Estimation of dose reference levels in computed tomography for select procedures in Kerala, India

Sir,

The authors in their earlier article[1] had estimated tentatively the diagnostic reference levels (DRL) as the third quartile values of weighted computed tomography dose index ($CTDI_w$), volumetric CTDI ($CTDI_v$), and dose length product (DLP); after a detailed survey of the distribution of dose received by patients during diagnosis using CT scanners located in Puducherry region of South India. The procedure and details of dosimetry using standard head and body phantoms and pencil ionization chamber were fully discussed in that article. The present work is a logical extension of the earlier study, conducted for the Kerala region and was undertaken as part of the establishment and consolidation of DRL values for the southern zone of India, comprising the states of Tamil Nadu,[2] Puducherry, Kerala, Karnataka, and Andhra Pradesh. The importance of establishment of regional DRL values can be gauged from the fact that in advanced countries like US, the mean dose and dose range received by patients in CT examinations has diminished considerably in subsequent years.[3]

The 16 CT scanners that have been used for the current study are spread over eight major cities out of 13. Table 1 summarizes the make and model of the CT scanner used for this study.

From each machine the data which includes patient's physical parameter and routine scanning parameters were collected for 50 head, 50 chest, and 50 abdomen procedures (a total of 150 × 16 = 2,400 procedures) performed over a period of 1 year (2013). The data abstraction has been done as per 'Nationwide Evaluation of X-ray Trends' (NEXT) protocol.[4]

In each category of machine (i.e., A, B, C, and D) the lowest, highest, and mean operating parameters are presented in Table 2.

Before carrying out the regional dose estimation, complete QA (electrical, mechanical, and radiation checks) were performed for all the machines involved in this work. One among these tests was the measurement of $CTDI_w$ for standard protocol involving tube potential of 80, 100, and 120 kV, tube current-time product of 100 mA and 5 mm slice thickness. These values were compared with the $CTDI_w$ displayed in the console to ensure that the radiation output from the machines were satisfactory.

The CT dose indices were measured based on the five-point method proposed by European guidelines.[5] Though the patient data abstraction has been done for 50 head, 50 chest, and 50 abdomen procedures per machine, the phantom study was carried out only for 20 head, 20 chest, and 20 abdomen procedures for each machine (total measurements 60 × 16 = 960). These 20 scan parameters per procedure per machine were selected by omitting the repetitions.

As detailed in the earlier article, the CTDI as defined below:

$CTDI = [1/nT] \int D_z\, dz$ (integration limits from −50 mm to +50 mm) → (1) was measured exactly by the pencil chamber-electrometer system and displayed on the dosimeter unit. CTDI is defined for a single complete rotation of the CT scanner. In the equation above, n is the number of data channels in the multiscan CT scanner, T is the slice thickness corresponding to one channel, and the integration is done over the length of the pencil chamber (100 mm). In our particular case nT = 5 mm (the slice thickness selected). The $CTDI_w$ was measured based on the five-point method proposed in European guidelines[5] and the other quantities, $CTDI_v$, and DLP have been defined earlier similarly.[1]

The 75th percentile of $CTDI_v$ and DLP for head, chest, and abdomen procedures, thus calculated was taken as their respective third quartile value and finally they have been compared with the standard reference.[6,7]

Table 1: Details of computed tomography scanners

Make	*Slice*	*Model*	*No. of scanners*	*Denoted as*
Siemens	6	Somatom	2	B1, B2
	16	Somatom emotion	3	C1, C2, C3
	64	Somatom sensation	3	D1, D2, D3
General electric	16	Brivo and lightspeed	1 and 2	C4 and C5, C6
	64	Highspeed VCT	1	D4
Toshiba	1	Asteion	1	A1
	6	Asteion	1	B3
Philips	1	Secura	1	A2
	16	Brilliance	1	C7

VCT: Volume computed tomography

The $CTDI_{100,\ c}$ and $CTDI_{100,}$ *P* was measured for the different tube voltage and tube current time product used for the respective CT scanners for the selected procedure. Using these values; $CTDI_w$, $CTDI_v$, and DLP were calculated. In each group of machine (i.e., A, B, C, and D) the lowest, highest, and mean $CTDI_v$ and DLP is presented in Table 3.

The measured $CTDI_v$ and DLP were compared with the $CTDI_v$ and DLP obtained from the control console and is presented in Figures 1 and 2.

