



Diagnostic Radiology Original Research

Does Contrast Dose Based in Lean body Weight Allow Lesser Volumes on High BMI Patients for CT Angiography?

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Received : 02 May 2021

Accepted : 17 June 2021

Published : 14 July 2021

DOI

10.25259/JCIS_97_2021

Quick Response Code:



ABSTRACT

Objectives: The objective was to evaluate whether contrast dose based on lean body weight (LBW) protocol has the potential to reduce contrast volume in patients with high basal metabolic index (BMI) compared to total body weight (TBW)-based protocols.

Material and Methods: The Institutional Review Board approval was obtained for this prospective study. Initially, a pilot study with a sample size of 150 patients was conducted to estimate the average fat fraction in our population. Then, CT angiography (CTA) for the thoracic and abdominal aorta was performed using a 256-multidetector computed tomography scanner in 117 patients who were undergoing screening for aortic aneurysm and vascular assessment of prospective transplant donors. The patients were divided into two groups: A TBW group ($n = 60$) and LBW group ($n = 57$). Lean body weight (LBW) was estimated from the patient weight, height, and gender using Hume's equation. The TBW group received 1.2 ml/kg contrast dose and the LBW group received 1.6 ml/kg contrast dose to achieve approximately equal iodine dose in both groups. Differences in the degree of aortic enhancement between the estimated LBW and TBW group were evaluated. In higher BMI patients (>25), the mean aortic enhancement (MAEnh) and the contrast volume delivered between the LBW and TBW group were compared.

Results: Mean aortic enhancement (MAEnh) 422.45 (± 74.5) Hounsfield unit (HU) in the TBW group and 432.67 (± 69.4) HU in the LBW group showed no statistical difference ($P = 0.439$). In population with BMI >25 , the contrast delivered in LBW protocol patients was significantly less ($P = 0.00$) compared to TBW protocol patients, with no significant difference in the MAEnh between the groups ($P = 0.479$).

Conclusion: CTA using a LBW protocol helps to significantly reduce the volume of contrast delivered, especially in patients with BMI >25 compared to TBW protocol, without compromising the aortic enhancement.

Keywords: Body mass index, CT angiography, Estimated lean body mass, Hounsfield units, Lean body weight, Mean aortic enhancement, Milligram iodine, Multidimensional computed tomography, Region of interest, Total body weight

INTRODUCTION

Body size parameters such as body weight,^[1-4] cardiac output,^[2,5,6] and body surface area^[7] are important parameters that affect the vascular enhancement in CT angiography (CTA). A fixed contrast volume irrespective of iodine concentration is usually administered to all patients in many radiology departments as standard patient protocol for CTA.^[8-10] However, fixed iodine

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dose injection protocols have shown that the major vessel enhancement reduces with increasing body weight.^[11,12] Few departments have adopted contrast dose protocol based on total body weight (TBW).^[13,14] Although the TBW is the most important factor that determines the iodine dose needed for the constant enhancement, contrast volume based only on TBW often results in high volumes.^[15] Awai *et al.*^[16] have shown that almost constant aortic enhancement in CT aortography is obtained when contrast volume is delivered based on TBW. Contrast administration dose tailored to lean body weight (LBW) is now emerging as a promising alternative to TBW. Ho *et al.*^[17] showed that contrast injection based on LBW reduced interpatient variability of aortic enhancement. Yanaga *et al.* have studied the degree of aortic enhancement adjusted for estimated LBW in a Japanese population and observed lower interpatient variability than contrast dose protocol based on TBW. Calculating contrast dose based on LBW has the potential to reduce contrast dose delivered to the patients, compared to protocols based on TBW. We investigated the value and effectiveness of contrast dose protocol based on LBW in comparison with that of TBW in the sample.

MATERIAL AND METHODS

The Institutional Review Board approval was obtained for this prospective study. Informed consent was taken from all patients before CT scan.

Patients population

The study was conducted from June 2017 to June 2019. Initially, a pilot study with a sample size of 150 patients (male 80:female 70, average age 45 years) was conducted to estimate the average fat fraction in our population. The average fat fraction was estimated to be 25% in the study. Then, a total of 117 patients were enrolled in a prospective manner in this study. The patients referred for CTA for suspected aneurysm, vascular occlusive disease, or organ donor evaluations were included. Patients with low ejection fraction <50% were excluded as it may interfere with contrast dynamics and subsequent timing of acquisition. Patients with moderate-to-severe renal failure were also excluded. Among the 117 patients, 57 patients (male 29:female 28; average age 48.72) were enrolled to LBW group and rest 60 patients (male 31:female 29; average age 49.8) were enrolled in the TBW group randomly.

