EVALUATION OF THE AORTIC ARCH FROM THE SUPRASTERNAL NOTCH VIEW USING FOCUSED CARDIAC ULTRASOUND

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Abstract

Background—The suprasternal notch view (SSNV) is an additional echocardiographic view not routinely used by emergency physicians (EPs) performing focused cardiac ultrasound (FOCUS).

Objective—This pilot study determined the ease and self-perceived accuracy of the SSNV as performed by EPs. Additionally, we assessed the accuracy of FOCUS including the SSNV in thoracic aortic measurements compared to chest CT angiography (CTA).

Methods—This was a prospective, observational, pilot study of adult patients undergoing chest CTA. Thoracic aortic measurements were recorded at the sinus of Valsalva, sinotubular junction, and ascending aorta at its widest diameter in the parasternal long axis (PSL) view and SSNV. EPs rated ease of acquisition and self-perceived accuracy of thoracic aorta measurements. Two blinded radiologists performed thoracic aortic CTA measurements at predefined locations corresponding to the ultrasound measurements.

Results—Of the 79 patients (median age 57 years) enrolled, the SSNV was obtained in 97% of cases. EPs rated the ease of obtaining the SSNV as "easy" in 64.5% of cases and "very difficult" in 7.6% of cases. The mean difference between ultrasound (FOCUS plus SSNV) and CTA measurements were 1.2 mm (95% limits of agreement −2.9 to 5.3) at the sinus of Valsalva, 1.0 mm (95% limits of agreement −5.5 to 3.6 mm) at the sinotubular junction, 0.8 mm (95% limits of agreement −6.2 to 4.6 mm) at the proximal ascending aorta, and 0.6 mm (95% limits of agreement −2.8 to 4.0) at the aortic arch.

Conclusions—Our findings suggest that the SSNV is an easily attainable and accurate view of the thoracic aorta that can be obtained by EPs in the majority of ED patients.

Keywords

ultrasound; cardiac; aorta

INTRODUCTION

Focused cardiac ultrasound (FOCUS) is an integral component in the evaluation of emergency department patients with chest pain, dyspnea, or hypotension. Such patients often present with a wide differential diagnosis from benign conditions to life-threatening emergencies, including thoracic aortic pathology. There is a critical need to gain a better understanding of the utility of point-of-care ultrasonography in the evaluation of patients with suspected thoracic aortic pathology (1).

FOCUS incorporates four standard views: subxiphoid, parasternal long axis, parasternal short axis, and apical four chamber. The 2010 American Society of Echocardiography/ American College of Emergency Physicians Consensus statement reports that the goals of FOCUS are to answer specific questions regarding the presence of pericardial effusion, cardiac tamponade, right ventricular dilation, global left ventricular systolic function, and the presence of cardiac activity (in cases of cardiac arrest) (2). The role of FOCUS in patients with suspected aortic pathology is to assess for pericardial or pleural effusions, as well as to evaluate the diameter of the aortic root. A root diameter >4 cm is suggestive of dilation based on imaging guidelines (2,3). The suprasternal notch view (SSNV) is an additional view commonly used among cardiac sonographers and recommended by the American Society of Echocardiography, but not routinely used by emergency physicians (EPs) performing FOCUS (4). The SSNV permits visualization of the aortic arch and the origins of the innominate artery, left common carotid, and the left subclavian artery.

Data are minimal regarding the utility of FOCUS in the evaluation of patients with suspected disease of the thoracic aorta (5). A recent study performing aortic arch analysis using the SSNV on 2,000 patients referred to an echocardiography lab for routine transthoracic echocardiography demonstrated that adequate images were obtained in 1,826 patients (91%) with 39 patients (2%) demonstrating aortic arch pathology (6). The authors therefore suggested that aortic arch analysis via the SSNV be routinely assessed in adults undergoing transthoracic echocardiography.

Goals of This Investigation

The primary objective of this pilot study was to determine the ease and self-perceived accuracy of obtaining the SSNV in FOCUS examinations performed by EPs. A secondary objective was to assess the accuracy of FOCUS, including the SSNV, in measuring thoracic aortic dimensions as compared to measurements obtained by chest CT angiography (CTA).

MATERIALS AND METHODS

Study Design, Setting, and Selections of Participants

This was a prospective observational study at a single-center, urban, academic ED with >60,000 annual visits. Study subjects included a convenience sample of adult ED patients undergoing clinically indicated chest CTA. Patients were excluded if they had undergone chest CTA at an outside hospital and were subsequently transferred to our ED.

