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ORIGINAL ARTICLE

Prevalence of aortic root dilation in patients with CT angiography of the aorta

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PURPOSE
To investigate the prevalence of aortic root dilation in patients who underwent CT angiography of the thoracic aorta.

MATERIALS AND METHODS
In 95 patients, 64-slice multislice computed tomography was performed for evaluation of the thoracic aorta. Measurements of the annulus, sinuses of valsalva (SOV), sinotubular junction (STJ), and maximum ascending aorta (AAo) were made by double oblique multiplanar reformation (MPR). For the AAo, STJ, and SOV, dilation was defined as greater than 40 mm; for annulus, the dilation criterion was greater than 27 mm.

RESULTS
Overall, 52 patients were diagnosed with a dilated AAo. Of those patients with dilated AAo, 28 patients had a dilated annulus, 27 patients had dilated SOV, and 11 patients had STJ dilation. Forty-three patients presented with normal AAo; 12 patients had annulus dilation; 12 patients had SOV dilation; and 4 patients had STJ dilation. In patients with dilated AAo, 38% also had a dilated annulus, 52% showed SOV dilation, and 21% presented with STJ dilation, compared to 28% annulus dilation, 28% SOV dilation, and 9% STJ dilation in patients with an AAo of normal caliber.

CONCLUSION
Our data indicate a higher prevalence of aortic root dilation among patients with dilated AAo.

Key words: • aortic root dilation • CT angiography • thoracic aorta

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Thoracic aortic aneurysm (TAA) is a potentially life-threatening disorder if not diagnosed before the development of dissection and rupture. TAA is defined as a localized dilation of the aorta to more than 50% of baseline. The incidence of TAA is estimated at 6 people per 100,000 per year, and the mean age at diagnosis is 60–70 years. (1). Of all patients presenting with TAA, 60% involve the aortic root and/or ascending aorta (2). The aortic root is described as the part of the aorta that supports the aortic valve leaflets, delineated superiorly by the sinotubular junction (STJ) and inferiorly by the annulus (3). Determination of the segment, or segments involved in the dilation has clinical and surgical significance.

Multi–detector row computed tomography (MDCT) is an emerging noninvasive tool for the accurate detection and segmentation of TAA. The current generations of 64-slice scanners, with submillimeter slice collimation and high temporal resolution, have improved our ability to identify and localize TAA. Retrospective electrocardiographically (ECG)-gated MDCT has enabled high quality multiplanar reformation (MPR) and volume-rendered (VR) images. Thus, visualization of the extension of the aneurysm as well as estimation of diameter of the aortic annulus, sinuses of valsalva and sinotubular junction are possible.

Although there have been extensive studies on measurements of the aortic valve with MDCT, little imaging information is available on the rate of dilation of the different aortic segments and aortic root structures (4, 5). Recently, Lu et al. (6) reported normal measurements of the ascending aorta (the mean diameters of the coronary sinus, sinotubular junction and ascending aorta were 34.2 mm, 29.7 mm and 32.7 mm, respectively) in 78 patients with MDCT. Accordingly, the present study was undertaken to explore the physical dimensions of the aortic root and its structures at the level of the sinuses of valsalva, annulus, sinotubular junction, and AAo with MPR in a patient population scanned for CTA of the aorta.

Materials and methods

Subjects

The patient population participating in this retrospective study was comprised of individuals who had been scanned for thoracic aortic aneurysm and/or dissection at our institution between December 2005 and January 2007. The study was approved by the institutional committee on human research. An honest broker prepared and presented all CT images and medical information in a coded, unidentified manner; the investigators were privy only to the age and sex of individual patients. The data were retrospectively reviewed to exclude all patients documented with coexistent proximal aortic pathology or surgery. Patients with Marfan syndrome, bicuspid aortic valve, or a history of prior aortic surgery were excluded. The final study group comprised 95 that had had multidetector CT angiography (CTA): the mean age for the group was 64 (age range, 34–87); the 61 men had a mean age of 64 (age range, 25–87), and the 34 women had a mean age of 66 (age range, 29–89).

