Evaluation of contrast medium injection protocols for aortic CT angiography with CT contrast medium dose adjusted to body surface area

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**Purpose**

The motivation for this study is as follows: in clinical use, body weight protocol tends to overestimate for large patients or underestimate for small patients for CT angiography. Bae et al. proposed using BSA rather than BW to determine the contrast dose for CTA (1).

The BSA protocol provides a better adjustment of iodine dose for a wide range of body sizes than body weight. But, they didn't specifically investigate the patient's cardiac condition affects the degree of enhancement, and they did not actually adopt a BSA protocol for CTA. They only showed strong correlations.

Yanaga (2) had the first clinical trial that adopted a contrast material injection protocol with the dose adjusted according to BSA in patients undergoing CTA and evaluated the effectiveness on aortic enhancement.

But, they made use of the evaluation of enhancement in a different way. Because they did not use variance of enhancement, but they evaluated by using average enhancement.

We assessed the effectiveness of enhancements on BSA protocol by using standard deviation and distributions of aortic enhancement.

This study evaluated the efficiency of the computed tomography angiography (CTA) protocol with the contrast medium (CM) dose adjusted to body surface area (BSA).

**Methods and Materials**

**Patient:**

Between April 2011 and April 2012, we enrolled 225 patients (169 male and 56 female; age range, 48-98 years; mean age, 64 years) in this study.

The study population consisted of 90 patients with thoracic aortic aneurysms (TAAcs), 90 patients with abdominal aortic aneurysms (AAAcs), and 45 patients with TAA and AAA (see figure 1).

The fixed group consisted of 60 male and 15 female with a mean height±S.D. of 164.9±9.1cm, mean body weight±S.D. of 60.8±9.2 kg. The body weight group consisted of 56 male and 19 female with a mean height±S.D. of 165.1±9.4cm, mean body weight±S.D. of 58.1±11.6 kg. The BSA group consisted of 53 male and 22 female with a mean height±S.D. of 165.2±9.4cm, mean body weight±S.D. of 58.1±12.5 kg.
Statistical assessments among three groups were performed using non-repeated Measures ANOVA and 3x2 Chi square test.

These three groups had no significant difference in height (P=0.6287), body weight (P=0.410) and sex distribution (P=0.658).

CT imaging protocol:

All patients were scanned with a 64-MDCT scanner (Toshiba Aquilion 64, Toshiba Medical). The imaging parameters were detector collimation, 64 × 0.5 mm; helical pitch, 0.70; gantry rotation time, 0.5 second; reconstructed section thicknesses, 5.0 and 1.0 mm; reconstruction intervals, 5.0 and 1.0 mm; tube voltage, 120 kV; and planned tube current-time product, 300 mAs. The automatic tube current modulation technique was used. All patients were scanned from the top of the thorax to the symphysis pubis in a cephalocaudal direction. They were instructed to hold their breath with inspiration during scanning.

Bolus tracking (Real Prep, Toshiba Medical) was used for the scanning delay. Scanning started automatically 10 seconds after contrast enhancement reached 100 HU in a region of interest (ROI) within the descending aorta (see figure 2).

Contrast Material (CM) injection protocols:

The contrast material, iopamidol (Isovue, Bracco), contained 370 mg I/mL. It was administered with a mechanical power injector (Stellant D, MEDRAD) via a 20-gauge cannula inserted into an antecubital vein.

We created three CM injection protocols for CTA as fixed (Fix) with the CM injection rate fixed at 1.11 g/sec regardless of patient's body weight (BW) and BSA; BW protocol with the CM injection rate adjusted to BW (17.35 mg/sec/kg); BSA protocol with the CM injection rate adjusted to BSA (652 mg/sec/m²). These CM injection protocols were equivalent to injection of 75 ml into a 64-kg Japanese adult male at 3.0 ml/sec.

In all patients, the contrast medium was injected during a fixed injection duration of 25 seconds. After contrast injection, all patients received 30mL of saline solution delivered at 3.0 ml/sec. All patients raised their arms above their shoulders during contrast injection and scanning (see figure 3).

