Original

Alternative Starting Position for CT Coronary Angiography

Yoshiro Hori*[1], Shota Kawasaki[2], Junya Nakashima[2],
Yuki Tashiro[1], Akio Kotake[1], Kyoko Nagai[1],
Eliko Tanaka[1], Nobuyuki Takeyama[1], Takaki Hayashi[1]
and Toshi Hashimoto[1]

Abstract : We examined whether the superior margin of the left main bronchus is the best landmark for the starting position of computed tomography coronary angiography (CTCA). We retrospectively evaluated 693 consecutive CTCAs. From the scout scanogram, the superior margin of the left main bronchus was noted. The relationships among and distance between the superior margin of the left main bronchus and the left coronary system were analyzed. The superior margin of the left main bronchus extended caudally to the superior margin of the left coronary system in 13 patients (1.9%). The addition of 1 cm to the superior margin of the left main bronchus kept it caudal to the superior margin of the left coronary system in only one patient (0.1%). On the scout scanogram, 1 cm above the superior margin of the left main bronchus is the most appropriate starting position for CTCA.

Key words : coronary arteries, computed tomography angiography, tracheal bifurcation,
left main bronchus, starting position

Introduction

Computed tomography coronary angiography (CTCA) is an accurate imaging method for evaluation of coronary artery disease[1-5]. Strategies for radiation dose reduction in CTCA include electrocardiography (ECG)-based[6,7] or attenuation-based tube current modulation[8], tube voltage decrease in low[9]- and normal-weight[10] patients and prospective ECG gating[11-13]. Lower radiation exposure has become possible by combining these dose reduction technologies using recently improved equipment, but we believe that further reductions in radiation exposure can be achieved by limiting the coverage of the z-axis.

For CTCA, a location just below the tracheal bifurcation is frequently used as the starting position[14,15]. However, this location is too far from the superior margin of the left coronary system, rendering unnecessary radiation exposure. Pre-contrast chest CT is sometimes used for the selection of an appropriate starting point; however, this method results in surplus radiation exposure of about 5 mSv, even with the use of reduced-dose chest CT[16]. A pre-contrast scan

[1] *Department of Radiology, Division of Radiology, Showa University Fujigaoka Hospital,* 1-30 Fujigaoka, Aobaku, Yokohama, Kanagawa, 227-8501, Japan.
[2] *Department of Radiological Technology, Showa University Fujigaoka Hospital.*
* To whom corresponding should be addressed.

to estimate the coronary calcium score can be used to determine the correct starting position for CTCA. However, newer equipment using dual energy technology is able to skip the pre-contrast scan[17]. Therefore, using the scout scanogram to determine the optimal starting position of CTCA could avoid extra radiation exposure.

To investigate this theory, we concentrated on the left main bronchus as a new landmark to replace the current landmark of the tracheal bifurcation. In fact, there is no anatomical relationship between the left coronary system and the tracheal bifurcation[14]. As the left coronary system is located inferior to the left pulmonary artery, and the left pulmonary artery runs superior to the left main bronchus, we considered that the superior margin of the left main bronchus may be a more suitable landmark for the left coronary system (Fig. 1).

Therefore, in this study, we examined whether the superior margin of the left main bronchus is a good landmark for the starting position of a CTCA.

Materials and methods

Study Population

Our institutional review board approved this study (permission number 2016118) and waived the need for written informed consent. We retrospectively reviewed the records of 693 consecutive patients undergoing CTCA with a single-source 64-detector scanner (Discovery CT750 HD ; GE Healthcare, Milwaukee WI, USA) as part of a routine clinical evaluation for possible coronary artery disease between January 2016 and December 2016. Exclusion criteria included previous allergic reactions to iodinated contrast material, renal insufficiency, and previous coronary artery bypass graft surgery.

Fig. 1. The coronary and pulmonary arteries and bronchial tree. The left coronary system is located caudal to the left pulmonary artery which runs over the superior margin of the left main bronchus, making the superior margin of the left main bronchus a more suitable landmark for the left coronary system.

CT scan protocol

The scan sequence included a scout scanogram, pre-contrast chest axial scan, test-bolus scan, and the actual CTCA. We performed the pre-contrast axial scan for calcium scoring and to determine the coverage range that would include the entire heart for the CTCA. The CTCA was performed after administration of the contrast medium using the delay calculated during the test-bolus scan. A bolus of contrast medium was injected at a rate of 0.07 ml / kg / s for 15 s, followed by a bolus injection of 30 ml saline at the same rate. For the CTCA scan, we used a rotation time of 350 ms, 64 × 0.625 mm collimation, 0.18–0.24 pitch, and a tube voltage of 120 kV for patients with a body mass index (BMI) ≥ 20 kg / m^2 or 100 kV for those with a BMI < 20 kg / m^2. We determined a tube current of 250–800 mA based on the patient's BMI to preserve similar image noise. Scans were acquired in the craniocaudal direction. The patient's ECG was recorded to allow for retrospective image reconstruction.

