose estimation analysis and diagnostic reference level for the radiation for national and international level. A conversion factor can be developing so that CT scanner output can be translated into estimate of a patient dose. The Estimate of a patient dose must use patient – size – specifics. So CTDI alone cannot Estimate patient dose in a multi slice or single slice CT scanners only that multi slice CT scanner deliver higher radiation dose than single slice CT scanner, CTDI is measure in every period of time for quality assurance to know how the CT scanner is operated.

Keywords: CT dose index (CTDI), Volume CT dose index ($CTDI_{vol}$), Patient dose, CT scanners, Estimate.

Introduction

Like conventional x-ray machine and fluoroscopy Computed Tomography (CT) uses X-ray to form images, CT scanners emits radiation during scanning, CT has undergone a remarkable revolution during the past decades [1]. With the addition of high frequency generators with high power rating, the number of request for CT scan has gone high which result in increasing concern of radiation dose to patient [2]. There are several measures of radiation dose, each of which is used for different purpose. The most readily available are dose index known as the Volume Computed Tomography Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP) which are displayed on the CT scanner console. Though these dose indices are not an estimate of actual patient's dose, as the patient's Size and absorption characteristics are not consider [4].

CT scanners have gone through a number of design changes since the technology was first introduced in 1971. From the date of discovery to date there are seven generation of CT scanners, the aim is to provide faster acquisition times, better spatial resolution and shorter computer reconstruction times. Computed Tomography Dose Index (CTDI) has been the pillar of CT dosimetry for about 30years, CTDI measurements are performed at the periphery of two standard 16cm or 32cm diameter cylindrical phantom for head and body respectively [12]. CT scanners usually display two dose index, $CTDI_{vol}$ (mGy) and DLP (mGy-cm), the $CTDI_{vol}$ is based on radiation dose measurements on an individual scanner completed by a medical physicist with a pencil ionization chamber and either a 16cm-or-32cm diameter CTDI cylindrical phantom. $CTDI_{vol}$ is the dose index of a CT scanner, not an indication of a patient dose [13].

Aim and objectives

Dose in CT has been a main topic in medical physics for at least a decade; this was for good reason since increasing use of CT inevitably led to an increase of cumulative dose to the population (which contribute to 19% of total world radiation) and inappropriate use of CT in some cases lead to an unreasonably high exposure of patients. However ''CTDI and Patient dose'' they do not always seem to be realistic and sometimes are unnecessarily complicated, The CTDI should not and need to be changed and expanded to assess patient dose. The patient dose estimate (both organ and effective dose), should be scanner-and patient-specific [14]. The Aim of this is to study the ROLE OF CTDI IN ESTIMATING THE PATIENT DOSE FROM SINGLE SLICE CT TO MULTI SLICE CT SCANNERS. The objective of this paper is to provide more reliable and understandable information regarding the role of CTDI in estimating the patient dose from single slice CT to multi slice CT scanners.

Correspondence
Mudassir Umar Ali
Msc Physics (Medical
physics), Department of
Physics & Department of
Radiology and Imaging
Sharda University and
Sharda Hospital, Greater
Noida Knowledge Park III,
Gutam Buddha Nagar
201308, Uttar Pradesh India.

Material and method

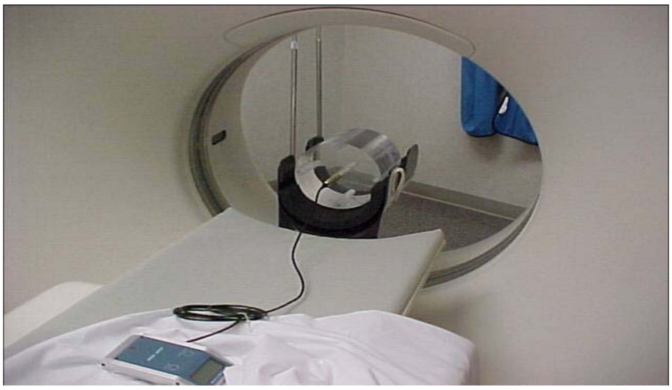

Fig 1: A scanner, phantom with ionization chamber placed in the central insert and an electrometer.