Image acquisition

Contrast-enhanced multi–detector row CT examinations were performed in the supine position, during a single breath hold, using a 64-channel multislice system (VCT, GE Healthcare, Milwaukee, Wisconsin, USA). All CT scans were preceded by a scout acquisition. For bolus tracking, 15 transverse sections were acquired successively at the level of pulmonary bifurcation. Scanning began at the same time as intravenous administration of the contrast agent. A total of 15 mL of an iodinated contrast agent, containing 350 mg of iodine per milliliter Ioversol (Optiray, Mallinckrodt, St. Louis, Missouri, USA), was injected at a rate of 5 mL/s, followed by a bolus of 25 mL saline solution given at 5 mL/s. A region of interest was positioned in the aorta at the level of pulmonary bifurcation and enhancement values (in Hounsfield units) within this region were plotted against time; bolus tracking technique was used to trigger image acquisition.

Retrospective ECG-gating was performed during continuous CT data acquisition. The slice thickness was 0.63 mm, the gantry rotation speed was 350 ms per rotation, and the tube voltage was 120 kV for a current range of 550 to 750 mA (depending on patient size). ECG-modulated tube current was used, with the maximum current applied during 70% to 80% of the cardiac cycle, and less was applied during the remainder of the R–R cycle. This examination was performed by adjusting the current setting according to the patient size. For ECG-controlled tube current modulation, the tube output was raised to a preset level for each cardiac cycle during 70% to 80% of the diastolic phase; the data were reconstructed from these phases. During the remaining part of the cardiac cycle, the tube output was reduced. When employed for coronary CT angiography, this technique has been shown to achieve an overall ionizing radiation exposure savings of 30–50% without compromising image quality (7, 8). Depending on the thoracic dimensions, the scanning time varied between three and four seconds. During scanning, 50 mL Optiray, a 40-mL mixture of 50% Optiray/50% saline, and 50 mL saline were injected at a rate of 5 mL/s via an 18G right antecubital catheter. Images were reconstructed 75% into the cardiac cycle.

Post-processing

The CT data sets were transferred and post-processed at the Advantage 4.3 workstation (GE Healthcare) during the initial CT examination, and an official CT report was produced from the post-processed information using the GE tool. Image analysis was performed both by using trasverse source and MPR images. All images were reviewed on a picture archiving and communications system. All MDCT images were interpreted at the time of image acquisition by board-certified staff radiologists. The dimensions of the aortic root and ascending aorta (AAo) were evaluated in detail with MPR. We measured four segments in each patient, including the annulus, sinuses of valsalva (SOV), sinotubular junction (STJ), and the largest diameter of the AAo. For the AAo, STJ and SOV, we defined dilation as having a diameter greater than 40 mm, and for the annulus, dilation was defined as having a diameter greater than 27 mm.

Statistical analysis

Descriptive exploratory analysis was performed on the aortic root area. All statistical analyses were performed using commercially available software (SSPS 11.5 for Windows, SPSS Inc., Chicago, USA). Data are expressed as mean±standard deviation (SD), with ranges provided when appropriate. The Pearson chi-square test was used for statistical analysis; P values less than 0.05 were considered statistically significant.

Results

Overall, 52 patients had dilation of the AAo with a mean diameter (MD) of 50±10 mm. Forty-three patients had non-dilated AAo with a MD of 33±6 mm. In patients with dilated AAo, the mean age was 66±16 years; patients with normal AAo had a mean age of 62±13 years. The ages of the two groups were not statistically different. We also compared the two groups in terms of gender distribution: the male:female ratios were 16:27 and 17:35 in the groups with normal and dilated AAo, respectively. There was no statistically significant difference in terms of gender distribution in these groups. Patients were matched for age (P = 0.205) and sex (P = 0.645) across the two groups. Of those patients with dilated AAo, 28 patients had a dilated annulus (mean diameter [MD]±SD, 32±4 mm), 27 patients had a dilated SOV (MD, SD: 47 mm, 8 mm), and 11 patients had STJ dilation (MD, 43±3 mm) (Tables 1–3). We observed normal dimensions for the ascending aorta in 43 patients, and of those patients with normal caliber ascending aorta, 12 had annulus dilation (MD, 27±8 mm), 12 had SOV dilation (MD, 48±10 mm), and 4 patients had STJ dilation (MD, 51±11 mm) (Fig. 1). Higher prevalence of aortic root dilation was observed in patients with dilated AAo. In patients with dilated AAo, we observed that 38% had annulus dilation, 52% had a dilated SOV, and 21% had STJ dilation, compared to 28%, 28%, and 4% for annulus, SOV and STJ dilation, respectively, in patients with a normal ascending aorta (Tables 1–3). We found a statistically significant difference in the incidence of SOV dilation in the patient population with the dilated AAo compared with the normal AAo (P = 0.018). There were no statistically significant differences in terms of annulus (P = 0.645) and STJ (P = 0.279) dilation between the two groups (Fig. 2).

