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Influence of Body Mass Index and Abdominal Circumference on Radiation Dose During Abdominopelvic Computed Tomography

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Contrast-enhanced examinations of the abdomen region have a greater radiation exposure due to the multiphase abdominal computed tomography (CT) protocols. The use of automatic tube current modulation is known to reduce radiation dose and maintain or improve image quality for abdominal CT. However, using automatic tube current modulation can increase radiation dose for individuals with a larger body habitus. The study aimed to assess the influence of body mass index and abdominal circumference on the effective dose for routinely performed contrast-enhanced abdomen and pelvis scans. A total of 160 subjects referred for routine CT abdomen and pelvis were included in the study and categorised into three groups according to their body mass index (BMI) [underweight: <18.5 kg/m2, normal: 18.5-24.9 kg/m2, overweight: 25-29.9 kg/m2 and obese: (=30 kg/m2]. All the scans were performed on a 128 MDCT scanner by Philips. The effective dose was calculated from the dose length product using region-specific conversion factors. The effective dose was found to be 21.47 ± 2 mSv for the underweight group, 22.75± 2.3 mSv for the normal group, 25.02 ± 2.8 for the overweight group, and 29.7 ± 6.7 mSv for the obese group. The study reported a 32.39 % increase in effective dose for obese patients. The study also reported a significant increase in effective dose as BMI and abdominal circumference increased.

Keywords: Abdominopelvic Scans; Computed Tomography; Effective Dose.

Computed tomography is an essential imaging modality that produces tomographic images of specific areas to diagnose various pathologies. In the US, it is estimated that around 62 million CT scans are done annually[1]. Due to the rapid advances in imaging technology, such as faster scan times, advanced multi-planar reconstruction techniques, reduced artefacts, improved contrast, and spatial and temporal resolution, there has been a dramatic increase in CT scans[2-3]. Compared to the more common conventional x-ray examinations, CT alone involves larger radiation doses, with the majority resulting from examinations of the chest, abdomen, and pelvis[1,4-6]. Moreover, the wide use of multidetector-row CT scanners can increase abdominal CT examinations. Despite its advantages in imaging, concerns have been raised regarding radiation exposure. A study conducted by Gonzalez and Darby reported a 0.6-3.2 % risk of cancer from all diagnostic procedures using x-rays[7]. Contrast-enhanced examinations of the abdomen region have a greater radiation exposure due to the multiphase abdominal CT protocols. Risk can be best quantified by effective dose. An effective dose can be defined as the weighted sum of all the equivalent doses in all tissues and organs[8, 9]. The effective dose can vary depending on the scanner design, exposure factors set, scan range and patient size[10]. The effective dose can be reduced by choosing the appropriate scan volume and adjusting scan parameters like pitch, kVp, mAs, rotation time, slice width, slice gap, and dose modulation techniques. Automatic tube current modulation was first introduced in 1998. Various methods of automatic tube current modulation (ATCM) are currently used. The longitudinal tube current modulation adjusts the mA on the z-axis, and the angular tube current modulation adjusts the mA on the x and y-axis. The angular-longitudinal (x, y, z) tube current modulation adjusts mA in all three planes. Automatic tube current modulation is known to reduce radiation dose and maintain or improve image quality for abdominal CT.[11-13]. However, automatic tube current modulation can increase radiation dose for individuals with a larger body habitus.[10,11,13,14]. Most clinicians prefer to obtain a constant image quality and, therefore, utilise the same noise index and reference mAs; this, in turn, can increase the radiation dose to oversized patients. Therefore, the study aims to determine how body mass index and abdominal circumference affect the effective dose for routine contrast-enhanced abdomen and pelvis scans using a 128-slice CT scanner with ATCM.

MATERIALS AND METHODS

A total of 160 participants above the age of 18 years referred for routine CECT abdomen and pelvis were included in the study. Study approval was obtained from the institutional ethics committee. Prior to the scan, data on patient characteristics such as height, weight, BMI and abdominal circumference were collected. The BMI was categorised as underweight (<18.5 kg/m2), normal (18.5- 24.9 kg/m2), overweight (25-29.9 kg/m2) and obese (e"30 kg/m2) as per the WHO classification (15). The 160 patients were divided according to their BMI into four groups, with 40 patients in each group. All scans were performed on a Philips 128-Slice Incisive CT scanner. A standard triple-phase abdomen and pelvis protocol was used for imaging. The scanning parameters for the protocol is shown in table 1. Tube current was controlled by a 3D dose modulation technique that adjusts the angular and longitudinal mA according to the body habitus and the DRI (dose right index). The area coverage for the CT abdomen and pelvis extended from the domes of the diaphragm to the symphysis pubis.

Radiation dose

The dose information on the CT console was used to write the dose length product for each series. The effective dose was then found by multiplying the dose length product[8,10] by the region-specific conversion factor (0.015).

