Circulation: Cardiovascular Imaging

CARDIOVASCULAR IMAGES

Three-Dimensional Growth Analysis of Thoracic Aortic Aneurysm With Vascular Deformation Mapping

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Patients with thoracic aortic aneurysm undergo regular imaging surveillance, commonly with computed tomography angiography (CTA). Aortic diameter measurements are the standard metric for assessing aortic growth and risk for adverse events, but are subject to significant measurement variability, on the order of 1 to 5 mm, a problem that is compounded when serial studies are compared.[1,2] Vascular deformation mapping (VDM) is a recently developed technique that uses serial CTA examinations to quantify interval aortic growth in a 3-dimensional (3D) manner.[3] VDM measures the local change in aortic wall dimensions between 2-time points through registration of clinical CTA data followed by quantification of local aortic wall deformation (ie, growth) between studies using a spatial Jacobian analysis. The determinant of the spatial Jacobian at each voxel is normalized by the time interval to yield a deformation rate (|J|/y) and, this data are superimposed on a 3D model of the aorta to allow for topographical depiction of aortic growth. The spatial Jacobian tensor is a dimensionless parameter, thus paired luminal circumference measurements are used to calculate aortic growth rate (mm/y). We present the case of a young woman with aortitis and a rapidly enlarging ascending aortic aneurysm undergoing presurgical evaluation, studied as part of a Health Insurance Portability and Accountability Act-compliant and Institutional Review Board–approved study at the University of Michigan. Although the tubular ascending aorta met size criteria for surgical repair, an accurate assessment of growth in adjacent segments was desired to determine the extent of repair (ie, how much aorta to resect), as replacement of the aortic root and arch carry added technical challenges and patient risk. Maximal diameter measurements were performed on clinical CTA studies spanning a 2-year period acquired on the same dual-source CT scanner (Siemens SOMATOM Force; Siemens Healthcare AG, Erlangen, Germany) but acquired at difference centers (Figure 1). Rapid growth of the mid-ascending level was clearly detected by diameter measurements with a calculated growth rate of ≈9 mm/y. Although there was ≈1 mm of increase in the maximal aortic diameter at the level of the sinuses, proximal arch, and distal arch, the conclusion of clinical diameter assessment was that these segments were stable within the limits of measurement variability (ie, ±2 mm).[4] Subsequently, VDM analysis was performed on the same CTA studies (Figure 2; Video 1), and results were validated by comparison with paired luminal circumference measurements (Figure 3). In agreement with diameter measurements, rapid growth (9.2 mm/y) was noted at the ascending aorta by VDM analysis, and the aortic root dimension were stable over the 2-year interval. VDM analysis demonstrated that growth of the ascending aorta extended proximally to involve the sinotubular junction, from which both the right and left coronary ostia arose, implying the need for coronary reimplantation. In disagreement with diameter assessment low intensity (1.0 mm/y), eccentric growth was noted at the proximal arch, with a higher degree of growth along the greater curvature (yellow arrow) than the lesser curvature (purple arrow). Last, an area of low-intensity

Key Words: aorta ■ aneurysm ■ computed tomography angiography ■ disease progression ■ risk

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growth (0.8 mm/y) was detected at the mid-descending level, which was not clinically suspected but consistent with the patient's aortitis (blue arrowhead). Using VDM results, a surgical repair strategy was devised that maximized resection of diseased aortic tissue while balancing surgical risk (Figure 2; gray dotted line). Aortic growth occurs as a result of failing aortic wall structural integrity; however, diameter-based assessments are often limited for confident detection of slow because of measurement variability and do not depict growth in a 3D manner. VDM is a new imaging analysis technique that overcomes these limitations, whereas harnessing the high-resolution, volumetric data produced by modern CTA techniques, allowing for a more comprehensive depiction of aortic growth that can be applied to inform surgical planning and advance understanding of thoracic aortic aneurysm disease progression.