International recognizes materials are considered in this study, a CT scanner, a chamber connected to E-electro meter was calibrated by a secondary standard dosimetry laboratory (SSDL) for beam quality range connected with those CT scanner spectra. The phantom size will be chosen in order to represent the attenuation and absorption of characteristics of the average size of adult body. In the estimating the dose deliver to the patient the phantom material must be taken into account according to the IAEA protocol TRS 277 [8].

In dose measurement the radiation dose attributable to scattered radiation is considerable, and can be higher than the radiation dose from the primary beam. The CTDI measurement protocol seeks to measure the scattered radiation dose from adjacent CT slices in a practical manner. Medical physicist usually measures the CTDI with the use of a long thin pencil ionization chamber, a single CT image is acquired at the center of the pencil chamber, and the CTDI is determined from this single CT scan. To calculate the CTDI, all of the energy deposition along the length of the ion chamber is assigned to the thickness of the CT slice [3]. The CTDI is giving by:

$$CTDI = \frac{1}{NT}\int_{-\infty}^{\infty} D(z)dz \qquad 1$$

The CTDI is always measured in the axial scan mode for a single rotation of the x-ray source, and theoretically estimates the average dose within the central region of a scan volume consisting of multiple, neighboring CT scans [Multiple Scan Average Dose (MSAD)].

The CTDI varies across the field of view (FOV). For example, for body CT imaging, the CTDI is typically a factor or two higher at the surface than at the center of the FOV. The average CTDI across the FOV is estimated by the Weighted CTDI (CTDIw), which is given as:

$$CTDI_W = \frac{1}{3}CTDI_{100center} + \frac{2}{3}CTDI_{100periphery} \qquad 2$$

Where:

$$CTDI_{100} = \frac{1}{NT}\int_{-50mm}^{50mm} D(z)dz \; 3$$

To characterize dose for a specific scan protocol, which almost always involves a series of scans, it is important to take into account any gaps or overlaps between the x-ray beams from consecutive rotations of the x-ray source. This is accomplished with use of a dose descriptor known as the Volume CTDIw (CTDIvol), where:

$$CTDI_{VOL} = \frac{N\times I}{I} \times CTDI_W \qquad 4$$

I = the table increment per axial scan (mm) and the pitch in given as:

$$PITCH = \frac{I}{N\times T} \qquad 5$$

Thus volume $CTDI_{Vol}$ becomes:

$CTDI_{Vol} = \frac{1}{PITCH} \times CTDI_W$ 6 $CTDI_w$ represents the average absorbed radiation dose over x and y directions at the center of scan from a series of axial scans and $CTDI_{vol}$ represent the average absorbed radiation dose over x, y and z direction. To better represent the overall energy delivered by a given scan protocol, the absorbed dose can be integrated along the scan length to calculate the Dose-Length Product (DLP) [5] given as:

$DLP(mGy - cm) = CTDI_{vol} \times Scan\ Length$ 7 For a CT scan of length (L), initial in the mid-thigh region, the normalized absorbed dose to an organ [D'$_{organ}$ (L)] is defined as the organ dose divided by the corresponding $CTDI_{vol}$. Where $CTDI_{vol}$ is the volume used to carry out the specific examination. Values of the DLP can be used to estimate patient effective dose [6], this gives an estimate of the patient effective dose.

Radiation dose estimate in ct scanner

Early estimates of dose from a CT examination did not use the CTDI methodology and measured only the dose from a single scan acquisition. Specifically, only the peak radiation dose emitted by the scanner from a single tube rotation and at a single table position was measured, and this underestimated the dose delivered to a typical adult patient by a factor of two to three, also for this underestimation was that the measurement neglected the "tails" of the dose distribution caused by scattered radiation produced from scans at adjacent table positions Fig (2), Because most clinical examinations involve multiple scans (ie, gantry rotations) as the patient is translated through the gantry, the dose distribution to the patient is the sum of the overlapped "single-scan" dose distributions Fig (3). For examinations with a sufficient number of scans, the average dose over the central scan width of the imaged anatomy will reach an equilibrium value, which is referred to as the multiple scan average dose (MSAD) Fig (3).