From Figures 1 and 2, it can be noted that the percentage difference between the measured and console $CTDI_v$ and DLP for the head, chest, and abdomen procedure lies within the acceptable limits (expected ±20% and maximum ±40%) recommended by Atomic Energy Regulatory Board (AERB),[8] which is based on International Commission on Radiological Protection (ICRP) standards. This confirms that the CT scanner has delivered the optimized radiation dose to the patients. However, it can also be observed from Figures 1and 2 that the $CTDI_v$ and DLP for chest and abdomen procedures and the percentage difference between the measured and console $CTDI_v$ for certain machines is above ±20%. This may be ascribed to deviations from routine scan parameters viz. pitch, field of measurements, beam shaping filter, kV, slice thickness, slice collimation, acquisition, tube rotation, exposure time per rotation, scan mode, angular tube current modulation, longitudinal tube current modulation, and couch increment; and hence it is suggested that such CT scanners should undergo periodical quality assurance (QA).[9] If these routine scan parameters for chest and abdomen procedures are optimized, then the dose indices could be brought down within the limits recommended by AERB, and this would lead to a good scan practice.

The 75th percentile point of the $CTDI_v$ and DLP distributions was calculated as the respective DRLs. The mean, range, and third quartile values are tabulated in Table 4. The DRL thus calculated for Kerala region has been compared with DRL proposed by European Commission (EC)[6,7] as they were the pioneers in this kind of study.

The data presented in Table 4 indicates that the DRL estimated for $CTDI_v$ for the CT scanners operating in Kerala is lower than the ones set by EC because average European adult patient size (density of the scan region) is more compared to Indian patients and hence the machine operating parameters used by the scanners operating in those countries are on the higher side. However, the DRL for DLP [Table 5] indicates that the value is higher when compared to ECs DRL. This may be attributed to longer scan length set for these machines. The radiographer has to customize it depending on the

Table 2: Lowest, highest, and mean of the operating parameters

Type of machine	*Head*				*Chest*				*Abdomen*			
	Tube potential (kV)	*Tube current time product (mAs)*	*Scan length (cm)*	*Pitch*	*Tube potential (kV)*	*Tube current time product (mAs)*	*Scan length (cm)*	*Pitch*	*Tube potential (kV)*	*Tube current time product (mAs)*	*Scan length (cm)*	*Pitch*
A1, A2	130, 130	320, 360, 340	25, 26, 26	1.0	120, 130, 125	260, 300, 280	30, 30	1.0	120, 130, 125	280, 320, 300	45, 50, 48	1.0
B1-B3	120, 130, 123	200, 280, 246	22, 28, 26	0.9, 1.1, 0.9	120, 120	140, 220, 186	30, 40, 35	1.0, 1.6, 1.3	120, 120	180, 240, 213	50, 55, 53	1.0, 1.5, 1.2
C1-C7	120, 130, 124	180, 260, 227	26, 30, 28	0.7, 1.3, 1.0	110, 130, 118	90, 200, 162	30, 40, 34	1.0, 1.8, 1.4	110, 130, 118	95, 260, 182	38, 50, 43	1.0, 1.6, 1.2
D1-D4	120, 130, 123	200, 310, 258	25, 30, 29	0.6, 1.2, 0.8	110, 120, 118	95, 240, 167	30, 40, 36	1.1, 1.6, 1.3	110, 120, 118	110, 260, 193	40, 50, 48	1.0, 1.5, 1.2

indications and it must be always controlled to the region of interest to avoid unnecessary radiation dose to the patients. It is important that the DRL has to be brought below the ECs DRL value at least in the following years, which can be achieved by choosing optimal scan length in accordance with various clinical indications. As far as chest and abdomen scans are concerned, acceptable scan parameters have been used.

If all the radiological departments that are operating the CT scanners in Kerala try to maintain $CTDI_v$ and DLP lower than the one proposed as DRL, of course without compromising the image quality, it is sure that in the subsequent years, the dose distributions for the three procedures would narrow down and a more refined DRL could be achieved as obtained in other countries.[3] This practice will surely ensure the optimal dose received by the patients, thus preventing them from receiving unnecessary radiation dose. This practice would also promote safety awareness among the radiographers.

Table 3: Lowest, highest, and mean $CTDI_v$ and DLP

Type of machine	*Lowest, highest, mean $CTDI_v$ and DLP*					
	Head		*Chest*		*Abdomen*	
	$CTDI_v$ (mGy)	*DLP (mGy.cm)*	*$CTDI_v$ (mGy)*	*DLP (mGy.cm)*	*$CTDI_v$ (mGy)*	*DLP (mGy.cm)*
A1, A2	60.41, 62.39, 61.4	1510, 1622, 1566	1.86, 2.64, 2.2	55, 79, 67	3.48, 3.92, 3.7	174, 176, 175
B1-B3	47.46, 50.23, 49.10	1091.86, 1406.44, 1275.72	3.01, 4.84, 3.95	105.35, 160.8, 137.11	5.04, 6.91, 6.02	370.15, 389.5, 378
C1-C7	37.81, 44.68, 41.11	1075.8, 1368.3, 1155.89	4.04, 7.03, 5.06	121.2, 210.9, 169.2	6.07, 10.32, 7.94	280, 459.5, 341
D1-D4	35.53, 43.81, 39.6	1002, 1314, 1138	4.39, 7.10, 5.6	175, 337, 236	5.79, 12.14, 8.6	289, 493, 401