ARTICLE INFORMATION

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Sources of Funding

Dr Burris received a Research Fellow Grant from the Radiologic Society of North America (RF1502) and Dr Ross, US National Institutes of Health R35CA197701 and U01CA166104.

Disclosures

Drs Burris, Hoff, Kazerooni, and Ross are entitled to royalties from the licensure of intellectual property studied in this research. The Vascular Deformation Mapping technology has been licensed to Imbio, LLC, a company in which Dr Ross has a financial interest. The other author reports no conflicts.

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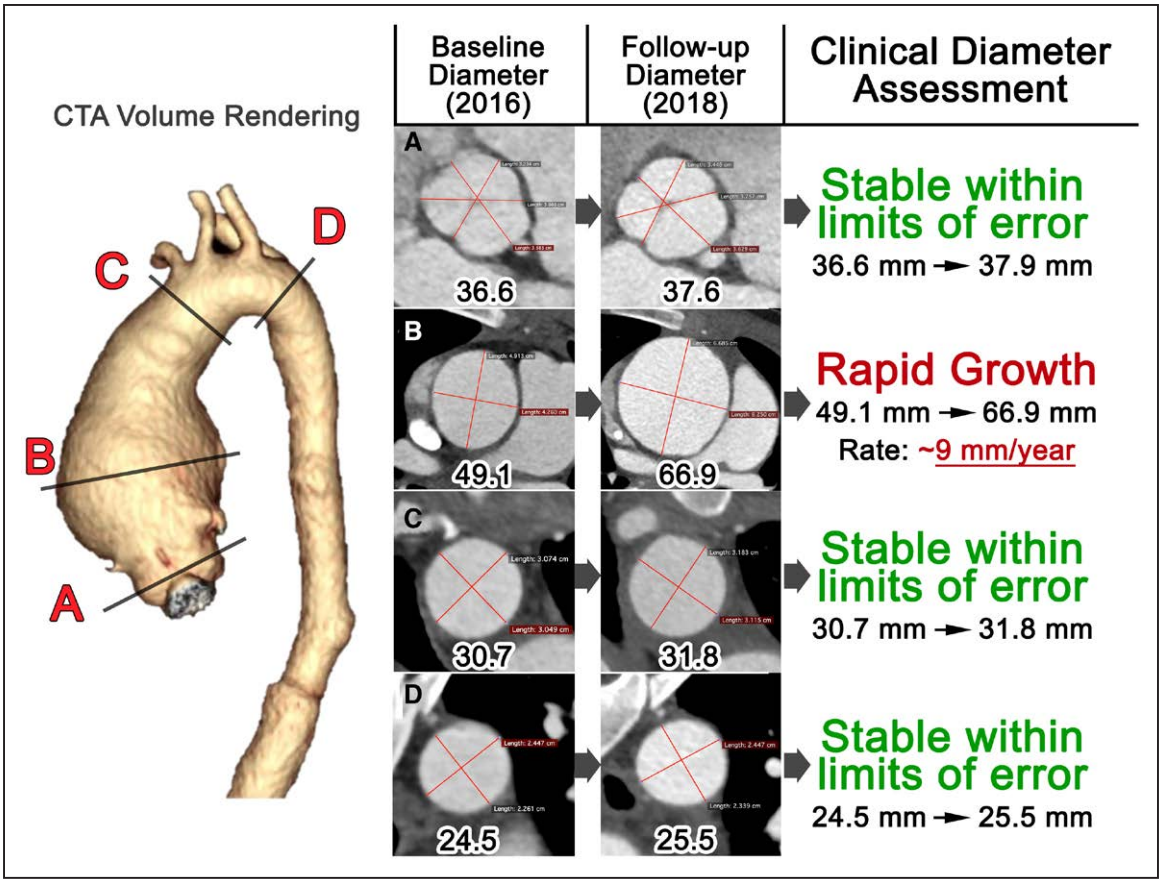

Figure 1. Aortic growth assessment by diameter measurements: Three-dimensional volume rendering of the most recent computed tomography angiography (CTA) examination (left) demonstrating standard locations for clinical aortic diameter measurements, including sinuses of Valsalva (A), midascending (B), proximal arch (C), and distal arch (D).

