Clinical Investigation

Pseudoaneurysm in the Left Ventricular Outflow Tract after Prosthetic Aortic Valve Implantation

Evaluation upon Multidetector-Row Computed Tomography

I-Chen Tsai, MD
Shih-Rong Hsieh, MD
Ming-Sheng Chern, MD
Hsiao-Ting Huang, MD
Min-Chi Chen, RT
Wei-Lin Tsai, MD
Clayton Chi-Chang Chen, MD

Key words: *Aneurysm, false/etiology/radiography; aortic valve/radiography; blood coagulation disorders/etiology; echocardiography; heart valve diseases/complications/radiography; heart valve prosthesis implantation; imaging, three-dimensional; radiographic image interpretation, computer-assisted; sensitivity and specificity; thrombosis/radiography; tomography, X-ray computed/methods; ventricular outflow obstruction/etiology/radiography*

From: *Department of Radiology (Drs. C.-C. Chen, M.-C. Chen, Huang, I.-C. Tsai, and W.-L. Tsai) and Cardiovascular Center (Dr. Hsieh), Taichung Veterans General Hospital, Taichung 407; and Faculty of Medicine & Institute of Clinical Medicine (Drs. Chern, I.-C. Tsai, and W.-L. Tsai), National Yang-Ming University, Taipei 112; Taiwan*

Funding support: *This research was supported in part by Taichung Veterans General Hospital under grants TCVGH-975506C, TCVGH-985506C, and TCVGH-975504A.*

Address for reprints: *Hsiao-Ting Huang, MD, Department of Radiology, Taichung Veterans General Hospital, No. 160, Sec. 3, Taichung Harbor Road, Taichung 407, Taiwan, ROC*

E-mail: *sillyduck@vghtc.gov.tw*

The high accuracy of multidetector-row computed tomography (MDCT) in evaluating prosthetic valve disorders has been confirmed. This, we believe, is the 1st report of the use of MDCT to detect and evaluate left ventricular outflow tract (LVOT) pseudoaneurysms in patients who have undergone aortic valve replacement with prosthetic valves. We used MDCT to scan 21 such patients, 3 of whom had a small pseudoaneurysm in the LVOT. Each pseudoaneurysm projected away from the LVOT and had a narrow neck that was located just below the sewing ring of the prosthetic aortic valve. One pseudoaneurysm was not thrombotic, 1 was partially thrombotic, and 1 was completely thrombotic. One of these had gone undetected earlier on transthoracic echocardiography.

We consider MDCT to be superior to echocardiography in the detection of LVOT pseudoaneurysms in patients who have undergone aortic valve replacement with prosthetic valves. We publicize our results in the hope that larger studies will be undertaken in order to investigate the prevalence and clinical implications of our findings. ***(Tex Heart Inst J 2009;36(5):428-32)***

Aortic valve replacement is the ultimate treatment for severe aortic valve diseases.[1] Regular follow-up with cross-sectional imaging and early intervention to treat valvular disorders are crucial toward improving survival rates after valve replacement.[1] Disorders include thrombus formation,[2,3] pannus formation,[4,5] valve dysfunction,[3,5,6] suture dehiscence (paravalvular leakage),[5] and left ventricular outflow tract (LVOT) pseudoaneurysm.[7-9] Most prosthetic valve disorders can be accurately diagnosed with the use of multidetector-row computed tomography (MDCT),[2-6] and with better accuracy than that of transthoracic echocardiography.[5] However, MDCT findings of LVOT pseudoaneurysm have not, to our knowledge, been reported heretofore in the medical literature. We present our MDCT findings of LVOT pseudoaneurysm, drawn from our studies of patients in a 1,500-bed tertiary-referral medical center. Clinical implications of the imaging results will also be discussed.