Discussion

There are numerous approaches to the diagnosis of dilation of the AAo and aortic root, including echocardiography, computed tomography, and magnetic resonance imaging. However, ECG-gated CTA has an important advantage compared with other imaging modalities. Especially at the level of the aortic root, heartbeat-related artifacts are the most prominent and challenging problem for accurate measurements of the annulus, SOV, and STJ. The addition of ECG-gating to CTA significantly reduces this motion artifact and thus enabled us to measure root diameters precisely (9). This is especially important in the planning of endovascular procedures where precise sizing of the graft is required.

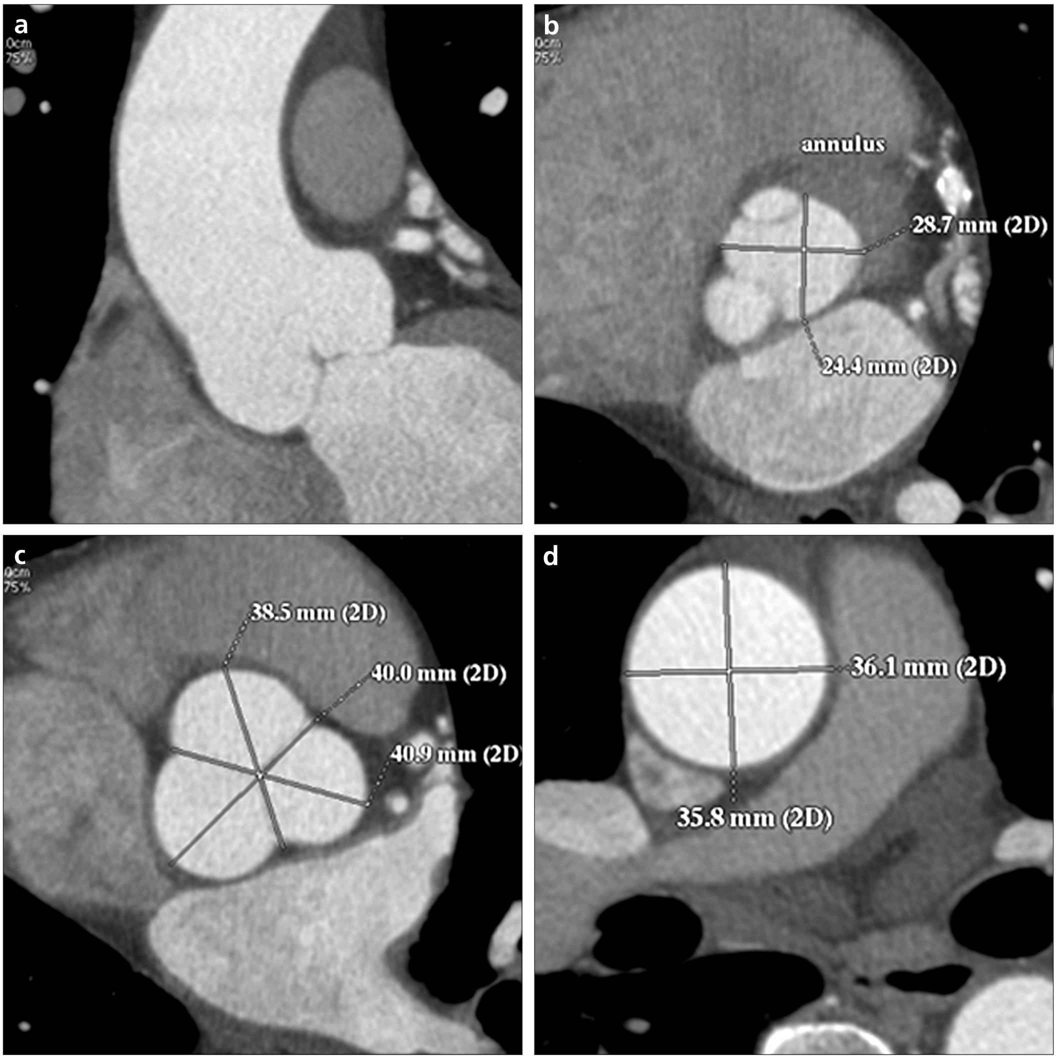

Figure 1. a–d. Sinuses of valsalva dilation in a 55-year-old patient. Double-oblique reconstruction of contrast-enhanced, retrospectively ECG-gated multi–detector row CT **(a)** demonstrates aortic valve closure during diastole at 75% of the R–R interval, dilation in the annulus **(b)** (2.8 cm) and SOV **(c)** (4.1 cm); a normal-sized ascending aorta **(d)**.

Table 1. Distribution of ascending aorta and annulus dilation

	Ascending aortic dilation	
Annulus dilation	Absent	Present
Absent	31 (72%)	32 (62%)
Present	12 (28%)	20 (38%)
Total	43 (100%)	52 (100%)

Table 2. Distribution of ascending aorta and sinus of valsalva dilation

	Ascending aortic dilation	
SOV dilation	Absent	Present
Absent	31 (72%)	25 (48%)
Present	12 (28%)	27 (52%)
Total	43 (100%)	52 (100%)