One of five trained study investigators who were blinded to chest CTA results obtained and recorded US images and performed measurements at the time of image acquisition. Eligible patients were screened and enrolled based on availability of study investigators. Four of the five investigators were emergency US fellowship-trained attending physicians and one was a senior emergency medicine resident. Two of the investigators (KAK, JSR), including the senior resident physician, performed the majority of the studies (90%). Verbal informed consent was obtained from all study participants at the time of enrollment. The Institutional Review Board approved this study.

Interventions

Training protocol—Study investigators developed a training protocol detailing standardization of all US views and measurements. Three of the five investigators (KAK, EP, JSR) spent two 30-min training sessions with the chief sonographer of the institution's echocardiography laboratory. Subsequently, two of the investigators developed a 10-min training video. The training of the additional investigators included watching this video, followed by a 20-min practical session led by the same investigators (refer to video, available at http://youtu.be/jZWV8JrZhiw).

Imaging protocol—After verbal consent, study investigators who were blinded to CTA measurements performed the traditional FOCUS examination with the addition of the SSNV. The SSNV is obtained using a phased array transducer in the suprasternal notch with the probe marker oriented toward the patient's right hip (Figure 1). To optimize the images, the patient's head was rotated to the side and, if necessary, a towel roll was placed under the patient's shoulders to further extend the neck. Ultrasound measurements were performed by a single investigator at the sinus of Valsalva, sinotubular junction, and ascending aorta at its widest diameter as visualized using a traditional parasternal long axis (PSL) view. These three sites are recommended by the 2015 American Society of Echocardiography guidelines in order to measure the thoracic aorta (7). Based on guidelines, echocardiographic measurements of the thoracic aortic arch were obtained using the SSNV at its widest visualized diameter (Figure 2). The SSNV allows for visualization of more distal aspects of the aorta otherwise not visualized on the PSL view. The sequence of US and CTA imaging was not standardized. Measurements were obtained during diastole, using a leading-edge-to-leading-edge method (from outer wall to inner wall). Based on current guidelines, we chose a single cutoff of >40 mm to define thoracic aortic dilation (2,3). Images were recorded as cine loops using one of three ultrasound machines: Zonare Z.one Ultra (Zonare, Mountain View, CA); Philips CX30, or Philips CX50 (Royal Philips Electronics, Amsterdam, The Netherlands). All examinations were performed using phased array transducers.

Chest CTA studies were performed on a 2×128-slice scanner (Definition FLASH, Siemens Healthcare, Forchheim Germany) and read by two emergency radiologists who were not clinically involved with the patient. Both radiologists read each study and were blinded to CTA study indications, imaging results, FOCUS results, and clinical presentation. They performed thoracic aortic measurements on all enrolled patients at predefined locations corresponding to the FOCUS measurements (sinus of Valsalva, sinotubular junction, ascending and aortic arch at the widest diameter). Although most conventional CTA measurements are taken from outer wall to outer wall, the radiologists in this study designed a protocol where they used the leading edge method in hopes of obtaining greater consistency between US and CTA measurements. The mean measurements from the two radiologists were used in the final analysis.

Survey protocol—Immediately after performing the FOCUS examination, the study investigator completed a written survey rating the overall ease of image acquisition at the SSNV and PSL view, as well as the self-perceived accuracy of their images (see Appendix A). EPs rated the ease of acquiring images using a 4-point scale from "unable to obtain adequate images" to "easy" (defined as adequate images obtained on the first attempt). "Moderately difficult" was defined as some adjustments needed, but images ultimately obtained and "extremely difficult" was defined as many adjustments needed resulting in suboptimal images. Accuracy was rated on a 3-point scale from "inaccurate" to "extremely accurate" based on the providers' estimate of how well their measurements would correlate to measurements obtained by chest CTA. The EPs performing the examination also noted if they suspected any abnormality on the PSL or SSNV, specifically if they suspected aortic dilatation or dissection.

Data acquisition—Study investigators collected descriptive data prospectively on the enrollment form as well as from retrospective chart review using electronic medical records to determine patient demographic characteristics and indication and type of CTA performed.

Outcomes

For our primary outcome, we assessed the ease of obtaining the SSNV in addition to the standard FOCUS views, as well as the self-perceived accuracy of these measurements obtained by EPs. For our secondary outcome, we assessed the diagnostic accuracy of FOCUS, including the SSNV, in measuring thoracic aortic dimensions as compared to measurements obtained by chest CTA.