$CTDI_v$: Volumetric computed tomography dose index, DLP: Dose length product

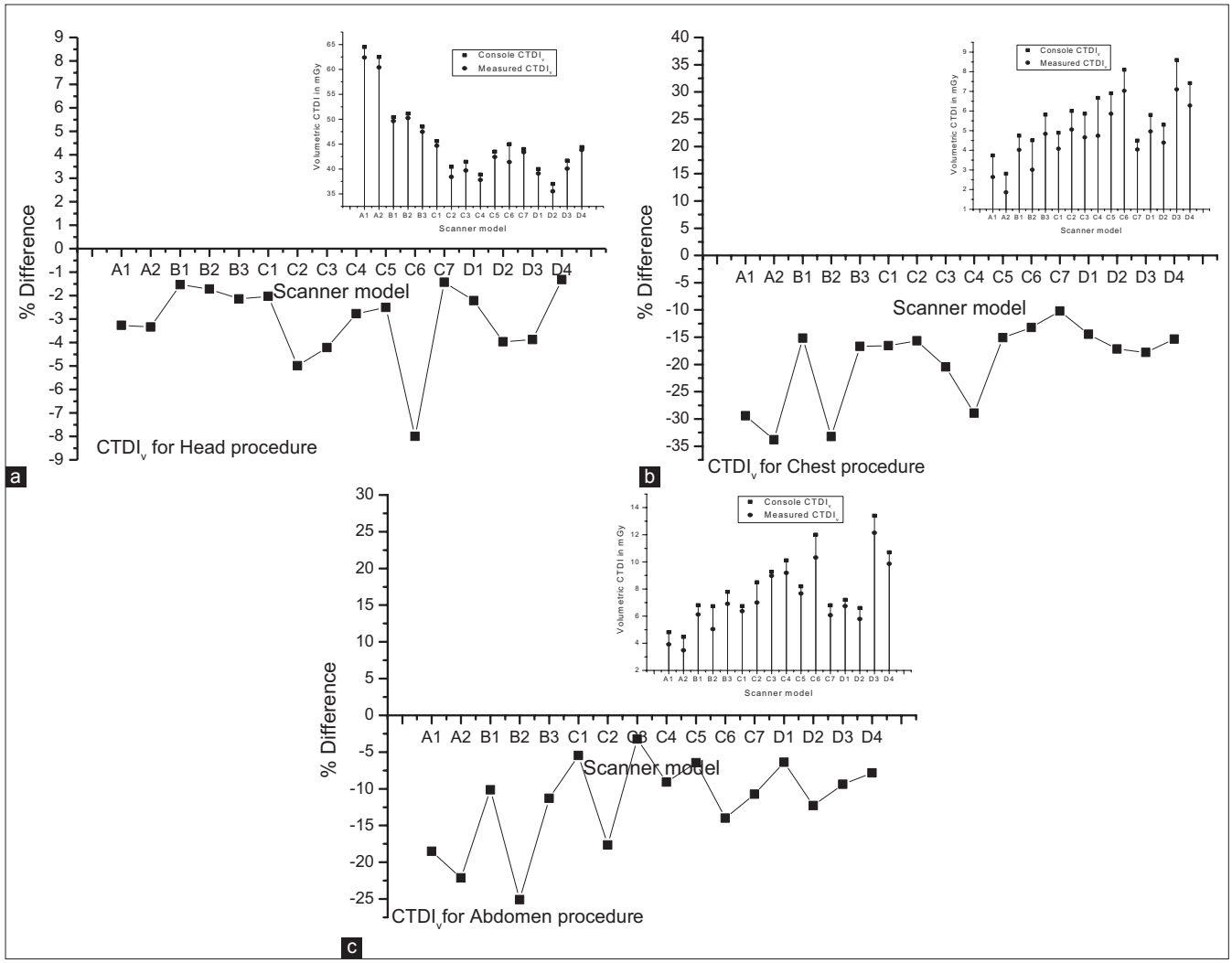

Figure 1: Percentage difference between console and measured CTDIv for (a) head, (b) chest, and (c) abdomen procedures. CTDIv = Volumetric computed tomography dose index