Maximum aortic diameter measurements (in mm) at each location are shown at baseline (2016) and follow-up (2018) CTA examinations at the matched locations, using double-oblique technique.

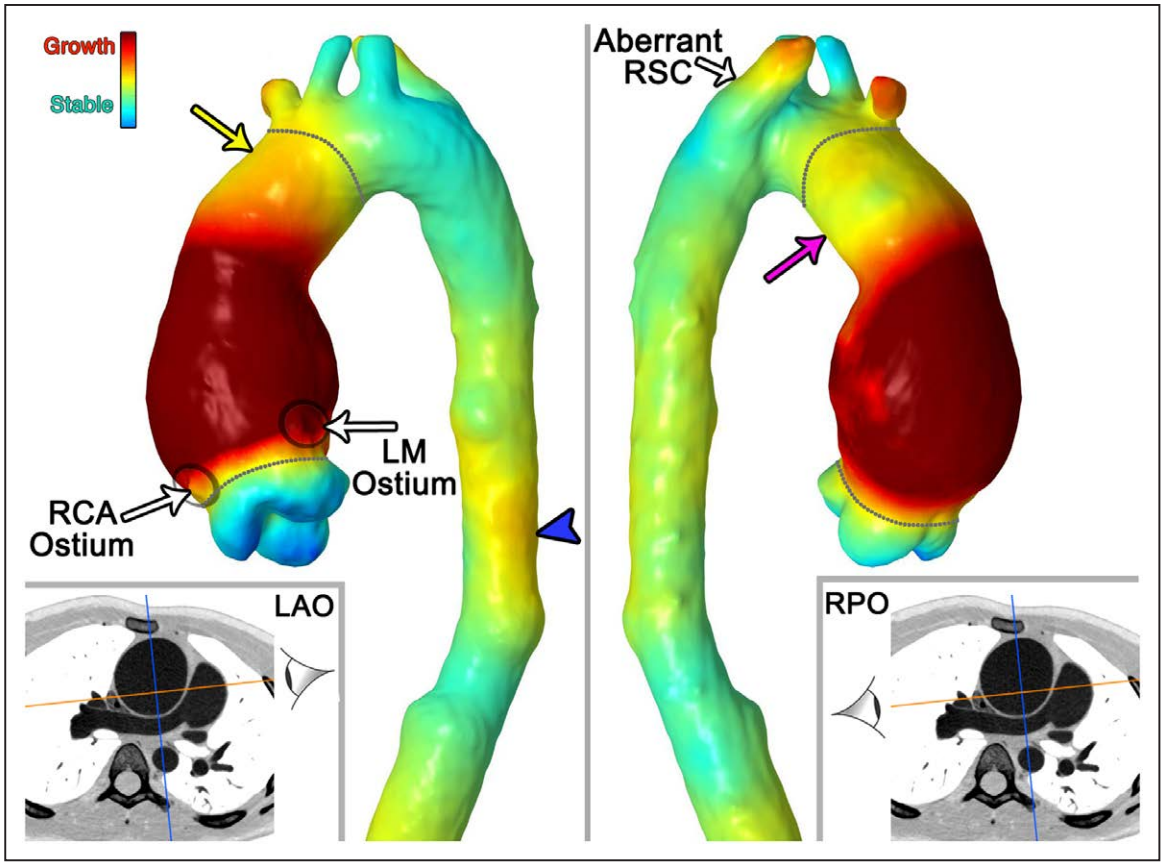

Figure 2. Result of vascular deformation mapping (VDM) shown in left anterior oblique (LAO; left) and right posterior oblique (RPO; right) projections.

The color scale represents the degree of measured aortic wall deformation by spatial Jacobian analysis and is normalized by the interval between computed tomography angiography examinations to yield a growth rate (|J|/y). Based on VDM analysis, growth of the ascending aorta involved the right coronary (RCA) and left main coronary (LM) ostia. (white arrows), and eccentric growth was noted in the proximal arch, which was higher in degree along the greater curvature (yellow arrow) than the lesser curvature (purple arrow). A focal region of growth was detected at the mid-descending level (blue arrowhead). An aberrant origin of the right subclavian artery was incidentally noted.

