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Thoracic aortic strain can affect endograft sizing in young patients

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Objective: **Aortic computed tomography angiography (CTA) examination with electrocardiography gating is becoming the clinical routine image acquisition protocol for diagnosis and intervention planning. To minimize motion artifact, the images are reconstructed in the diastolic phase of the cardiac cycle. The aim of our study was to quantify aortic strain in an elderly nonaneurysmatic patient cohort and to identify the phases of the R-R cycle that correspond to the minimal and maximal aortic diameters. The quantification of aortic strain may enable the improvement of intervention planning and the introduction of more effective dose-saving protocols for CTA scans.**

Methods: **We assessed CTA images of 28 patients (14 men; mean age, 74 years). Aortic calcium score was calculated on native images. Angiography images were reconstructed in equally spaced 10 phases of the R-R cycle. After semiautomatic centerline analysis, we measured the cross-sectional areas in each of the 10 phases at 9 specific segments between the ascending aorta and the common iliac bifurcation representing the attachment sites of thoracic and abdominal stent grafts. Area-derived effective diameter, pulsatility ($A_{max} - A_{min}$), and strain [$(A_{max} - A_{min})/A_{min}$] were calculated. Repeated measurements were taken to evaluate inter-reader and intrareader reproducibility (10-10 patients each).**

Results: **A total of 4320 measurements were performed. We found significant difference between diastolic and systolic diameters ($D_{D,Z0} = 33.2$, $D_{S,Z0} = 34.4$; $P < .001$). Pulsatility values of the vessel diameters were 1.0 to 1.1 mm in the thoracic aorta, 0.7 to 0.9 mm in the abdominal aorta, and 0.5 to 0.6 mm in the common iliac arteries. Negative, moderate correlations were found between aortic strain and age ($r = -0.586$; $P = .001$), aortic strain and plaque area ($r = -0.429$; $P = .026$), and age and body mass index ($r = -0.412$; $P = .029$). We found positive, moderate correlation between age and plaque area ($r = 0.594$; $P = .001$). The aortic pulsatility curve has a positive extreme at 30% and a negative extreme at 90% of the R-R cycle throughout the aorta. Lin concordance coefficients were 0.987 for inter-reader and 0.994 for intrareader correlations.**

Conclusions: **Aortic strain can be reliably quantified on electrocardiography-gated CTA images. Pulsatility of the aorta can be substantial in the thoracic aortic segments of young patients; therefore, the routine use of systolic images is not recommended. In addition, we demonstrated that images at 30% of the heart cycle correspond to the largest diameter of the aorta. (J Vasc Surg 2015;62:1479-84.)**

There is growing evidence that endovascular aortic repair (EVAR) can be safely and effectively performed in thoracic and abdominal aortic diseases, such as aortic aneurysm and acute aortic syndrome.[1-5] Simultaneously, a shift in the last 15 years can be observed from open repair to EVAR; however, there is an ongoing debate as to whether we should push the boundaries too far in favor of EVAR.[6] Thoracic and abdominal EVAR is associated with lower mortality rates compared with open repair, but there is a non-negligible number of EVAR patients who suffer late complications of the stent grafts caused by migration and endoleaks.[7-9] As both undersizing and excessive oversizing are known to be associated with complications in the short and long term, precise sizing of the stent graft is crucial.[8,10,11]

Previous generations of computed tomography (CT) scanners with a lower number of detector rows and slower gantry rotation without electrocardiography (ECG) synchronization produced images with a blurred aortic contour and a somewhat averaged aortic diameter because of aortic wall motion. Nowadays, technologic advances allow rapid ECG-gated CT angiography (CTA) of the whole aorta during a single breath-hold, confronting us with new problems: which phase of the cardiac cycle should be used for image acquisition or reconstruction?[12] Conventionally, diastolic images are preferred as systolic images are often compromised by motion artifacts. However, aortic diameter changes during the R-R cycle can be substantial, especially in the young; wavy aortic contour on pediatric CT images is a usual finding. If the systolic-diastolic difference of the aortic diameter is considerable, this can result in an undersized stent graft.[12]

In this study, our primary objective was to measure the strain of the whole aorta on ECG-gated CTA images in an

