Estimation of regional anatomical dimensions of the adult and pediatric Indian population from Computed Tomography to generate reference values for radiation dosimetric calculations

Dissertation submitted for

M.D Anatomy Branch V Degree Examination,

The Tamil Nadu Dr. M.G.R. Medical University

Chennai, Tamil Nadu.

May – 2018

DECLARATION

I hereby declare that the dissertation entitled **"Estimation of regional anatomical dimensions of the adult and pediatric Indian population from Computed Tomography to generate reference values for radiation dosimetric calculations"** is a bonafide research work done by me under the supervision of Dr. Sunil Holla, Professor of Anatomy, Christian Medical College, Vellore, in partial fulfilment of the requirements for the MD Anatomy examination (Branch V) of the Tamil Nadu Dr. M.G.R. Medical University, Chennai to be held in May 2018.

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CHAPTER 1. AIM

Estimation of regional anatomical dimensions of the adult and pediatric Indian population from Computed Tomography images to generate reference values for radiation dosimetric calculations.

CHAPTER 2. OBJECTIVE

i. To estimate the anatomical dimensions of head, thorax and abdomen of the adult and pediatric Indian population from Computer Tomograms (CTs).

ii. To generate reference values specific for age and gender that can be used for calculating the safe radiation dose for the adult and pediatric Indian population.

CHAPTER 3. INTRODUCTION

Computed tomography (CT) has played a tremendously important role in diagnosing diseases as compared with other radiological procedures even though it imparts high radiation doses to patients(1). A CT topogram refers to a scout image as shown in Figures 1, 4 and 8. From these images, we can measure the scan length. However, a CT tomogram refers to an image of the cross section of the region under study as shown in Figures 2, 3, 5, 6, 7, 9 and 10. From these images, we can obtain antero-posterior and lateral dimensions of the region.

It is well understood that radiation effects are characterized by a threshold dose, above which the radiation results in carcinogenesis and induction of genetic mutations. Children are more radiosensitive than adults, and the risk of them developing radiation-induced malignancies is two to three times higher than that of adults (2–4). Technological developments have improved the speed of the procedure and quality of the images, leading to increased use of CT worldwide. However, the International Commission on Radiological Protection (ICRP) states that radiation doses from CT are relatively high, and technological developments and advances in CT generally have not led to a reduction in the radiation dose per examination according to the physical parameters of the patient. Optimizing the radiation dose during CT examinations is necessary as there is an increasing number of CTs performed each day. The calculation of radiation doses from CT scanners are generally done using phantoms and are extrapolated using calculations for the duration of the scans. Optimizing the dose to enable safe radiation to patients is based on the ‘reference man’ model. According to the International Commission on Radiological Protection (ICRP) 1974 definition, a ‘Reference man’ was defined as, “a healthy young adult male between 20-30years of age, weighing 70 kg, 170 cm in height, and living in a climate with an average temperature of 10°C to 20°C. He is a Caucasian and is a Western European or North American in habitat and custom”. However, since the vast majority of people including women and children fall outside this definition, using this model is scientifically inappropriate. Children are often exposed to adult radiation doses. Over the last decade, there has been a shift from the past emphasis on 'Reference Man', to the more relevant use of age and gender-specific ‘reference values’.

The ICRP, 2001 in their annual report recommend national authorities to adopt dose reference levels (DRL’s) based on relevant regional, national or local data in order to reduce unnecessary exposures in diagnosis. Recommending bodies such as the National Radiological Protection Board (NRPB), United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) and the European Commission suggest reference doses, in which the weighted CT Dose Index (CTDIw) and dose length product (DLP) are used as dose derivatives for CT examinations.

CTDIw and DLP are dose related quantities used for establishment of dose reference levels (DRLs) for optimizing patient exposure. Effective radiation doses are directly proportional to the scan lengths in computed topograms and increases exponentially as scan length increases to achieve good-quality images. Effective doses are usually estimated by multiplying the DLP values by normalized co-efficients found in the 'European guidelines on quality criteria of CT (5).

There has been a lack of data on average scan lengths and normalized co-efficient values of specific anatomical regions of the adult and pediatric Indian population. This study aims to generate age and gender-specific data that would facilitate the calculation of the appropriate radiation dose for the Indian adult and pediatric population.

CHAPTER 4. REVIEW OF LITERATURE

The introduction of reference man:

The importance of defining a “reference individual” for radiation dose measurement is seen as a prerequisite for organizations which set standard protocols. The concept of the Standard Man was introduced at the Chalk conference for Permissible Dose in 1950. This was accepted and implemented as having the reference values for diagnostic procedures. A decade later, this data was reviewed and updated to stand up to the requirements of developing technology, as new formulations were brought about to calculate the permissible dose. This brought about an updated version of the Standard Man, details of which were published in ICRP Publication 22, 1960.

In 1963, a committee started to review and further add to the concept of the Standard Man. The name “Standard Man” was changed to “reference man”. The review accommodated the changing protocols in radiation protection (16).

Reference values are crucial to determine radiation dose for many diagnostic radiological procedures and are incorporated in the machines. For creating the reference man, a collection of anatomical dimensions is necessary. With advancements in technology, the parameters required to acquire an image based on a given radiation dose changes for different scanners due to the type of detectors and software used. These preset factors change according to the anatomical region, based on size and shape as well as the population. The preset values are entered into the system as small, medium and large individuals and the exposure parameters are set accordingly. Current scanners mostly use data available from the North American and European population (18). In the Indian population, preset values for these machines are rather sparse as there are no reports on an Indian simulation. The reference model adheres to a set of reference values collected from topographic and tomographic images from CT scans (19). A separate model would be needed for adults and children, since it has been reported that children are more radiosensitive than adults (6).

According to the International Commission on Radiological Protection (ICRP) 89, the reference man was developed on factors like mass of individual organs like brain, glands, tongue, liver, pancreas, stomach, esophagus, colon, lungs, trachea, body fat, skin, reproductive organs, height, weight, along with physiological parameters like total body water content, secretions, respiratory indices like oxygen consumption and so on. They also studied fetuses and their growth patterns through the various Carnegie stages of development. The study included newborns, children in the age group of 1-15 years of age, and adults. However, details of methodology were not explained clearly.

In ICRP 26, the risks associated with radiation were documented, and to prevent this hazard, three principles were described in estimating radiation dose. They were to limit radiation dose by: 1) proper justification, 2) the optimal level of protection and 3) to use a standardized individual dose in adults and children.

ICRP 60, essentially dealt with revising its proposed recommendations and also added more safety precautions for radiological protection. With every publication of the ICRP, came the need to not only update the values of the reference man, but also include other ethnicities to the collection. Studies published by International Atomic Energy Agency (IAEA) 1998, have given data on the Japanese, Chinese and Indian reference population. However, these studies have measured the mass of organs and included the heights of their respective population. Details of methodology as to how they collected the measurements have not been explained. The need was to monitor the radiation dose as per individual requirement, and to balance requirement with the quality of scanned image. The human body changes with growth not only in size, as measured by parameters such as height and weight, but also internally, with organs reaching their respective size and positions only at a later stage in life. These changes are constant and hence there is a need for an age-specific reference man. With changes during puberty, pregnancy and menopause, factors like body mass index, weight and bone density all play a role in determining the dimensions of the reference model. There are many changes in the body of a child. A developing fetus is considered to be viable at 28 weeks of intrauterine life and there will be changes in the thorax topography as compared to a 20-week fetus (7). With progressive growth, the lungs expand, hence a large portion of the heart gets covered by the lung margin. The stomach expands after rotation and is positioned in the left hypochondrium with the development of the liver.

When children start walking, they adopt an erect posture and there are marked changes in the topography of the abdomen and pelvis notably in the lumbar spine, which increases in length as the child starts to walk and run. With adolescence, the growth spurt of boys becomes more than that of girls. Body fat diminishes in early childhood to increase during puberty.

In 1984, ICRP 89 stated the importance of creating a reference child as parameters for a child are not the same as that of an adult. Children grow rapidly in the first year of life, and from then onwards a drastic change in growth can be noticed every 3- 4 years. ICRP 89 reported extensive data on topographic images of organ volumes and the mass of the body, without information on tomographic images.

According to NRPB, the measurements to create a reference man were topographic and tomographic images. These were measured for the pediatric and adult population. The regions measured were only of head and thorax.

We have used these guidelines in our study. The landmarks used for the head were petrous ridge, outer table vertex, and inner table vertex. For standardization we have used the similar landmarks like level of eyeball and have classified them separately into topographic and tomographic measurements. Similarly for the thorax, NRPB used landmarks like carina of trachea and base of lung. We have also used these landmarks in topographic and tomographic measurements. For the abdomen there were no measurements done by NRPB.

Role of CT in eliciting data for reference man

Since the advent of Computed tomography (CT) in the 1970s, its role has been of immense value in diagnostic radiology. Though modalities of diagnostic imaging such as MRI and ultrasound are other options and are also popular among imaging techniques, CT continues to play a vital role in imaging due to its numerous advantages(1). In CT, the internal structures of the body are reconstructed from multiple x-ray beam projections to form a cross sectional image. CT has high spatial resolution, which makes it possible to differentiate tissues that differ in physical density by less than 1%. In multi detector CT, due to isotropic resolution, axial slices can be reformatted to visualize images in either coronal or sagittal sections depending on the diagnostic purpose. It is a moderate- to- high radiation diagnostic technique which is non-invasive in nature. Useful applications of CT include CT angiography, which does not require the invasive insertion of a catheter, and is a new investigation developed as a result of the improvised resolution that CT offers.

CT machines have provided the added advantage of producing a three-dimensional image of the organ or the region of interest(8). There is a rising trend of using CT diagnostic imaging for pediatric diagnosis and also for adult screening for malignancies (8).

Radiation dose-dependent factors:

The radiation dose is calculated from parameters set by CT scanners and is dependent on the scan length of the radiogram. Scan length is directly proportional to the number of image slices generated by the CT scanner. For example, the scan length of a child is less when compared to an adult and hence the scanner generates less number of image slices. So also, the area of the cross section is important to calculate the radiation dose for the individual.

CHAPTER 5. MATERIALS AND METHODS

The study was approved by the institutional review board as a collaborative project involving the departments of Anatomy and Radiology, Christian Medical College, Vellore. For the study, we used images available in the picture archival and communication system (PACS) database of Christian Medical College. The images were viewed using GE Web viewer Centricity Internet Explorer 7 version. The data included for the study are archived and recent patient topographic and tomographic scans done during the period 2010 to 2017. These were performed using three Multi detector Computed tomography (MDCT) scanners - Philips Brilliance 6 (Best, Netherlands); Siemens Somaton Emotion 16 (Erlangen, Germany) and GE 750HD Discovery (USA). The study was on scans of head, thorax and abdomen including the pelvis. The specific details such as name, hospital identity, gender, date of study, date of birth and address were entered into an Excel spreadsheet. Convenience sampling method was used as there was a limited time frame of 2 years to complete this study.

Table 1 A. Sample size and distribution of pediatric population

	Age (years)	CT Brain	CT Thorax	CT Abdomen and Pelvis	Total number of scans	
0-5 years	0-2	20	20	20	60	240
	3	20	20	20	60	
	4	20	20	20	60	
	5	20	20	20	60	
6-10 years	6	20	20	20	60	300
	7	20	20	20	60	
	8	20	20	20	60	
	9	20	20	20	60	
	10	20	20	20	60	
11-15 years	11	20	20	20	60	300
	12	20	20	20	60	
	13	20	20	20	60	
	14	20	20	20	60	
	15	20	20	20	60	
16-18 years	16	20	20	20	60	180
	17	20	20	20	60	
	18	20	20	20	60	
Total number of scans		**340**	**340**	**340**	**1080**	

Table 1B. Sample size and distribution of adult population

	CT Brain	**CT Thorax**	**CT Abdomen and Pelvis**	**Total no. of scans**
Adult male	250	250	250	750
Adult female	250	250	250	750
Total number of scans	**500**	**500**	**500**	**1500**

Table 1C. Topographic and Tomographic image landmarks

Region scanned	**Topographic (Scan length) measurements**	**Levels at which measurements of tomographic images were done**
Brain	Vertical distance of the CT of Brain- (Bv)	Level B1- At the level of eyeball
		Level B2- At the level of lateral ventricle
Thorax	Vertical distance of the CT of Thorax- (Tv)	Level T1 - At the level of apex of lung
		Level T2 - At the level of carina of trachea
		Level T3- At the level of base of lung
Abdomen	Vertical dimension of the CT of Abdomen- (Av1)	Level A1-At the level of upper abdomen
	Vertical distance of the CT of Abdomen and Pelvis – (Av2)	Level A2- At the level of iliac crest

The details of name, gender, hospital number, date of study, date of birth and address were entered, and the image number was entered for all sections that were measured for all the regions studied

5.1. Adult and pediatric CT Brain

5.1. A. Topographic image

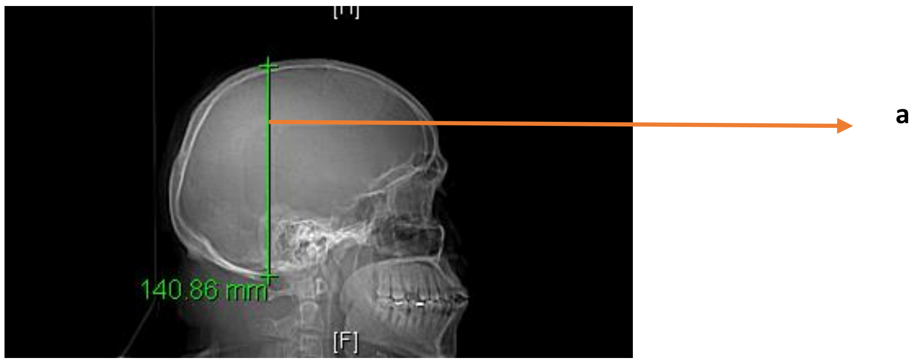

Figure 1.CT Brain- Scan Length from Topographic Image (Bv)

Measurement	Specifications
a= Scan length (Bv)	Vertical distance from lower border of mastoid process to outer-most point on superior aspect of skull

5.1. B. Tomographic images

For tomographic images, two levels were chosen for taking measurements - at which distinct landmarks were visible.

i. Level B1- At the level of eyeball.