Table 3. Distribution of ascending aorta and sinotubular junction dilation

	Ascending aortic dilation	
Sinotubular junction dilation	Absent	Present
Absent	39 (91%)	41 (79%)
Present	4 (9%)	11 (21%)
Total	43 (100%)	52 (100%)

Feuchtner et al. and Alkadhi et al. (10, 11) have shown that MDCT can be used for anatomic delineation of the aortic valve area by performing MPR of axial images using a 16-channel ECG-gated CTA during coronary imaging. We used 75% of the R–R interval to generate MPR using 64-channel MDCT during CTA of the aorta. The annulus, SOV, STJ, and AAo diameters measured from the MPR images were unaffected by heart beat-related motion artifacts.

Dilation of the sinuses of valsalva can severely impair aortic valve competence (5, 12). Palmieri et al. (12) examined the relationships between SOV dilation and aortic regurgitation in 2096 hypertensive and 361 normotensive participants. They found a strong association between SOV dilation and the degree of aortic regurgitation. Accordingly, we observed 52% SOV dilation, with a mean diameter of 48 mm, in patients with dilated AAo and 28% SOV dilation, with a mean diameter of

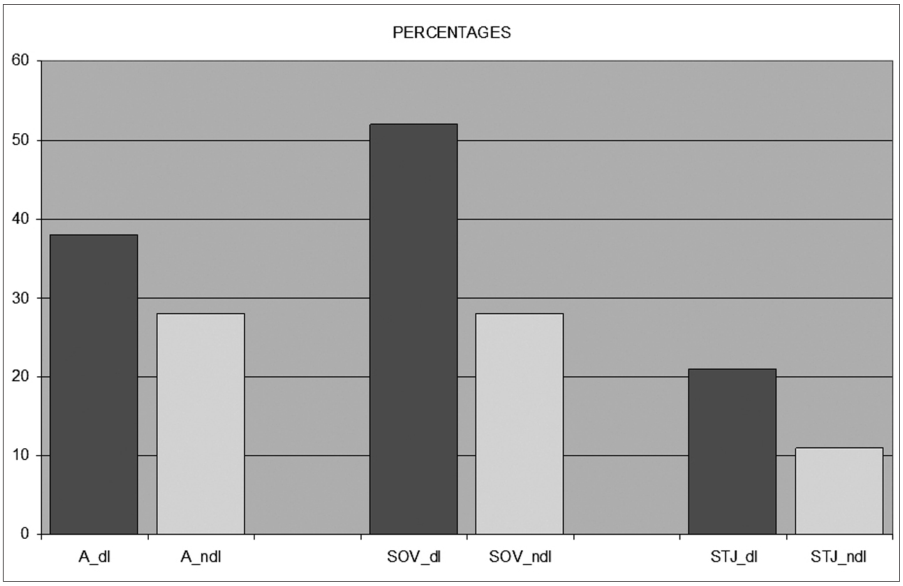

Figure 2. Diagram of the percentages of aortic root dilation (A_dl, SOV_dl, and STJ_dl are patients with ascending aortic aneurysm; A_ndl, SOV_ndl, STJ_ndl are patients with normal ascending aortas) (A, annulus; SOV, sinuses of valsalva; STJ, sinotubular junction; dl, dilated ascending aorta; ndl, non-dilated ascending aorta).