Analysis

Descriptive data were expressed as mean ± standard deviation (SD) or median (interquartile range [IQR]) for continuous variables, and as numbers and percentages for categorical variables. We estimated a sample size of 80 subjects to obtain 95% limits of agreement between CTA and ultrasound measurements with a precision of ± 0.4 SDs.

We used Bland-Altman plots with 95% limits of agreement to examine agreement for aortic measurements between the FOCUS and CT measurements. Using receiver operator characteristic curve with a cutoff of 40 mm, we calculated the sensitivity and specificity of

FOCUS for thoracic aortic dilation using the largest measurement on CT as the reference standard. Additionally, we used *t*-test and Wilcoxon Mann-Whitney test (based on variable distribution) to compare the US and CTA measurements for both the senior resident and US fellowship-trained attending. All analyses were performed using Stata 11.0/SE software (Stata Corporation, College Station, TX).

RESULTS

Characteristics of Study Subjects

From April 2013 to March 2014, ninety-seven patients were enrolled, as detailed in the patient flow diagram (Figure 3). Eighteen of the initial FOCUS studies were unavailable for review due to a US system hard-drive malfunction that resulted in image loss, leaving 79 patients for the final analysis. In this cohort, the median age was 57 years (range 22–92 years) and 56.0% were female. Demographic and clinical data are presented in Table 1. The most common presenting chief complaints prompting chest CTA included chest pain (48.1%), shortness of breath (39.2%), and hypoxia (13.9%). In this cohort, 78.4% of the CTAs performed were specifically protocolled to detect pulmonary embolus, while 21.5% were protocolled to detect aortic dissection (AD).

Imaging Findings

The SSNV was obtained in 97.0% of enrolled patients. EPs rated the ease of obtaining the SSNV as "easy" (defined as obtaining adequate images on the first attempt) in 64.5% of cases and "very difficult" in 7.6% of cases. The more traditional parasternal cardiac view was rated as "easy" and "very difficult" in 76.0% and 3.8% of cases, respectively (Figure 4). Emergency physicians rated their self-reported accuracy of the SSNV obtained as "extremely" accurate in 61.0% of cases and inaccurate in 3.8% of cases.

The mean difference with 95% limits of agreement between FOCUS and mean CTA measurements was 1.2 mm (−2.9 to 5.3 mm) at the sinus of Valsalva, 1.0 mm (−5.5 to 3.6 mm) at the sinotubular junction, 0.8 mm (−6.2 to 4.6 mm) at the proximal ascending aorta, and 0.6 mm (−2.8 to 4.0 mm) at the aortic arch (Figure 5).

The majority of studies were performed by two of the five study investigators, one being the senior resident (40%). There was no statistically significant difference ($p > 0.05$) between the senior resident and the US fellowship-trained sonographer for any of the four measurements.

In 7 patients with dilatation of 40 mm by CTA, FOCUS (including SSNV) had a sensitivity of 71.4% (95% confidence interval [CI] 29%–96.3%), specificity of 100% (95% CI 94.9%–100%), and area under curve of 0.857 (95% CI 0.676–1) for detection of proximal aortic dilatation. Two of 7 aortic dilations were only seen on CTA, but not detected by the EPs performing the FOCUS examination. These two cases detected on CTA and missed on US were just over the criteria of 40 mm, both measuring 41 mm. The five additional cases of dilatation detected on US and CTA were the following: 42.5 mm, 41 mm, 42.5 mm, 41.7 mm, and 43.8 mm.

DISCUSSION

This is the first study we are aware of evaluating the SSNV as part of the focused cardiac evaluation in the ED. Our findings suggest that the SSNV may be a relatively easy view to obtain for EPs.

In nearly all cases in our study, an SSNV was feasible after a limited amount of training. These data suggest that the SSNV may be technically attainable for EPs and could be considered as an additional view to the traditional FOCUS views.

Our findings suggest that measurements of the thoracic aorta using FOCUS plus SSNV show a substantial level of agreement (within 1 mm) when compared to measurements made by CTA. This expands on previous findings by Taylor et al.'s retrospective study that reviewed the imaging of 90 ED patients and demonstrated good agreement between retrospective measurements made on FOCUS examination (not including SSNV) compared to CTA measurements of the thoracic aorta (5).