This level was chosen since the eyeball was distinctly seen in all scans. The image chosen to measure was the lowest one with the lens clearly seen as shown in Figure 2.

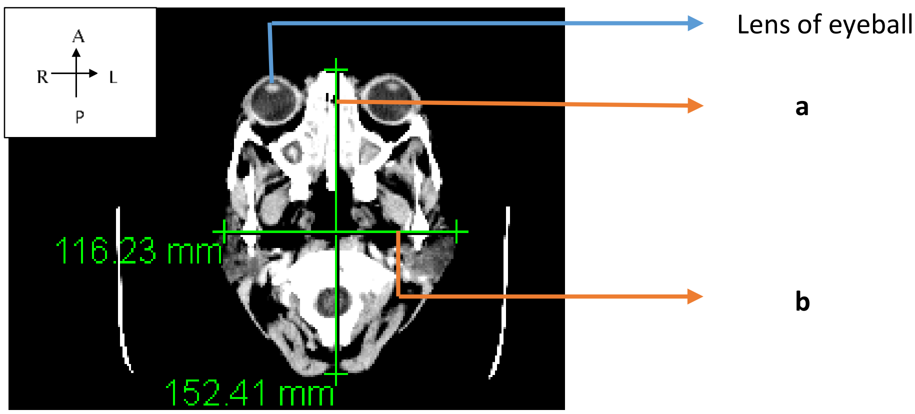

Figure 2. CT Brain- Measurements of Tomographic Image - At Level of Eyeball (Level B1)

Measurement	Specifications
a=Antero-posterior distance	From a transverse plane at the maximum convexity of the nasal bone to the transverse plane at the outer-most point on the posterior aspect of the skull.
b=Lateral or transverse distance	From the antero-posterior plane of the lateral-most convexity of the skull on the right to the antero-posterior plane of the corresponding point on the left.

ii. Level B2- At the level of lateral ventricle.

This level was chosen since the lateral ventricle was a distinctly seen landmark. On scrolling vertically upwards through the images, the image chosen to measure was the one when the lateral ventricle first assumed the shape of a butterfly, as shown in Figure 3.

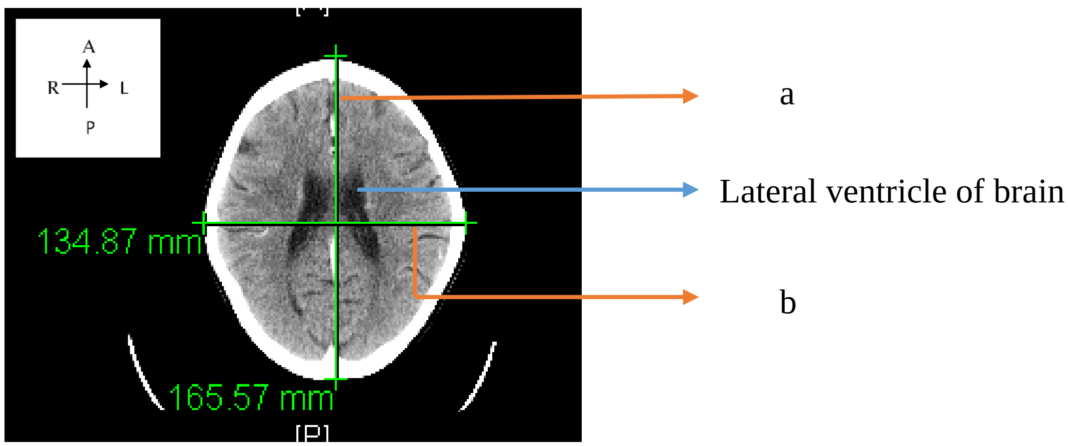

Figure 3.CT Brain- Measurements of tomographic image- At Level of Lateral Ventricle (Level B2)

Measurement	Specifications
a=Antero-posterior distance	From a transverse plane at the outer-most point on the maximum convexity of the anterior aspect of the skull to a transverse plane at the corresponding point on the posterior side.
b=Lateral or transverse distance	From an antero- posterior plane at the outer-most point on the lateral-most convexity of the skull on the right to an antero-posterior plane at the corresponding point on the left.

5.2. Adult and pediatric CT thorax

5.2. A. Topographic image

The topographic image measurement of scan length was done by carefully counting the vertebrae from below upwards starting from the lowest part of the 5th lumbar vertebra, as this vertebra was distinctly seen in all scans.

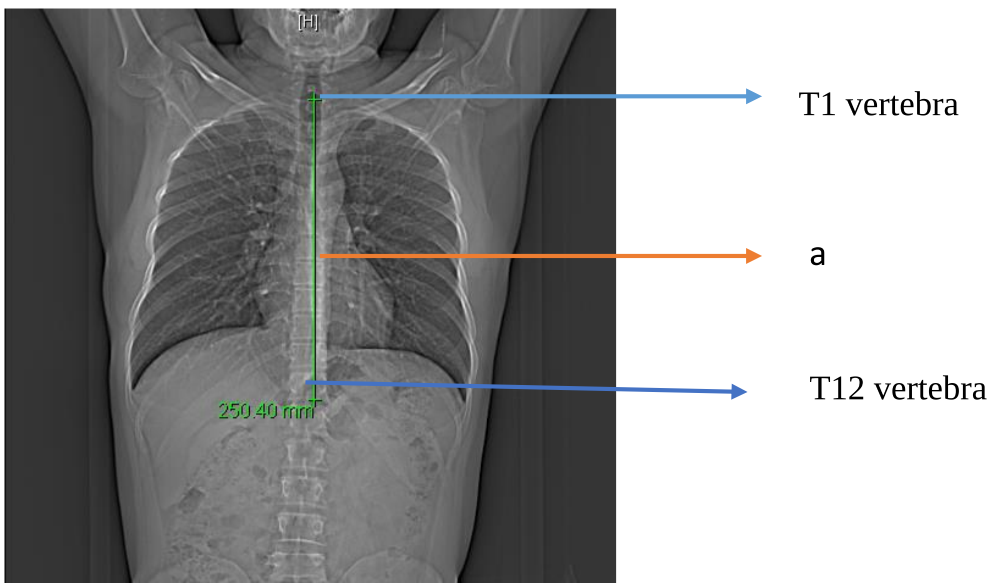

Figure 4.CT Thorax-Scan Length from Topographic Image- Vertical distance of CT thorax (Tv)

Measurement	Specifications
a= Scan length	Lower border of T12 vertebra to upper border of T1 vertebra

5.2. B. Tomographic image

For tomographic images of the thorax, measurements were done at two levels where there were distinct landmarks.

5. 2. B. i. At the level of upper part of thorax (Level T1)

Tomographic image measurements at the level of upper part of thorax were done. The level of this image was chosen when there was the presence of all of the following specific landmarks -air shadows, the sternum and a spinous process of a vertebra.

The levels in the thorax were called T1, T2 and T3 **referring to** the first, second and third levels of the thorax, and not referring to the vertebral levels T1, T2 or T3.

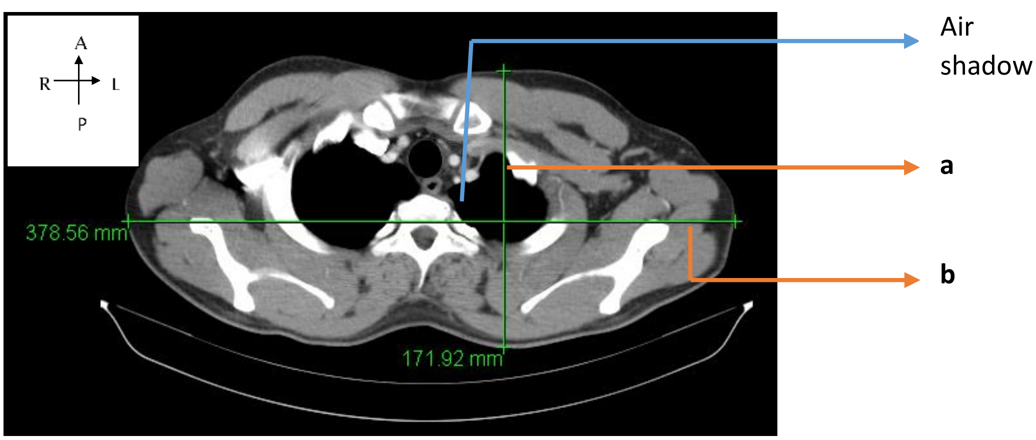

Figure 5.CT Thorax- Tomographic Image Measurements- At Apex of Lung (Level T1)

Measurement	Specifications
a=Antero-posterior distance	From a transverse plane at anterior-most point of skin on the anterior aspect of left side to the transverse plane of the corresponding point of the skin on the posterior side
b=Lateral or transverse distance	From an antero-posterior plane at the maximum convexity of skin of left side to an antero-posterior plane at the corresponding point on the opposite side.

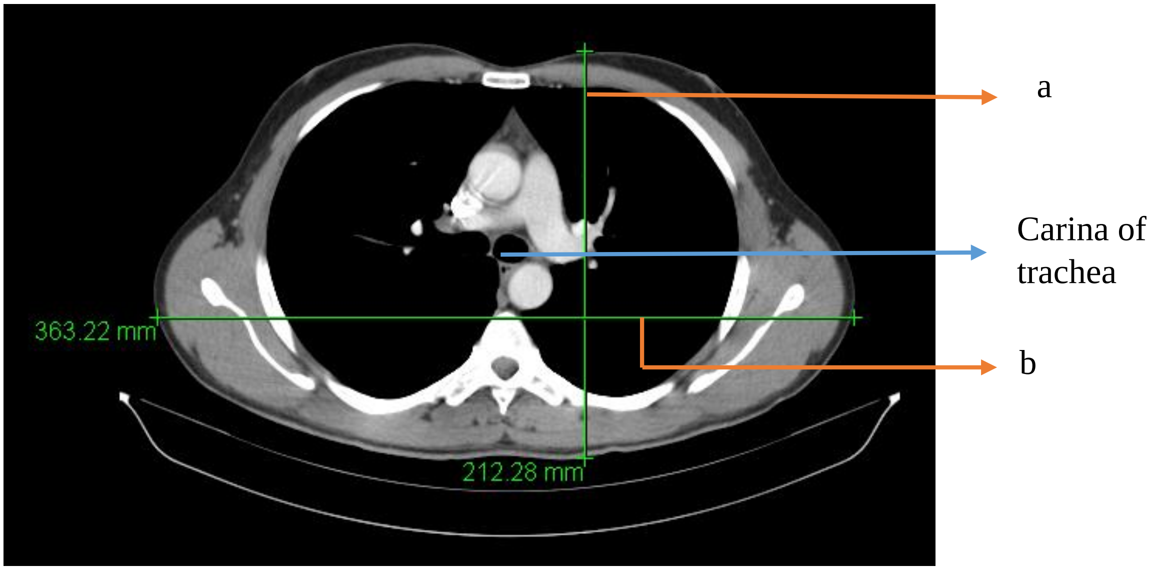

Figure 6.CT Thorax- Measurements of Tomographic Image- At Carina of Trachea-(Level T2)

Measurement	Specifications
a=Antero-posterior distance	From a transverse plane at the anterior-most point of skin on the anterior aspect of left side to a transverse plane at the corresponding point of the skin of the posterior side.
b=Lateral or transverse distance	From an antero-posterior plane at the maximum convexity of skin of left side to an antero-posterior plane at the corresponding point on the opposite side.

5. 2. B. iii. At the Level of Base of Lung (Level T3)

The tomographic section at the level of base of lung was selected by confirming the presence of the diaphragm in the next lower section. Thus the base of lung section is the lowest section of the thorax that is devoid of the diaphragm on the right side.

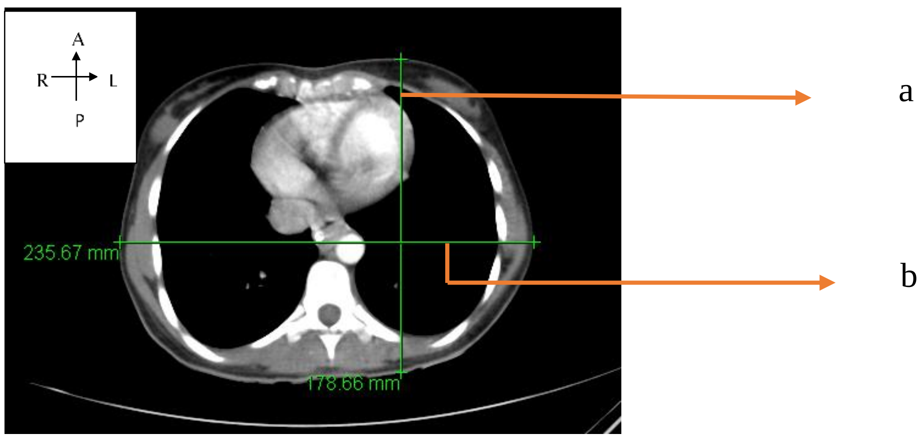

Figure 7.CT Thorax- Measurements of Tomographic Image- At Base of Lung (Level T3)

Measurement	Specifications
a=Antero-posterior distance	From a transverse plane at the anterior-most point of skin on the anterior aspect of left side to a transverse plane at the corresponding point of the skin of the posterior side
b=Lateral or transverse distance	From an antero-posterior plane at the maximum convexity of skin of left side to an antero- posterior plane at the corresponding point on the opposite side.