48 mm, in the patient population with normal AAo. These findings might be important in terms of early diagnosis of aortic regurgitation in this patient population. Isolated SOV dilation was observed in six cases. However, concurrent dilation of the SOV and annulus was the most frequent combination.

The sinotubular junction is a circular structure composed of elastic tissue that supports peripheral attachment of aortic valve leaflets (13). Aneurysmatic dilation of the STJ is also the major cause of aortic valvular incompetence, even when the leaflets remain structurally intact. Dilation of the STJ pulls the commissures of the aortic valve apart, preventing the cusps from coapting and leading to central aortic insufficiency. Aortic valve-sparing operations are an alternative to aortic root replacement in patients with STJ aneurysms. In this study, we observed an occurrence of 21% STJ dilation in patients with AAo, while 9% of patients with normal AAo had STJ dilation. Isolated STJ dilation was not observed in our study; STJ dilation generally occurred in conjunction with dilation of the SOV and annulus.

The aortic annulus is described as the area of collagenous condensation at the point of valve leaflet attachment (13). Dilation of the annulus results in non-coaptation of the aortic cusps and, eventually, in aortic insufficiency. Dilation of the annulus may cause the aortic insufficiency more frequently than dilated STJ (14). In this study, 28% of patients with normal caliber ascending aorta and 38% of patients with dilated AAo had annulus dilation. Concurrent dilation of the annulus and SOV was observed in most cases; hence, dilation of the annulus, SOV and STJ were often seen together rather than individually.

In this study, we observed that a dilated AAo was associated with a slightly higher prevalence of annulus, SOV and STJ dilation. However, annulus, SOV, and STJ dilation was also observed in patients with an ascending aorta of normal caliber. This finding could be important for early diagnosis of isolated aortic root dilation. Idiopathic aortic root dilation is the most common, definable cause of severe aortic regurgitation (15). High prevalence of root dilation in this study could be due to the older age of the patient population. It might be also due to our selection of a patient population with predisposed clinical risk factors. In the studies of Agmon et al. and Cassottana et al. (16, 17), age-appropriate dilation of the aortic root, ascending and descending aorta has been reported. However, our cut-off value for dilation was higher than for the expected age-appropriate dilations. In our study, the age difference between patient populations with and without an aneurysm was not statistically significant. It has been also shown that aortic size is greater in men than women; however, the distribution of males and females was homogeneous for the two groups.

Our study had several limitations. First, we only included patients who had predisposing factors for the root dilation. This potentially could have led to an inclusion bias, because all of the patients in our study population had undergone CTA for either thoracic aortic aneurysm or dissection. Another important limitation is the level of radiation exposure with ECG-gated MDCT and the injection of potentially nephrotoxic contrast material. As a result, MDCT probably will not become a first-line diagnostic tool for the assessment of aortic root pathologies. Our findings should be confirmed with a longitudinal study on the management and development of aortic insufficiency in these patients.

Our data reveal a statistically significant association between AAo and SOV dilation. Therefore, SOV dilation and loss of leaflet coaptation can result in significant aortic regurgitation in such patients. This finding is particularly important for surgical planning, which is mainly affected by the status of the aneurysm to the other segments of the thoracic aorta. Modern valve-sparing procedures for aortic insufficiency associated with root enlargement require resection of the dilated sinuses, followed by remodeling of the aortic root or re-implantation of the aortic valve inside a Dacron tube graft (2, 18, 19).

In conclusion, measurement of the aortic root using MPR in patients scanned for TAA is of clinical and surgical importance. These measurements are necessary for early diagnosis and follow-up in patients presenting with aortic root dilation and for planning the surgical approach. Because aortic root repair surgeries have become more popular, ECG-gated MDCT angiography with concomitant planimetric measurements of the aortic root structures would be an excellent tool for accurate assessment of root anatomy and dimension in routine clinical assessments.