Data Analysis

To analyze the data we used pre-contrast 2.5 mm axial sections and 0.625 mm CTCA axial sections reconstructed at the 75% R-R interval. From the scout scanogram, points just below the tracheal bifurcation and at the superior margin of the left main bronchus were noted and the table positions were determined from the pre-contrast axial images (Fig. 2). The superior margin of the left coronary system and the superior margin of the left atrial appendage were defined, and the table positions were recorded from the CTCA axial images. The landmarks in 70 randomly-selected examinations were evaluated by two readers independently (one radiologist with 20 years of experience and one radiological technologist with 9 years of experience) for the assessment of inter-observer variability.

The relationships between the point just below the tracheal bifurcation, the superior margin of the left main bronchus, the superior margin of the left coronary system, and the superior margin
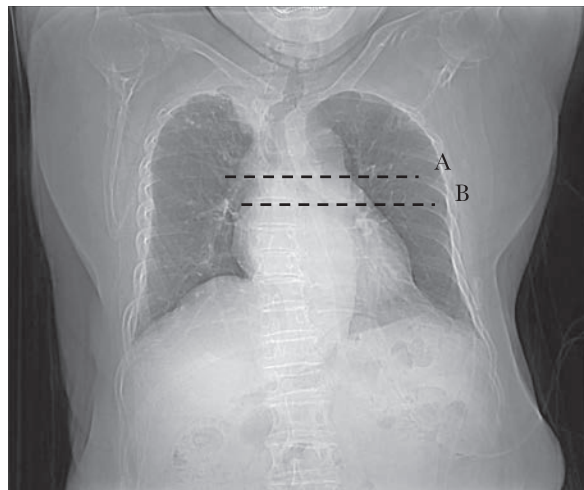

Fig. 2. The scout scanogram. The tracheal bifurcation (dotted line A) and the superior margin of the left main bronchus (dotted line B) are usually well depicted on the anteroposterior view.

of the left atrial appendage were analyzed and the distance between each of these anatomic landmarks was calculated.

Radiation Dose

To estimate the radiation dose, the dose–length product (DLP) and the volume CT dose index were noted from the scan protocol recorded with each CT examination. The effective CTCA dose was derived from the product of the DLP and a conversion coefficient for the chest, according to a method proposed by the European Working Group for Guidelines on Quality Criteria for Computed Tomography[18]. The applied conversion coefficient ($k = 0.014$ mSv $\times$ mGy^{-1} $\times$ cm1^{-1}) was averaged between males and females.

Statistical Analysis

All statistical analyses were performed with EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan)[19], which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). More precisely, it is a modified version of R commander designed to add statistical functions frequently used in biostatistics. A *P*-value of < 0.05 was considered statistically significant for all tests. A paired t-test was used for the pairwise statistical testing of the distances between the superior margin of the left coronary system, and the tracheal bifurcation and superior margin of the left main bronchus. An F-test was used to assess the range of distances between the superior margin of the left coronary system, and the tracheal bifurcation and superior margin of the left main bronchus. The inter-observer variability between the two readers determining the selected landmarks was calculated using the intraclass correlation coefficient.

Results

The tracheal bifurcation was caudal to the superior margin of the left coronary system in two patients (0.3%), and caudal to the superior margin of the left atrial appendage in 11 patients (1.6%). However, the superior margin of the left main bronchus was caudal to the superior margin of the left coronary system in 13 patients (1.9%), and caudal to the superior margin of the left atrial appendage in 148 patients (21.4%) (Table 1).

The distance between the tracheal bifurcation and the superior margin of the left coronary system was 34.4 ± 10.2 mm (range, -6.9 to 66.1 mm), and the distance between the superior margin of the left main bronchus and the superior margin of the left coronary system was 18.8 ± 9.3 mm (range, -11.6 to 47.5 mm). The distance between the superior margin of the left main bronchus and the superior margin of the left coronary system was significantly shorter than the distance between the tracheal bifurcation and the left coronary system ($P < 0.0001$; Fig. 3). The range of distances between the superior margin of the left main bronchus and the superior margin of the left coronary system was also significantly narrower than between the tracheal bifurcation and the superior margin of the left coronary system ($P < 0.05$). With the addition of 1 cm to the superior margin of the left main bronchus, it remained caudal to the superior

Table 1. The relationship of the craniocaudal direction of the tracheal bifurcation (TB), the superior margin of the left main bronchus (LMB), the superior margin of the left coronary system (CA), and the superior margin of the left atrial appendage (LA).