5.3. Adult and pediatric CT abdomen

5.3. A. Topographic image

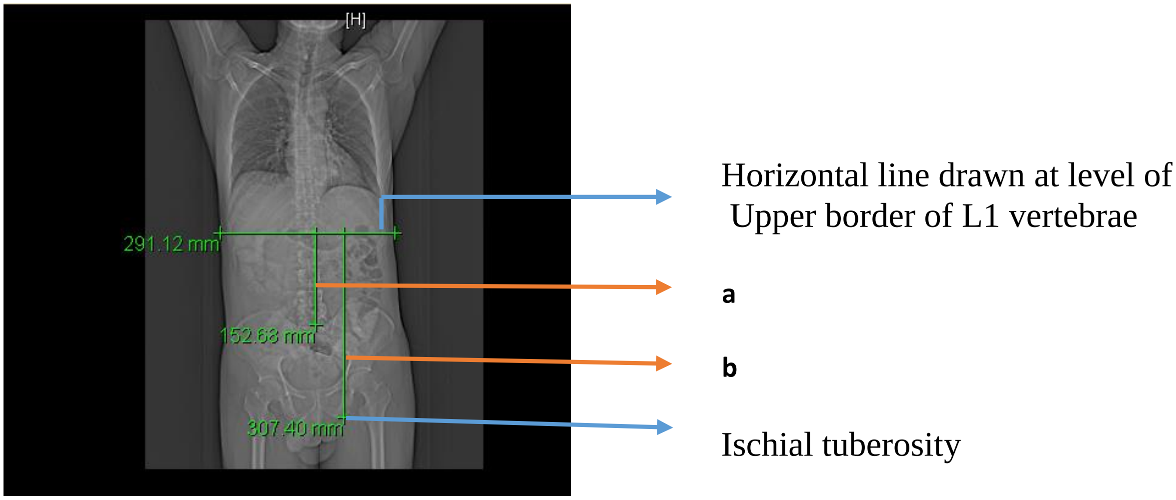

Figure 8.CT Abdomen- Measurements of Topographic Scan Length Image- Vertical distance of abdomen (Av1) and Vertical distance of abdomen and pelvis (Av2)

Measurement	Specifications
a= Scan length of abdomen (Av1)	Lower border of L5 vertebra to upper border of L1 vertebra
b=Scan length abdomen and pelvis (Av2)	Lower border of ischial tuberosity to a line drawn at the upper border of L1 vertebra

5.3. B. Tomographic images

In the tomographic images of CT abdomen two levels were selected for taking measurements

5.3. B. i. At the level of Upper Abdomen- Level A1

This level was chosen as it possible to locate it in all scans. It was the highest level where the posterior aspect of the liver was seen as a distinct margin with a space separating it from the vertebral column.

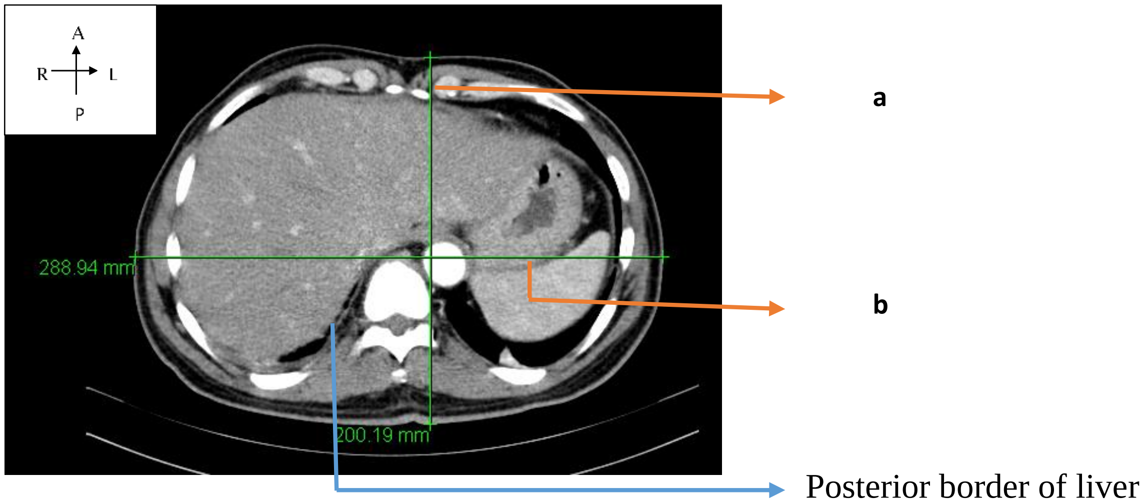

Figure 9. CT Abdomen- Measurements of Tomographic Image - At the Level of Upper Abdomen – Level A1

Measurement	Specifications
a=Antero-posterior distance	From a transverse plane at the anterior-most point of skin on the anterior aspect of left side to a transverse plane at the corresponding point of the skin of the posterior side
b=Lateral or transverse distance	From an antero-posterior plane at the maximum convexity of skin of left side to an antero-posterior plane at the corresponding point on the opposite side

5.3. B. ii. At the level of iliac crest- Level A2

The level chosen was the highest point of iliac crest as it could be distinctly seen and could be specifically selected in all scans. It was also described in the report by Dunn et al., 2003.

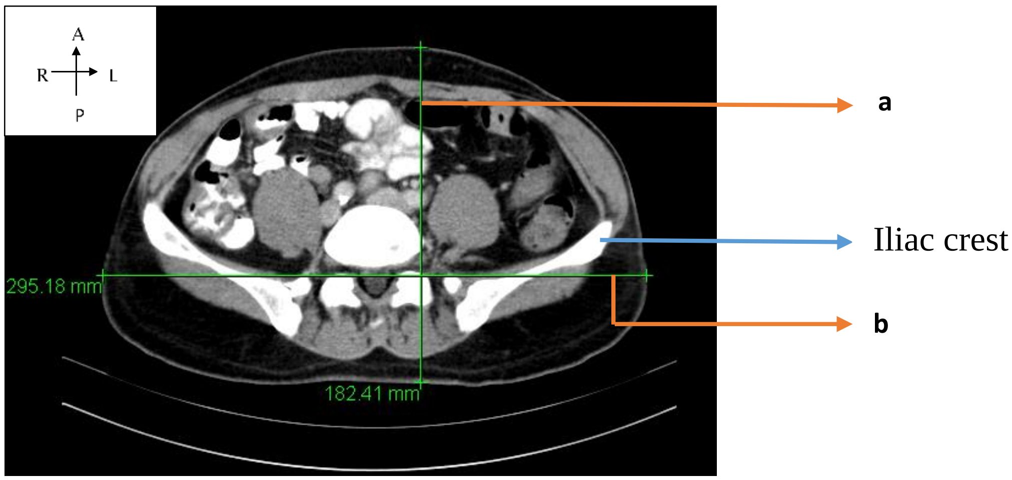

Figure 10. CT Abdomen- Measurements of Tomographic Image - At the Level of Iliac Crest (Level A2)

Measurement	Specifications
a=Antero - posterior distance	From a transverse plane at the anterior-most point of skin on the anterior aspect of left side to a transverse plane at the corresponding point of the skin of the posterior side.
b=Lateral or transverse distance	From an antero-posterior plane at the maximum convexity of skin of left side to an antero-posterior plane at the corresponding point on the opposite side

5.4. Data analysis

Data analysis was done by a biostatistician at the Department of Biostatistics at Christian Medical College, Vellore.

Statistical methods:

Categorical variables, such as gender, were summarized using frequencies and percentages. Normally distributed quantitative variables were summarized using mean and standard deviation. Independent t-test was used to compare the means between two groups and one-way ANOVA was used to compare the means between more than two groups. For all the analyses, 5% levels of significance were considered to be significant. All the statistical analyses were done using STATA v. 13. 1.

CHAPTER 6. RESULTS

We had reviewed CT scans of a total of 2580 adults and 1080 children. The results of CT Brain, CT Thorax, and CT Abdomen and Pelvis are described below. In each region the results are described in the following order:

i. Topographic measurements

ii. Tomographic measurements

iii. Calculation of effective diameter

Effective diameter refers to the diameter at a region that is used for calculation of the surface area of the cross section. It is calculated from tomographic measurements-antero-posterior (AP) and lateral distances. It directly reflects the circumference of the measured region. By calculating this measurement, we can construct the phantom model.

$$\textbf{Effective diameter} = \sqrt{\textbf{(Mean AP dimension x Mean Lateral dimension)}}$$

6.1. CT Brain

Almost equal numbers of boys and girls were selected as shown in Figure 11.

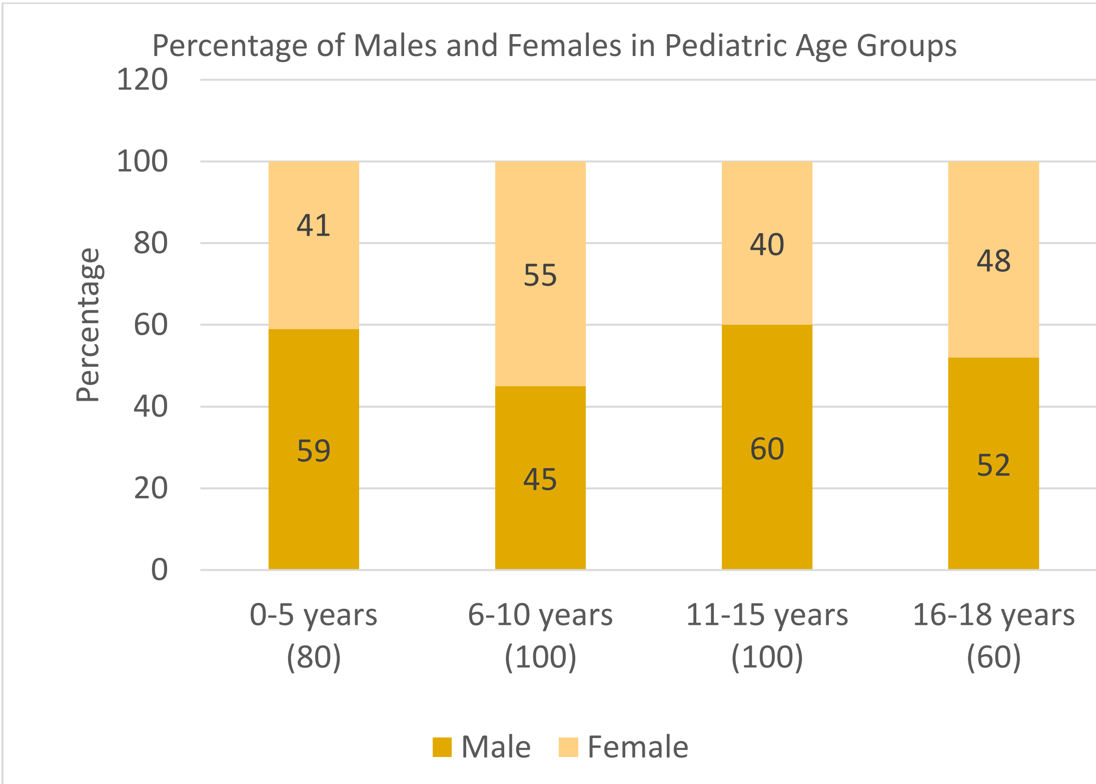

Figure 11. CT Brain- Percentage of Males and Females in Pediatric Age Groups (the total number, n, is given in brackets)

6.1 A. TOPOGRAPHIC IMAGE MEASUREMENTS

The observations of scan length from topographic images of CT Brain are tabulated in Table 2A and are also depicted in Figure. 12.

Table 2A.CT Brain- Scan lengths from Topographic Image Measurements (Bv) of Pediatric Age Groups and Adults

CT Brain- Scan Lengths from Topographic Image Measurements (Bv)			
Age (years)	Mean (mm)	SD	Range (mm)
0-5	114.35	10.86	82.45-129.86
6-10	122.99	8.34	103.22-142.10
11-15	126.78	7.94	105.42-155.74
16-18	130.70	7.85	114.20-157.03
Adult males	140.32	9.38	99.43-217.2
Adult females	131.47	9.23	105.03-199.53

As seen in the Table 2A, the mean scan length increased progressively from 0-5 year age group to 18 years of age children. The mean scan length was higher in adult males than in adult females. The scan length increased by 1.07 times from 0-5 year age group to 6-10 year age group [this increase was calculated by dividing the higher value mean (122.99) by the lower value mean (114.35)]. The calculation of this increase can be used for estimating the change in the measure. The scan length increased by 1.03 times from 6-10 years age group to 11-15 year age group. The scan length increased by 1.03 times from 11-15 year age group to 16- 18 year age group. This is also depicted in the Figure 12.

Out of the 500 adults studied, 250 were males and 250 were females. For the adult male group, the mean scan length for the brain was 140.32 mm when compared to the adult female group, in which the mean scan length was 131.47 mm. This shows the scan length of males was 7% higher than in females.