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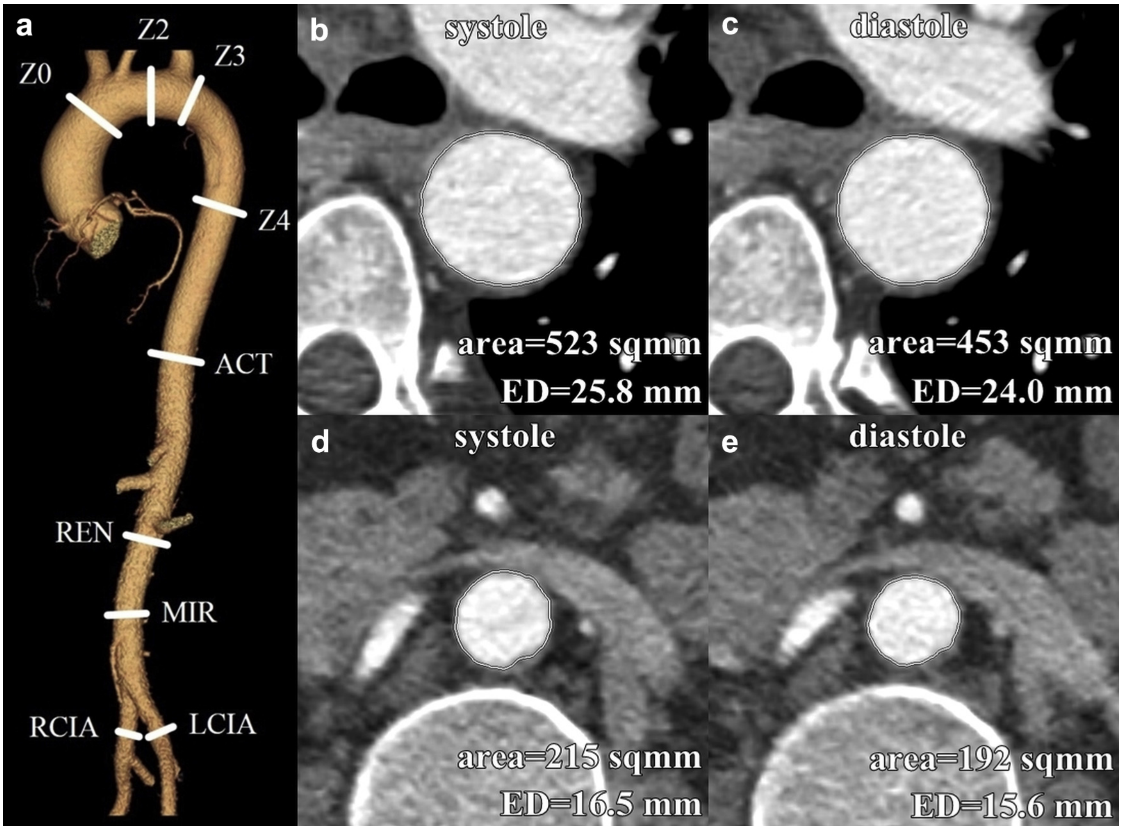

Fig 1. a, Locations of cross-sectional area measurements. *ACT,* At 5 cm above celiac trunk origin; *LCIA,* left common iliac artery; *MIR,* middle infrarenal aorta; *RCIA,* right common iliac artery; *REN,* below renal ostia; *Z0, Z2, Z3, Z4,* Ishimaru zones of the thoracic aorta. **b** to **e,** Systolic and diastolic phase cross-sectional images perpendicular to the centerline at the level of Z4 (**b** and **c**) and REN (**d** and **e**). *ED,* Area-derived effective diameter.

elderly patient cohort with atherosclerotic but otherwise normal aorta. Our secondary objective was to identify the phases of the R-R cycle that correspond to the maximal (systolic) and minimal (diastolic) diameters, enabling us to introduce dose-saving options for CTA scans of future patients.

METHODS

CT imaging. Imaging of the aorta was performed in 28 patients (14 men; mean age, 72.9 ± 12.0 years) with a 256-slice multidetector CT scanner (Philips Brilliance iCT; Koninklijke Philips N.V., Best, The Netherlands) using an ECG-gated protocol tailored for imaging of the aorta. The study was performed on images readily available from patients being evaluated for transcatheter aortic valve repair (TAVR) or from patients with suspected acute aortic syndrome.

Hemodynamic parameters were measured with an electronic sphygmomanometer before administration of contrast material. A low-dose (tube voltage, 100 kV) native scan was followed by retrospective ECG-gated CTA of the whole aorta (100 kV) with a reduced field of view to maximize spatial resolution. Nonionic contrast agent was injected into an antecubital vein at a flow rate of 4 to 5 mL/s using a power injector. Images were reconstructed using a sharp convolution kernel and iterative reconstruction algorithm (iDose,[4] Koninklijke Philips N.V.) with a slice thickness of 1 mm and an increment of 1 mm. Multiphase images were reconstructed corresponding to every 10% of the R-R cycle, resulting in 10 series of images for each patient. Data sets were transferred to stand-alone workstations for further analysis.

Image analysis. Image analysis, vessel segmentation, and cross-sectional measurements were performed by two independent radiologists experienced in cardiovascular imaging. Aortic calcifications were calculated using the dedicated coronary calcium scoring software of an Extended Brilliance Workspace (HeartBeat CS; Koninklijke Philips N.V.).

CTA images were analyzed using an Advantage Workstation (GE Healthcare Europe GmbH, Freiburg, Germany). After automatic vessel segmentation and centerline detection, cross-sectional area of the lumen was measured in a semiautomatic fashion at the following nine locations: ascending aorta proximal to the brachiocephalic trunk (Ishimaru Z0), between left common carotid