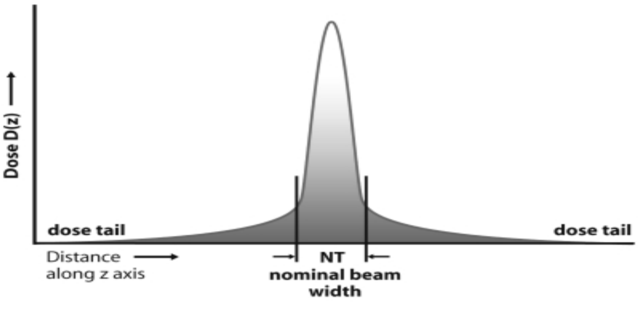

Fig 2

Fig.2 Schematic illustrates the profile of radiation dose delivered during a single CT scan. The CTDI equals the shaded area divided by the section thickness (NT). Radiation dose profile along a line perpendicular to the scan plane shows a peak dose level at the center of the primary beam and long dose tails caused by scattered radiation. *NT* = nominal beam width.

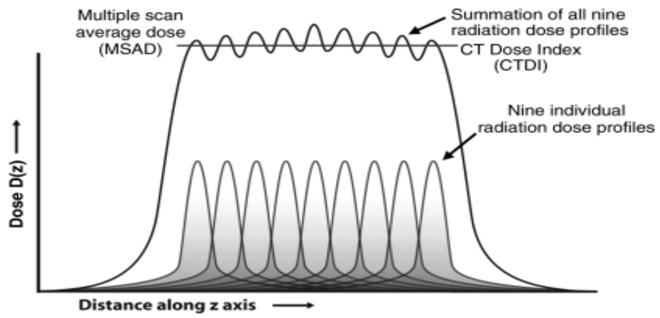

Fig 3

Fig.3 Schematic illustrates the profile of radiation delivered during multiple CT scans. The radiation dose profiles from nine adjacent transverse CT scans along a line perpendicular to the transverse scans, when summed, produces the MSAD profile. The value of MSAD is the average value of this profile over one scan interval in the central portion of the profile.

From single slice CT to multi slice CT scanners, there is belief that CTDI should estimate the patient dose, as opposed to quantifying the radiation output of CT systems. In fact, because patients and the wide range of clinical applications and scan protocols used to scan them vary so dramatically, there is no single phantom that can be used to accurately estimate the dose to all patients.