Patients and Methods

Patient Enrollment

We first reviewed all cardiac computed tomographic (CT) images of patients who had undergone aortic valve replacement from January 2005 through December 2008 in the cardiovascular center of our 1,500-bed hospital. We then performed MDCT in the patients who had prosthetic valve disorders (suspected or actual) or coronary artery disease. The study overlapped with a related investigation and was performed by virtue of a waiver from the hospital's institutional review board. Written informed consent for MDCT scanning was obtained from all of the patients.

Characteristics of the Patients

We recorded each patient's age, sex, clinical history, symptoms upon presentation, initial indication for valve replacement, surgical procedure, echocardiographic record, time interval between valve replacement and MDCT scan, and current clinical condition.

Imaging Protocol and Interpretation

The MDCT studies were performed by using a Brilliance CT 40-channel system (Koninklijke Philips Electronics N.V.; Best, The Netherlands).[5] The tube voltage was 120 kV, the effective tube current was 400 to 950 mA per section in accordance with each patient's body weight, the pitch was 0.2, and the rotation time was 0.42 sec.[5] In addition, electrocardiographic gating was applied in a craniocaudal direction from the carina to the lower border of the heart. Online electrocardiography-based dose modulation was not used, because the integrity of systolic-phase images (crucial in the evaluation of prosthetic valve motion) could have been impaired. The CT protocol was the same as that used for the "ischemic heart routine" described elsewhere.[10]

Every patient whose heart rate was faster than 60 beats/min was given a 10- to 40-mg oral dose of propranolol 1 hour before MDCT. A 20G intravenous catheter was placed in each patient's right antecubital vein, and 100 mL of iohexol was injected at a flow rate in accordance with the "contrast-covering time" concept.[11] (This concept has proved to be useful in evaluating intracardiac prosthetic devices[12] in patients of different body weights.[11,13]) A 30-mL saline bolus was then administered at the same flow rate. In order to synchronize the imaging with the injection of the contrast agent, we used a bolus-tracking technique with a threshold of 150 Hounsfield Units and a region of interest in the ascending aorta. Two senior technologists performed the MDCT studies. Images were reconstructed from 0 to 90% of the R–R interval, at 10% intervals.

A cardiac radiologist (I.-C. T.) who was experienced in intracardiac prosthetic-device evaluation used a dedicated Extended Brilliance Workspace workstation (Philips) to interpret the MDCT data. The 10-phase images were loaded into cine-viewer software in order to evaluate valvular motion in various planes. For the detection of loose sutures, pannus, or pseudoaneurysm, special attention was given to the relationship between the sewing ring and the surrounding valvular annulus. Pseudoaneurysm was defined as a narrow-necked, wide-based cavity that surrounded the prosthetic valve.[5]

When a patient had a pseudoaneurysm, we reviewed the suturing technique by referring to the surgeon's notes and confirmed the method upon MDCT. We recorded the pseudoaneurysm's size, neck diameter, thrombotic status, and location in reference to the anatomy of the sinus of Valsalva.

Results

Twenty-one patients who had undergone aortic valve replacement during the 4-year study period were initially eligible for MDCT. A patient was excluded due to severe beam-hardening artifact.[5] The remaining 20 patients included 2 with tissue valves and 18 with mechanical valves.

Of the 20 patients, 13 had no valvular abnormalities. In the remaining 7 patients, we found 2 pannus formations with valvular dysfunction and 1 without dysfunction, 1 instance of suture dehiscence, and 3 LVOT pseudoaneurysms (Figs. 1, 2, and 3). Table I shows the characteristics of the 3 patients with LVOT pseudoaneurysm.