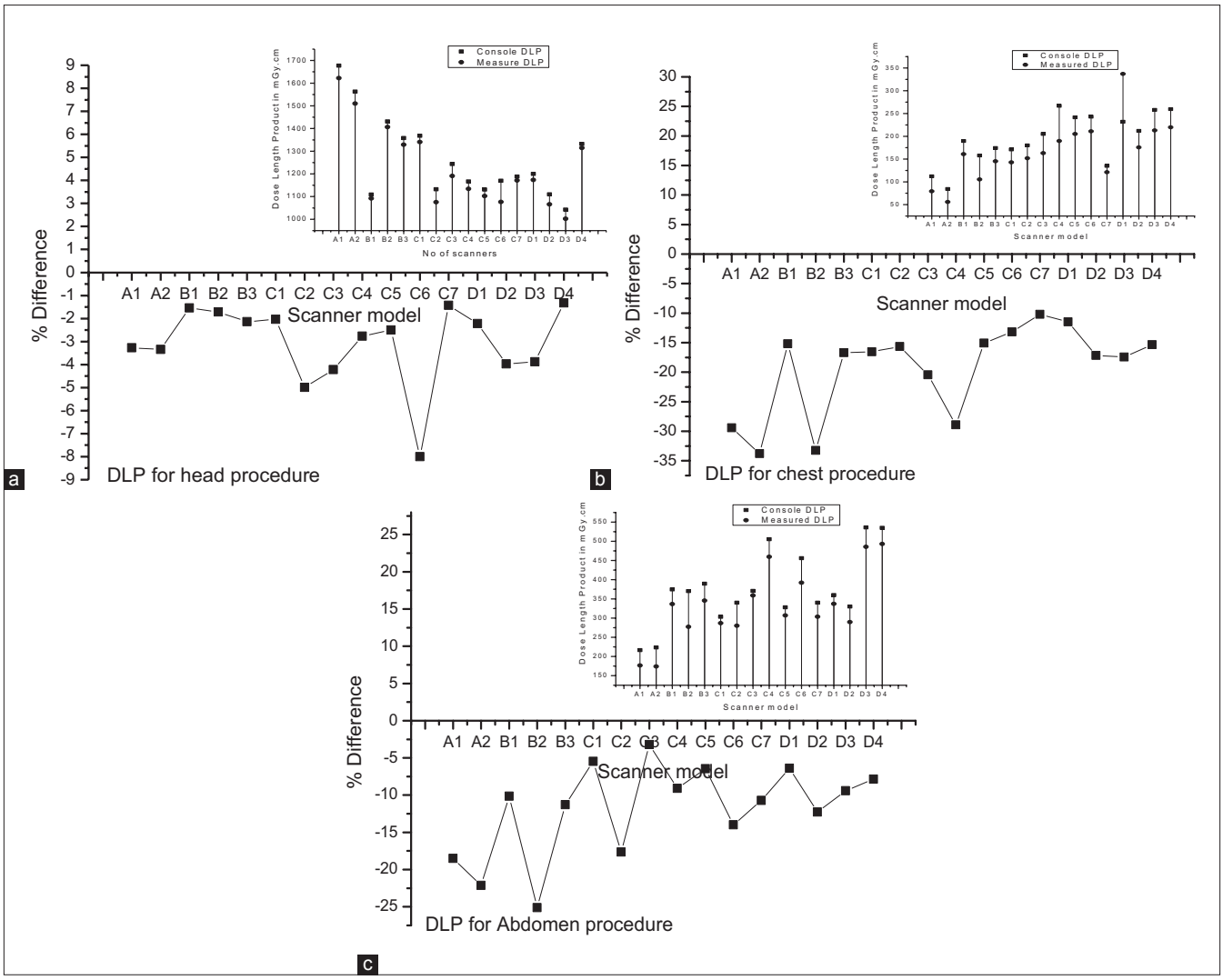

Figure 2: Percentage difference between console and measured DLP for (a) head, (b) chest, and (c) abdomen procedures. DLP = Dose length product

Table 4: Mean, range, and third quartile values for volumetric CTDI for select procedures

Study region	*Volumetric CTDI (mGy)*			
	Mean and range	*Third quartile value*	*EC 1999[6] and 2004[7]*	*Puducherry 2013[1]*
Head	43 (27)	49	60	32
Chest	5 (5)	7	35	12
Abdomen	7 (9)	9	35[7]	16

[7]Revised value, CTDI: Computed tomography dose index

Table 5: Mean, range, and third quartile values for DLP for select procedures

Study region	*DLP (mGy.cm)*				
	*Mean and range**	*Third quartile value*	*EC 1999[6] and 2004[7]*	*Tamil Nadu* 2011[2]*	*Puducherry 2013[1]*
Head	1172 (620)	1338	1050	-	925
Chest	162 (164)	209	900	557	456
Abdomen	322 (319)	383	900[7]	521	482

*$CTDI_v$ value is not available, [7]revised value. DLP: Dose length product, EC: European commission

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DOI: 10.4103/0971-6203.158701