Although only 7 patients in our study had aortic pathology, we found FOCUS with SSNV to demonstrate high specificity for thoracic aorta dilatation compared to CTA. We believe this tool has the potential to help initiate emergent treatment as well as prioritize further testing and triage decisions by the EP. Although not the primary outcome of our study, these findings should be considered hypothesis generating, especially in light of the currently scant literature that evaluates the utility of FOCUS in the evaluation of thoracic aortic disease. Further prospective studies are needed to fully evaluate the test characteristics of FOCUS and the SSNV for the detection of aortic pathology.

Limitations

As image acquisition was performed by EPs with significant FOCUS experience, our findings may not apply to providers without advanced US training. Training investigators for the study included a brief video and hands-on scanning session lasting <30 min; EPs without advanced US training may require additional training to perform similarly. While two providers made the majority of measurements, one was a senior resident and therefore does suggest this novel cardiac view is attainable for those without US fellowship training.

We compared our ultrasound measurements to CTA using two different CTA protocols (pulmonary embolism and aortic dissection) and, although unlikely, this may have had an effect on our results. Additionally, although the radiologists attempted to replicate the measurements made on FOCUS examinations, the exact location of these measurements is not a traditionally reported component of CTA. A small number of patients with aortic pathology were enrolled, limiting the conclusions that can be drawn from this study regarding diagnostic accuracy of FOCUS with an additional SSNV in detecting thoracic aortic pathology.

CONCLUSIONS

In this prospective pilot study, EPs were able to perform the SSNV of the thoracic aorta and obtain accurate measurements as compared to chest CTA in the majority of cases. Further

research is warranted to determine the diagnostic accuracy and clinical utility of the SSNV in addition to FOCUS for the identification of aortic pathology in the ED.

Acknowledgments

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APPENDIX A: SURVEY TOOL

BWH Date of study: __ / __ / ___   Sonographer: _____

PLACE STICKER HERE

Name:
MRN#
Date:

Machine: ☐ Alpha ☐ Bravo

Subject Age: yrs
Subject Estimated Height: ft in
Subject Estimate Weight: lbs

1) Rate the ease of acquiring your parasternal long axis views:
    ☐ Unable to obtain (unable to obtain adequate images)
    ☐ Very difficult (many adjustments needed to obtain adequate images)
    ☐ Moderately difficult (minor adjustments needed to obtain adequate images)
    ☐ Easy (adequate images obtained on first attempt)

2) Rate the accuracy of your parasternal long axis views:
    ☐ Inaccurate (images will not be accurate measurements compared to CT)
    ☐ Somewhat accurate (images will be somewhat close to those compared to CT)
    ☐ Extremely accurate (images will be extremely close to those compared to CT)

3) Rate the ease of acquiring your suprasternal notch view:
    ☐ Unable to obtain (unable to obtain adequate images)
    ☐ Very difficult (many adjustments needed to obtain adequate images)
    ☐ Moderately difficult (minor adjustments needed to obtain adequate images)
    ☐ Easy (adequate images obtained on first attempt)

4) Where did you take your measurements of the aortic arch diameter?
    ☐ At the level of the proximal brachiocephalic artery
    ☐ Where the largest diameter was visualized

5) Rate the accuracy of your suprasternal notch view:
    ☐ Inaccurate (images will not be accurate measurements compared to CT)
    ☐ Somewhat accurate (images will be somewhat close to those compared to CT)
    ☐ Extremely accurate (images will be extremely close to those compared to CT)

6) Do you suspect any abnormality on your parasternal long axis view?
    ☐ No   ☐ Yes, aortic enlargement   ☐ Yes, aortic dissection   ☐ Yes, pericardial effusion

7) Do you suspect any abnormality on your suprasternal notch view?
    ☐ No   ☐ Yes, aortic enlargement   ☐ Yes, aortic dissection

ARTICLE SUMMARY

1. Why is this topic important?

Suprasternal notch view (SSNV) is an additional echocardiographic view not routinely used by emergency physicians (EPs) performing focused cardiac ultrasound (FOCUS). This view may be a feasible addition to the traditional FOCUS examination that may provide additional information in the evaluation of the thoracic aorta.

2. What does this study attempt to show?

This pilot study attempts to show the ease in image acquisition and self-perceived accuracy of the SSNV as performed by EPs.