All 3 patients were experiencing nonspecific or atypical chest pain. Patients 1 and 3 were examined several

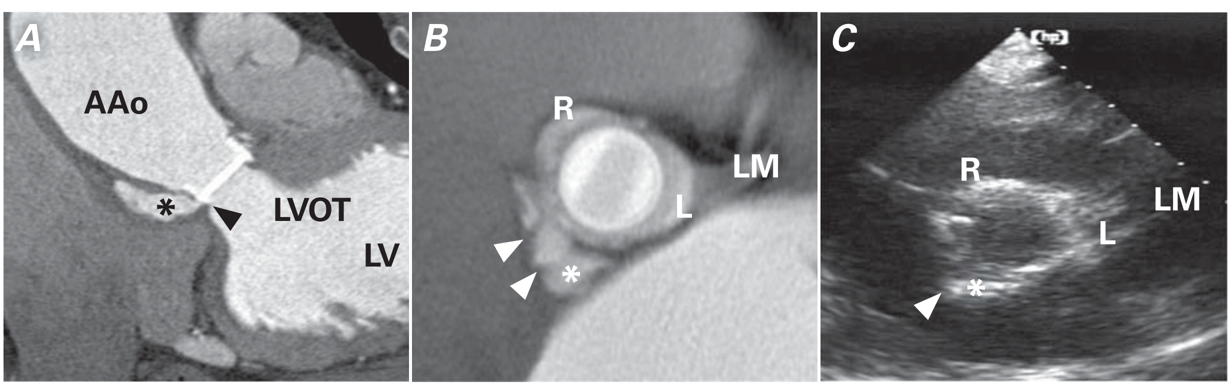

Fig. 1 Patient 1. ***A***) Cardiac multidetector-row computed tomography (MDCT) (coronal image) shows a 2.8-mm neck (arrowhead) on the noncoronary side of the left ventricular outflow tract (LVOT), just below the sewing ring of the prosthetic aortic valve. The neck enters a small pseudoaneurysm (asterisk) that surrounds the ascending aorta (AAo). ***B***) In short-axis view, MDCT shows the pseudoaneurysm (asterisk) on the noncoronary side of the aortic root, with folds inside (arrowheads). ***C***) Echocardiographic short-axis view. The pseudoaneurysm was initially not diagnosed upon echocardiography. Review revealed the pseudoaneurysm (asterisk) as a hyperechogenic focus on the noncoronary side of the aortic root, mimicking a normal noncoronary cusp. The hyperechogenicity (arrowhead) is considered to be related to the folds inside the pseudoaneurysm. The appearance of the pseudoaneurysm is similar to the right (R) and left (L) coronary cusps.

LM = left main coronary artery

Click here for real-time motion image: Fig. 1A years after their aortic valve replacements; their pseudoaneurysms were not large (dimensions, 25 × 21 × 10 mm^3 and 15 × 15 × 10 mm^3, respectively). Patient 2 was examined 1 year after valve replacement; his pseudoaneurysm was large (dimensions, 77 × 73 × 50 mm^3).

Each pseudoaneurysmal neck was located just below the sewing ring of the prosthetic valve. The necks were all of small diameter (range, 1.7–2.8 mm). Each pseudoaneurysm projected away from the LVOT and extended to the ascending aorta or aortic root. The thrombotic status of each pseudoaneurysm differed from the rest: no thrombus (Fig. 1), partial thrombus (Fig. 2), and total thrombus with rim calcification (Fig. 3).

Patient 1 had undergone transthoracic echocardiography 1 month before her MDCT examination; however, the pseudoaneurysm had not been detected then.