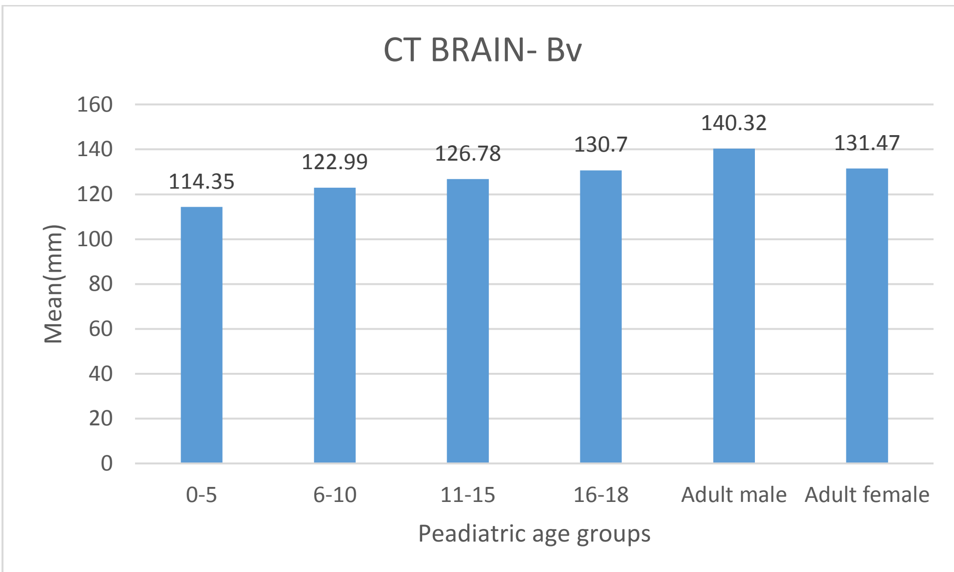

Figure 12. CT Brain- Scan length from Topographic Images (Bv) in the Pediatric and Adult Groups

The scan lengths ranged between 82.45 to 217 mm in the pediatric to the adult population. There were statistically significant differences between the mean scan lengths of the pediatric groups and the adult groups ($p < 0.001$) as seen in Table 5E. These observations may be used while calculating the radiation dose to patients of different age groups.

6.1. B. Results of Tomographic Images

At levels B1 and B2, both antero-posterior (AP*) and lateral (Lat*) distances were measured as shown in Figure 2 and 3. The observations recorded on tomographic images of CT Brain have been tabulated in Table 2B.

Table 2B. CT Brain - Tomographic Measurements of Pediatric age groups and adults at levels B1 and B2.

Level B1- At the Level of the Eyeball						
	Mean (mm)		SD		Range (mm)	
	AP*	Lat*	AP *	Lat*	AP*	Lat*
0-5 years	132.57	108.87	12.8	12.86	95.24-176.28	75.53-141.6
6-10 years	145.12	120.12	9.34	10.34	128.81-173.96	102.53-154.57
11-15 years	155.63	128.84	10.6	9.69	135.59-184.12	102.98-157.06
16-18 years	163.6	134.14	11.81	10.83	143.86-190.79	109.97-163.17
Adult males	180.76	142.07	8.97	8.7	149.35-206.45	106.36-177.39
Adult females	165.6	130.78	9.54	9.17	137.8-197.37	107.14-154.72
Level B2- At the Level of the Lateral Ventricle						
0-5 years	150.26	130.31	14.45	10.74	107.5-180.98	93.07-155.55

6-10 years	159.25	135.12	10.22	7.52	128.85-181.17	112.69-157.5
11-15 years	165.26	137.98	8.67	5.88	143.64-182.34	124.31-151.51
16-18 years	168.49	140.79	11.72	7.06	146.54-235.18	122.81-159.95
Adult males	176.11	141.52	7.66	6.88	152.56-192.98	126.1-179.92
Adult females	168.21	134.91	7.33	6.27	143.16-194.29	104.35-151.83

6.1. B. i. At Level B1-

As seen from Table 2B, at the level of the eyeball, with increasing age there was an increase in both AP and lateral distances. The AP distance increased by 1.09 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.07 times in the AP distance from 6-10 year age group to 11-15 year age group. There was an increase by 1.05 times in the AP distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.09 times in AP distance from the dimensions measured in females to males.

Also seen from Table 2B, the lateral distance increased by 1.1 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.07 times in the lateral distance from 6-10 year age group to 11-15 year age group. There was an increase by 1.04 times in the lateral distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.086 times in lateral distance from the dimensions measured in females to males.

6.1. C. ii. At Level B2

As seen in Table 2B, with increasing age, at the level of the lateral ventricle, there was an increase in both AP and lateral distances. The AP distance increased by 1.05 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.03 times in the AP distance from 6-10 year age group to 11-15 year age group. There was an increase by 1.03 times in the AP distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.04 times in AP distance from the dimensions measured in females to males.

Also seen from Table 2B, the lateral distance increased by1.03 times from 0-5 year age group to 6-10 year age group. There was an increase by1.02 times in the lateral distance from 6-10 year age group to 11-15 year age group. There was an increase by1.02 times in the lateral distance of 11-15 year age group to 16-18 year age group. Among adults, there was an increase by1.04 times in the lateral distance from the dimensions measured in females to males.

At the level of the eyeball, from 0-5 age group to adult, the AP distance falls in the range of 95.24-206.45 mm, and the lateral distance falls in the range of 75.53-177.39mm.

At the level of the lateral ventricle, from 0-5 age group to adult, the AP distance falls in the range of 107.5-235.18 mm and lateral distance falls in the range of 93.07-179.92 mm.

By observing the above range of values at the level of the eyeball and the level of the lateral ventricle, there appears to be an increase in dimensions of the AP and lateral distances from the level at the eyeball to the level of the lateral ventricle.

These measurements will be used to calculate the effective diameter.

6.1. C. CT Brain- Effective Diameter

The effective diameter was obtained from the AP dimensions and lateral dimensions which were measured from tomographic images. The effective diameter calculated showed a steady rise from 0-5 age-group children to 18 year age-group children. The effective diameter was more for adult males than adult females. The observations recorded of effective diameter are tabulated in Table 2C.

Table 2C: Effective Diameter for CT Brain

Level B1-At level of the eyeball			
Age (years)	AP Dimension (mm)	Lateral Dimension (mm)	Effective Diameter(mm)
0-5 years	132.57	108.87	120
6-10 years	145.12	120.12	132
11-15 years	155.63	128.84	142
16-18 years	163.6	134.14	148
Adult Males	180.76	142.07	160
Adult Females	165.6	130.78	147
Level B2- At the lateral ventricle (mm)			
0-5 years	150.26	130.31	140
6-10 years	159.25	135.12	147
11-15 years	165.26	137.98	151
16-18 years	168.49	140.79	154
Adult Males	176.11	141.52	158
Adult Females	168.21	134.91	151

For level of the eyeball, effective diameter increased by 1.1 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.07 times in effective diameter from 6-10 year age group to 11-15 year age group. There was an increase by 1.04 times in effective diameter from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.08 times in effective diameter from females to males.

For the level of the lateral ventricle, effective diameter increased by 1.05 times from 0-5 age group to 6-10 year age group. There was an increase by 1.02 times in effective diameter from 6-10 year age group to 11-15 year age group. There was an increase by 1.01 times in effective diameter from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.04 times in effective diameter from females to males.

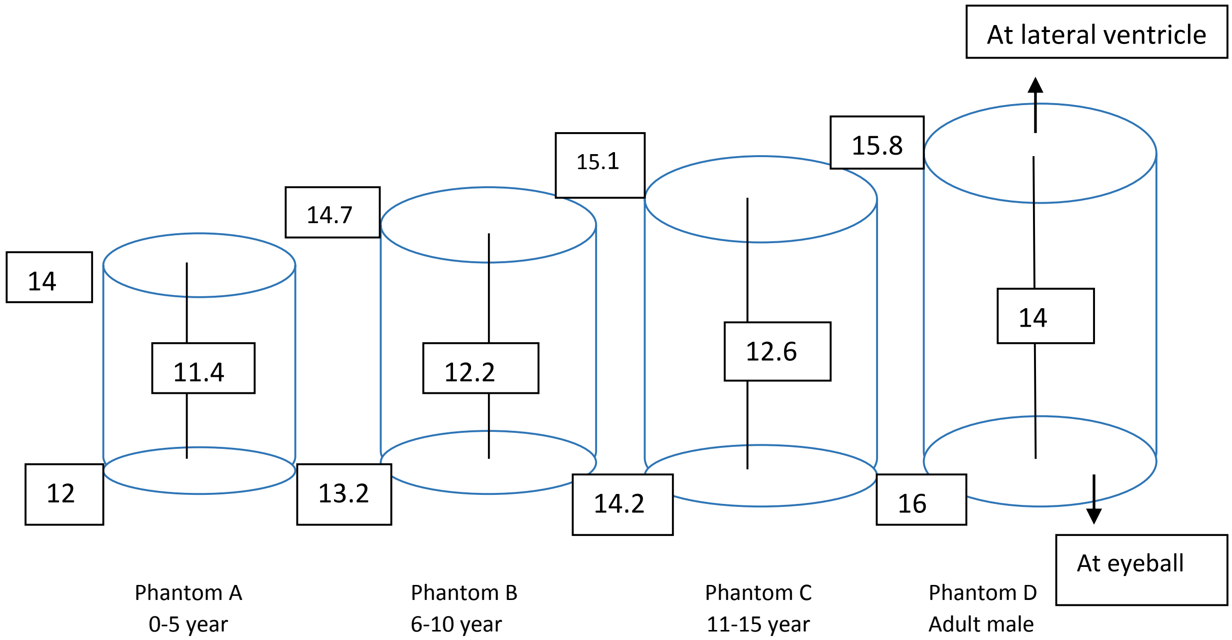

Figure 13. Effective Diameter and Scan Length (in cms) for Phantom for CT Brain

For example: For Phantom D of Adult Male, 14 cm is the scan length and 15.8 cm and 16 cm are the effective diameters at the levels mentioned

6.2. CT Thorax

Almost equal numbers of boys and girls were selected as shown in Figure 14.

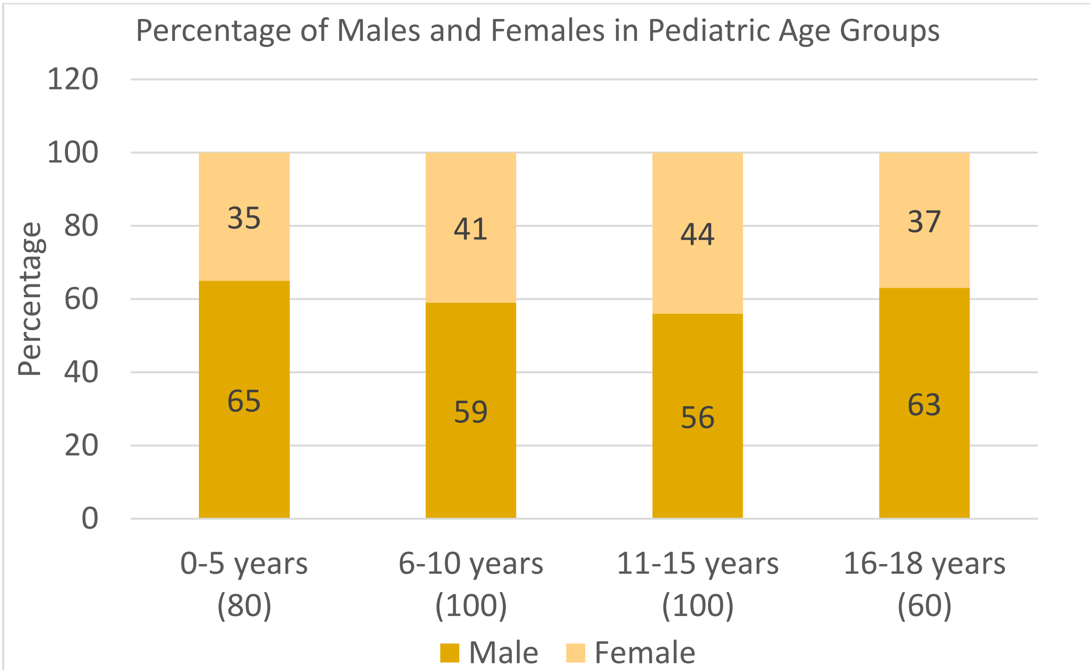

Figure 14. CT Thorax - Percentage of Males and Females in Pediatric Age Groups (the total number, n is given in brackets)

6.2. A. TOPOGRAPHIC IMAGE MEASUREMENTS

The observations of scan length from topographic images of CT Thorax are tabulated in Table 3A and are also depicted in Figure 15.

Table 3.A. CT Thorax- Scan length from Topographic Image Measurements (Tv) of Pediatric Age Groups and Adults

CT Thorax- Scan Length from Topographic Image Measurements- Tv			
Age (years)	Mean (mm)	SD	Range (mm)
0-5	157.7	41.3	72.63-279.1
6-10	184.8	36.86	120.11-320.57
11-15	216.99	32.3	143.11-366.98
16-18	241.74	35.7	119.66-322.15
Adult males	249.98	20.3	200.12-309.4
Adult females	224.15	20.1	179.03-321.44

As seen in the Table 3A, the mean scan length increased progressively from 0-5 year age group to 18 years of age children. The mean scan length was higher in adult males than adult females. The scan length increased by 1.17 times from 0-5 year age group to 6-10 year age group. The scan length increased by 1.17 times from 6-10 year age group to 11-15 year age group. The scan length increased by 1.11 times from 11-15 year age group to 16-18 year age group.