Abdomen vs phantom

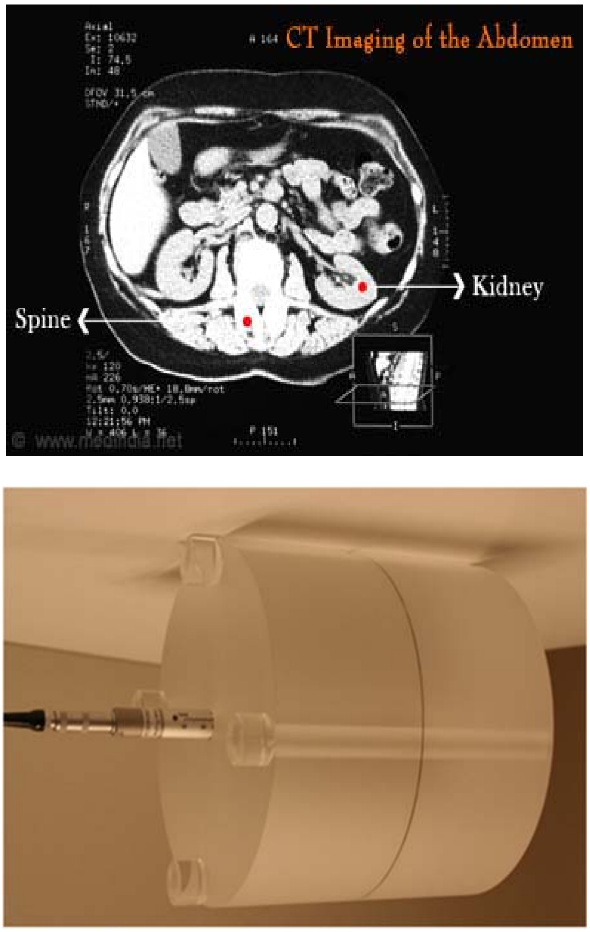

Fig4: shows shapes of abdomen and phantom for dose over/under estimation

Any dose metric designed to estimate patient dose for a "typical" adult will underestimate the actual absorbed dose for a pediatric patient (since the phantoms are cylindrical in shapes and the human body are not perfect cylindrical like the phantoms), can also overestimate the actual absorbed dose for an obese patient. Instead, because the volume CTDI (CTDI_{vol}) is displayed on the scanner console before the initiation of a scan (to allow the operator to confirm that the proper scanner output is programmed) and recorded as part of the patient's examination information, many users incorrectly assume that it is the dose to that particular patient. The CTDI values are included in either a screen-captured "patient dose report" or a structured Digital Imaging and Communications in Medicine dose report, which reinforces the incorrect belief that CTDI is a measure of patient dose. In fact, the actual dose to any given patient is directly dependent on the size and shape of the patient. The CTDI_{vol} is a standardized measure of the radiation output of a CT system, measured in a cylindrical acrylic phantom that enables users to gauge the amount of emitted radiation and compare the radiation output between different scan protocols or scanners. Complex calculations are required to map scanner output to patient dose, taking into account the patient's size, irradiated organs, body composition, and scan range. CTDI_{vol} provides a very useful way to compare the doses delivered by various scan protocols or to achieve a specific level of image quality for a specific size patient. With use of technique charts and diagnostic reference levels, CTDI_{vol} can be used to prescribe the right dose for a specific patient size and diagnostic task. The CTDI_{vol} tells the medical physicist precisely how the machine was operated, and it can be used, in conjunction with information regarding patient size and the scanned anatomy, to estimate patient dose. Dose estimates can be for organ dose, skin dose, or a mean dose in the center of the scan volume. The CTDI values are not; however, patient dose estimates [7].

Table 1: CTDI doses for the CT/i and LightSpeed scanners (@ 120 kVp and 340 mAs)

Phantom size	Location	CTDI for single slice (GE CT/i) mGy	CTDI for multi-slice scanner (4 slice GE light speed) mGy
Head	Periphery	40	48
Head	Center	40	48
Body	Periphery	20	32
Body	Center	11	14

***IAEA-CN-85-63**

Table.1 show that the CTDI for multi-slice(The multi-slice system used to acquire the data uses multiple detectors that can cover between 20 mm and 40 mm of axial distance, and can acquire 4 simultaneous sections for each 360° revolution of the x-ray tube) is higher than that of single slice CT scanners, that is multi-slice CT scanner emits higher radiation dose due to wide x-ray beam profiles which are needed to maintain a constant radiation dose for an irradiated section whilst the focal spot moves during the rotation of the x-ray tube. Computed Tomography Dose Index (CTDI) data are shown in summary in Table 1. The CT/i dose data are for a section thickness of 10 mm, and the Light Speed data are for four 5mm sections *(*= 20 collimator thickness). These data show that for the same techniques (kVp/mAs), the Light Speed has a 20% higher head dose and 40% higher body dose.

From single slice to multi slice CT scanners CTDI index is a simple standardized measure of the dose output of the CT scanner and can therefore be used during quality assurance or to compare different scan techniques. Regarding the doses really delivered to the patient during CT exams, it revealed a systematic underestimation of up to (30%–35%). The doses informed by the CT scanner at the end of the exams are still based on the CTDI paradigm [8]. Radiologists and technologists should be familiar with and aware of the dose indices normally displayed on the CT scanner console. These indices include the volumetric CT dose index ($CTDI_{vol}$) and the dose-length product (DLP). The $CTDI_{vol}$, which was introduced to take into account the pitch of helical acquisitions, represents the average dose delivered within the reconstructed section, and is calculated as the weighted CTDI divided by the pitch. The DLP is the $CTDI_{vol}$ multiplied by the scan length expressed in centimeters. It gives an indication of the energy imparted to organs, and can be used to assess overall radiation burden associated with a CT study. CT scanners now routinely record the $CTDI_{vol}$, and, in some cases, the DLP. Although the $CTDI_{vol}$ is not the dose to a specific patient, it is an index of the average radiation dose from a CT series. For each protocol selected, and for each patient, the dose indices displayed on the control panel should be carefully monitored and determined to be within a reasonable range to prevent accidental overexposure to the patient both in single slice, 2 slice or multi slice CT scanners [10].