Calculation of fat fraction in our population

A group of 150 consecutive adult patients who were referred for CT scans was included in the study. This step preceded the main study. Hume's equations were used to calculate the LBW from the height, TBW, and sex of the patients.

Percentage of fat fraction was calculated using the following formula, fat fraction percentage = $\frac{TBW-LBW}{TBW} \times 100$. The average fat fraction of our population was 25%. At 25% fat fraction, the LBW will correspond to 75% of TBW.

Calculation of LBW

The LBW was calculated using Hume's equation
Hume's equation:^[18]

For males,

$$eLBM = 0.32810W + 0.33929H - 29.5336$$

For females,

$$eLBM = 0.29569W + 0.41813H - 43.2933$$

Hume's equation derived body compositions such as fat mass and lean body mass are quite similar to that obtained in dual-energy X-ray absorptiometry which is now considered as a reference method to body composition in clinical practice.

Contrast injection protocols

The contrast material used was Iohexol with iodine concentration of 350 mg/ml. It was administered with a mechanical power injector through an 18 G cannula inserted into the antecubital vein. The patient in the TBW group was given contrast dose tailored to their TBW at a dose of 1.2 ml/kg. The patients in the LBW group were given contrast dose tailored for LBW at a dose of 1.6 ml/kg. By delivering 1.2 ml/kg contrast in TBW group and 1.6 ml/kg in LBW, we achieved approximately equal iodine dose in both groups. Fixed injection duration of 15 s was employed for both groups to deliver constant dose of iodine to all patients. The mean injection rate for TBW group was 4 ml/s (ranging from 2.3 to 5.2 ml/s), and for the LBW group, it was 4 ml/s (ranging from 2.2 to 5.4 ml/s). Saline flush was delivered at the same rate as the contrast medium.

Scanning protocols

The patients were scanned with a 256 slice multidimensional computed tomography (MDCT) (iCT, Philips Health Care). The imaging parameters were as follows: Detector collimation 128 × 0.625, helical pitch 0.912, gantry rotation time 0.5 s, tube voltage of 120 kVp, reconstructed section thickness of 5 mm and 1 mm, and reconstruction interval of 5 mm and 1 mm. All scans were done from neck to pubic symphysis in a cephalocaudal direction with breath hold. Both unenhanced and enhanced CT images were obtained. Bolus tracking was used for triggering the scan. Scanning started automatically 5 s after contrast enhancement had reached 120 Hounsfield unit (HU) in the region of interest (ROI) in the ascending aorta.

Quantitative assessment

Aortic enhancement was determined with ROI curve at six sites: The ascending aorta at the level of pulmonary trunk,

the descending thoracic aorta at the level of pulmonary artery trunk, thoracic aorta at the level of top of liver dome, celiac artery origin level, at the level of left renal artery, and just above the aortic bifurcation on both enhanced and unenhanced images. All ROIs were fixed at 100 mmsq. The values of attenuation were obtained at each level from both the enhanced and unenhanced images. The difference between the enhanced and non-enhanced attenuation was considered as the aortic enhancement at that level. The mean aortic enhancement (MAEnh) was defined as the mean value of the aortic enhancement from the six levels. We compared the MAEnh of the TBW group and LBW group. To further elucidate the effect of TBW on aortic enhancement, the TBW and LBW groups were further divided into two subgroups based on basal metabolic index (BMI <25 and >25). BMI-based subcategorization was considered much more generalizable as it maintains relatively constant value when compared with body weight across different geographic populations. BMI of >25 was considered to define obese subjects.

Statistical analysis

Statistical analysis was performed with SPSS software (version 22). Basic descriptive statistics such as arithmetic mean, median, mode, and standard deviation were used. The population characteristics such as age, gender, height, body weight, BMI, number of aneurysms, and diameter of aneurysms which may directly or indirectly affect the contrast dose and aortic attenuation between both groups (LBW/TBW) were compared with independent *t*-test and Chi-square tests. The MAEnh in the TBW group and the LBW group was compared with using two-tailed Student’s independent *t*-test. The degree of interpatient variability of MAEnh in both the LBW and TBW groups was compared. The BMI subgroups <25 and ≥25 in both the TBW/LBW groups were compared for the MAEnh and contrast volume. For all statistical analysis, *P* < 0.05 was considered to indicate a significant difference.