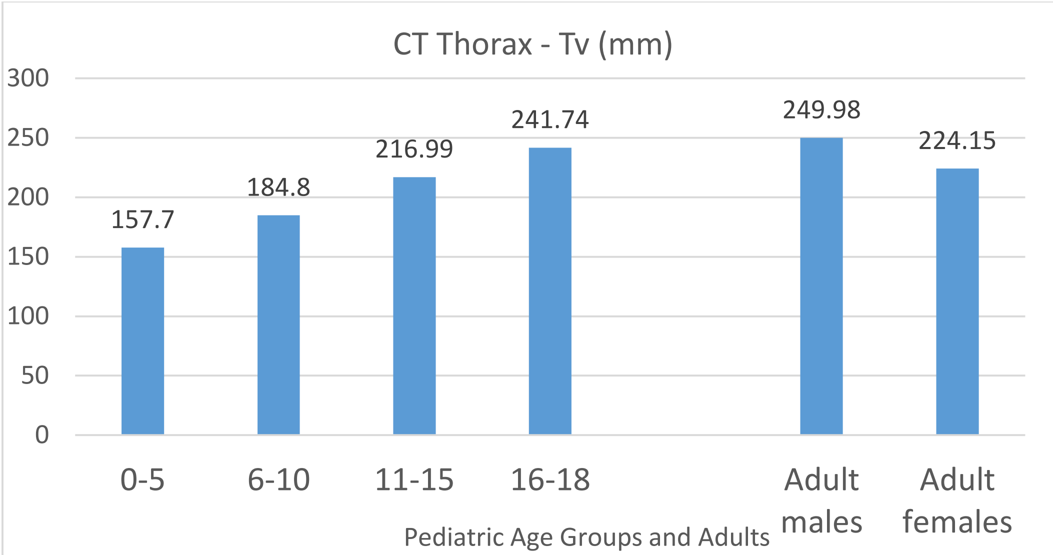

Figure 15. CT Thorax- Scan length of Thorax of Pediatric Age Groups and Adults.

There was a statistically significant difference in the mean scan length of the pediatric and adult groups ($p < 0.001$) as in Table 5F. These observations may be used while calculating the radiation dose to patients of different age groups.

6.2. B. Results of Tomographic Images

At levels T1, T2, T3, both antero-posterior (AP) and lateral distances are measures as shown in figure 5, 6 and 7. The observations recorded on tomographic images of CT Thorax are tabulated in Table 3B, Table 3C and Table 3D.

6.2. B. i. LevelT1 - At Level of the Upper Thorax

As seen from the Table 3B, at the level T1, with increasing age there was an increase in both AP and lateral distances. The AP distances increased by 1.18 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.2 times in the AP distance from 6-10 year age group to 11- 15 year age group. There was an increase by 1.09 times in the AP distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.03 times in the AP distance from the dimensions measured in females to males.

Also seen from Table 3B, the lateral distance increased by 1.19 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.23 times in the lateral distance from 6-10 year age group to 11-15 year age group. There was an increase by 1.12 times in the lateral distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.06 times in lateral distance from the dimensions measured in females to males.

Table 3B: CT Thorax- Tomographic Measurements at the Upper Part of Thorax

Level T1 - At Level of the Upper Part Of Thorax						
	Mean (mm)		SD		Range (mm)	
	AP*	Lat*	AP *	Lat*	AP*	Lat*
0-5 years	86.92	202.93	10.04	24.35	(65.1-119.21)	(136.13-288.67)
6-10 years	103.36	243.35	16.89	41.86	(60.99-164.34)	(100.08-341.6)
11-15 years	124.62	299.91	24.71	42.83	(85.52-209.89)	(148.07-389.69)

16-18 years	136.55	335.99	28.34	44.44	(93.23-235.41)	(229.2-484.44)
Adult males	206.00	357.57	20.40	31.52	(158.74-258.89)	(184.70- 472.37)
Adult females	198.32	337.02	25.62	39.39	(144.37-305.98)	(206.11-464.22)

From Table 3B, at the upper part of thorax, the range of values for AP distance was 65.1 to 305.9 8 mm and Lateral distance was 136.13 to 484.44 mm from 0-5 age group to adult population.

6.2. B. ii. Level T2- At the Level of Carina of Trachea

As seen from the Table 3C, at the level T2, with increasing age there was an increase in both AP and lateral distances. The AP distances increased by 1.21 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.21 times in the AP distance from 6-10 year age group to 11- 15 year age group. There was an increase by 1.1 times in the AP distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.03 times in the AP distance from the dimensions measured in females to males.

Also seen from Table 3C, the lateral distance increased by 1.24 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.24 times in the lateral distance from 6-10 year age group to 11-15 year age group. There was an increase by 1.11 times in the lateral distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.03 times in lateral distance from the dimensions measured in females to males.

Table 3C: CT Thorax- Tomographic Measurements at level of the Carina of Trachea

Level T2- At Level of the Carina of Trachea						
	Mean (mm)		SD		Range (mm)	
	AP*	Lat*	AP *	Lat*	AP*	Lat*
0-5 years	110.62	186.81	12.78	23.77	(83-147.12)	(132.64-257.65)
6-10 years	134.54	231.83	19.4	32.9	(94.42-185.85)	(151.03-324.42)
11-15 years	164.01	288.45	23.84	36.7	(120.34-232.27)	(217.2-391.23)
16-18 years	181.23	321.01	23.48	42.22	(142.77-262.65)	(229.74-468.87)
Adult males	206	348.22	20.43	26.99	(158.74-258.89)	(267.04-453.68)
Adult females	198.32	337.02	25.62	39.39	(144.37-305.98)	(206.11-464.22)

From Table 3C, at the carina of trachea, the range of values for AP distance was 83 to 305.98 mm and Lateral distance was 132.64 to 468.87mm from 0-5 age group to adult population.

6.2. C. iii. Level T3- At Level of the Base of Lung

As seen from the Table 3D, at the level T3, with increasing age there was an increase in both AP and lateral distances. The AP distances increased by 1.19 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.18 times in the AP distance from 6-10 year age group to 11- 15 year age group. There was an increase by 1.09 times in the AP distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.03 times in the AP distance from the dimensions measured in females to males.

Also seen from Table 3D, the lateral distance increased by 1.23 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.21 times in the lateral distance from 6-10 year age group to 11-15 year age group. There was an increase by 1.10 times in the lateral distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.02 times in lateral distance from the dimensions measured in females to males.

Table 3D: CT Thorax- Tomographic Measurements at the Base of Lung

Level T3 - At the Base of Lung						
	Mean (mm)		SD		Range (mm)	
	AP*	Lat*	AP *	Lat*	AP*	Lat*
0-5 years	125.89	174.01	13.2	21.3	(92.76-155.62)	(118.8-236.18)
6-10 years	150.35	214.07	18.3	25.1	(109.44-203.18)	(162.65-296.4)
11-15 years	177.99	259.65	21.4	34.8	(138.63-245.39)	(191.16-373.48)
16-18 years	195.28	287.51	24.23	40.59	(159.24-282.1)	(214.71-416.34)
Adult male	215.73	312.73	22.96	29.5	(158.24-277.98)	(229.88-433.71)
Adult female	208.32	304.7	21.26	40.19	(158.24-274.51)	(194.61-431.19)

From Table 3D, at the base of lung, the range of values for AP distance was 92.76 to 282.1 mm and Lateral distance was 118.8 to 433.71 mm from 0-5 age group to adult population.

6.2. C Results of effective diameter

The effective diameter was obtained from the AP dimensions and lateral dimension which is measured from tomographic images. The effective diameter calculated showed a steady rise from 0-5 age group children to 18 year age group children. The effective diameter was more for Adult male than Adult female. The results of effective diameter are tabulated in Table 3E.

Table 3E: Effective Diameter for CT thorax

Effective Diameter For CT Thorax(mm)			
At level of upper part of thorax (Level T1)			
Age (years)	Mean Antero posterior dimension (mm)	Mean Lateral dimension (mm)	Effective Diameter (mm)
0-5 years	86.92	202.93	133
6-10 years	103.36	243.35	159
11-15 years	124.62	299.91	193
16-18 years	136.55	335.99	214
Adult Males	164.95	357.57	243
Adult Females	160.8	352.12	238
At level of carina of trachea (Level T2)			
0-5 years	110.62	186.81	144
6-10 years	134.54	231.83	177
11-15 years	164.01	288.45	218
16-18 years	181.23	321.01	241
Adult Males	206	348.22	268

Adult Females	198.32	337.02	259
At level of base of lung (Level T3)			
0-5 years	125.89	174.01	148
6-10 years	150.35	214.07	179
11-15 years	177.99	259.65	215
16- 18 years	195.28	287.51	237
Adult Males	215.73	312.73	264
Adult Females	208.32	304.7	252

For level of the upper part of thorax, effective diameter increased by 1.19 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.21 times in effective diameter from 6-10 year age group to 11-15 year age group. There was an increase by 1.10 times in effective diameter from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.02 times in effective diameter from females to males.

For the level of the carina of trachea, effective diameter increased by 1.22 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.23times in effective diameter from 6-10 year age group to 11-15 year age group. There was an increase by 1.10 times in effective diameter form 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.03 times in effective diameter from females to males.

For the level of the base of lung, effective diameter increased by 1.2 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.2 times in effective diameter from 6-10 year age group to 11-15 year age group. There was an increase by 1.1 times in effective diameter from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.04 times in effective diameter from females to males.

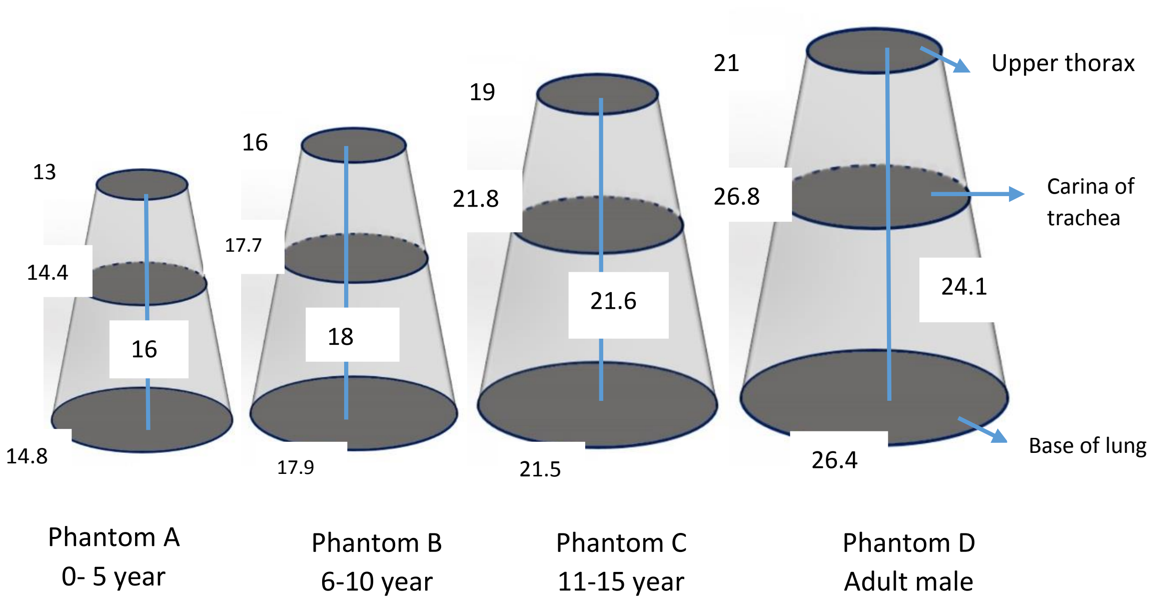

Figure 16. Effective Diameter (cm) and Scan Length of Thorax Phantom (cm)

For example: For Phantom D, 21, 26.8 and 26.4 are the effective diameters at the levels mentioned; 24.1 is the scan length

6.3. CT Abdomen

Almost equal numbers of boys and girls were selected as shown in Figure 17.

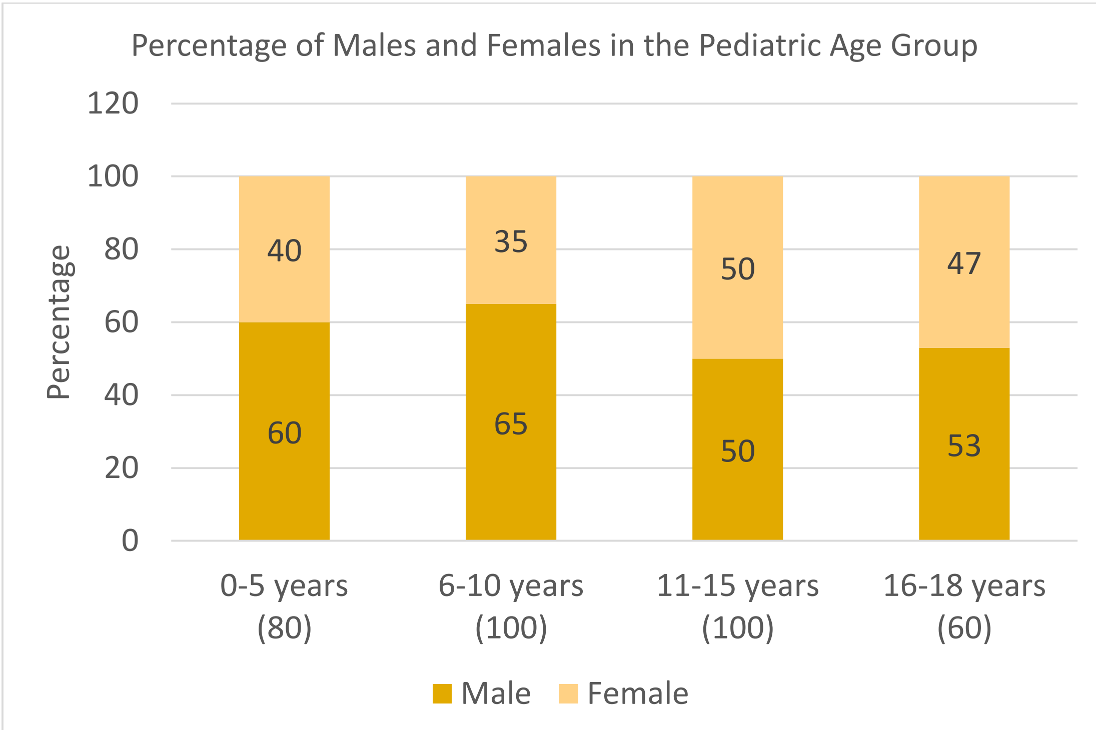

Figure 17. CT Abdomen- Percentage of Males and Females in the Pediatric Age Group (the total number, n, is given in brackets)

6.3. A. TOPOGRAPHIC IMAGE MEASUREMENTS

The observations of scan length from topographic images of CT Abdomen are tabulated in Table 4A and are also depicted in Figure 18.