Quantitative Assessment:

We measured aortic enhancement by placing manually defined ROIs. Aortic attenuation was determined on enhanced images at four sites: the ascending aorta at the aortic arch, the descending aorta at the level of the celiac trunk and the top of the renal artery, and
at the external iliac artery. Measurements were performed on 1.0-mm-thick images. The contrast enhancement values at the four measured levels were averaged.

**Statistical Analysis:**

To compare enhancements and distributions of aortic enhancement, we analyzed the standard deviation (SD) by Bartlett's test and distribution of numerical data on enhancement among three categories by Yates 3×3 chi-squared test. For statistical analyses we used statistical software (JMP version 9.02, SAS Institute Inc). A p value of < 0.05 was considered to indicate a significant difference.

**Images for this section:**

![Patient population](image)

**Fig. 1:** Patient population
Scanning Protocol

All patients were scanned with a 64-slice CT scanner (Toshiba Aquilion 64) with the following settings:

- Tube voltage: 120 kV
- Gantry rotation time: 0.5 second
- Detector collimation: 64 × 0.5 mm
- Helical pitch: 0.70
- Tube current: automatic tube current modulation technique was used.
- Reconstructed section thicknesses: 5.0 and 1.0 mm
- Bolus Triggering
  - Trigger threshold 100 HU, average scan time 14.9 seconds, trigger delay 10 seconds

Fig. 2: Scanning protocol
**Contrast Material injection protocols**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Contrast Material</th>
<th>Injection Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed protocol</td>
<td>(IF)=1.11 gI/sec</td>
<td>25 sec</td>
</tr>
<tr>
<td>With Saline chase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW protocol</td>
<td>17.35 mgI/sec/kg</td>
<td>25 sec</td>
</tr>
<tr>
<td>With Saline chase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BSA protocol</td>
<td>652 mgI/sec/m²</td>
<td>25 sec</td>
</tr>
<tr>
<td>With Saline chase</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 3:** Contrast material injection protocols
Results

SDs of aortic enhancement among the fixed, BW, and BSA groups were 66, 57, and 43HU, respectively. The variation of aortic enhancement were statistically different among the three groups. The BSA group demonstrated the least variation in enhancement and showed the best and most consistent enhancement of the three groups (see figure 4).

The good enhancement were 49% (Fixed group), 56% (BW group) and 72% (BSA group), respectively.

The distribution of Aortic attenuation values were statistically different among the three groups (P<0.01) (see figure 5).

Images for this section:

Fig. 4: Variation in enhancement among three groups
Fig. 5: Distribution of enhancement among the three groups
Conclusion

A patient's body weight and the amount of contrast medium are closely related to the degree of contrast enhancement. When consistent contrast enhancement is desired, the amount of administered iodine should be adjusted according to the patient's body weight. A large patient needs more iodine than a small patient to achieve the same magnitude of enhancement. One simple scheme for adjusting the amount of iodine mass with the body weight is to use a simple linear scale-for example, to double the iodine mass when the patient's body weight doubles. However, this simple body-weight-based linearity may not provide an accurate estimate of the required contrast medium dose, particularly in obese patients who have a lot of body fat that is not metabolically active and thus contribute little to dispersing or diluting the contrast medium in the blood.

Body surface area accounts for both the body weight and height factors and perhaps is more appropriate for obese patients because a 1:1 direct increase in contrast volume with body weight may overestimate the contrast medium dose needed in obese patients. We propose that one approach to adjust the amount of administered contrast medium with respect to the patient's body surface area is to estimate the required amount of contrast medium proportional to the two-thirds power of the body weight.

Our study has some limitations. The range of BWs and mean BW are lower in Japanese individuals than in North Americans and Europeans. Therefore, the applicability of our results to populations with a greater BW must be confirmed.

The BSA protocol is the optimal patient-based CM injection protocol for clinical CTA examination because it provides more consistent and good aortic enhancement regardless of the patient's body weight.

References

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