RESULTS

There was no significant difference with regard to the age (*P* = 0.66), gender (*P* = 0.854), height (*P* = 0.117), body weight (*P* = 0.062), BMI (0.459), or number/diameter of aneurysms (*P* = 0.32/0.98) in the TBW group and the LBW group [Table 1].

Analysis of MAEnh between the TBW group and the LBW group

MAEnh 422.45 ± 74.5 HU for the TBW group and 432.67 ± 69.4 HU for the LBW group shows no significant difference (*P* = 0.439) [Figure 1 and Table 2]. The measures of dispersion in the TBW group, such as the standard deviation (74.4) and mean standard error (12.76), were higher than in the LBW group

Table 1: Sample characteristics and its significant values. Population characteristics show that groups have no significant difference.

| Characteristics | TBW group | LBW group | P value |
|---------------------------|------------|-------------|-----------------------------------|
| Age | | | |
| Mean | 49.8 years | 48.72 years | 0.66 (two-tailed <i>t</i> -test) |
| Range | 28–83 | 23–86 | |
| Gender | | | |
| Male | 31 | 29 | 0.854 (Chi-square <i>t</i> -test) |
| Female | 29 | 28 | |
| Height | | | |
| Mean | 163 | 160.58 | 0.117 (two-tailed <i>t</i> -test) |
| Range | 145–180 | 147–178 | |
| Body weight | | | |
| Mean | 70.4kg | 65.4 kg | 0.062 (two-tailed <i>t</i> -test) |
| Range | 48–76 kg | 48–91 kg | |
| Basal metabolic index | | | |
| Mean | 27.23 | 26.67 | 0.459 (two-tailed <i>t</i> -test) |
| Range | 20–36 | 19–39 | |
| Number of aneurysms | | | |
| Thoracic aortic aneurysm | 7 | 5 | 0.320 (Chi-square test) |
| Abdominal aortic aneurysm | 5 | 8 | |

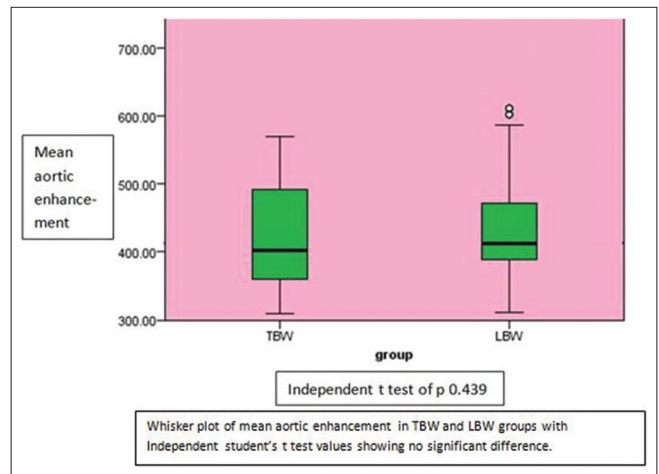


Figure 1: Whisker plot of mean aortic enhancement in the TBW and LBW groups with independent Student’s *t*-test values showing no significant difference. LBW: Lean body weight, TBW: Total body weight.

(standard deviation, 69.6 and mean standard error, 11.5). This shows lesser interpatient variability of the aortic enhancement in the LBW group when compared to the TBW group [Figure 2].

Table 2: Statistical data of mean aortic enhancement in the TBW group and LBW group.

| Group | Mean aortic enhancement |
|--------------------|-------------------------|
| TBW | |
| Sample size | 60 |
| Mean | 422.45 |
| Median | 402.00 |
| Mode | 360 |
| Standard deviation | 74.404 |
| Range | 260 |
| Minimum | 310 |
| LBW | |
| Sample size | 57 |
| Mean | 432.67 |
| Median | 423.50 |
| Mode | 336 |
| Standard deviation | 69.607 |
| Range | 300 |
| Minimum | 311 |

LBW: Lean body weight, TBW: Total body weight

Analysis of MAEnh and contrast volume between the categories based on BMI in TBW and LBW group

In the BMI ≤25 category, there was no significant difference in the body weights in the TBW group and LBW group. The mean contrast volume delivered 76.95 ± 10.7 ml in the TBW group and 76.23 ± 9.2 ml in the LBW group shows no significant difference (P = 0.819). The MAEnh 412.79 ± 71 HU in the TBW group and 445.68 ± 87 HU in the LBW group shows no significant difference, P = 0.199 [Tables 3 and 4, Figure 3].