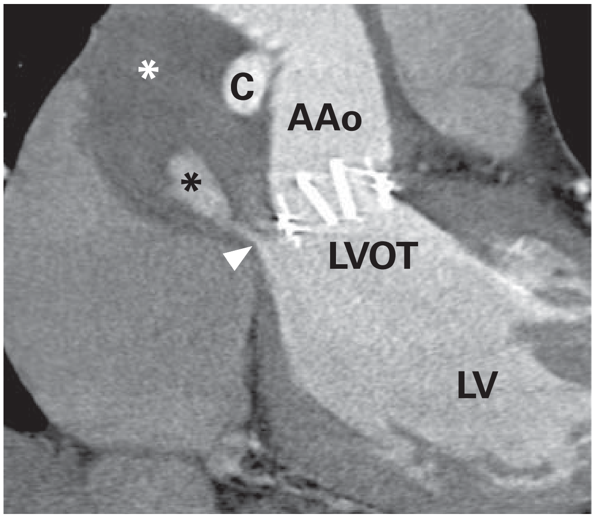

Fig. 2 *Patient 2. Cardiac multidetector-row computed tomography (coronal image) shows a 2.6-mm neck (arrowhead) on the noncoronary side of the left ventricular outflow tract (LVOT), just below the sewing ring of the prosthetic aortic valve. The neck enters a large pseudoaneurysm (asterisks), and thrombus (white asterisk) surrounds the ascending aorta (AAo).*

C = Cabrol shunt; LV = left ventricle

Click here for real-time motion image: Fig. 2

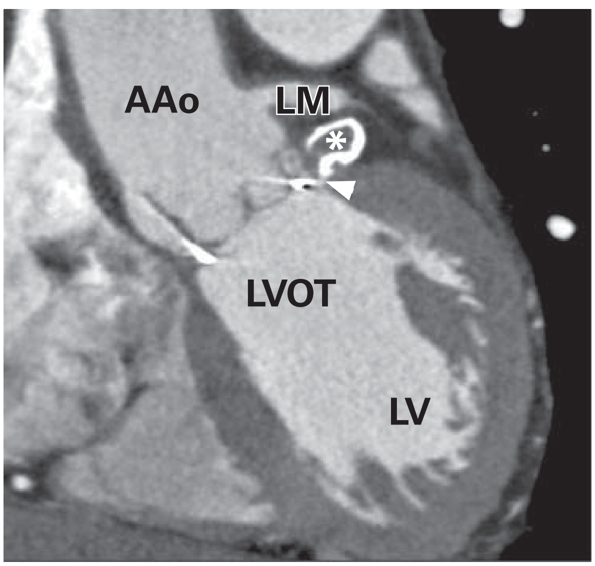

Fig. 3 *Patient 3. Cardiac multidetector-row computed tomography (coronal image) shows a 1.7-mm neck (arrowhead) on the left coronary side of the left ventricular outflow tract (LVOT), just below the sewing ring of the prosthetic aortic valve. The neck enters a small, thrombotic, peripherally calcified pseudoaneurysm (asterisk) that surrounds the aortic root.*

AAo = ascending aorta; LM = left main coronary artery; LV = left ventricle

Click here for real-time motion image: Fig. 3

Discussion

Pseudoaneurysm is a common postoperative disorder after prosthetic aortic valve replacement. However, only a few investigators have reported the condition.[7-9] The limited diagnostic ability of echocardiography, in the presence of vague symptoms, might underlie the sparse reporting in the medical literature. Our patients' nonspecific symptoms mimicked those of coronary artery disease (which was later excluded upon MDCT), and the pseudoaneurysms were found incidentally.

The development of pseudoaneurysms after aortic valve replacement is attributed to suturing technique.[7,14] When a tight suture tears the LVOT wall, the high-velocity blood flow in the LVOT enters the tear and forms a pseudoaneurysm. If the tearing is severe, suture dehiscence and paravalvular leakage can occur. The use of pledgets can avert loosened sutures and paravalvular leakage by dispersing the pressure and patching the suture tear.[15] However, our patients 1 and 2 underwent pledgeting and still developed pseudoaneurysms, suggesting that pledgeting ameliorates but does not completely prevent tearing.

Barbetseas and colleagues[7] used echocardiography to evaluate pseudoaneurysm formation after aortic valve replacement. The pseudoaneurysms in their patients were all larger than 5 cm in diameter. Our patients' lesions were 2.8 cm or smaller in diameter. Echocardiography failed to detect one of these (Fig. 1). We believe that the size differential between the lesions in the 2 studies verifies the high spatial resolution of MDCT in comparison with that of echocardiography.