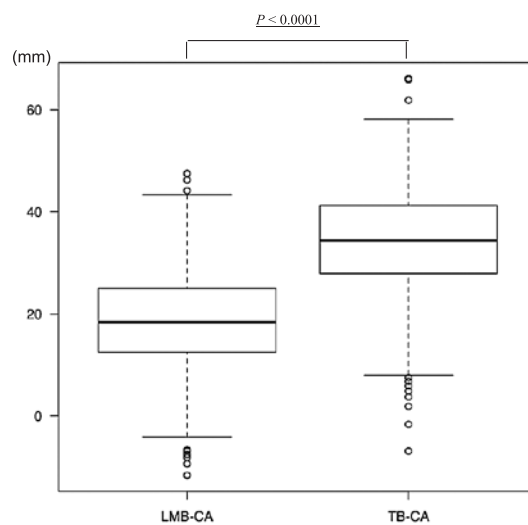|	Caudal to CA	Caudal to LA
TB	2 (0.3%)	11 (1.6%)
LMB	13 (1.9%)	148 (21.4%)
1 cm above LMB	1 (0.1%)	

Numbers are reported as N (%).

Fig. 3. Box plot demonstrating the distance between the anatomic landmarks. The distance between the superior margin of the left main bronchus (LMB) and the superior margin of the left coronary system (CA) was significantly shorter than the distance between the tracheal bifurcation (TB) and the superior margin of the left CA ($P < 0.0001$).

margin of the left coronary system in only one patient (0.1%).

The average reduction in scan length when using the superior margin of the left main bronchus as the starting position for the CTCA (i.e., the difference in the z-axis distances from the tracheal bifurcation and from the superior border of the left main bronchus, taken from the scout scanogram) was 15.6 ± 5.2 mm (range, 0–33 mm).

The intraclass correlation coefficients indicating the inter-observer variability in determining the landmarks were similar. The inter-observer variability rates were 0.994 (95% confidence interval, 0.991–0.997) for identifying the tracheal bifurcation and 0.991 (95% confidence interval, 0.931–0.997) for identifying the superior margin of the left main bronchus.

Discussion

Our study showed that the superior margin of the left main bronchus was more caudal than

the superior margin of the left coronary system in 13 patients (1.9%). However, adding 1 cm to the superior margin of the left main bronchus resulted in only one patient (0.1%) with the left main bronchus caudal to the superior margin of the left coronary system, suggesting that 1 cm above the superior margin of the left main bronchus is the most appropriate starting position for CTCA.

The distance between the tracheal bifurcation and the superior margin of the left main bronchus was 15.6 ± 5.2 mm (0–30 mm). Using our standard retrospective ECG-gating CTCA protocol, the DLP was 1139 ± 255 mGy-cm at 120 kVp and 657 ± 178 mGy-cm at 100 kVp. This is almost the same result as that of the PROTECTION I data[20]; the 75th percentile for DLP for coronary CT angiography in a typical-sized patient was found to be 1,152 mGy-cm. Therefore, each reduction in scan length of 15 mm corresponds to an average radiation dose reduction of 0.96–1.72 mSv. Using a 1 cm border above the superior margin of the left main bronchus as the starting position for the CTCA is associated with an average scan length decrease of 5.6 mm, which corresponds to an average radiation dose reduction of 0.36–0.64 mSv.

We now use the pre-contrast axial scan to determine the CTCA starting position, but this adds to the radiation exposure. If the CTCA scan length can be planned on a scout scanogram, this unnecessary radiation exposure could be avoided. Furthermore, it is possible to combine this technique with other dose reduction techniques, further lowering the dose.

The range of the distances between the superior margins of the left main bronchus and left coronary system was significantly smaller than the range between the tracheal bifurcation and the superior margin of the left coronary system, suggesting a closer anatomical relationship between the left coronary system and the left main bronchus than between the left coronary system and the tracheal bifurcation. Thus, the left main bronchus seems to be a rational choice of landmark.

The level of agreement between two different observers for the location of the superior margin of the left main bronchus was as good as their agreement for the location of the tracheal bifurcation.

When adapting the superior margin of the left main bronchus as the starting position, the superior margin of the left atrial appendage was out of the scan range in 148 patients (21.4%). Therefore, if there is a question of left atrial appendage thrombus, then a repeat scan including the left atrial appendage would be necessary.

Limitations

Our study has several limitations. First, CTCA axial images were only reconstructed at the 75% R-R interval, which is almost the middle diastolic phase, when the coronary arteries are in their most cranial position in the cardiac cycle. Thus, if the coronary arteries are included in the scan range at the 75% R-R interval, they may be included in the scan range at another phase. Second, we used a 2.5 mm-section for pre-contrast imaging and a 0.625 mm-section for CTCA imaging. Third, we have only discussed the starting position of the CTCA, and not its end position. Leschka *et al*[21] reported that the cardiac apex can be identified on the scout

scanogram in 74% of patients. Therefore the end position of the CTCA can be identified from the scout scanogram and no landmark is needed.

Conclusions

In conclusion, 1 cm above the superior margin of the left main bronchus on a scout scanogram appears to be the most appropriate starting position for CTCA.

Conflict of interest disclosure

The authors declare no conflicts of interest regarding this study.

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