In the BMI >25 subgroup, there was no significant difference in the body weights in the TBW group and LBW group. The mean contrast volume delivered 91.38 ± 7.2 ml in the TBW group and 81.39 ± 8.98 ml in the LBW group shows no significant difference, P = 0.00. The contrast volume delivered to the patients in the TBW group was significantly higher compared to the patients in the LBW group. The MAEnh 409.78 ± 47.9 HU in the TBW group and 417.8 ± 50.4 HU in the LBW group of patients shows no significant difference, P = 0.479 [Tables 3 and 4, Figure 4]. Figure 5 demonstrates comparison of the measurement of aortic enhancement in two individuals with same age but significantly different BMI.

DISCUSSION

Results showed that there is no significant difference in MAEnh between patients from the TBW group and LBW group. The interpatient variability of MAEnh was higher when the contrast titration followed the TBW protocol than the LBW protocol. Another key result may be the higher contrast volume delivered to patients with higher BMI in the TBW group.

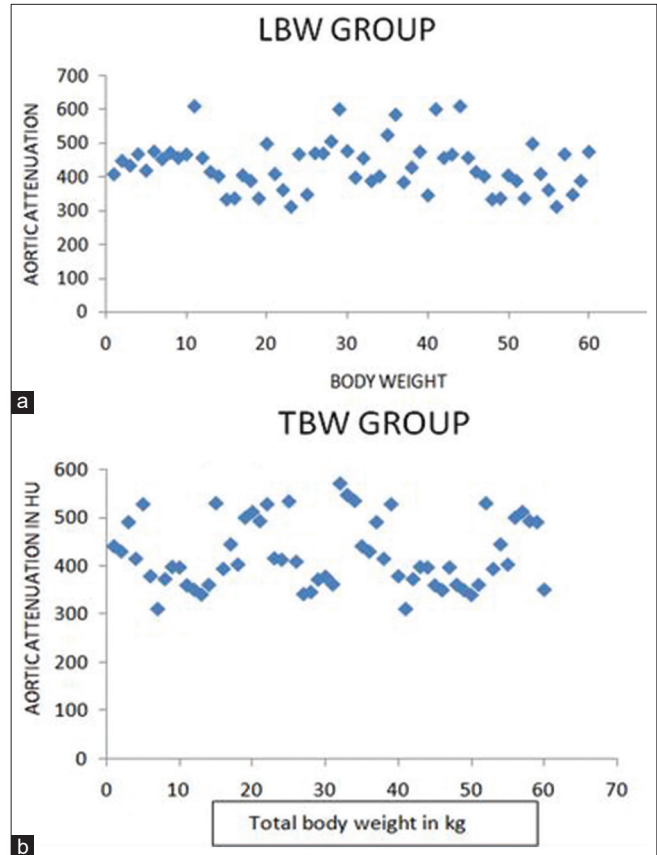


Figure 2: (a) Mean aortic enhancements observed for the range of body weights in the LBW group. (b) Mean aortic enhancements observed for the range of body weights in the TBW group. Figures show decreased interpatient variability of mean aortic enhancement in the LBW group compared with the TBW group. BMI: Basal metabolic index, LBW: Lean body weight, TBW: Total body weight.

A HU value of ≥200 HU is the minimum aortic enhancement value considered necessary for diagnostically optimal CT aortography.^[19] In the BMI category >25, the MAEnh of the LBW group had no significant difference when compared to the TBW group. However, the contrast volume delivered in the TBW group was higher. Contrast dose titrated with the LBW protocol significantly reduced the contrast volume in patients with higher BMI. The technical factors that contribute to aortic enhancement are contrast volume, injection rate, iodine concentration of contrast, and injection duration.^[15] For a given injection duration, aortic enhancement is directly proportional to iodine dose per body weight. Tanikake *et al.*^[20] stated that the aortic attenuation value exceeding 400 HU is necessary for excellent depiction of the aortic branches in CT aortography. In the study, the mean aortic attenuation in both the TBW protocol and LBW protocols shows MAEnh well above 400 HU. This shows that our protocols that delivered iodine concentration of 350 mgI at a fixed injection duration of 15 s were diagnostically appropriate for CT aortography.