The $CTDI_{vol}$ remains, however dose index independent of the length of the scan. To better represent the total radiation dose delivered it is necessary to introduce a CT dose index that take into account the full extent of the acquired volume, therefore the DLP was introduced as the dosimetric value that characterize a complete acquisition scan. Both these dosimetric quantities are sensitive to the variation of scanning parameters such as tube voltage (KVp), current (mAs), gantry rotation time, pitch and bowtie filtration, but they are independent of the size of the patient. The $CTDI_{vol}$ and its DLP are display for a reference phantom (head or body), the diameter of which (16 or 32cm) is selected by the scanner. The radiation dose received by a patient during a CT examination depends on both the radiation output of the scanners both in (single slice, 2-slice or multi slice CT scanners) and the size of the patient, $CTDI_{vol}$ provides information regarding only the output of the device, without taking into account the size of the patient being examine, from these reasons it does not allow a specific estimate of the radiation dose for a given individual. So to estimate the radiation does accurately as possible a working group (AAPM Task group report 204, 2011) develop conversion factors that could be applied to the dose index the $CTDI_{vol}$. This allows an estimate of the patient dose according to the individual's specific dimensions, which is called a size-specific dose estimate (SSDE) [11].

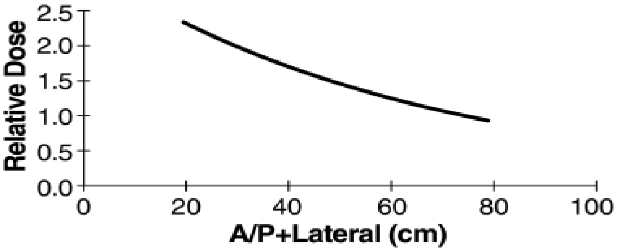

Fig 5. Relative dose of an abdomin of difference patient size

FIG.5 shows relative dose (mean patient dose per 1 mGy of scanner output, $CTDI_{vol}$) for an abdominal CT scan and different patient sizes (here represented by the sum of anterior posterior [*A/P*] and lateral dimensions). Over the range of patient sizes from a newborn to a large adult, relative dose is exponentially related to patient size.

There are several measures of radiation dose, each of which is used for a different purpose. The most readily available are dose indices known as the Volume Computed Tomography Dose Index ($CTDI_{vol}$) and dose length product (DLP) which are displayed on the CT scanner console. These values are obtained in the factory by scanning two acrylic cylinders (one with a 16-cm diameter, and the other with a 32-cm diameter) on a representative sample of each CT scanner. In clinical use, when the CT settings for a patient examination are selected, the machine calculates the $CTDI_{vol}$ for these cylinders ("CTDI phantoms"). This method is highly accurate for estimating the radiation dose to the phantom, thus characterizing the radiation output of the scanner. However, these dose indices are not an estimate of the actual patient's dose, as the patient's size and absorption characteristics are not considered. When exam parameters are manually set, the exposure displayed $CTDI_{vol}$ would be the same even if no patient was in the scanner. Again, these indices tell the user how much radiation the scanner produces, not how much a patient receives [4]. In comparing the performance of a multi slice CT to that of single slice CT scanners shows that dose index ($nCTDI_w$) values were systematically higher for the multi-slice system (up to 30% - 36%) and the dose-length product (DLP) values on the multi-slice scanner exceeded the equivalent single-slice DLP values [9], Due to the wide X-ray beam profile.