Table 4A. CT Abdomen-Scan Length from Topographic Image Measurements (Av1 & Av2) of Pediatric Age Groups and Adults

CT Abdomen- Scan Length from Topographic Image Measurements (Av1 & Av2)						
Age (years)	Mean (mm)		SD		Range (mm)	
	Av1	Av2	Av1	Av2	Av1	Av2
0-5	106.09	195.61	28.54	50.16	50.24-195.87	99.27-339.14
6-10	125.88	238.84	23.09	42.04	78.03-202.97	147.18-377.96
11-15	145.26	279.78	19.36	29.38	100.78-195.57	204.4-367.28
16-18	149.4	295.78	20.81	36.53	112.07-202.56	215.35-420.39
Adult males	160.59	311.56	17.08	27.1	113.18-224.07	189.08-385.95
Adult females	151.48	297.15	28.23	24.36	96.74-381.49	198.19-364.94

As seen in the Table 4A, the mean scan length increased progressively from 0-5 year age group to 18 years of age children. The mean scan length was higher in adult males than adult females. The scan length of abdomen increased by 1.18 times and scan length of abdomen and pelvis increased by 1.22 times from 0-5 year age group to 6-10 year age group. The scan length of abdomen increased by 1.15 times and scan length of abdomen and pelvis increased by 1.17 times from 6-10 year age group to 11-15 year age group. The scan length of abdomen increased by 1.02 times and scan length of abdomen and pelvis increased by 1.05 times from 11-15 year age group to 16-18 year age group.

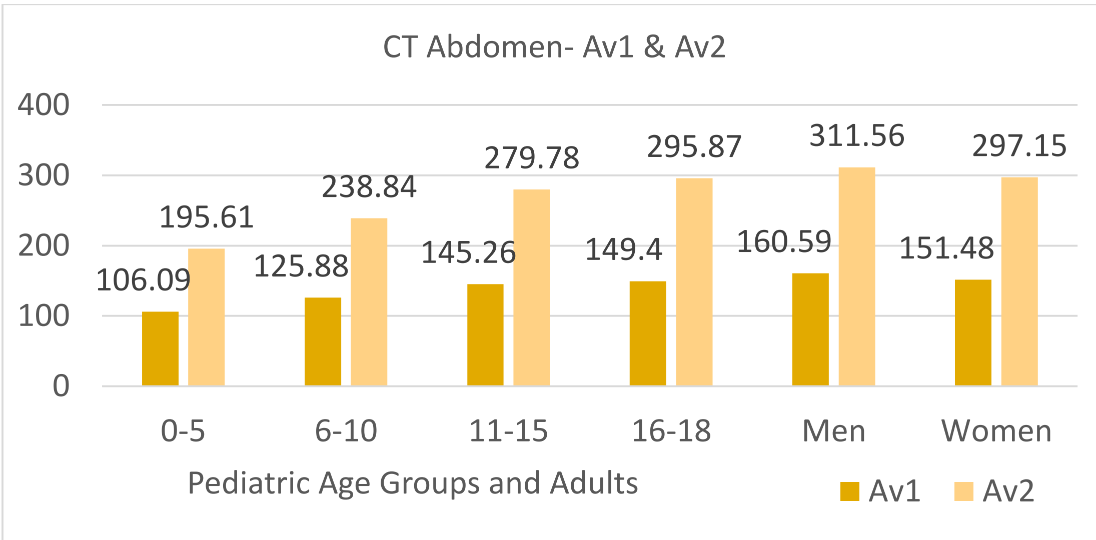

Figure 18. CT Abdomen- Scan Length from Topographic Image of Abdomen and Abdomen and Pelvis- Av1 & Av2 (mm) of Pediatric age groups and Adults.

There was a statistically significant difference in the mean scan lengths of the pediatric and adult groups ($p < 0.001$) as in Table 5G. This result is of vital importance while estimating radiation dosimetric value calculation.

6.3. B. Results of Tomographic Images

At levels A1 and A2, both antero-posterior (AP) and lateral distances are measured as shown in Figure 9, 10. The observations recorded on tomographic images of CT Abdomen are tabulated in Table 4B and Table 4C.

6.3. B. i. At the level of the Upper part of the abdomen – Level A1

As seen in the Table 4B, at the level A1, with increasing age there was an increase in both AP and lateral distances. The AP distances increased by 1.25 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.06 times in the AP distance from 6-10 year age group to 11- 15 year age group. There was an increase by 1.05 times in the AP distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.02 times in the AP distance from the dimensions measured in females to males.

Also seen from Table 4B, the lateral distance increased by 1.18 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.18 times in the lateral distance from 6-10 year age group to 11-15 year age group. There was an increase by 1.06 times in the lateral distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.07 times in lateral distance from the dimensions measured in females to males.

Table 4B: Tomographic Image Measurements of CT Abdomen at Level A1

Level A1- At the Level of the Upper Abdomen						
	Mean (mm)		SD		Range (mm)	
	AP*	Lat*	AP *	Lat*	AP*	Lat*
0-5 years	117.59	158.98	13.08	10.48	76.95-140.09	139.45-176.82
6-10 years	147.21	189.05	20.82	17.72	108.64-228.39	144.48-247
11-15 years	156.13	224.45	18.55	24.97	113.56-228.39	177.22-349.67
16-18 years	164.25	240.09	16.34	22.76	124.82-197.65	194.63-316.97
Adult males	196.73	269.35	29.55	25.58	131.05-309.94	212.79-354.43
Adult females	191.05	250.43	30.13	31.2	131.05-309.18	180-371

From Table 4B, at the upper abdomen, the range of values for AP distance was 76.95 to 309.94 8mm and Lateral distance was 139.45 to 371 mm from 0-5 age group to adult population.

6. 3. B. ii. At Level of the Iliac Crest – Level A2

As seen from Table 4C, at the level of the iliac crest, with increasing age there was an increase in both AP and lateral distances. The AP distances increased by 1.11 times from 0-5 year age group to 6-10 year age group. There was an increase by

1.14 times in the AP distance from 6-10 year age group to 11- 15 year age group. There was an increase by 1.04 times in the AP distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 0.99 times in the AP distance from the dimensions measured in females to males.

Also seen from Table 4C, the lateral distance increased by 1.18 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.21 times in the lateral distance from 6-10 year age group to 11-15 year age group. There was an increase by 1.07 times in the lateral distance from 11-15 year age group to 16-18 year age group. Among adults, there was an increase by 1.00 times in lateral distance from the dimensions measured in females to males.

From Table 4C, at the upper abdomen, the range of values for AP distance was 63.55 to 368.4 mm and Lateral distance was 77.65 to 427.5 mm from 0-5 age group to adult population.

Table 4C. Tomographic Measurements of CT Abdomen at Level A2

Level A2- At level of the Iliac Crest						
	Mean (mm)		SD		Range (mm)	
	AP*	Lat*	AP *	Lat*	AP*	Lat*
0-5 years	103.41	148.46	19.54	18.05	63.55-148.13	77.65-182.06
6-10 years	114.85	175.36	19.38	20.52	79.83-191.77	123.54-272.1
11-15 years	131.65	212.79	21.23	22.68	92.41-219.47	164.84-277.75
16-18 years	137.52	229.66	21.7	24.54	97.73-203.68	168.7-294.57
Adult males	180.72	267.03	34.03	34.75	99.57-284.49	126.36-361.89
Adult females	181.99	266.93	40.07	40.5	90.94-368.4	144.21-427.05

6.3. C. Effective Diameter

The effective diameter was obtained from the antero-posterior dimensions and lateral dimensions which were measured from tomographic images. The effective diameter calculated showed a steady rise from 0-5 age group children to 18 year age group children. The effective diameter was more for Adult males than Adult females. The results of effective diameter are tabulated in Table 4D.

Table 4D: Effective Diameter for CT Abdomen

Effective diameter for CT abdomen (mm)			
Level A1- At level of the Upper Abdomen			
	AP dimension (mm)	Lateral dimension(mm)	Effective Diameter (cm)
0-5 years	117.59	158.11	13.6
6-10 years	147.21	189.05	16.0
11-15 years	156.13	224.45	18.7
16-18 years	164.25	240.09	19.9
Adult Males	196.73	269.35	23.3
Adult Females	191.05	250.43	21.9
Level A2- At level of the Iliac Crest			
0-5 years	103.41	148.46	12.4
6-10 years	114.85	175.36	14.2
11-15 years	131.65	212.79	16.7
16-18 years	137.52	229.66	17.8
Adult Males	180.72	267.03	22.0
Adult Females	181.99	266.93	22.0

From Table 4D, effective diameter increased by 1.17 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.16 times in effective diameter from 6-10 year age group to 11-15 year age group. There was an increase by 1.06 times in effective diameter from 11-15 year age group to 16-18 year age group.

Among adults, there was an increase by 1.09 times in effective diameter from females to males.

At the level of the iliac crest, the effective diameter increased by 1.14 times from 0-5 year age group to 6-10 year age group. There was an increase by 1.17 times in effective diameter from 6-10 year age group to 11-15 year age group. There was an increase by 1.06 times in effective diameter from 11-15 year age group to 16-18 year age group. There was no increase in effective diameter between adult male and adult female.

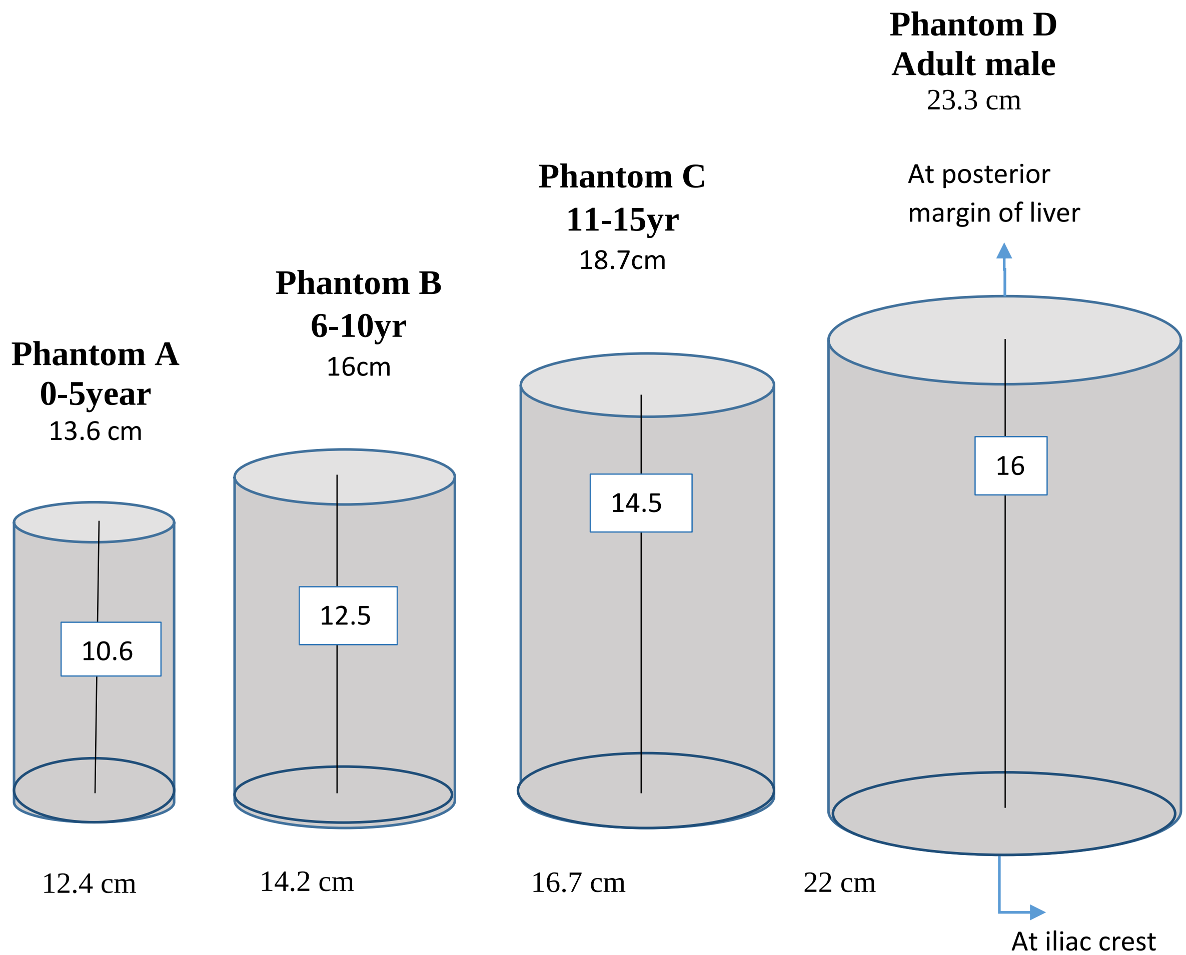

Figure 19. Effective Diameter (cm) and Scan Length (cm) for CT Abdomen Phantom

For example: For Phantom D adult male, 23.3 and 22 are effective diameters at the mentioned levels and 16 is the scan length

CHAPTER 7. DISCUSSION

The objective of the study was to estimate the anatomical dimensions of head, thorax and abdomen of the adult and pediatric Indian population from Computer Tomograms (CTs) of head, thorax and abdomen and generate age-specific and gender-specific reference values for dosimetric calculations in the adult and pediatric population in India for radiation protection purposes.