Miller and Dinsmore[8] used angiography to evaluate abscess formation after aortic valve replacement. Lesion location and distribution were similar to those in our study. However, because of the inherently limited 2-dimensional projection of angiography, the entry points (the pseudoaneurysmal necks) could be seen only during surgical exploration.[8] Unlike angiography, MDCT is a noninvasive, volumetric, cross-sectional imaging method that is unhampered by superimposition.

TABLE I. Characteristics of Patients in Whom LVOT Pseudoaneurysms Formed after Prosthetic Aortic Valve Replacement

Variable	Patient 1	Patient 2	Patient 3
Age, yr	78	23	76
Sex	Female	Male	Male
Indication for valve replacement	Aortic stenosis	Marfan syndrome with ascending aorta dilation and aortic regurgitation	Rheumatic heart disease with aortic regurgitation
Surgical procedure	Mechanical aortic valve replacement	Ascending aorta replacement with mechanical aortic valve replacement	Tissue aortic valve replacement
Suture technique	Horizontal mattress sutures with pledgets	Horizontal mattress sutures with pledgets	Simple interrupted sutures without pledgets
Transthoracic echocardiography	Yes	No	No
Indications for MDCT	Vague chest discomfort; CAD suspected	Atypical chest pain; CAD suspected	Atypical chest pain; CAD suspected
Time between aortic valve replacement and MDCT, yr	13	1	11
Location of pseudoaneurysm in LVOT	Noncoronary side	Noncoronary side	Left coronary side
Thrombosis	None	Partial	Total
Neck diameter, mm	2.8	2.6	1.7
Size of pseudoaneurysm, mm^3	25 × 21 × 10	77 × 73 × 50	15 × 15 × 10
Treatment	None specific	Patient refused reoperation	None specific
Current condition, after MDCT	Stable for 18 months	Stable for 10 months	Stable for 18 months

CAD = coronary artery disease; LVOT = left ventricular outflow tract; MDCT = multidetector-row computed tomography

The patients who were studied by Barbetseas and colleagues[7] underwent surgery due to the large size of the pseudoaneurysms. In patients who have not undergone surgery, pseudoaneurysms in the LVOT can result from infection.[16] Indeed, in Miller and Dinsmore's series,[8] surgery was indicated for this reason, whereas our patients exhibited no infection. Patients 1 and 3 received no specific treatment, and patient 2 declined reoperation. The natural history of the small, uninfected lesions in our patients 1 and 3 is unclear. All 3 patients have been in stable condition since the MDCT examination.

It is noteworthy that our patients' pseudoaneurysms were, in turn, not thrombotic, partially thrombotic, and completely thrombotic—indicating that pseudoaneurysms may spontaneously develop thrombosis whether flow is turbulent or slow. In accordance with previous reports and ours, pseudoaneurysms can be infected, stable, or thrombotic. We recommend that the prevalence and clinical implications of these last be investigated via future cohort studies.

Limitations of the Study

Our study was limited by several factors. The number of patients was small. In order to enroll more patients than were yielded by our 4-year experience in a single center, a multicenter or nationwide study should be undertaken. We wish to publicize our findings in hopes of inspiring such larger studies. Next, the retrospective aspect of our study may have hampered us by imposing bias in the selection of patients who were to undergo MDCT. However, in our hospital, MDCT is the 1st-line method for detecting prosthetic valve disorders, and we consider any bias to be negligible. Finally, there was no surgical confirmation of the findings. Regardless, the accuracy of MDCT in evaluating prosthetic valve disorders has been reported,[5] and surgical exploration is not considered necessary in patients who experience only vague symptoms.

Conclusion

To our knowledge, this is the 1st report of the use of MDCT to detect LVOT pseudoaneurysms in patients who have undergone aortic valve replacement with prosthetic valves. The high spatial resolution of MDCT can clearly reveal the details of paravalvular structures without hindrance from acoustic shadowing or the limited acoustic window and spatial resolution of echocardiography. Even small and totally thrombotic pseudoaneurysms can be evaluated well. In our study, the sizes of the pseudoaneurysms and the locations of their necks were readily detected upon MDCT. Further studies in larger cohorts of patients are warranted.