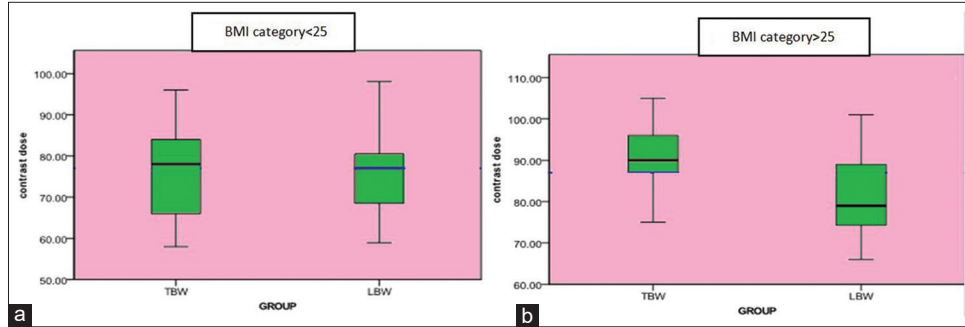


Figure 3: a) Whisker plot of BMI category <25 showing no significant difference in the contrast dose delivered in both the LBW and TBW group. b) BMI category >25 show higher dose of contrast dose delivered to the TBW group than the LBW group. LBW: Lean body weight, TBW: Total body weight.

Table 3: Statistical data of contrast dose and mean aortic enhancement based on LBW and TBW protocols categorized based on BMI (<25/>25).

| BMI categories | | n | Mean | Std. deviation | Std. error mean |
|----------------|-------------------------|-----|------|----------------|-----------------|
| Less than 25 | Contrast dose | TBW | 21 | 76.95 | 10.742 |
| | | LBW | 21 | 76.23 | 9.289 |
| | Mean aortic enhancement | TBW | 21 | 412.79 | 71.042 |
| | | LBW | 21 | 445.68 | 87.563 |
| More than 25 | Contrast dose | TBW | 39 | 91.38 | 7.169 |
| | | LBW | 36 | 81.31 | 8.892 |
| | Mean aortic enhancement | TBW | 39 | 409.72 | 47.939 |
| | | LBW | 36 | 417.81 | 50.477 |

LBW: Lean body weight, TBW: Total body weight, BMI: Basal metabolic index

It is desirable to use the minimum diagnostically appropriate amount of contrast medium to minimize the risk of contrast induced nephropathy and reduce the cost of the study.^[21] Reducing the contrast volume also decreases the use of higher rate of injection in obese patients in a TBW-based or fixed-dose-based injection protocol.^[15] Reduction in the higher rate of injection in these patient may be advantageous because it decreases the size of the cannula required for vascular delivery of the contrast medium and risk of extravasations.^[15]

Lean body mass is calculated by subtracting weight of body fat from TBW. The total blood volume per body weight, is less in a lean body weight estimation since the adipose tissue is poorly perfused compared to solid organs, including muscle. The contrast dose injection based on the TBW is based on the hypothesis that the entire body component consists of non-fat mass. Hence, patients with higher fat composition tend to get higher contrast volume if the contrast injection is based on TBW. In this scenario, the contrast injection based on LBW can directly benefit patients.

In obese patients, the image noise is increased due to reduce the photon flux and increased X-ray scattering in the excess peripheral body fat. High image noise may reduce the visibility of the small aortic branches.^[22] One solution for this is to increase the iodine dose for better depiction of smaller vessels. This can be avoided using adaptive noise reduction filters and iterative reconstructions help to achieve simultaneous noise reduction and edge preservation.^[23] Contrast delivery based on LBW protocol would be a useful adjunct to these techniques to preserve image quality in obese patients.

Yanaga *et al.*,^[15] conducted a similar study in a Japanese population, compared the TBW and estimated LBW protocols. The study obtained significant difference in the MAEnh and contrast dose in the category ≥ 70 kg (heavier patients) on the TBW and LBW group that makes the LBW protocol inappropriate. The present study shows no significant difference of MAEnh in both groups and significantly lower contrast volume delivered in the LBW group. This could be attributed to categorization based on BMI and the higher fat fraction of the Indian population when compared with that of the Japanese population.

Limitations

The range and body weight of the sample from South India would be different from that of a Japanese or European cohort. Therefore, the applicability of contrast dose tailored to estimate LBW protocol is population specific. This can be attributed to the difference in the fat fraction and distribution of fat. The present study used the estimated or calculated LBW instead of measured LBW to avoid a cumbersome process. The patient with low cardiac output and large aneurysms was not included in this study as the timing of the scan and injection durations were not individualized.