The current CT scanners used in India use measurements of the European population to make dosimetric calculations for radiation assuming the Indian population to have the same proportions and measurements. However, anthropological studies have described differences in body dimensions between racial groups, and hence, dimensions of body proportions of the average Indian in all likelihood will not be the same as that of the European population. It should also be noted that since the Indian population is diverse with different sub populations having varied body proportions, one reference value for an age group and gender may not be representative of the entire Indian population. The weight, height, BMI and waist circumference measurements of the subjects in this study were not available though they would have been useful.

Hence our objective was to specifically create an Indian Reference man, woman, and child, based on age groups of 0-5years, 6-10 years, 11-15 years, and 16-18 years.

The Standard Man was first described at the Chalk conference for Permissible Dose in 1950. A standard was needed, as the advent of radiological procedures needed a guideline to function appropriately. Ten years later, the concept of Standard Man needed to be updated, as new mechanical ways in the scanners were designed to deliver a specified radiation dose. This brought about an updated version of the Standard Man, details of which were published in ICRP Publication 22, 1960. With every update, were also changing protocols of radiation dose. Hence, there came a need to have a reference child, a reference woman, and a reference man. Anatomical distances and physiological parameters of the European population were studied in detail. Hence this population formed the standard dimensions for the reference man. The methodology they used to collect information on these variables was not explained clearly in these studies. They did however publish details of mass of various organs and physiological aspects of the body in relation to age (16).

The term reference man and woman has been dealt with in other clinical fields describing the calorie intake with relation to body proportions. This has helped to standardize health parameters such as appropriate weight for particular height measurements.

Our study will be useful to calculate radiation dose reference values based on effective dose for Indian population in the future.

This study has provided the reference scan length for head, thorax and abdomen along with antero-posterior, lateral distances and effective diameter for head, thorax and abdomen. With these three measurements, a phantom model of the various pediatric age groups, adult male and adult female for the Indian population can be created. This information can lead to the development of Indian phantom cylinders.

Our parameters were categorized in two sets of images, topographic and tomographic. A topographic image refers to a scout image which is very similar to an X-ray image AP view. By this measurement, we obtained the scan length of the individual. Similar measurements have been dealt with in NRPB 67. The NRPB 67 essentially dealt with the application of some clinical aspects by including CT scans of head with trauma, and CT scans of thorax done to rule out malignancy.

This study used CT scans done for various clinical conditions and so all the scans done were not done on healthy subjects. Some clinical conditions used as parameters for the study by NRPB 67 were diffuse lung disease, malignancy, lymphoma, head trauma, abdominal abscess. They mentioned that they included only average-sized patients, but have not disclosed details of the average-sized patient. Parameters such as weight and height of the patient were not mentioned. In NRPB 67, regions of the head and thorax were measured for both adults and children. The abdomen region was measured only for adults and not children. NRPB 67 divided the pediatric group into 0-1 years, 5 years, and 10 years.

In our study, we have classified the pediatric age group into 0-5 year, 6-10 years, 11-15 years and 16-18 years. We have provided the topographic and tomographic images for pediatric and adult population for head, thorax and abdomen.

India is a diverse country with a multi-racial population having varied physical build. Christian Medical College encounters patients from all over the country. So our approach to this issue was to measure these scans irrespective of their place of origin, and come to a conclusion as to what represents the average size of the Indian population. Table 5A, 5B and 5C reports the scan length of the Indian population and the European population.

Table.5A. Comparison of scan length between NRPB and our study

<table>
<tr><td colspan="4">Comparison of Scan length (mm) from Topographic Images between NRPB and our study- CT Brain</td></tr>
<tr><td>Age</td><td>Our study</td><td colspan="2">NRPB 67</td></tr>
<tr><td>0-1 years</td><td>104.12 (n=20)</td><td>101</td><td rowspan="3">n= 56, (not stratified according to age)</td></tr>
<tr><td>5 year</td><td>115.1 (n=20)</td><td>117</td></tr>
<tr><td>10year</td><td>123.02 (n=20)</td><td>124</td></tr>
<tr><td>Adults</td><td>135.89 (n=500)</td><td colspan="2">131 (n=476)</td></tr>
</table>

From the above table, for 0-1 age group, our study showed an increase by 1.03 times in scan length on comparing with results reported by NRPB 67. For the 5 year age group, scan length reported by NRPB 67 showed an increase by 1.01 times over our study results. For 10 year old age child, scan length reported by NRPB 67 showed an increase by 1.00 times over our study results. For adults, our study showed an increase by1.03 times in scan length on comparing with results reported by NRPB 67.

Table.5B. Comparison of scan length between NRPB and our study

Comparison of Scan length (mm) from Topographic Images between NRPB and our study- CT Thorax			
Age	Our study	NRPB	
0-1 year	123.75 (n=20)	156	(n=16), not stratified according to age)
5 year	172.41 (n=20)	186	
10 year	202.35 (n=20)	231	
Adults	237.01 (n=500)	247 (n=984)	

From the above table, for 0-1 age group, scan length reported by NRPB 67 showed an increase by1.26 times over our study results. For the 5 year age group, scan length reported by NRPB 67 showed an increase by 1.07 times over our study results. For 10 year old age group, scan length reported by NRPB 67 showed an increase by1.14 times over our study results. For adults, scan length reported by NRPB 67 showed an increase by 1.04 times over our study results.

Table.5C. Comparison of scan length between NRPB and our study

Comparison of Scan length (mm) from Topographic Images between NRPB and our study - CT Abdomen		
Adults	Our study	NRPB
Abdomen	156.02 (n=500)	290 (n=193)
Abdomen with pelvis	304.32 (n=500)	411 (n=239)

From the above table, scan length of adult abdomen reported by NRPB 67 showed an increase by 1.85 times over our study results. Scan length of adult abdomen and pelvis reported by NRPB 67 showed an increase by 1.35 times over our study results. NRPB 67 reviewed CT Abdomen scans for only adults and not children.

From scan length, variables like CTDI vol and DLP, which are required to calculate the radiation dose, can be calculated.

Tomographic Measurements:

Tomographic images refer to axial images, or rather, cross sectional images of that region. By measuring cross sections of images, we will be able to get antero-posterior and lateral distances of that individual. This will help us in calculating effective diameter of the individual. Effective diameter refers to a circle with the same area as the cross section of a patient. It is related to the diameter of that individual at that region.

It is calculated

Effective diameter= $\sqrt{\textbf{(Mean AP dimension x Mean lateral dimension)}}$**.**

AAPM 204 used various methods to collect antero-posterior and lateral diameters.

i. Physical measurements using anthropomorphic phantoms

Anthropomorphic torso phantoms of ranges of sizes from newborn to adult with lateral distances of 9 cm to 39 cm were used. To determine the diameter for different types of body like a rounder newborn, three additional phantoms were made by adding tissue equivalent material on top of the existing phantoms. These phantoms were scanned using various CT scanners. The scan length for an abdominal CT scan for each torso phantom was calculated based on clinical experience.

ii. Physical measurements using cylindrical phantoms

Toth and Strauss (TS) used X- ray attenuation, expressed in terms of a water equivalent diameter to describe patient size for the standard 15 cm long, 16 cm diameter and 32 cm diameter PMMA phantoms, and a 15 cm long, 10 cm diameter PMMA cylinder. The lateral distance of the patient was measured using electronic calipers.

iii. Monte Carlo measurements on Voxelised phantoms

A cohort of 8 voxelised patient models known as GSF models were used to represent a range of sizes from newborn to large adult that included males and females. Simulated abdominal CT exams were performed for all patient models on each scanner model. The scan length obtained was proportional to the scan length typical for each body size simulated and this ranged from 15 cm to 33cm. To obtain tomographic measurements, the outer perimeter of each patient was measured at the central slice of the abdominal scan region.

iv. Monte Carlo measurements on simple cylindrical phantoms

Zhou and Boone used cylinders of different compositions like water, PMMA, polyethylene ranging from diameter 1cm to 50 cm in 22 increments and an average scan length of 100 mm was used. These measurements were then used for radiation dosimetric calculations.

In general, the methods described above were used to construct a reference phantom. From this phantom they calculated topographic and tomographic measurements, which were then used to calculate the radiation dose.

After collecting the required tomographic images, we obtained an effective diameter for various pediatric age groups and adult males and adult females.

This technique of using tomographic images is fairly easy and cost effective, compared to the methods employed by AAPM 204 and NRPB.

From the sum of AP and lateral distances at various regions measured, we calculated the effective diameter and compared the effective diameter from our study to the effective diameter reported by AAPM 204.

AAPM 204 does not report effective diameter according to age but according to the sum of AP and lateral diameter. The effective diameter reported by AAPM 204 was not compared to age group. The effective diameters of our study and AAPM 204 are tabulated in Table 4B.Column A represents the sum of antero-posterior and lateral distances in cm. Column B reports the corresponding effective diameter for the corresponding sum of -antero posterior and lateral distances. Column C is the effective diameter reported by AAPM 204 for the corresponding value in column A.

For example:

Column A value **28** is the rounded sum of 11.7 (AP) and 15.8 (Lateral) [obtained from the tomographic measurement from this study]. Column B value **13.6** is calculated from the formula of effective diameter and it corresponds to the same dimensions of Column A (antero-posterior and lateral distances). Column C is the AAPM 204 reported value **13.7** for the rounded sum value of 28.

Table 5D. Comparison of effective diameter between AAPM 204 and our study

A	B	C
AP + Lateral (cm)	Our study Effective diameter (cm)	AAPM 204 Effective diameter (cm)
24	12	11.7
25	12.4	12.2
28	13.6	13.7
28	14	13.7
28	14.2	13.7
29	13.3	14.2
29	14.2	14.2
30	14.4	14.7
30	14.7	14.7
30	14.8	14.7
30	15.1	14.7
32	15.8	15.7
32	16	15.7
34	16.7	16.7
35	16.9	17.2
36	17.9	17.6
37	17.7	18.1
37	17.8	18.1
38	18.7	18.6

A	B	C
AP + Lateral (cm)	Our study Effective diameter (cm)	AAPM 204 Effective diameter (cm)
40	19.9	19.6
42	19.3	20.6
44	21.5	21.6
44	21.9	21.6
45	21.8	21.8
48	23.7	23.6
50	24.1	24.6
52	24.3	25.6
54	25.9	26.6
54	26.4	26.6

The results shown in Table 5D on the effective diameter have minimal deviations, and which were mostly within 4% compared to the AAPM 204 report. Hence the method reported in this project is reasonable to develop specified phantoms based on the effective diameter.

CT Brain

Table 5E. CT Brain- Comparison between Pediatric and Adult Topographic and Tomographic Images

Landmarks	Pediatric n=340 Mean (mm)±SD	Adult n=500 Mean (mm) SD	P value
Scan Length of CT Brain- Bv	123.41±24.6	135.89±12.5	<0.001
Level at eyeball- Antero Posterior distance	148.47±15.48	173.17±11.96	<0.001
Level at eyeball- Lateral distance	122.47±14.11	136.40±10.55	<0.001
Level at lateral ventricle – Antero posterior distance	160.5± 12.98	172.16± 8.47	<0.001
Level at lateral ventricle- Lateral distance	135.81±8.68	138.21±7.36	<0.001

As seen from Table 5E, there was a significant difference in the measurements between children and adult. The scan length increased by 1.10 times from children to adults. The AP distance increased from children to adults by 1.16 times and by 1.07 times at the level of eyeball and at the level of lateral ventricle, respectively. The lateral distance increased from children to adults by 1.11 times and by 1.01 times at the level of eyeball and at the level of lateral ventricle, respectively. With increasing age, the growth of the brain increases more in the AP direction than lateral direction.

CT Thorax:

Table 5F: CT Thorax- Comparison between Children and Adults

CT Thorax- Comparison between Children and Adults			
	Children n=340 Mean (mm) ± SD	Adults n=500 Mean (mm) ± SD	P value
Scan length of CT Thorax - Tv	197.93± 47.03	237.01± 23.98	<0.001
Level of upper thorax- AP distance	111.6± 27.42	162.86± 24.59	<0.001
Level of carina of trachea- AP distance	145.81± 32.63	202.13± 23.44	<0.001
Level of base of lung- AP distance	160.63± 31.61	215.32± 24.54	<0.001
Level of upper thorax- Lateral distance	266.84± 61.97	354.89± 35.81	<0.001
Level of carina of trachea- Lateral distance	253.62± 59.39	342.65± 34.18	<0.001
Level of base of lung- Lateral distance	230.99± 51.06	308.75± 35.46	<0.001

As seen from Table 5F, there was a significant difference in the measurements between children and adults (P=0.001). The scan length increased by 1.19 times from children to adults. The AP distance increased from children to adults by 1.45

times, 1.38 times and 1.34 times at the level of upper part of lung, the carina of trachea and at the base of lung, respectively. The lateral distance increased from children to adults by 1.32 times, 1.35 times, 1.33 times at the level of the upper part of lung, the carina of trachea and the base of lung, respectively. With increasing age, the AP direction progressively increases at levels from upper thorax to base of lung. The lateral direction progressively decreases at levels from upper thorax to base of lung. The section at upper thorax included the upper aspect of both upper limbs which explains the increased lateral distance at upper thorax. (Refer Figure 5). This will be useful in fabricating a phantom for thorax region which includes the entire area of trunk.