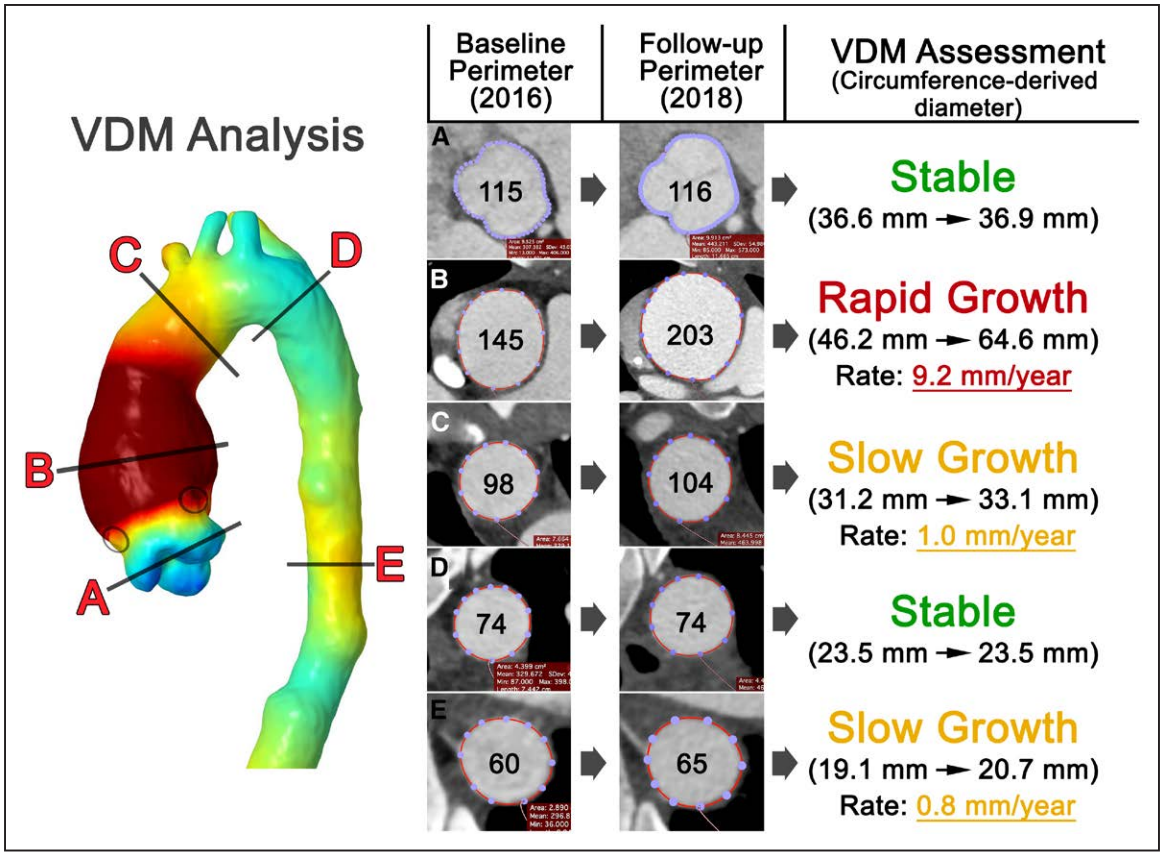

Figure 3. Vascular deformation mapping (VDM) results were validated through measurement of change in aortic perimeter measurements (in mm) between baseline (2016) and follow-up (2018) computed tomography angiography studies at 5 standard locations: sinuses of Valsalva (A), mid-ascending (B), proximal arch (C), distal arch (D), and mid-descending (E).
Aortic circumference was used to calculate a derived diameter for growth rate assessment (circumference [in mm]/π].