Discussion and conclusion

From single slice to multi slice CT scanners the CTDI estimate the radiation dose of the CT scanner, in which the $CTDI_{vol}$ is display on the console of the CT scanner which can be change by changing the CT parameters which can be decrease in order to reduce the patient dose. The CTDI is not an estimate of the patient dose since the patient characteristics are not considered. The CTDI of a single slice CT display is less than that of multi slice CT scanner this is due to the fact that multi slice CT scanner deliver higher dose compare to the single slice CT scanner, which is due to the use of wide X-ray beam profiles which are needed to maintain a constant radiation dose for an irradiated section while the focal spot moves during the rotation of the X-ray tube. The estimate of a patient dose must use patient – size – specific dose estimates not use only the scanner outputs (CTDI or DLP). So CTDI cannot estimate patient dose because there is no single phantom that can estimate patient dose for all patients. The CTDI ($CTDI_{vol}$) is display on the scanner console before the beginning of the scan, this shows that is not the patient dose but can be use with other parameters to estimate the patient dose by considering the patient characteristics (size, organ dose, skin dose, etc). CTDI is measure usually after every 6 month for the quality assurance purpose to assess how the scanners is operated, and $CTDI_{vol}$ is not the estimate of the patient dose since would be the same even if there is no patient in the CT scanner account. CTDI gives the quantitative dose estimation analysis and diagnostic reference level for the radiation for national and international level. Values were systematically higher for the multi-slice CT scanners and the dose-length product (DLP) values on the multi-slice scanner exceeded the equivalent single-slice DLP values, except in the case of the head multi-slice protocol. For multi-slice CT, the reduction in patient scan time was a more than a factor of two for head scans.

In conclusion, it is imperative that measures of the radiation output of a CT system can be easily and practically measured in a consistent and robust fashion. The $CTDI_{vol}$ tells the medical physicist precisely how the machine was operated, and it can be used, in conjunction with information regarding patient size and the scanned anatomy, to estimate patient dose. Dose estimates can be for organ dose, skin dose, or a mean dose in the center of the scan volume. The CTDI values are not, however, patient dose estimates, must use patient size–specific dose estimates—they cannot use only scanner output ($CTDI_{vol}$ or DLP). Rather, use of the known exponential relationship between patient size and absorbed dose will allow patient size–specific dose estimates to be made from scanner output values. This paper will help in

- Giving the calculative analysis of radiation dose of CT scanners
- The Quality Assurance of the machine
- Estimation of dose in the CT scanners
- Patient dose knowledge
- Radiation safety since we can adjust the protocol to reduce the patient dose

Acknowledgement

I pay my sincere respect to my supervisor Ms. Bushra Khan Lecturer department of Radiology and Imaging Sharda University and Sharda Hospital, I am very thankful for your support, guidance and contribution toward this study. I wish to thank Dr. Munendra Singh, HOD department of physics School of Basic Science and Research Sharda University for his support and guidance throughout my program at Sharda University.

References

1. Jiang, Hsiaeh. Computed Tomography, Second Edition. Principle, Design, Artifacts, and Recent Advance. Ch1 2009.
2. Satish K Bhargava, Sumeet Bhargava. Text Book of Radiology for Residents and Technicians. Fourth Edition, Ch18 p (367-392).
3. Jerrold T Bushberg, Anthony V, Seibert Edwin M, Leidholot JR, John M. Boone. The Essential Physics of Medical Imaging. Second Edition, Ch13 p (327-369).
4. Frush. Radiation Protection and Dose monitoring In Medical Imaging. J Patient Saf., 2012, 8.
5. American Association of Physicist in Medicine Report. 2008, 96.
6. Role of the Manufacturer. Radiation Dosimetry in CT.: Imaging Med. 2011; 3(2):247-259.
7. Cynthia, H. Mccollough *et al.* CT Dose Index and Patient Dose: They Are Not The Same Thing. Radiology. 2011 may; 259(2) 311-316, PMCID: PMC3079120.
8. C. Descamps: Measurements of The Dose Deliver During CT Exams Using AAPM Task Group Report NO.111: JACMP Vol 13. No. 6(2012).
9. Moro. L, et al: Single – Slice and Multi – Slice CT: Dosimetric Comparison with Diagonostic Reference Dose Levels. Radio med 2001 Oct, 102(4): 262-5.
10. M. Castillo Editorials |AJNR 31: 1-4| Jan 2010.
11. Gianluca, Valera et al: Evaluating the Appropriateness of Dosimetric Indices in Body CT: RadiolMed (2015) 120; 466-473.
12. John Damilakes: How to Estimate Patient Doses From CT, ERS News February 2015.
13. Keith J. Strauss: Method to Estimate Radiation Dose to Pediatric Patients from CT Scans. Pediatr Radiol (2011) 41 (suppl 1): 5210-5211.
14. W. Kalender. CTDI And Patient Dose: A European Perspective AAPM 54th Annual Meeting July 29 – August 2, 2012 Charlotte, NC.