Conflict of interest disclosure

The authors have no financial relationships to disclose.

References

1. Isselbacher EM. Thoracic and abdominal aortic aneurysms. Circulation 2005; 111:816–828.
2. Ince H, Nienaber CA. Etiology, pathogenesis and management of thoracic aortic aneurysm. Nat Clin Pract Cardiovasc Med 2007; 4:418–427.
3. Berdajs D, Lajos P, Turina M. The anatomy of the aortic root. Cardiovasc Surg 2002; 10:320–327.
4. Kim M, Roman MJ, Cavallini MC, Schwartz JE, Pickering TG, Devereux RB. Effect of hypertension on aortic root size and prevalence of aortic regurgitation. Hypertension 1996; 28:47–52.
5. Seder JD, Burke JF, Pauletto FJ. Prevalence of aortic regurgitation by color flow Doppler in relation to aortic root size. J Am Soc Echocardiogr 1990; 3:316–319.
6. Lu TL, Huber CH, Rizzo E, Dehmeshki J, von Segesser LK, Qanadli SD. Ascending aorta measurements as assessed by ECG-gated multi-detector computed tomography: a pilot study to establish normative values for transcatheter therapies. Eur Radiol 2009; 19:664–669.
7. Jakobs TF, Becker CR, Ohnesorge B, et al. Multislice helical CT of the heart with retrospective ECG gating: reduction of radiation exposure by ECG-controlled tube current modulation. Eur Radiol 2002; 12:1081–1086.
8. Salem R, Remy-Jardin M, Delhaye D, et al. Integrated cardio-thoracic imaging with ECG-gated 64-slice multidetector-row CT: initial findings in 133 patients. Eur Radiol 2006; 16:1973–1981.
9. Morgan-Hughes GJ, Owens PE, Marshall AJ, Roobottom CA. Thoracic aorta at multi-detector row CT: motion artifact with various reconstruction windows. Radiology 2003; 228:583–588.
10. Alkadhi H, Wildermuth S, Plass A, et al. Aortic stenosis: comparative evaluation of 16-detector row CT and echocardiography. Radiology 2006; 240:47–55.
11. Feuchtner GM, Dichtl W, Schachner T, et al. Diagnostic performance of MDCT for detecting aortic valve regurgitation. Am J Roentgenol 2006; 186:1676–1681.
12. Palmieri V, Bella JN, Arnett DK, et al. Aortic root dilatation at sinuses of valsalva and aortic regurgitation in hypertensive and normotensive subjects: The Hypertension Genetic Epidemiology Network Study. Hypertension 2001; 37:1229–1235.
13. Underwood MJ, El Khoury G, Deronck D, Glineur D, Dion R. The aortic root: structure, function, and surgical reconstruction. Heart 2000; 83:376–380.
14. Lansac E, Di Centa I, Raoux F, et al. Aortic annuloplasty: towards a standardized approach of conservative aortic valve surgery. MMCTS 2007; 2007:1958–1964.
15. Roman MJ, Devereux RB, Niles NW, et al. Aortic root dilatation as a cause of isolated, severe aortic regurgitation. Prevalence, clinical and echocardiographic patterns, and relation to left ventricular hypertrophy and function. Ann Intern Med 1987; 106:800–807.
16. Agmon Y, Khandheria BK, Meissner I, et al. Is aortic dilatation an atherosclerosis-related process?: clinical, laboratory, and transesophageal echocardiographic correlates of thoracic aortic dimensions in the population with implications for thoracic aortic aneurysm formation. J Am Coll Cardiol 2003; 42:1076–1083.
17. Cassottana P, Badano L, Piazza R, Copello F. Dimensions of the proximal thoracic aorta from childhood to adult age: reference values for two-dimensional echocardiography. Ligurian Group of SIEC (Italian Society of Echocardiography). G Ital Cardiol 1997; 27:686–696.
18. Davies JE, Sundt TM. Surgery insight: the dilated ascending aorta--indications for surgical intervention. Nat Clin Pract Cardiovasc Med 2007; 4:330–339.
19. Gleason TG. Current perspective on aortic valve repair and valve-sparing aortic root replacement. Semin Thorac Cardiovasc Surg 2006; 18:154–164.