3. What are the key findings?

Of the 79 patients enrolled in this pilot study, the SSNV was obtained in 97% of cases. EPs rated the ease of obtaining the SSNV as "easy" in 64.5% of cases.

4. How is patient care impacted?

Based on this pilot study, the SSNV is an attainable and accurate view of the thoracic aorta. Further research is warranted to determine the diagnostic accuracy and clinical utility of the SSNV in addition to FOCUS for the identification of aortic pathology in the ED.

Figure 1.
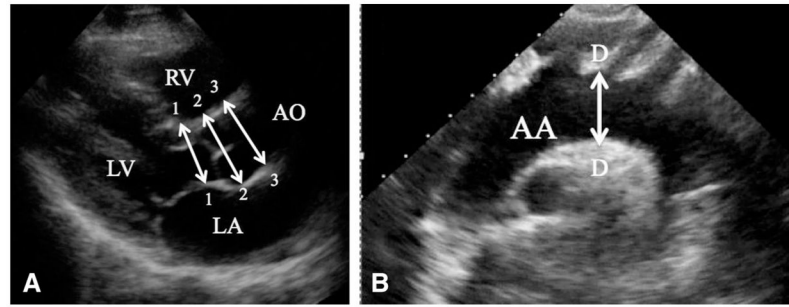Suprasternal notch view probe positioning.