CONCLUSION

A contrast injection protocol based on the LBW delivers less volume of contrast media in patients with high BMI. It is,

Table 4: Statistical analysis of weight, contrast dose, and mean aortic enhancement involved in LBW and TBW protocols at BMI categories of less than 25 and more than 25.

| BMI | Levene's "F" test for equality of variance | | "t" test for equality of means | | | | | | |
|-------------------------|--|-------|--------------------------------|----|--------------------------|-----------------|-----------------------|---|-------|
| | F | Sig | t | df | Sig. (two-tailed t-test) | Mean difference | Std. error difference | 95% confidence interval of the difference | |
| | | | | | | | | Lower | Upper |
| Less than 25 | | | | | | | | | |
| Contrast dose | 0.821 | 0.371 | 0.230 | 39 | 0.819 | 0.720 | 3.127 | -5.606 | 7.046 |
| Mean aortic enhancement | 0.581 | 0.451 | -1.30 | 39 | 0.199 | -32.892 | 25.168 | -83.799 | 18.01 |
| More than 25 | | | | | | | | | |
| Contrast dose | 2.084 | 0.153 | 5.391 | 73 | 0.000 | 10.079 | 1.870 | 6.373 | 13.80 |
| Mean aortic enhancement | 0.549 | 0.461 | -0.712 | 73 | 0.479 | -8.088 | 11.365 | -30.706 | 14.56 |

LBW: Lean body weight, TBW: Total body weight, BMI: Basal metabolic index

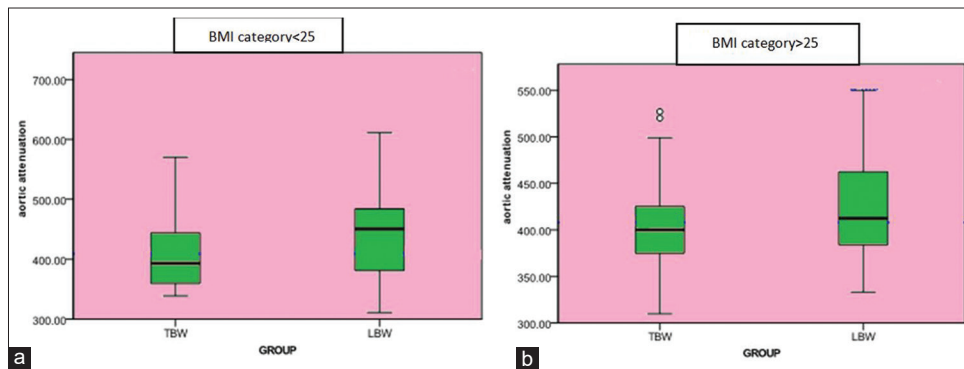


Figure 4: (a) Whisker plot of BMI category <25 showing no significant difference in the mean aortic enhancement delivered in both the LBW and TBW group. b) BMI category >25 showing no significant difference in the mean aortic enhancement delivered in both the LBW and TBW group. BMI: Basal metabolic index, LBW: Lean body weight, TBW: Total body weight.

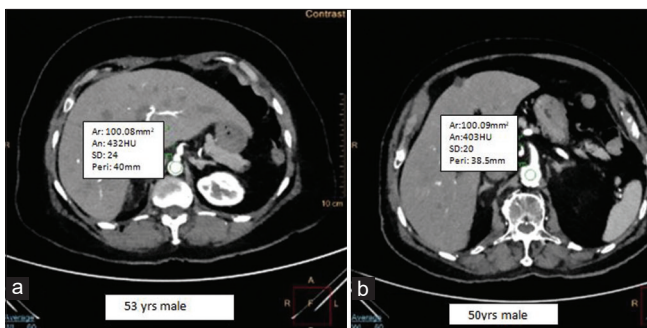


Figure 5: (a) MDCT angiogram image with contrast delivery based on lean body weight protocol in patient with BMI of 21.5 shows attenuation of 432 HU and (b) patient with BMI 33 showing CT attenuations 403 HU, respectively. MDCT: Multidimensional computed tomography, BMI: Basal metabolic index, HU: Hounsfield unit.

however, necessary for each distinct population to derive the fat fraction before following this protocol.

Declaration of patient consent

The Institutional Review Board (IRB) permission obtained for the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Chandrasekharan R, Kulkarni CB, Pullara SK, Moorthy S. Does contrast dose based in lean body weight allow lesser volumes on high BMI patients for CT angiography? *J Clin Imaging Sci* 2021;11:38.