CT ABDOMEN:

Table 5G: CT Abdomen – Comparison of Topographic and Tomographic Images between Children and Adult

Comparison between children and adults			
	Children n=340 Mean (mm)± SD	Adult n=500 Mean (mm) ± (SD)	p value
Scan length of abdomen	130.95± 28.4	156.02± 23.75	<0.001
Scan length of abdomen and pelvis	250.5± 54.4	304.32± 26.72	<0.001
Level at upper abdomen-AP distance	142.18± 24.65	196.32± 30.60	<0.001
Level at iliac crest- AP distance	121± 24.04	181.35± 37.14	<0.001
Level at upper abdomen-Lateral distance	200.97± 37.37	259.87± 30.03	<0.001
Level at iliac crest - Lateral distance	189.4± 36.83	266.97± 37.70	<0.001

As seen from Table 5G, there was a significant difference in the measurements between children and adults (p=0.001). From children to adults, the scan length of abdomen and abdomen and pelvis increased by 1.19 times and 1.21 times respectively. The AP distance, from children to adults increased by 1.38 times and 1.49 times at the level of upper abdomen and the level of iliac crest, respectively. The lateral distance, from children to adults increased by 1.29 times and 1.4 times at the level of the upper abdomen and level of iliac crest, respectively. With increasing age, the abdomen is wider at the level of upper abdomen when compared to level at iliac crest in the AP direction. In the lateral direction, the abdomen initially decreases from upper abdomen to iliac crest and after 18 years of age, the abdomen width appears to be relatively wider at the iliac crest when compared to upper abdomen.

Scope of the study

The calculation of CTDI vol and DLP for our scanners is dependent on the topographic and tomographic values. Currently, the present phantoms for CT scanners measure 16 cm and 32 cm. A 16 cm phantom is used for pediatric CT scans and for adult CT Brain. A 32 cm phantom is used for adult CT Thorax and Adult CT Abdomen. For a CT Brain investigation of a 6 year old child, routinely the 16 cm phantom model is used. From this study, we have obtained the effective diameter of the CT Brain of 0-5 age group to 16-18 age group, which was in the range of 12-14.8 cm at the level of eyeball and 14-15.4 cm at the level of lateral ventricle. Similarly, we have obtained the effective diameter of the CT Thorax of 0-5 age group to 16-18 age group, which was in the range of 13.3- 21.4 cm at the level of upper thorax, 14.4 24.1 cm at the level of carina of trachea, and 14.8-23.7 cm at the level of base of lung.

We have also obtained the effective diameter of CT abdomen of 0-5 age group to 16-18 age group which was in the range of 13.6-19.9 cm at the level of upper abdomen and 12.4-17.8 cm at the level of iliac crest.

Using this data, phantoms can be constructed objectively keeping in mind that the dimensions of pediatric population do vary with increasing age and the use of the same 16 cm phantom for an investigation like CT Brain for all pediatric population will expose the patient to risks of radiation overdose.

This data shows the need for age specific reference values for construction of CT phantoms. There were statistically significant differences among the measurements of various regions of brain, thorax and abdomen from 0-5 age groups till adults.

CHAPTER 8. LIMITATIONS OF THE STUDY

1. The present retrospective study has included CT scans for patients who had undergone CT scans for various clinical reasons, and so these are not CTs of healthy individuals.

2. We did not classify the scans into those of thin built, medium built or heavily built individuals because we needed an overview to see the range of examined individuals.

3. We proposed to complete 20 scans for every month of age for the first year of life. On attempting to measure this, we noted that there were many cases of hydrocephalus with dilated ventricles or head trauma. These were not included in the study as it would give a falsely high value and will not predict the average head dimensions.

CHAPTER 9. CONCLUSIONS

This study has shown the scan lengths and the antero-posterior and lateral anatomical dimensions of brain, thorax and abdomen for the Indian population using computed tomography. This information is useful for the radiological community to relate scan lengths and tomographic dimensions to reconstruct a patient specific phantom meant for estimating radiation dose imparted to patients from CT scanners. Anatomical dimensions for Indian adults and children have been measured from Computed Topograms in this study, and two important parameters which were scan length and effective diameter at specified levels of the CT of Brain, Thorax and Abdomen were obtained. Using this data, phantoms can be constructed objectively keeping in mind that dimensions of pediatric population do vary with increasing age and also vary with gender. This study justifies the need for age specific reference values for construction of CT phantoms as there is a statistically significant difference among the various regions of Brain, thorax and abdomen from 0-5 age group till adults.

Reference phantom models based on CT of brain, thorax and abdomen of children and adults of the Indian population were constructed. This was done using effective diameter and scan length as shown in Figure 13, 16, 19.

There are differences in anatomy between the Indian population and the European population as studied by NRPB 67. The results on the effective diameter have minimal deviations which is mostly within 4% compared to the AAPM 204 report. Hence the method reported in this project is reasonable to develop specified phantoms based on the effective diameter.

For CT Brain, it was observed that with increasing age, the growth of the brain increases more in the AP direction than lateral direction. For CT thorax, it was observed that with increasing age, while the AP direction progressively increases at levels from upper thorax to base of lung while the lateral direction progressively decreases at levels from upper thorax to base of lung. The section at upper thorax included the upper aspect of both upper limbs which explains the increased lateral distance at upper thorax. This will be useful in fabricating a phantom for thorax region which includes the entire area of trunk. For CT Abdomen, it was observed that with increasing age, the abdomen was wider at the level of upper abdomen when compared to level at iliac crest in the AP direction. In the lateral direction, the abdomen initially decreases from upper abdomen to iliac crest and after 18 years of age, the abdomen width appears to be wider at the iliac crest when compared to upper abdomen.

The method used to collect these anatomical dimensions is easy, simple and reproducible when compared to methods adopted by AAPM 204.

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CHAPTER 11. ANNEXURES

OFFICE OF RESEARCH
INSTITUTIONAL REVIEW BOARD (IRB)
CHRISTIAN MEDICAL COLLEGE, VELLORE, INDIA

Dr. B.J. Prashantham, M.A., M.A., Dr. Min (Clinical)
Director, Christian Counseling Center,
Chairperson, Ethics Committee.

Dr. Alfred Job Daniel, D Ortho MS Ortho DNB Ortho.
Chairperson, Research Committee & Principal

Dr. Biju George, MBBS., MD., DM
Deputy Chairperson,
Secretary, Ethics Committee, IRB
Additional Vice-Principal (Research)

March 19, 2016

Dr Vandana Nathan,
PG Registrar,
Department of Department of Anatomy,
Christian Medical College,
Vellore 632 004.

Sub: **Fluid Research grant project NEW PROPOSAL:**
Estimation of regional anatomical dimensions of the adult and pediatric Indian population from Computed Tomography to generate reference values for radiation dosimetric calculations.
Dr. Vandana Nathan (Employment Number: 21215), PG Registrar, Anatomy, Dr. Sunil Holla (Employment Number: 10732), Anatomy; Dr. Ivan James Prithishkumar (Employment No.: 283950,) Anatomy Dr. Roshan Livingstone (Employment number: 30596), Radiology Dr. Shyamkumar NK, Radiology, Dr. Aparna Shyam, Radiology, Dr. Hannah K, Radiology, Dr. Antoniswamy, Biostatistics

Ref: IRB Min No: 9720 [OBSERVE] dated 10.11.2015

Dear Dr Vandana Nathan.

I enclose the following documents:-

1. Institutional Review Board approval 2. Agreement

Could you please sign the agreement and send it to Dr. Biju George, Addl. Vice Principal (Research), so that the grant money can be released.

With best wishes,

Dr. Biju George
Secretary (Ethics Committee)
Institutional Review Board

Dr. BIJU GEORGE
MBBS., MD., DM.
SECRETARY - (ETHICS COMMITTEE)
Institutional Review Board,
Christian Medical College, Vellore - 632 002.

Cc: Dr. Sunil Holla, Dept. of Anatomy, CMC

1 of 4

Ethics Committee Blue, Office of Research, 1st Floor, Carman Block, Christian Medical College, Vellore, Tamil Nadu 632 002
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Dr. B.J. Prashantham, M.A., M.A., Dr. Min (Clinical)
Director, Christian Counseling Center,
Chairperson, Ethics Committee.

Dr. Alfred Job Daniel, D Ortho MS Ortho DNB Ortho.
Chairperson, Research Committee & Principal

Dr. Biju George, MBBS., MD., DM
Deputy Chairperson,
Secretary, Ethics Committee, IRB
Additional Vice-Principal (Research)

March 19, 2016

Dr Vandana Nathan,
PG Registrar,
Department of Department of Anatomy,
Christian Medical College,
Vellore 632 004.

Sub: **Fluid Research grant project NEW PROPOSAL:**
Estimation of regional anatomical dimensions of the adult and pediatric Indian population from Computed Tomography to generate reference values for radiation dosimetric calculations.
Dr. Vandana Nathan (Employment Number: 21215), PG Registrar, Anatomy, Dr. Sunil Holla (Employment Number: 10732), Anatomy; Dr. Ivan James Prithishkumar (Employment No.: 283950,) Anatomy Dr. Roshan Livingstone (Employment number: 30596), Radiology Dr. Shyamkumar NK, Radiology, Dr. Aparna Shyam, Radiology, Dr. Hannah K, Radiology, Dr. Antoniswamy, Biostatistics

Ref: IRB Min No: 9720 [OBSERVE] dated 10.11.2015

Dear Dr Vandana Nathan

The Institutional Review Board (**Blue**, Research and Ethics Committee) of the Christian Medical College, Vellore, reviewed and discussed your project titled "Estimation of regional anatomical dimensions of the adult and pediatric Indian population from Computed Tomography to generate reference values for radiation dosimetric calculations" on November 10th 2015.

The Committee reviewed the following documents:

1. IRB Application format
2. Proforma
3. Cvs of Drs. Aparna Shyam, Shyamkumar NK, Hannah K, Ivan James Prithishkumar, Sunil Holla, Roshan Livingstone, Vandana Nathan, Antoniswamy
4. No. of documents 1 - 3

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The following Institutional Review Board (Blue, Research & Ethics Committee) members were present at the meeting held on November 10th 2015 in the CREST/SACN Conference Room, Christian Medical College, Bagayam, Vellore 632002.

Name	Qualification	Designation	Affiliation
Dr. Nihal Thomas	MD, MNAMS, DNB(Endo), FRACP (Endo) FRCP(Edin) FRCP (Glasg)	Professor & Head, Endocrinology. Additional Vice Principal (Research), Deputy Chairperson(Research Chairperson), Member Secretary (Ethics Committee), IRB. CMC, Vellore	Internal, Clinician
Dr. Vivek Mathew	MD (Gen. Med.) DM (Neuro) Dip. NB (Neuro)	Professor, Neurology, CMC, Vellore	Internal, Clinician
Dr. Mathew Joseph	MBBS, MCH	Professor, Neurosurgery, CMC, Vellore	Internal, Clinician
Dr. Chandrasingh	MS, MCH, DMB	Professor, Urology, CMC, Vellore	Internal, Clinician
Dr. Balamugesh	MBBS, MD(Int Med), DM, FCCP (USA)	Professor, Pulmonary Medicine, CMC, Vellore	Internal, Clinician
Rev. Joseph Devaraj	BSc, BD	Chaplaincy Department, CMC, Vellore	Internal, Social Scientist
Dr. Rajesh Kannangai	MD, PhD.	Professor, Clinical Virology, CMC, Vellore	Internal, Clinician
Dr. Niranjan Thomas	DCH, MD, DNB (Paediatrics)	Professor, Neonatology, CMC, Vellore	Internal, Clinician
Dr. Inian Samarasam	MS, FRCS, FRACS	Professor, Surgery, CMC, Vellore	Internal, Clinician
Dr. B. J. Prashantham	MA(Counseling Psychology), MA(Theology), Dr. Min(Clinical Counselling)	Chairperson, Ethics Committee, IRB. Director, Christian Counseling Centre, Vellore	External, Social Scientist

Dr. B.J. Prashantham, M.A., M.A., Dr. Min (Clinical)
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Deputy Chairperson,
Secretary, Ethics Committee, IRB
Additional Vice-Principal (Research)

Dr. Ratna Prabha	MBBS, MD	Associate Professor, Clinical Pharmacology CMC, Vellore	Internal, Pharmacologist
Dr. Jayaprakash Muliyil	BSc, MBBS, MD, MPH, Dr PH (Epid), DMHC	Retired Professor, CMC, Vellore	External, Scientist &Epidem
Mrs. Emily Daniel	MSc Nursing	Professor, Medical Surgical Nursing, CMC, Vellore	Internal, Nurse
Ms. Grace Rebecca	MSc (Biostatistics)	Lecturer, Biostatistics, CMC, Vellore	Internal, Statistician
Mr. C. Sampath	BSc, BL	Advocate, Vellore	External, Legal Expert
Dr. Anuradha Rose	MBBS, MD, MHSC (Bioethics)	Associate Professor, Community Health, CMC, Vellore	Internal, Clinician

We approve the project to be conducted as presented.

Kindly provide the total number of patients enrolled in your study and the total number of withdrawals for the study entitled: "Estimation of regional anatomical dimensions of the adult and pediatric Indian population from Computed Tomography to generate reference values for radiation dosimetric calculations" on a monthly basis. Please send copies of this to the Research Office (research@cmcvellore.ac.in)

Fluid Grant Allocation:

A sum of 12,000/- INR (Rupees Twelve thousand only) will be granted for 24 months

Yours sincerely

Dr. Biju George
Secretary (Ethics Committee)
Institutional Review Board

Dr. BIJU GEORGE
MBBS., MD., DM.
SECRETARY - (ETHICS COMMITTEE)
Institutional Review Board,
Christian Medical College, Vellore - 632 002.

IRB Min No: 9720 [OBSERVE] dated 10.11.2015

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Proforma:

CT Brain

Name	Hospital No.	Date of birth	Date of study	Gender	Address	Region	Scan length	Eyeball		Lateral ventricle	
						Brain		AP	Lateral	AP	Lateral

CT Thorax

Na me	Hospital No.	Date of birth	Date of study	Gender	Address	Region	Scan length	Upper thorax		Carina of trachea		Base of lung	
						Thorax		AP	Lateral	AP	Lateral	AP	Lateral

CT Abdomen

Name	Hospital No.	Date of birth	Date of study	Gender	Address	Region	Scan length (Av1)	Scan length (Av2)	Upper abdomen		Iliac crest	
						Abdomen			AP	Lateral	AP	Lateral