Statistical analysis

All statistical analysis was performed using the EZR software. Baseline characteristics (age, abdominal circumference), scanning parameters (mA, mAs, scan length, and scan time) and the effective dose was summarised using descriptive characteristics for each BMI group. One-way ANOVA was done to evaluate the difference in effective dose between the groups.

RESULTS

A total of 40 patients were included in each BMI group. The underweight group included 14 females and 26 males. The normal group included 10 females and 30 males, the overweight group included 16 females and 24 males, and the obese group included 24 females and 16 males. The

Table 1. Routine protocol for CECT Abdomen and pelvis

Scanning parameters	Abdomen and pelvis
kVp	120
Reference mA	80-250
Slice thickness	5 mm
Rotaion time	0.5
Collimation	64 X 0.625
Pitch	1.10

patients' characteristics for each BMI group are summarised in table 2. One-way ANOVA showed no significant difference in age among the groups (p=0.163) and a significant difference in abdominal circumference among the groups (p<0.001).

Scanning/exposure parameters

The scanning/exposure parameters for various BMI groups for all series in a CECT abdomen and pelvis scan are depicted in tables 3, 4, 5 & 6. The results reported a significant difference in mAs and mA among all groups for all series in a triple-phase CECT abdomen and pelvis (p<0.05). For scan length, the results showed a significant difference in scan length among all groups for the plain, arterial, Porto venous, and delayed series in a triple-phase CECT abdomen and pelvis (p<0.05).

Table 2. Mean and standard deviation of age and abdominal circumference among various BMI groups for triple phase CECT abdomen and pelvis scan

BMI Categories	Age (years)	Mean abdominal circumference (mm)
Underweight	44.8 ± 19	739.2±59
Normal	49.2± 18	886.7±101
Overweight	50.9± 17	1016.8±58
Obese	53.5±13.7	1167± 97

Table 3. Mean mA among various BMI groups for triple phase CECT abdomen and pelvis scan

Abdominal			mA		
series	Underweight	Normal	Overweight	Obese	p-value
Plain	151.8± 15.4	184±32.5	195±41.8	217±8.9	<0.001
Arterial	177.2±10.2	188.4±11.2	191.1±20.5	201.2±39.9	<0.001
Porto-venous	178.2±9.7	186.9±9.3	189.4±15.3	197.6±28	<0.001
Delayed	176.8±7.3	179.5±7.9	182.2±11	207.1±51.4	<0.001

Table 4. Mean mAs among various BMI groups for triple phase CECT abdomen and pelvis scan

Abdominal			mAs		
series	Underweight	Normal	Overweight	Obese	p-value
Plain	70.7± 4.1	85.8±12.8	97.1± 12.9	114.5±23.8	<0.001
Arterial	90.7±1.6	91.9± 3.9	95.4±5.6	111.7±22.2	<0.001
Porto-venous	90.8±1.7	91.1±2.5	93.3±3.8	106.4±18.5	<0.001
Delayed	87.8±1.6	88.7±3.2	90.8±5.2	107±22.2	<0.001

Table 5. Mean Scan length among various BMI groups for triple phase CECT abdomen and pelvis scan

Abdominal			Scan length		
series	Underweight	Normal	Overweight	Obese	p-value
Scano	520± 68.1	532.2± 55.8	540.4± 62.8	550.9±67.4	0.1
Plain	493± 35.7	495.2±39.6	520.3± 56.7	521.7±52.6	0.005
Arterial	492± 37.8	492.4± 39.7	515.2±49.7	526.4±49.4	0.001
Porto-venous	493.7 ± 37.2	498.1±38.7	521.3±56.2	526.8±48.2	0.002
Delayed	281.6±53.4	287.8±43.9	299.6±56.4	311.6±32.1	0.02

However, they showed no significant difference in the scanogram among the groups. The results also reported a substantial difference in scan time among all groups for scanogram, plain, arterial, and Porto-venous phases ($p<0.05$). However, they showed no significant difference in the delayed phases among the groups.

Radiation dose

The mean effective dose and dose length product across all BMI groups for the CECT abdomen and pelvis is demonstrated in Table 7. The study results showed increased DLP and effective dose with increasing BMI. One-way ANOVA showed a significant difference in DLP

Table 6. Mean Scan time among various BMI groups for triple phase CECT abdomen and pelvis scan

Abdominal series	Underweight	Normal	Scan time Overweight	Obese	p-value
Scano	5.1± 0.6	5.1± 0.5	5.3 ± 0.6	5.4±0.6	0.04
Plain	6.2± 0.4	6.2±0.5	6.5± 0.6	6.6±0.6	0.009
Arterial	6.8±0.5	6.8± 0.5	7.1± 0.6	7.3±0.6	0.001
Porto-venous	6.9±0.4	6.9±0.5	7.1±0.7	7.3±0.6	<0.001
Delayed	4.3±0.9	4.4±0.5	4.4± 0.7	4.6± 0.4	0.2

Table 7. Descriptive statistics showing mean and standard deviation of DLP and Effective dose for each BMI group