References

1. Groves P. Valve disease: surgery of valve disease: late results and late complications. Heart 2001;86(6):715-21.
2. Leborgne L, Renard C, Tribouilloy C. Usefulness of ECG-gated multi-detector computed tomography for the diagnosis of mechanical prosthetic valve dysfunction. Eur Heart J 2006;27(21):2537.
3. Numata S, Okada H, Kitahara H, Kawazoe K. Four-dimensional evaluation of implanted mechanical valve with 64-row multi-detector computed tomography. Eur J Cardiothorac Surg 2007;31(5):934.
4. Teshima H, Hayashida N, Fukunaga S, Tayama E, Kawara T, Aoyagi S, Uchida M. Usefulness of a multidetector-row computed tomography scanner for detecting pannus formation. Ann Thorac Surg 2004;77(2):523-6.
5. Tsai IC, Lin YK, Chang Y, Fu YC, Wang CC, Hsieh SR, et al. Correctness of multi-detector row computed tomography for diagnosing mechanical prosthetic heart valve disorders using operative findings as a gold standard. Eur Radiol 2009;19(4):857-67.
6. Teshima H, Aoyagi S, Hayashida N, Shojima T, Takagi K, Arinaga K, Yoshikawa K. Dysfunction of an ATS valve in the aortic position: the first reported case caused by pannus formation. J Artif Organs 2005;8(4):270-3.
7. Barbetseas J, Crawford ES, Safi HJ, Coselli JS, Quinones MA, Zoghbi WA. Doppler echocardiographic evaluation of pseudoaneurysms complicating composite grafts of the ascending aorta. Circulation 1992;85(1):212-22.
8. Miller SW, Dinsmore RE. Aortic root abscess resulting from endocarditis: spectrum of angiographic findings. Radiology 1984;153(2):357-61.
9. Gupta R, Jammula P, Huang MH, Atar S, Ahmad M. An unusual complication after aortic valve replacement. J Clin Ultrasound 2006;34(7):361-4.
10. Tsai IC, Lee T, Lee WL, Tsao CR, Tsai WL, Chen MC, Ting CT. Use of 40-detector row computed tomography before catheter coronary angiography to select early conservative versus early invasive treatment for patients with low-risk acute coronary syndrome. J Comput Assist Tomogr 2007;31(2):258-64.
11. Tsai IC, Lee T, Chen MC, Tsai WL, Lin PC, Liao WC. Homogeneous enhancement in pediatric thoracic CT aortography using a novel and reproducible method: contrast-covering time. AJR Am J Roentgenol 2007;188(4):1131-7.
12. Lee T, Tsai IC, Fu YC, Jan SL, Wang CC, Chang Y, Chen MC. MDCT evaluation after closure of atrial septal defect with an Amplatzer septal occluder. AJR Am J Roentgenol 2007;188(5):W431-9.
13. Tsai IC, Chen MC, Jan SL, Wang CC, Fu YC, Lin PC, Lee T. Neonatal cardiac multidetector row CT: why and how we do it. Pediatr Radiol 2008;38(4):438-51.
14. Kouchoukos NT, Blackstone EH, Doty DB, Hanley FL, Karp RB. Aortic valve disease. In: Kirklin/Barratt-Boyes cardiac surgery: morphology, diagnostic criteria, natural history, techniques, results, and indications. 3rd ed. Philadelphia: Churchill Livingstone; 2003. p. 554-656.
15. Stiles GM, Kernen JA, Stiles QR. Suture technique in preventing dehiscence of prosthetic mitral valves. Arch Surg 1986;121(10):1136-40.
16. Da Col U, Ramoni E, Di Bella I, Ragni T. An unusual left ventricular outflow pseudoaneurysm: usefulness of echocardiography and multidetector computed tomography for surgical repair. Cardiovasc Intervent Radiol 2009;32(1):188-91.