Figure 2.
(A) Parasternal long axis view with sites of measurement. (B) Suprasternal notch view (SSNV) with sites of measurement. 1 = sinus of Valsava; 2 = sinotubular junction; 3 = ascending aorta. AA = aortic arch; AO = ascending aorta; D = widest diameter of aortic arch measurement; LA = left atrium; LV = left ventricle; RV = right ventricle.
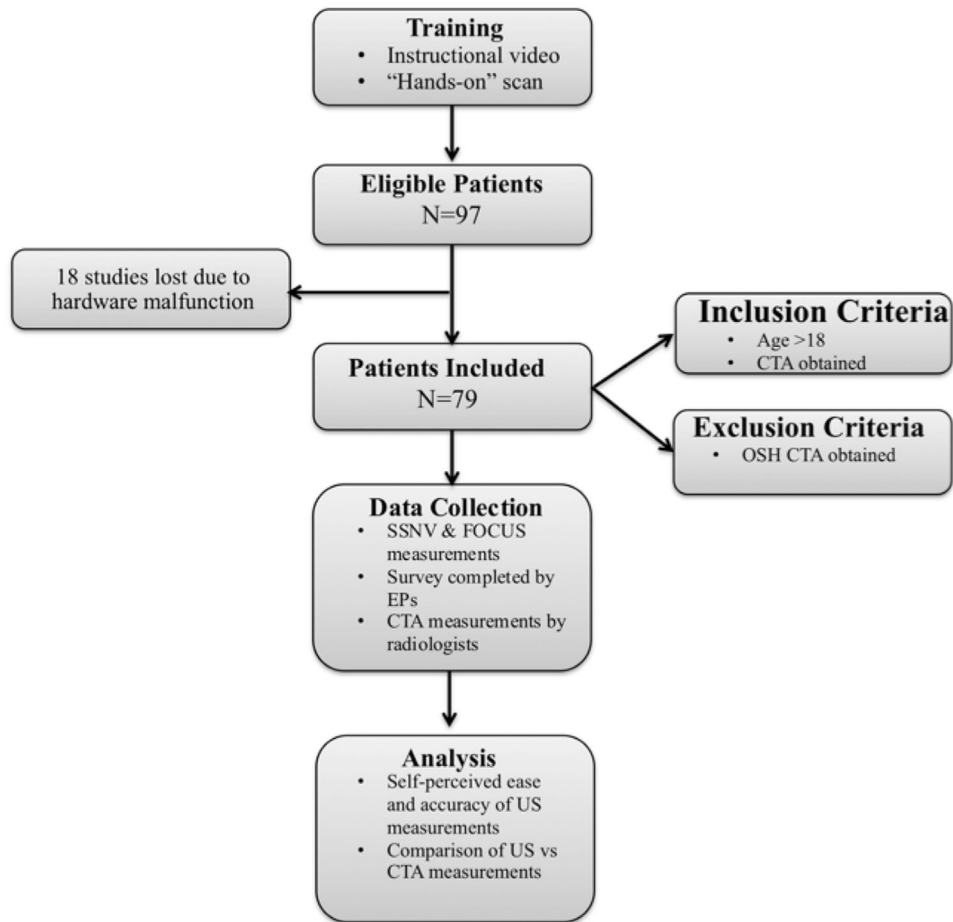
Figure 3.
Study flow chart. SSNV = suprasternal notch view; CTA = computed tomography angiography; FOCUS = focused cardiac ultrasound; EP = emergency physician; US = ultrasound; OSH = outside hospital.
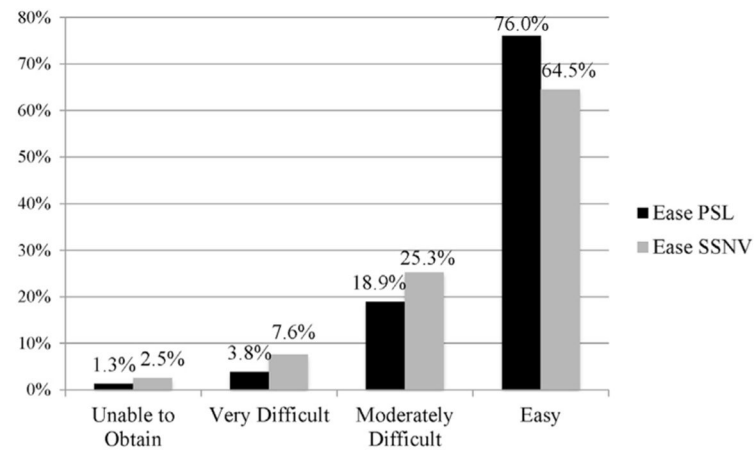
Figure 4.
Survey results on ease of obtaining parasternal long axis (PSL) view and suprasternal notch view (SSNV) images (unable to obtain, very difficult to obtain, moderately difficult to obtain, easy to obtain).
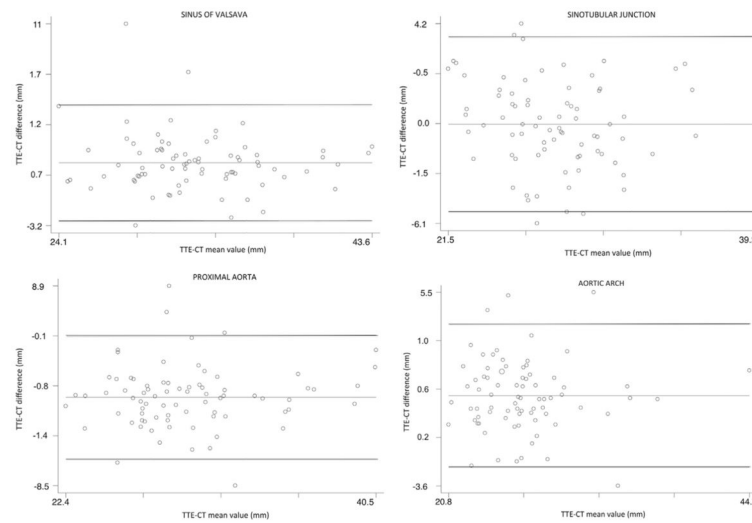
Figure 5.
Bland-Altman plots of ultrasound vs. computed tomography angiography (CTA) measurements. The difference between ultrasonography and CTA measurements (mm) is plotted against the mean ultrasound and CTA measurements. The horizontal line represents the mean difference at each location and the bold lines the 95% limits of agreement. TTE = transthoracic echocardiography.

Table 1

Baseline Characteristics of Patients (n = 79)

Characteristic	
Age (y), mean ± SD	57 ± 19
Female, n (%)	44 (56)
Weight (kg), mean ± SD	81 ± 22
Risk factors for aneurysm, dissection, and PE, n (%)	
Hypertension	48 (60.7)
Coronary artery disease	7 (8.8)
Diabetes mellitus	7 (8.8)
History of neoplasm	18 (22.7)
History of aortic aneurysm	2 (2.53)
History of aortic dissection	4 (5.1)
History of PE/DVT	10 (12.6)
Study indication (%)	
Chest pain	38 (48.1)
Shortness of breath	31 (39.2)
Back pain	6 (7.6)
Syncope/presyncope	3 (3.8)
Hypoxia	11 (13.9)
Protocol of CTA, n (%)	
Aortic dissection	17 (21.5)
Pulmonary embolism	62 (78.4)

CTA = computed tomography angiography; DVT = deep venous thrombosis; PE = pulmonary embolus.