BMI group	Dose length product mGy*cm	Effective dose (mSv)
Underweight	1431.3± 136	21.47 ±2
Normal	1516.6 ± 155	22.75 ±2.3
Overweight	1668.1 ± 191	25.02±2.8
Obese	1984.6 ± 448	29.7±6.7

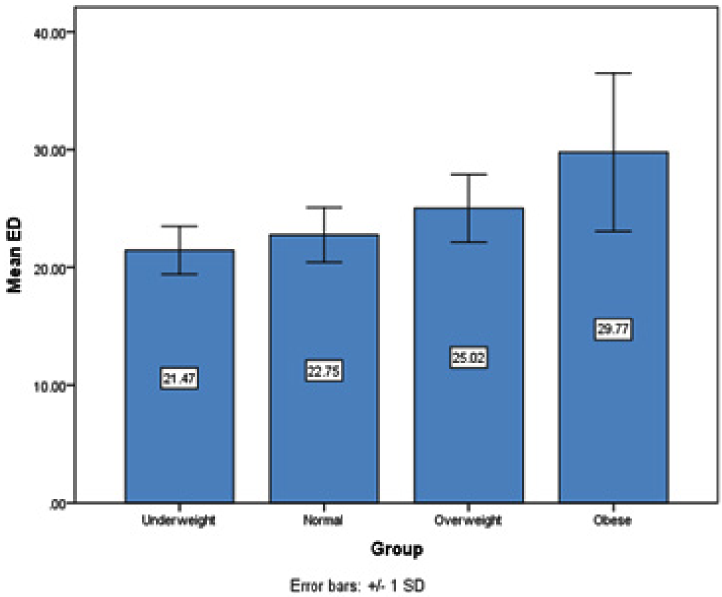

Fig. 1. Bar diagram with error bars. Bars depict the mean ED across various BMI groups and Error bars represent the standard deviation

and effective dose among the groups (p=<0.001), as shown in figure 1.

DISCUSSION

Radiation dose in CT has always been a cause of concern due to its associated radiation dose. With the advancements in CT scanners, various strategies have been developed to optimise the radiation dose. Along with optimising exposure factors based on body habitus, the introduction of automatic tube current modulation (ATCM) has contributed to dose reduction while maintaining the diagnostic quality of images. Various studies have reported a decrease in radiation dose while utilising the ATCM technique[15, 16,17]. As per the study by Livingstone et al., the use of the dose modulation technique resulted in a dose reduction of 16-28%. Although tube current modulation can reduce the overall radiation dose, various studies have reported a potential risk of increased radiation dose in oversized or obese patients due to the higher tube current used to maintain constant image quality[12, 18]. A study conducted by Schindera et al. on a phantom that was adjusted for three patient sizes demonstrated an increase in abdominal organ doses by 528 % in larger patients. Similarly, the present study reported a 32.39% increase in effective doses for obese patients. This increase in dose is due to the increase in scan parameters like mAs, mA and scan length to achieve consistent image quality. Another study conducted by Chan VO et al. reported a mean effective dose of 7.3 ± 0.9 mSv, 8.9 ± 1 mSv and 12±2.8 mSv for low, normal and high BMI, respectively[10]. The present study reported much higher values of effective dose for low BMI (21.47 ± 2), normal BMI (22.7 ± 2.3), overweight (25 ± 2.8) and obese (29.7 ±6.7)[10]. This could also be because the dose reported in the present study was the total dose obtained during the entire CECT abdomen and pelvis that included triple-phase like arterial, Porto-venous, and delayed phases rather than computing the dose from a single series. Nevertheless, dose optimisation techniques should be extended to obese patients as well, mainly because an increase in BMI is associated with an increase in effective dose. A study by Israel G M et al. reported that radiation given to a 100 kg patient is three times more when compared to a 60 kg patient, resulting in an organ dose that is twice as high[19]. Similarly, a study conducted by Chan VO et al. showed that for every kilogram of weight, there is an increase of 0.13 mSv of effective dose[10]. Therefore, more research can be done to investigate the usage of low kVp techniques for obese patients to optimise the dose. Also, a study conducted by Qurashi AA et al. showed that obese patients might benefit from fat deposition around their organs as it may improve inherent tissue contrast between the organs[20]. With more advancements in iterative reconstruction algorithms, there is scope for reducing the dose whilst maintaining the image quality. Although there are no dose limits for patients, establishing local, regional, or national DRLs may aid in radiation dose optimisation and thus reduce the risk of stochastic effects.

CONCLUSION

As obesity is a growing concern and since the CECT abdomen and pelvis play an essential role in diagnosing various pathologies, dose optimisation techniques must be extended for obese patients. The study results showed an increase in DLP and effective dose with increasing BMI and a 32.39 % increase in effective doses for obese patients. Therefore, designing protocols based on patient size, clinical indication, and system capability can help reduce radiation exposure to patients undergoing abdominopelvic examinations.

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Conflicts of Interest

We declare there is no conflict of interest regarding the publication of this paper.

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